GLOBAL JOURNAL OF ANIMAL SCIENTIFIC RESEARCH

G.J.A.S.R

Journal homepage: www.gjasr.com

Print ISSN:2345-4377 Online ISSN:2345-4385

Review Article

Thymus plant in animal nutrition: Review

Ashenafi Miresa

Department of Animal Sciences, College of Agriculture and Veterinary Medicine, Jimma University, Ethiopia

ABSTRACT

Aromatic plants such as thyme have been shown promising results as a natural feed additive in livestock feed due to the presence of bioactive compound in the herb. Carvacrol and thymol are among essential oil extracted from thyme with high phenolic contents used for commercial interest. Essential oil components extracted from thymus plants are used widely in pharmaceutical application and exhibit antimicrobial, antioxidant, anti-carcinogenesis, anti-inflammatory and used as immunostimulants without residual effect like synthetic antibiotics. Thyme essential oil had also the ability to inhibit methanogenic microbes; addition of essential oil to the rumen can reduce methane emitted from ruminant animals. The aerial part of thyme contains a high amount of carbohydrates and a low concentration of tannin. Incorporation of thyme in animal nutrition as a powder or essential oil extract form can promote growth, productive and reproductive performance, increase feed intake, improve digestion and absorption of nutrients, increase carcass quality, reduce morbidity and mortality rate. This paper aims to review the beneficial application and recent finding of thyme in livestock feed

Keywords: Thyme, animal feed, essential oil, livestock

INTRODUCTION

There are numerous aromatic plant and herbs exist worldwide, particularly originating from the Mediterranean area, such as lavender, thyme, winter savoury, rosemary, sage, peppermint, chamomile, Roman chamomile, French tarragon, bitter and sweet fennel(Christaki *et al.*, 2020; Piccaglia *et al.*, 1993) which are used in many aspects of our life such as pharmaceutical products, feed and food additives, cosmetics and preservatives (Máthé, 2015). Aromatic plants and herbs have been widely used for medical purposes not only for humans but for animals as well (Giannenas *et al.*, 2020). The ban of antibiotic use as a growth promoter in animal feeds led to an increased interest in finding alternatives to antibiotics for farm animals (Christaki *et al.*, 2012a; Maron *et al.*, 2013; Ronquillo and Hernandez, 2017). To alleviate the problem associated with the ban of antibiotics as a feed additive, currently, different researchers focuses on the usage of aromatic and medicinal plant as a feed additive

Corresponding Author: Ashenafi Miresa < wmirree@gmail.com >

Cite this Article: Miresa, A. (2020). Thymus plant in animal nutrition: Review. *Global Journal of Animal Scientific Research,* 8(1), 115-135.
Retrieved from http://www.gjasr.com/index.php/GJASR/article/view/38
Article History: Received: 2020-04-20 Accepted: 2020-06-05

(Christaki *et al.*, 2012b; Giannenas *et al.*, 2013). The essential oil present in herbal plants represent a wide range of biologically active compounds which may have positive effects on animal growth and health (Christaki *et al.*, 2020; Gadde *et al.*, 2017; Zeng *et al.*, 2015). These reveal considerable properties such as antimicrobial, antiviral, antifungus, antioxidant, antiinflammatory, and immunostimulatory (Adaszyńska-Skwirzyńska and Szczerbińska, 2017; Diaz-Sanchez *et al.*, 2015; Ribeiro-Santos *et al.*, 2018). Aromatic medicinal plants have shown the ability not only to treat diseases but also to support growth performance in farm animals (Franz *et al.*, 2010; Windisch *et al.*, 2008).

Thyme is a multi-purpose medicinal herb belongs to a family of Lamiaceae distributed over the world. The green part of thyme constitutes the most popular herbal medicine and spice used all over the world (Khan *et al.*, 2012). Essential oil present in thyme mainly thymol (5-methyl -1-2- isopropyl phenol) and carvacrol (5-isopropyl -1-2- isopropyl phenol) have been linked to antibacterial, antifungal, antioxidant, antiproliferative, antiviral, anti-carcinogenesis, anti-inflammatory, antispasmodic, immunostimulators, reduce methane emission and acaricidal properties (Amirghofran *et al.*, 2011; Grosso *et al.*, 2010; Orłowska *et al.*, 2015a; Salehi *et al.*, 2018; Varel and Wells, 2007). Several researchers explore the use of thyme either as a dried powder or essential oil extract in animal nutrition as a feed additive and or included as feed supplement(Al-Mashhadani *et al.*, 2011; Botsoglou *et al.*, 2002; Boutoial *et al.*, 2013; Eshete *et al.*, 2012; Gadde *et al.*, 2017; Khamisabadi, n.d.; Nieto *et al.*, 2012). Thymol essential oil had beneficial effects on animal performance by enzyme stimulation and improve digestibility when utilized with other feedstuff (Hernandez *et al.*, 2004; Lee *et al.*, 2003a). Essential oil found in thyme is used in animal nutrition, in particular as a herbal feed additive to improve animal by a performance by increasing digestive system secretion, enhancing absorption and metabolism of nutrients and to reduce hazardous compounds/free radicals from interacting with cellular biological compounds (Aboelwafa and Yousef, 2015a; Bastos *et al.*, 2011; Lu and Wu, 2012; Williams, 2001). Therefore this paper aimed to review the use of thymus plant in animal nutrition and their biological activity.

