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BASIL, THYME AND SAGE HERBAL PLANTS AND THEIR ASSOCIATED ESSENTIAL OILS AS FEED ADDITIVES IN CHICKEN BROILERS. A LITERATURE REVIEW

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Abstract

The use of different herbal plants and their associate essential oils as feed additives is of great importance for various purposes in poultry production. This trend started since 2006 due to ban on use of certain antibiotics in poultry diets, in the European Union, because they are suspected of contributing substantially to increasing resistance among human pathogens. Some investigations have shown that a number of plant feed additives and their essential oils, have shown significant beneficial effects on animal production, health status and meat quality. These natural feed additives not only act as antibiotic replacements for the animals, but also exert beneficial properties in the poultry products, especially, antioxidant properties in meat. However, the overall efficacy of herbal plants and their associate essential oils, together with their nutritive value with impact on the health status of animals and humans (via the food chain), requires constant research on standardization of correct dosages for particular functions to be studied.

Key words: *broiler chickens, essential oils, feed additives, herbal plants.*

INTRODUCTION

For more than seven decades, antibiotics have been applied at low levels in monogastric feed to promote growth performance. Indeed, the antibiotics growth promoters have proved that they are capable to improve performance and decrease mortality in monogastric animals, but due to continue and excess uses of antibiotics in food for animal production has developed bacterial resistance to antibiotic growth promoters and created public health threats. Compared with synthetic antibiotics or inorganic chemicals, plant-derived products (phytobiotics of phytogenic feed additives) are natural, less toxic than antibiotics, and typically residue free. Phytobiotics includes a wide range of plant-derived products such as spices, and botanical products such as aromatic, medicinal plants, their extracts and mainly their essential oils and oleoresins. They can be added to the diet of commercial animals to improve their productivity through enhancing feed properties, promoting animals' production performance, and improving the quality of products derived from these animals (Vlaicu et al., 2022). In addition to the above-mentioned definition, Windisch et al. (2008) have recommended some other commonly used terms to classify different phytogenic compounds based on their origin and processing, including herbs (flowering, non-woody and non-persistent plants), spices (herbs with an intensive smell or taste commonly added to human food), essential oils (volatile lipophilic compounds) and oleoresins (extracts derived by non-aqueous solvents). After many studies have been conducted the results still have inconsistent effects on poultry performance, mainly due to differences in their botanical origin, processing, and composition or their huge variety of chemical substances (Reisinger et al., 2011). These plant-based feed additives may improve the palatability of feed which may lead to advanced performance, have verified potent antioxidative and antimicrobial efficacy in broilers. A number of *in vivo* studies show that phytogenic feed additives may specifically enhance activities of digestive enzymes and nutrient absorption. Also, numerous experimental studies provide further comparisons of phytogenic feed additives with antibiotics and their analogous actions in the intestine, thus reflecting an overall improved animal health (Riyazi et al., 2015a; Sheoran et al., 2017; Nouri, 2019). The efficacy on feed conversion ratio, daily weight gain, feed consumption, higher apparent ileal digestibility of nutrients was also reported (Windisch et al., 2008, Hong et al., 2012). In addition, specific compounds of some plants and their extracts have the potential to enhance products quality through different mechanism, due to their antioxidant potential (Untea et al., 2020; Vlaicu et al., 2022; Saracila et al., 2022). Among potential candidates, basil, thyme and sage and their essential oils represent an exciting group of feed additives, originating from *Lamiaceae* family. However, the future of using herbal plants in animal feeding will be in great measure depend on the knowledge of chemical structure, their value and characteristics of practical herbs or their extract physiological needs and well-being of animal, and, above all on consumer's preferences and expectations. In this context, this paper reviews the different aspects of application of basil, thyme and sage plants and their essential oils in diets of broiler chickens and their impact as phytogenic feed additives.