Origin and distribution of Thymus plant

Thymus plantis a flowering plant of the family Lamiaceae commonly known as thyme, native to Europe, Asia and has a worldwide distribution (Dauqan and Abdullah, 2017; Hosseinzadeh *et al.*, 2015), native to the Western Mediterranean region, distributed over Europe, Asia, North Africa and the Canary Islands (Golmakani and Rezaei, 2008; Hadian *et al.*, 2014). Species of the genus Thymus are distributed throughout the arid, temperate and cold regions of the Old World north of the equator extending west to the coasts of Greenland (Morales, 1997). The origin of the *Thymus* genus is assumed to lie in South Europe, showing two different centres, i.e., the Iberian Peninsula (together with North West Africa) and the Balkan Peninsula (Orłowska *et al.*, 2015a). These plants are widely distributed throughout the world and have been used for many centuries in traditional medicine (Kirdok *et al.*, 2010). Thyme is cultivated in almost every country, as an aromatic for culinary uses (especially in the south of France, Spain, Morocco and North America (Weltgesundheitsorganisation, 1999).

In Ethiopia, *Thymus serrulatus* and *Thymus schimperi* are the common species of thymus plant which are locally called as *Tosign*(Damtie and Mekonnen, 2016; Jaafari *et al.*, 2007) while *Thymus Vulgaris* has been recently introduced (Derbie, 2009). *Thymus serrulatus* and *Thymus schimperi*are widespread to the Ethiopian highlands (Derbie, 2009), while.*Thymusvulgaris* is recently introduced into Ethiopia and cultivated in Wondogenet by the Essential Oil Research Center (Dagne *et al.*, 1998). *Thymus schimperi*is comparatively widespread in central, eastern and northern Ethiopia (Damtie and Mekonnen, 2016; Seifu, 2019). Bale, Shewa, Gonder, Jimma, Tigray and Wollo are the major growing areas in Ethiopia (Asfaw *et al.*, 2000; Kassegn, 2016; Parvez and Yadav, 2010). Generally speaking, thyme is an aromatic plant used for medicinal, flowering and ornamental and spice purposes almost everywhere in the world (Dauqan and Abdullah, 2017; Stahl-Biskup and Sáez, 2002).

Species of thymus plant

Thyme is the annual or perennial herbaceous plant that belongs to family Lamiaceae and consists of 250-400 species (Khan *et al.*, 2012; Stahl-Biskup and Sáez, 2002; Weltgesundheitsorganisation, 1999). There are numerous species of thymus plant almost all over the world and the most common are; Common thyme (*Thymus vulgaris*), Lemon thyme (*T. x. citriodorus*), Woolly thyme **(***Thymus pseudolanuginosus*), Creeping thyme **(***Thymuspraecox***)**, Wild thyme (*Thymusserpyllum*), Elfin thyme (*Thymusserpyllum***),** *Thymus schimperi*Ronniger and *Thymus serrulatus*. *Thymus vulgaris* is the most common and important species widely used as a flavouring agent, a culinary herb and a herbal medicine (Stahl-Biskup and Venskutonis, 2012).

Medicinal value

Thymus species are well known as medicinal plants because of their biological and pharmacological properties (Gumus *et al.*, 2017; Hadian *et al.*, 2014). Most aspects of medicinal use of *Thymus* species are related to their essential oil composition, which shows various levels of thymol and/or carvacrol (Grigore *et al.*, 2010; Zeghib *et al.*, 2017). Essential oil composition present in thymus species are investigated for their antibacterial, antifungal, antioxidant, antiproliferative, antiviral, anti-carcinogenesis, anti-inflammatory, antispasmodic and acaricidal properties which aid in maintaining health (Grosso *et al.*, 2010; Lawrence, 2005; Orłowska *et al.*, 2015b; Salehi *et al.*, 2018). According toHernández *et al.*, (Hernández *et al.*, 2018) thyme essential oil can extend the shelf-life of meat and baked goods and decontaminate lettuce inoculated with *Shigella*. According toDamtie and Mekonnen,(2016). *Thymus, serrulatus*and *Thymus schimperi*species found in Ethiopia are used to treat blood pressure, to treat general pain syndrome, influenza, abdominal pain, and to treat intestinal parasites like Ascaris.

The bioactive compound found in thyme decrease the activity of the cholesterol-synthesizing enzyme Hydroxymethylglutaryl Coenzyme A reductase, and thereby, decreases cholesterol levels of poultry (El-Ghousein and Al-Beitawi, 2009; Elson, 1995; Khaksar *et al.*, 2012). The study of Khaksar *et al.*, (Khaksar *et al.*, 2012) reported that supplementation of TEO significantly reduce the level of serum triglyceride, total cholesterol and glucose of Japanese quail. A study of Alamgeer *et al.*, (2014) found that an extract was able to significantly reduce heart rate in rats with high blood pressure, and it was also able to lower their cholesterol. A combination of thyme and ivy leaves helped to alleviate coughing and other symptoms of acute bronchitis (Kemmerich *et al.*, 2006). It is also soothing for sore throat, as thyme has antiseptic, antibiotic, and antifungal properties (Ekoh *et al.*, 2014).

Biological Activities

Anti-bacterial activity

Thymus plants are important medicinal herbs because these contain antimicrobial agents and different active phenolic substances such as thymol, carvacrol, terpinene and p-cymene (Demirci *et al.*, 2018; Liu *et al.*, 2017; Nascimento *et al.*, 2000; Šegvić Klarić *et al.*, 2007). (Palaniappan and Holley 2010) suggested that thymol can reduce bacterial resistance to common drugs, including penicillin. Essential oil of thyme and its major antibacterial agent thymol has been reported to possess antimicrobial impact both *in vivo* and *in vitro* against a wide spectrum of bacteria (Alali *et al.*, 2013; Burt *et al.*, 2005; Cerisuelo *et al.*, 2014; Di Pasqua *et al.*, 2006; Zhou *et al.*, 2007). Several researchers had been documented that antimicrobial properties of thymol molecule against several species of harmful bacteria such as *Vibrio parahaemolyticus, Vibrio harveyi, Lactococcusgarvieae, Pseudomonas, Salmonella, Listeria, Bacillus and Streptococcus iniae in in-vitro condition* (Ghasemi, 2010; Goudarzi *et al*., 2011; Gutierrez *et al*., 2008; Lu and Wu, 2012; Rassu *et al*., 2014; Soković *et al*., 2010). Radaelli *et al*., (2016) suggested that essential oil from thyme leaves was more effective against the growth of *Clostridium perfringens* bacteria than five other essential oils tested. The antimicrobial property of thymol might be due to the phenolic compounds which are suggested to interfere with the cell membrane of the bacteria thereby altering the internal pH and homeostasis (Boskabady *et al*., 2014; Kazemi Oskuee *et al*., 2011). Calsamiglia *et al.* (2007) suggested that the mode of action of the active compound found in thyme to destroy bacteria is by removing lipopolysaccharide membranes and increasing the permeability of cytoplasmic membranes.

Anti-oxidant activity

Antioxidants are compounds that inhibit oxidation of proteins, lipids, DNA or other molecules that occurs by blocking the propagation stage in oxidative chain reactions (Huang *et al*., 2005). Antioxidant compound maintain the nutritional quality of food when the added to food by minimizing the rancidity and hinder the formation of toxic oxidation products (Muanda *et al*., 2011). Several studies suggested that plants rich in antioxidants play a protective role in health and against diseases, and their consumption lowered risk of cancer, heart disease, hypertension and stroke (Elbashir *et al*., 2018; Lin *et al*., 2003; Muanda *et al*., 2011; Wintola and Afolayan, 2015). Researchers showed that the thymol and carvacrol content of thyme essential oil species possess strong antioxidant properties acting as radical scavengers, reducing agents, chelating transition metals, and inhibiting lipid peroxidation (Kindl *et al*., 2015; Nieto *et al*., 2011). Essential oil found in thyme exhibit a significant antioxidant effect in the serum and liver and significantly reduced the level of MDA (malondialdehyde), which is an indicator of tissue lipid peroxidation (Gumus *et al*., 2017; Lin *et al*., 2003). Essential oil extracted from plants like thyme are emerging as candidates for moderating the effects of the ageing process on skin by limiting biochemical consequences of oxidation (Angerhofer *et al*., 2009). Antioxidant activity of thymol is due to the presence of OH phenolic groups which donate hydrogen to the proxy radicals, produced during the first step in lipid oxidation, thus retarding the hydroxyl peroxide formation (Ezzat Abd El-Hack *et al*., 2016).