MATERIALS AND METHODS

Methodology of searching and selecting relevant articles

The present search was limited to article having full text available in English. Databases used included Web of Science, PubMed, Google Scholar, Springer Link, Springer Nature, MDPI and Elsevier. Primary search keywords used were basil, thyme, sage, essential oils, herbal plants, herbs, herbal formulations, chicken broilers, antioxidant effect, performances, etc. Searches were also done using the taxonomic names of the plants. Bibliographies of included studies were also searched for additional references. Book chapters, proceedings of conferences, if available online have been also incorporated wherever possible to best extent of their availability and access. From literature survey we found substantial number of papers which described mostly the chemical composition of the plants and their associate essential oils with antioxidant, antimicrobial, anticoccidial and growth promoting effects, used in different combinations. Based on the extensive search performed, the results are presented in divided sections classified based on the most effective effects described found. From over 150 research articles and review papers found, we included only those from 2006 till present, the rest of them being excluded, because the ban of antibiotics started from that year.

RESULTS AND DISCUSSIONS

Description of the reviewed herbal plants

Basil is the common name for the culinary herb *Ocimum basilicum* of the family *Lamiaceae* (Table 1). It has been widely used in traditional medicine in the treatment of headaches, coughs, constipation, diarrhoea, warts, worms, and kidney problems (Falowo et al., 2019). Also, various pharmacological actions have been described, such as stomachic, antioxidant, antiviral, antimicrobial, analgesic, anti-inflammatory, antidiabetic, and anti-stress activities, and emmenagogue properties, among others (Bilal et al., 2012). It is widely cultivated for the production of essential oils and also marketed fresh, dried, or frozen. Essential oils extracted from fresh leaves and flowers can be used as aroma additives in food, pharmaceuticals, and cosmetics and has been shown to possess antifungal, insect-repelling and toxic activities (Nadeem et al., 2020).

Table 1. Classification according to the Integrated Taxonomic Information System - Report

Item	Basil	Thyme	Sage
Kingdom	Plantae	Plantae	Plantae
Subkingdom	Viridiplantae	Tracheobionta	Viridiplantae
Superdivision	Embryophyta	Spermatophyta	Embryophyta
Division	Magnoliophyta	Magnoliophyta	Tracheophyta
Class	Magnoliopsida	Magnoliopsida	Magnoliopsida
Subclass	Asteranae	Asteridae	Asteranae
Order	Lamiales	Lamiales	Lamiales
Family	Lamiaceae	Lamiaceae	Lamiaceae
Genus	Ocimum L.	Thymus L.	Salvia L
Species	Ocimum basilicum L.	Thymus vulgaris L	Salvia officinalis L

Chemical investigations have shown that basil contains various active compounds, such as flavonoids, tannins, saponin, glycosides, terpenes and steroids (Lee et al., 2005), antioxidant capacity, polyphenols, vitamin E, luthein and zexanthin, minerals, especially zinc (Vlaicu et al., 2022).

Thyme (*Thymus vulgaris*) is a medicinal plant of the family *Lamiaceae* and has anticough, antibloating, antimicrobial, antifungal, and antispasmodic properties. Thyme is rich in carotenoids, fatty substances, bitter compounds, and a high level of manganese. Thyme essence contains pinne, deptante, carvacrol, and thymol, but its disinfecting property contains thymol and timic acid (Miraj & Kiani, 2016). Its oil also has antimicrobial activity against gram-positive and gram-negative bacteria (*Salmonella typhimurium, Clostridium perfringens, and hilcopilari*). Thyme was identified as useful herbal plant as natural additives in poultry diets. The studies in which thyme was tested, claims that compared with synthetic antibiotics, thyme may be used without any adverse effects (Bampidis et al., 2005). However, due to its compounds such as carvacrol, parasymon, and thymol, could present some side effects, which restrict its utilization in high dosages. Thymol is a phenol used as antiseptic and as stabilizing agent in drug products. Carvacrol is the main ingredient in the essential oil, insoluble in water but soluble in alcohol and ether (Seidavi et al., 2021).

Sage *(Salvia officinalis)* is a perennial green shrub with woody stems, greyish leaves, and blue to purplish flowers in the family of *Lamiaceae*. It grows worldwide and in traditional medicine, it has been used for the treatment of seizure, ulcers, gout, rheumatism, inflammation, dizziness, tremor, paralysis, diarrhea, mild dyspsia, and hyperglycemia (Garcia et al., 2016). Many researchers have investigated the common uses of sage and found different pharmacological functions such as anticancer, anti-inflammatory, antioxidant, antimicrobial, antimutagenic, hypolipidemic and hypoglycemic (Ghorbani & Esmaeilizadeh, 2017). It has been reported that the extract of sage exerted significant antibacterial activity against different bacterial species (*Bacillus mycoides, Bacillus subtilis, Enterobacter cloacae,* and *Proteus* spp.) (Stanojevic et al., 2010). Moreover, Kermanshah et al. (2009) found that the hydroalcoholic extract of sage has strong inhibitory effect on *Streptococcus mutans*, *Lactobacillus rhamnosus*, and *Actinomyces viscosus*. These demonstrated effects make sage as a valid alternative source to the traditional antibiotics (Khalil & Li, 2011; Hamidpour et al., 2014). As presented in Figure 1, there are many reasons for which we should use plants or essential oils as new generation of feed additives.

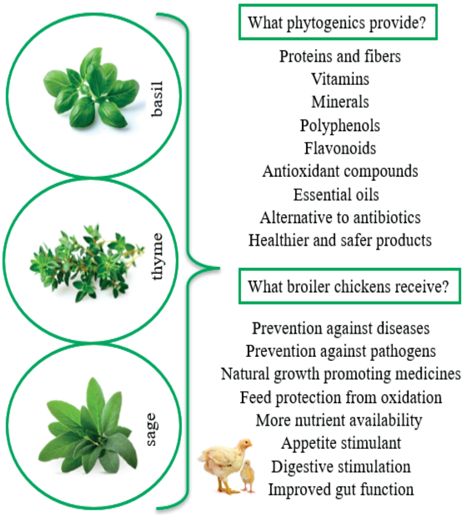

Figure 1. Schematic representation of benefits from using plants as feed additives in broiler diets

Chemical composition of basil, thyme and sage plants

Literature data revealed that the chemical composition of these herbs is very variable. Gurbuz& Ismael (2015) reported that crude protein in basil was 22.08% and 25.52% crude fiber content. Thyme is scarce in crude protein (5.23%) but with higher crude fiber (18.10%) content (Gerencsér et al., 2014). A very low concentration of crude protein in sage (1.3%) was reported by Khalil et al., (2012) but the content of crude fiber (31%), was the highest compared with basil and thyme.

Recently, Turcu et al. (2020) reported that thyme and sage have similar crude protein content (14.67% and 14.19%) but lower than basil (18.06%). Same authors, showed that the crude fiber content in these plants in relatively high (10.88% in basil, 20.24% in sage and 24.63% in thyme), which could be a limiting factor for their usage in broiler diets. Besides its high nutritional value, basil is also rich in vitamins, (C, E, K, A, β- carotene, B complex), minerals (Fe, Ca, Mg, P, Mn, Na, K, and Zn), and it also contains many secondary metabolites, (essential oils, phenols, flavonoids, anthocyanins, tannins, and steroids) (Filip, 2017). Similarly, it was reported that thyme contains minerals such as Zn, Ca, K, Na, Fe, P. The plant is also a rich source of many important vitamins such as B-complex, folic acid, beta carotene, vitamin A, K, E and C. Thyme is capable to provide about 0.35 mg of vitamin B6 which represents about 27% of daily recommended intake (Komaki et al., 2016).

Sage is also rich in minerals (P, Na, Fe, Ca, Cu, N, K, Mg, Zn) with significant contents of vitamins from which Vitamin C was the most abundant and variable (0.24 to 615.8 μg/mL) as reported by Yaman (2020).

Chemical composition of their essential oils

Essential oils are composed of a complex mixture of active substances extracted from plants through a steam distillation process or generated via chemical synthesis.

The concentration of the biologically active components in essential oils is variable and dependent on the species, the part of the plant used, soil, environmental conditions, and time of harvest (Lee et al., 2004). These substances can produce several beneficial effects, but the most important is to increase animal performance (Zhang et al. 2005).