Anti-inflammatory activity

There are diverse medicinal plants with anti-inflammatory activities that are effective in the treatment of inflammatory conditions with low or no side effect (93). Plant extract shows anti-inflammatory activities by hindering the process involved in inflammation (Oguntibeju, 2018). Thyme essential oil like thymol is a promising compound to be used in controlling inflammatory processes present in many infections as well as wound healing (Braga *et al*., 2006; Ocaña and Reglero, 2012; Riella *et al*., 2012). Fachini-Queiroz *et al*., (2012) suggested that thyme essential oils are attributable to the inhibition of inflammatory oedema and leukocyte migration. Essential oil from thyme and oregano can reduce the production of pro-inflammatory cytokines, and thus mitigate trinitrobenzene sulfonic acid (TNBS) induced colitis in mice (Bukovská *et al*., 2007). The major active molecules with anti-inflammatory action are phenols, terpenoids and flavonoids and these molecules suppress the metabolism of inflammatory prostaglandins (FrAnKIČ *et al*., 2009).

Antiviral activity

Essential oils from eucalyptus, tea tree and thyme and their major monoterpene compounds has shown inhibitory activity against Herpes simplex virus (HSV) (Astani *et al*., 2009;

Nolkemper *et al*., 2006). Lai *et al*., (2012) suggested that thymol and carvacrol are potential candidates for topical therapeutic application to reduce herpes simplex virus transmission. Thymol is a promising candidate for topical therapeutic application as an antiviral agent for the treatment of herpetic infections(Sharifi-Rad *et al*., 2017). KazemiOskuee *et al*., (2011) stated that essential oils such as thymol could act as an antiviral agent beside its antibacterial and antifungal abilities. Several antiviral agents from essential of some herb could do its role by one of two ways; first is inhibiting the activity of viral reproduction and other is inhibiting the formation of viral DNA or RNA(Jassim and Naji, 2003). As compared to antiviral drugs, essential oils have demonstrated virucidal properties with the advantage of low toxicity (Baqui *et al*., 2001).

Immunomodulatory effects

Immunomodulatory agents originated from plant will increases the immune responsiveness of the body against pathogens by activating the non-specific immune system (Ramesh *et al*., 2012). Susceptibility to infectious diseases could be minimized by using immune-stimulators such as herbal elements (Alagawany and El-Hack, 2015; Pérez-Rosés *et al*., 2015).Thyme also has immunomodulatory effects and may be able to help treat autoimmune conditions (Mahmoodi *et al*., 2019). Thymol and oregano essential oil can increase the immune response of broiler chickens which increase the ability of the defence system to cope with infectious organism (Acamovic and Brooker, 2005; Pérez-Rosés *et al*., 2015).

Botsoglou *et al*., (2002) suggested that thymol could improve the immune responses of chicks as a result of its antiviral, antibacterial and antioxidant activities. Al-Kassie (2009) observed a significant increase in red blood cell, haemoglobin, white blood cell and hematocrit values in broilers fed diets supplemented with oil extract derived from thyme and cinnamon compared with the control group. Thyme essential oil in chicken and common carps *(Cyprinuscarpio*) diet can stimulate humoral immune response by increasing antibody titers and increase lymphocyte count (Mosleh *et al*., 2013; Soltani *et al*., 2010). Emeish and El-Deen, (2016) concluded that thyme and fenugreek can positively stimulate the immune system of *Clariasgariepinus* and decrease the mortality rate in fish challenged with *Aeromonashydrophila*. The results obtained by Amirghofran *et al*., (2011) showed that extracts of *Thymus vulgaris*, *Thymus daenensis*, *Zataria multiflora* had immunomodulatory effects on the proliferation of lymphocytes.

Antifungal activity

Essential oil and other plant extracts like saponins, terpenoids, alkaloids, phenolic compounds, peptides and proteins are investigated for antifungal activities (Edeoga *et al*., 2005; Panghal *et al*., 2011). The thyme essential oil possesses a wide range spectrum of fungicidal effect against many species of moulds such as Penicillium, Aspergillus, Ulocladium, Alternaria, Trichoderma and Rhizopus, Absidia and Mucor, Cladosporium and Chaetomium(Šegvić Klarić *et al*., 2007). Fogging broiler houses with thyme essential oils may be an effective prevention method against fungal aerosol in broiler houses (Witkowska *et al*., 2016). Essential oil of *Thymus vulgaris* and thymol possess strong antifungal properties against *Fusarium* mycelium (Alexa *et al*., 2018), *Candida* species (de Castro *et al*., 2015), *Rhizopusoryzae*(Mota *et al*., 2012), *Trichophyton rubrum and Aspergillus species* (Khan *et al*., 2014) and *Saprolegniaparasitica* (Mousavi *et al*., 2014). Essential oil from the two thyme species, *Thymus camphoratus* and *Thymus carnosus*were more active against *Cryptococcus neoformans* and dermatophytesand very effective in inhibiting *C. Albicans* germ tube formation (Alves *et al*., 2019). The antifungal activity of *thymus* essential oil could be probably due to the high concentration of oxygenated monoterpenes (thymol) and monoterpene hydrocarbons (ρ-cymene) (Farsaraei *et al*., 2017).

Anti-parasitic activity

Oral administration of essential oil extracted from the thymus plant (*T. Vulgaris*) reduce *Trichinellosis*by 79.4% in mice(Attia *et al.*, 2015)**.** In a lab study, thyme essential oil killed all *Anisakis* larvae (immature worms) within 14 hours (Giarratana *et al.*, 2014) and effective against *Entamoeba histolytica*(Behnia *et al.*, 2008). Nilforoushzadeh *et al.*, (2008) investigated that thyme essential oil reduces skin sores caused by *Leishmania* parasite. Thyme extract reduce parasitic cysts caused by Toxoplasmosis. *gondii* in the brain by 24% (Eraky *et al.*, 2016) and killed 79% of adult *T. spiralis* worms and 71% of larvae (Attia *et al.*, 2015). Dietary supplementation of a herb mixture (Thymus vulgaris, Melissa officinalis and Echinacea purpurea) reduced the number of Ascarissuum infected pigs (Gaasenbeek *et al.*, 2007; van Krimpen *et al.*, 2010).

Reducing enteric methane emission

To alleviate the problem in animal nutrition and possibly reduce greenhouse gas like CH_4 and CO_2 emitted from animals, the use of a natural product as feed additive gaining interests (Wallace *et al.*, 2002; Wenk, 2003). The antimicrobial properties of essential oil extract from the aromatic plant have been shown through invivo and in-vitro studies to inhibit rumen microbes and to control fermentation gas, VFA and livestock waste odours (Broudiscou *et al.*, 2000; Wallace *et al.*, 2002). This means thymol inhibit growth of *Selenomonasruminantium* HD4 and *Streptococcus Bovis* JB1 which ferment glucose to lactate, CO_2 and CH_4. Thymol molecule significantly reduces pathogens (*Escherichia coli, Campylobacter*), odour, methane, CO2, urea and ammonia emissions from livestock production facilities (Varel *et al.*, 2007; Varel and Wells, 2007). Essential oil interacts with the microbial cell membrane and inhibits the growth of bacteria (Aljaafari *et al.*, 2019), thus the addition of plant EO extracts to the rumen results in an inhibition of deamination and methanogens, resulting in lower ammonia N, methane, and acetate, and higher propionate and butyrate concentrations (Baraz *et al.*, 2018; Calsamiglia *et al.*, 2007).

Salman *et al.*, (2018) revealed that the cumulative amount of gas resulting from the addition of the three essential oils (cumin aldehyde, eugenol, and thymol) to alfalfa was significantly reduced Thymol an essential oil derived from thymus and origanum plants was a strong inhibitor of methane production in-vitro (Evans and Martin, 2000). Thyme essential oil at higher dose level reduced total gas production, enhance the bypass activity of feed protein, feed degradability and ammonia nitrogen (NH_3-N) concentration (Ahari *et al.*, 2011; Günal *et al.*, 2017; Roy *et al.*, 2015). The study of Castillejos *et al.* (2006) suggested that the addition of thymol to rumen cultures at 500–1000 mg/L significantly reduce ammonia-N concentrations.