The chemical composition of basil leaves examined by gas chromatography showed that estragole (52.60%) and limonene (13.64%) are the dominants components followed by p-cymene (2.32%) and exo-fenchyle acetate, as reported by Chalchat & Özcan (2008).

The thyme extraction revealed that the two major components comprise of thymol (60.18%) and p-cymene (15.44%) and small quantities of other constituents including carvacrol (Ahmad et al., 2014).

The composition of sage essential oil is composed by cis-thujone (18–43%), trans-thujone (3–8.5%), camphor (4.5–24.5%), 1,8-cineole (5.5–13%), α-humulene (0–12%), α-pinene (1–6.5%), camphene (1.5–7%), limonene (0.5–3%), linalool, and bornyl acetate (2.5% maximum) as reported by Bettaieb et al., (2009).

Main activities and uses of basil, thyme and sage plants and their essential oils

The *Lamiaceae* family contains important aromatic plants used in traditional and modern medicine, in the food and pharmaceutical industries (Figure 2). Rosemary, basil, thyme, oregano, and sage are the most popular plants in Eastern European countries for traditional remedies and are often used for the treatment of gastritis, infections, dermatitis, bronchitis, and inflammation. Some of these plants have been extensively studied for their antioxidative and antimicrobial activity.

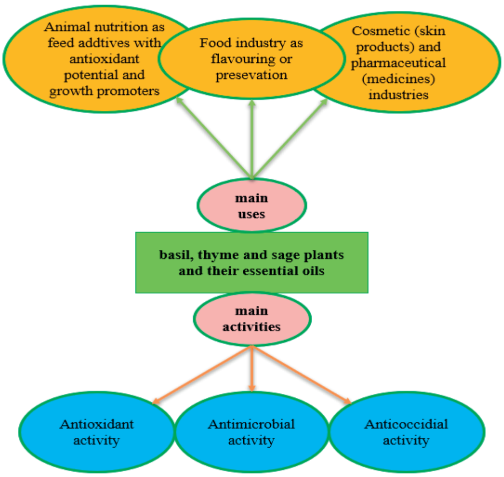

Figure 2. Overview of the main uses and activities of basil, thyme and plants and their essential oils

The vegetation of many European countries is rich in aromatic plants, for this reason makes these countries the major producers and processors of medicinal plants. Sage is mostly exploited for the extraction of essential oils of importance for the pharmaceutical, agronomic, and food industries. Basil and thyme are aromatic plants that are used extensively to add a distinctive aroma and flavour to food. The leaves can be used fresh or dried for use as a spice. Essential oils extracted from fresh leaves and flowers can be used as aroma additives in food, pharmaceuticals, and cosmetics (Javanmardi et al., 2002; Shahrajabian et al., 2020). The extracted essential oils are of scientific and popular interest because they may act synergistically with other techniques of preservation. Some studies reported that basil (Riyazi et al., 2015b), thyme (Saracila et al., 2021), sage (Traesel et al., 2011), rosehip (Vlaicu et al., 2017) oregano and rosemary (Mathlouthi et al., 2012; Turcu et al., 2018) oil extracts present antidiarrheal and anti-inflammatory properties and antimicrobial activity against different harmful bacteria and other microorganisms. They are generally recognized as safe (FAO, 2010), and they show antioxidant, antibacterial, antidiabetic, antimutagenic, non-toxigenic, and antimycotic properties which are promising for their use as bioactive compounds in different foods and feeds (Saad et al., 2013). However, even if FAO recently recognised essential oils as safe, they are used since 16 th century, when Paracelsus used the term essential oil to name the effective component of each drug as *"quinta essentia"* (Freires et al., 2015). Nevertheless, care must be taken because essential oils can also produce toxic effects in chickens when used in high doses and it was reported that they may be dose dependent (Zhang et al., 2005).