There is a negative relationship between methane production and propionate formation in the rumen (Tekippe *et al.*, 2012). Acetate and butyrate promote methane production while propionate formation decrease methane production as propionate formation functions as an H_2 sink in the rumen when less H_2 is directed toward methane production (Günal *et al.*, 2017; Moss *et al.*, 2000). According to Evans and Martin (Evans and Martin, 2000) when mixed ruminal microorganisms were incubated in medium that contained glucose, 400 µg/ml of thymol, the final pH and acetate to propionate ratio increased and decreased concentration of methane, acetate, propionate and lactate.

However, thymol treatment also inhibited acetate and propionate, and these changes in fermentation end products would not be nutritionally beneficial to the host animal (Evans and Martin, 2000). Even though thymol treatment decreased methane and lactate concentrations and increased final pH in mixed ruminal microorganism fermentation of glucose, concentrations of acetate and propionate were also reduced (Evans and Martin, 2000).

Chemical composition of Thyme

The chemical character of thyme represented by two main class of secondary products, the volatile essential oil which is responsible for the typical spicy aroma of thyme and non-volatile polyphenols (Figueiredo *et al.*, 2010; Stahl-Biskup and Sáez, 2002; Vila, 2002). The predominant compound among the essential oil components was thymol followed by carvacrol, *ρ*-cymene, γ-terpinene, camphene, caryophyllene and humulene (Al-Asmari *et al.*, 2017; Borugă *et al.*, 2014; Farsaraei *et al.*, 2017). The other bioactive component found in thyme are caffeic acid, gentisic, acid, *p*-coumaric acid, syringic acid, ferulic acid,flavonoids and *p*-hydroxybenzoic acid (Kivilompolo and Hyötyläinen, 2007; Stahl-Biskup and Venskutonis, 2012). The yield of natural products (essential oil and polyphenols) and proportion of individual constituents vary due to intrinsic (seasonal and ontogenetic variations) and extrinsic (soil, climate, light) factors (Reddy V, 2014; Stahl-Biskup and Venskutonis, 2012). Carvacrol and thymol are only a plant material with high phenolic contents used for commercial interest.

Proximate Composition of thyme

There is a very few document published on the proximate composition of thymus plant. In Ethiopian, the chemical compositions of wild thyme grown in a different part of the country are demonstrated by a few researchers. Among the wild thyme grown in Ethiopia *Thymus schimperi, Thymus serrulatus*and *Thymus vulgaris* are the common (Dagne *et al.*, 1998; Damtie and Mekonnen, 2016; Derbie, 2009). The chemical compositions of thyme were tested from their aerial parts of the plant. The flower parts have high protein and ash content as compared to the leaves and whole plant part and contain a high amount of carbohydrate (Kassegn, 2016). The study of Eshete *et al.* (2013) indicated that the chemical composition of *Thymus serrulatus* was 97.4(DM), 87.0(OM), 7.15(CP), 65.8(NDF), 52.0(ADF), 29.9(ADL) and 10.4(Ash). The chemical composition of *Thymus schimperi recorded* by (Kassegn, 2016) was 89.05 (DM), 10.19(CP), 4.99(EE), 15.76(CF), 10.83(Ash), 57.48(CHO) and 315.75 Kcal/100g of energy. The other study done in Saudi Arabia on *Thymus capitatus*indicated that crude protein content of the thymus species is very low when compared to those species is found in Ethiopia. According to (Khalil *et al.*, 2012)*Thymus capitatus* contain 3.3(CP), 4.2 (EE), 18.1(CF), 50.7(CHO), 2.2(Ash), 94.0(DM).

Anti-nutritional factors

The phenolic compounds found in thyme and other herb contain either non-soluble compounds (condensed tannin and lignin) and soluble compounds such as phenolic acid (gallic acid, rosmarinic acids, etc.), flavonoids (catechin, quercetin, etc.), quinones, phenolic diterpenes (carnosol and carnosic acid) (Jiang and Xiong, 2016; Jimenez-Garcia *et al.*, 2013; Puvača *et al.*, 2015). The anti-nutritional factor mainly found in thyme is tannin (Stahl-Biskup and Venskutonis, 2012). The flower, leaf and the whole thyme parts exhibited anti-nutritional factor contents of condensed tannin of 0.2, 0.4 and 0.9 µg/100 ml and total phenolic content of 0.5, 0.2 and 0.3 µg/100 ml, respectively (Kassegn, 2016).