Antioxidant activity of the reviewed plants and their essential oils

The antioxidant properties of many plants have been investigated, in the light of recent scientific developments, throughout the world due to their potent antioxidant activities. Due to carcinogenic effects of synthetic antioxidants, such as butylated hydroxy anisole (BHA), butylated hydroxy toluene (BHT) and tert-butyl hydroquinone (TBHQ) which are banned in Japan and certain European countries, research for a safer and effective natural antioxidant is underway and several natural feed additive sources are being examined. The basil plants are among the most important crops which essential oils stand out for the quality, quantity and chemical diversity. As reported by Turcu et al. (2020) basil plant presented high antioxidant capacity and moderate concentration of polyphenols when compared with other plants. Also, basil contains a wide range of essential oils rich in phenolic compounds and a wide array of other natural products including polyphenols such as total phenolics, phenolic acids, flavonoids and anthocyanins (Flanigan & Niemeyer, 2014). Of the phenolics, rosmarinic, cichoric caftaric and caffeic acids, have been characterized with the highest antioxidant activities, in basil (Baâtour et al., 2012). However, the composition of these compounds determined in basil varies among species, cultivars, plant part, and origin.

Another natural feed additive with high antioxidant capacity, polyphenols content and vitamin E is thyme (Turcu et al., 2020). Thyme contains high concentrations of phenolic components which are primarily responsible for its antioxidative activity. The most dominant phenols in thyme are thymol (12–61%) and carvacrol (0.4–20.6%), followed by 1,8-cineole, ρ-cymene, linalool, borneol, α-pinene and camphor (Dogu-Baykut et al., 2014). However, according to the World Health Organization, thymol residues in food are without danger to the consumer as long as they do not exceed 50 mg/kg (FAO/WHO, 2008).

Alongside with rosemary and oregano, sage has been showed to have the strongest antioxidant activity among the reviewed plants. The antioxidant activity in sage plant given by the total phenolics varied from 50.3 mg GAE/g to 167.1 mg GAE/g (Tosun et al., 2009; Turcu et al., 2020). The main effective phenols have been shown to be phenolic acids, carnosol derivatives, and flavonoids, namely, rosmarinic acid, carnosic acid, and carnosol followed by caffeic acid, rosmanol, rosmadial, genkwanin, and cirsimaritin (Farhat et al., 2014). Some of these phenolic compounds presented excellent scavenging activity of active oxygens such as superoxide anion radicals, hydroxyl radicals, and singlet oxygen, which further inhibit lipid peroxidation (Shivakumar and Yogendra, 2018) and increase the antioxidant capacity in meat (Vlaicu et al., 2021). For this reason, their corresponding extracts have been used to stabilize the fat content and shelf-life in products. However, the use of herbal plants and their essential oils as antioxidants in food industry still faces the problems of the interactions with food matrix components (fat, protein and starch), alteration of sensorial characteristics of foodstuff at high concentration, sensitivity to heat, light and oxygen during processing, utilization and storage, given by their high volatile character.

Antimicrobial activity of the plants and their essential oils

It is known that multidrug-resistant bacterial pathogens have raised a growing public health threat. For this reason, antibiotic-resistant microorganisms have been an ever-growing concern over the past years. Therefore, there is a continuous need for effective natural compounds to be used instead of synthetic ones. The investigations of herbal plants for their biologically active constituents have gained the attention of research communities as new sources of feed additives with antimicrobial activities. The medicinal plants contain various metabolites that demonstrate antimicrobial activity in vitro and vivo against harmful pathogens. The most concerning microorganisms are *Escherichia* coli, *Pseudomonas aeruginosa, Klebsiella pneumoniae, Acinetobacter baumanii, Helicobacter pylori, Mycobacterium tuberculosis*, penicillin-resistant *Streptococcus pneumoniae, Shigella, and Salmonella* (Abreu et al., 2012). Previously, many plants, essential oils and secondary metabolites derived from herbal plants from multiple countries/regions were tested against microbes that cause various infections (Verma et al., 2012; Gnat et al. 2017; Vlaicu et al., 2017; Turcu et al., 2018; Saracila et al., 2018). It has been also proven that plants with antimicrobial activity support more antagonistic endophytic bacteria against human pathogenic microbes due to their useful essential oils with antimicrobial properties (Nikolic et al., 2014). The natural antimicrobial agents present in thyme (thymol) have proven its effectiveness in medical, food, agricultural and veterinarian (Glenn et al., 2010) applications. Thymol is able to inhibit development of some bacteria, including the potential pathogenic strains of *Escherichia* coli, *Bacillus subtilis*, and *Staphylococcus aureus* (Qader et al., 2013). It was reported that beside thymol, its isomer carvacrol, as well as citronellal, eugenol from essential oil demonstrate antibacterial activity (Guimarães et al., 2019). The antimicrobial activity of thymol and carvacrol is much more effective due to their synergistic effect, compared with pure thymol (Burt et al., 2013). The aqueous extract of sage exerted significant antibacterial activity against different bacterial species such as, *Bacillus mycoides, Bacillus subtilis, Enterobacter cloacae*, and *Proteus* spp., making it as a valid alternative source to the traditional antibiotics (Stanojevic et al., 2010). These beneficial results are given by the plant extracts which exhibit the beneficial action by disrupting microbes' cell membrane; by stimulating and replicating the beneficial bacteria growth in gut, defending intestine from microbial attack; by stimulating the proliferation and growth of absorptive cells in gut; and by enhancing the production of digestive enzymes.

Anticoccidial activity of the plants and their essential oils

Coccidiosis represents a serious threat to the poultry industry, affecting production and causing high morbidity, mortality and significant costs resulting from treatment and prophylaxis. Coccidiosis is a parasitic disease caused by seven species of the genus *Eimeria* with different localizations within the intestinal tract of chickens. *Eimeria acervulina*, *Eimeria maxima* and *Eimeria tenella* are the most prevalent species in broilers in the intensive poultry management system (Haug et al., 2008). In-feed anticoccidials have been used for decades for managing avian coccidiosis and were very effective until drug resistance emerged. The use of natural remedies has become a promising alternative in combating coccidiosis in chickens. Among the most important areas of performance improvement for broiler chickens has been the advance in the use of feed additives with beneficial bioactive compounds that can protect against bacteria and parasites. Among other, the reviewed plants and their essential oils represent potential source of bioactive compounds that could be used as a natural growth enhancer with potent anticoccidial properties. As mentioned before, basil and thyme are naturally rich in thymol and carvacrol as major constituents. They are promising bioactive compounds because they can interfere with the membrane permeability of pathogens, causing a cascade of reactions that involve the entire cell and eventually leads to its death, as it was mentioned before (Nazzaro et al., 2013). Previously it was reported that they exerted an antiparasitic activity on *Eimeria* spp. and disrupted the invasion of *Eimeria tenella* (Burt et al., 2013; Jitviriyanon et al., 2016). Besides that, numerous other plant-based products have been found to be effective at treating chicken coccidiosis and intestinal pathogens. Some examples are thyme plant (Lahlou et al., 2021), sage extract (Arczewska-Wlosek & Swiatkiewicz, 2012), artemisia annua

(Saracila et a., 2017; Jiao et al., 2018), oregano (Vlaicu et al., 2018; Turcu et al., 2018; Sidiropoulou et al., 2020), garlic (Pourali et al., 2014), turmeric (Kim et al., 2013) and many others essential oils or plants mixtures. However, no information found regarding basil effect on anticoccidial activity. Nevertheless, the majority of these natural compounds do not always aim directly at the parasites but have immunomodulatory effects and antioxidative or anti-inflammatory properties which act on the intestinal tract, thus helping the host organism to fight against the coccidia and pathogens infection (Wunderlich et al., 2014; Vlaicu et al., 2020b). Beside the above mentioned main biological activities, these feed additives exhibit also antiviral, antibacterial, antifungal, anti-inflammatory, immunostimulatory effects and enhance the enzymatic activity in the intestinal tract when used in broilers diets. Moreover, these feed additives are excellent natural sources of growth and health promoting activities as presented in Figure 3.