Thymus plant in livestock feed

Many countries have already banned the use of antibiotics in animal production due to harmful residual effects and cost-effectiveness (Castanon, 2007; Kumar *et al.*, 2014). Natural herb and medicinal plants like thyme essential oil and their extracts have increasingly gained interest due to their potential use as feed additives in livestock to improve their general health and promote growth (Khan *et al.*, 2012; Melo *et al.*, 2015; van Krimpen *et al.*, 2010). Due to a wide variety of active components, different herbs and spice affect nutrient digestion in different ways like stimulation of saliva secretion, enhance the synthesis of bile acids, stimulate the function of pancreatic enzymes and increase the activity of digestive enzymes of the gastric mucosa (FrAnKIČ *et al.*, 2009). Supplementation of some herbal/medicinal plants or their extracts to animal diets improve productive and reproductive performance, enhance feed efficiency, digestion and absorption of nutrient, improve gut microbiota composition, enhance immune functions, antioxidant status, carcass traits and quality, and lowered morbidity and mortality rates (Aboelwafa and Yousef, 2015b; Alagawany and El-Hack, 2015; Alavinezhad and Boskabady, 2014; Dhama *et al.*, 2015). Thymol an essential oil extracted from thyme is used in animal nutrition as a feed additive to improve performance and feed utilization through manipulation of digestive function and reducing hazardous compounds/free radicals from interacting with cellular biological compounds (Aboelwafa and Yousef, 2015a; Bastos *et al.*, 2011; Lu and Wu, 2012).EOs can increase the performance of swine and growing-finishing pigs, alleviate transport stress in finishing pigs, and increase reproductive performance of boars and sows (Wei *et al.*, 2020).

Effects on poultry production

Thyme is one of the alternative medicinal herbs and is reported to increase appetite and feed intake as well as the secretion of endogenous digestive enzymes, and to strengthen the immune system when added to poultry feed, owing to the phenolic compounds it contains (Aeschbach *et al.*, 1994; Brenes and Roura, 2010; Cross *et al.*, 2007a). Cross *et al.*, (Cross *et al.*, 2007b) reported that thymus plant could be considered as a natural growth promoter instead of antibiotics. Thyme significantly improves body weight, some blood parameters, gut microflora and feed conversion ratios in both broiler chickens and quails when used as a growth promoter (Abdel-Latif, 2002; Gumus *et al.*, 2017; Khaksar *et al.*, 2012; Tolba and Hassan, 2003) as well as dressing percentage, liver, heart, gizzard and decreased abdominal fat (Abdel-Latif, 2002; Al-Kassie, 2009); and increases both body weight and daily weight gain when added to poultry rations (El-Ghousein and Al-Beitawi, 2009). Thymol and carvacrol essential oil in thymus plant could reduce cecal populations of *Salmonella* prevalence, *C. jejuni*and *S.* Enteritidis in chickens(Cerisuelo *et al.*, 2014; Venkitanarayanan *et al.*, 2013).

Effects on broiler production

The beneficial effects of thyme on broiler performance have been reported either alone or in combination with other agents (Al-Mashhadani *et al.*, 2011). Several studies suggested that Broiler chickens diet supplemented with thyme essential oil increase in body weight gain, improve feed conversion ratio, livability and profit in broiler production(Cross *et al.*, 2007b; Mansoub, 2011a; Ragaa *et al.*, 2016; Wade *et al.*, 2018). Thyme essential oil may be used as an alternative growth promoter with positive effects on economic performance and immune response (Attia *et al.*, 2017; Zhang *et al.*, 2005). According to the study of Toghyani *et al.*,(Toghyani *et al.*, 2010)supplementing broilers' diet with 5 g/kg thyme can improve growth performance without any detrimental impacts on immune responses and blood parameters.

El-Ghousein and Al-Beitawi, 2009) suggested that the antibacterial action of thyme may be involved in the improved performance of broilers. Broilers fed diets containing thyme had improved apparent total faecal digestibility and crude protein digestibility, which may be responsible for the enhanced performance of broiler chicks (Hernandez *et al.*, 2004). Correspondingly, Lee *et al.* (2003b) found that thyme increased the activities of pancreatic digestive enzymes including amylase, lipase, trypsin and chymotrypsin in broilers and concluded that such enzyme stimulating effects may result in better feed utilization and nutrient availability.

Supplementing broiler chicken diet with a blend of thyme essential oils could enhance broiler growth performance and contribute to food safety by lowering the incidence of horizontal transmission of Salmonella Heidelberg infection (Amerah *et al.*, 2012) and a potential candidate for the prevention and treatment of necrotic enteritis caused by *Clostridium perfringens* (Jerzsele *et al.*, 2012). Jang *et al.*, (2007) observed a significant increase in activities of pancreatic amylase, maltase and trypsin in broiler chickens that received different blends of commercial essential oils.

Effect on laying hens

Several studies revealed that the dietary inclusion of thyme essential oil improve productive performance of laying hens. Ali *et al.* (2007) reported that the addition of thyme in the diet of laying hens improve FCR and egg production, fertility and hatchability and decrease LDL, HDL, total cholesterol and total lipids in blood plasma, liver and egg yolk. The other study concluded that dietary inclusion of garlic and thyme can have beneficial effects on the performance of laying hens in terms of improving yolk colour (Ghasemi, 2010). Mansoub (2011b) noted that laying hens fed thyme powder improved egg production and quality. According to the finding of Orhan and ÖLMEZ (2011) egg production, FCR, feed consumption, egg weight and eggshell breaking strength were unaffected by feeding thyme to laying hens. Inclusion of used 0.1 and 0.2% thyme in laying hens and found that egg production and egg mass, feed intake and FCR did not change in either group, however, egg weight increased in birds fed the 0.1% herbal product (Ghasemi, 2010).

Thyme in sheep feed

Supplementation of thyme mixed in the diet of sheep will improve feed intake, digestibility, daily weight gain, final body weight, hot carcass and dressing percentage as well as improve sensory quality of meet (Eshete *et al.*, 2013). An addition of thyme oil in sheep feed at different level will able to modify rumen fermentation by changing protozoal activity and motility and could approximately normalized the adverse effects of aflatoxin, perhaps attributed to its effect on ruminal pH and improving digestibility and animal performance (Abdel-Fattah *et al.*, 2010). Adding 1.25g/kg DM of thyme EO to high-forage diet improved ruminal fermentation on the 28th day (Ribeiro *et al.*, 2019). Thyme EO significantly ($P<0.05$) increased milk total solids, solid not fat, protein and lactose of Barki ewes (Abeer *et al.*, 2019). Incorporation of thyme and rosemary distilled leaves to the diet of sheep improve the fatty acid profile of lamb meat (Martínez, 2013).

Other use of Thyme

The organoleptic characteristics of the food are very important attributes influencing the consumers' preference (Christaki *et al.*, 2020). The plant-derived essential oils like thymus plant, beyond their antimicrobial and antioxidant properties, can play a promising role for food preservation by retarding microbial growth and oxidative deterioration (Martínez-Graciá *et al.*, 2015; Pandey *et al.*, 2017). Essential oils of thyme and other aromatic herbs have been playing a key role since antiquity in animal nutrition to enhance feed flavour and thus improve the palatability (Diaz-Sanchez *et al.*, 2015; Valenzuela-Grijalva *et al.*, 2017). Thymol an essential oil present in thyme and other herb has been added as flavouring agents to food such as fish, red and white meat (Hanahan and Weinberg, 2011). The study of Hernández *et al.*, (2018) showed that there is an opportunity to increase the value of dried meat and reduce the risk of foodborne illnesses by applying thyme essential oils (TEO) during the drying process. According to Hernández *et al.*, (2018) using TEO has two-fold advantages (there is a high demand from consumers to use natural products as alternative additives to improve food quality and reduce the risk of microorganism).

CONCLUSION AND FUTURE PERSPECTIVES

The use of natural feed additive in animal nutrition as a growth promoter is currently gaining interest in many countries since the restriction of antibiotic. Aromatic and medicinal herbs like thyme are distributed over the world and used in wide-area like pharmaceutical, cosmetics and veterinary medicine. The essential oil found in thyme has a wide range of biological activities such as antimicrobial, antioxidants, anti-inflammatory, antiviral activity, immunomodulatory effects, antifungal activity, and anti-parasitic activity. The antimicrobial properties of thyme essential oil have been shown through invivo and in-vitro studies to inhibit rumen microbes and to reduce the production of methane, carbon dioxide and livestock waste odors. The chemical character of thyme represented by two main classes of secondary products, the volatile essential oil which is responsible for the typical spicy aroma of thyme and non-volatile polyphenols. The predominant and commercially important compound present in thyme was thymol and carvacrol. The flower part of the thymus plant have high protein and ash content as compared to the leaves and whole plant part and contain a high amount of carbohydrate. Inclusion of thyme in animal feed will improve productive and reproductive performance as well as overall all health. Further studies are necessary to further define the activity of thymus plant on animal performance, to evaluate its safety and anti-nutritional factor found in the plant. A deep knowledge of thyme essential oil application for various purposes and mechanism of action will need further studies.

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