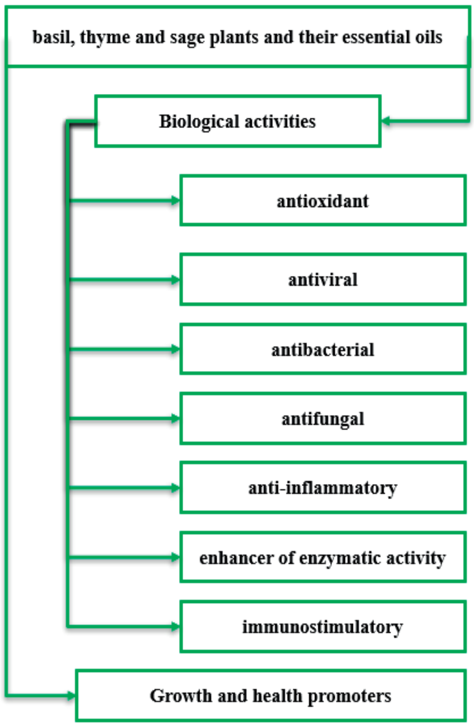

Figure 3. Major biological activities exhibited by herbal plants and essential oils used as feed additives in poultry

Growth and health promoting effect of reviewed plants and their essential oils in broiler chickens' diets

It has been mostly reported that addition of herbal plants and their associate essential oils to diets has growth promoting effect on broilers (Table 2). Gurbuz et al. (2016) compared the effect of 1% versus 1.5% of basil on broilers performance and obtained significantly ($P<0.05$) higher feed conversion ratio compared with control treatment. They suggested that 1% basil significantly increased the final body weight of chicken broilers compared with 1.5% basil or peppermint plant. Abbas (2010) has conducted an experiment feeding broilers with 3 g/kg basil and observed significantly ($P<0.05$) improved body weight. Higher quantity of basil (3%, 4% or 5%) showed that body weight, body weight gain and feed conversion ratio were significantly ($P<0.05$) increased as compared with the control, and significantly ($P<0.05$) decrease feed intake compared with the control group (Al-Kelabi, 2013).

The essential oils derived from basil plant (200, 400 and 600 ppm) in combination with probiotic (150 ppm) and antibiotic (150 ppm) had no effect on broilers performances in Arian broilers hybrids, but significantly decreased the total bacteria counts ($P<0.05$), without affecting the colony-forming units of lactobacilli (Riyazi et al., 2015a, b). Contrary, Elnaggar & El-Tahawy (2018), reported that 10 and 20 g/kg of basil powder and 0.5 and 1 g/kg basil essential oil on broilers diets significantly ($P<0.05$) improved body weight, with significant improvements in blood parameters and meat edible parts. The use of thyme at 5g/kg or 10 g/kg thyme powder and 0.5g/kg or 1g/kg thyme essential oil on broilers diets significantly ($P<0.05$) improved body weight as reported by Elnaggar & El-Tahawy (2018) and enhanced the health status by significantly decreased serum triglycerides and cholesterol. Significant body weight on broilers was also noted at 2% thyme with decreased feed intake and mortality (El-Ghousein & Al-Beitawi, 2009). Contrary, 100 or 200 ppm thyme essential oil, was reported to increase feed intake (Al-Kassie, 2009) but with increase final body weight. In addition, 0.2%, 0.5% or 0.8% of thyme plant produced beneficial effects on health status by increasing the immune status of birds (Hassan, & Awad, 2017; Ahmadian et al., 2020). The essential oil of thyme extract (thymol) at 0.04% inclusion level was reported to increased intestinal populations of beneficial bacteria such as *Lactobacillus* in broilers (Nouri, 2019). However, some reports showed no effects of thyme on broilers diet (Demir et al., 2008; Dahal & Farran et al., 2011). Limited studies have been documented to identify the effects of sage plant or essential oil in broilers feed, which makes sage a new unexploited source of feed additive. Hernandez et al. (2004) reported that a mixture of essential oils which contained sage, had no differences in feed intake, feed conversion or organs development, however improved apparent fecal digestibility of dry matter and ether extract. Also, 50, 100, and 150 mg/kg of essential oils of oregano, sage, rosemary, and pepper increase the health status of broilers, as reported by Traesel et al. (2011).

Table 2. Effect of application of plants and their essential oils in chicken broiler nutrition

Item	Obtained results	Reference
Basil	1% and 1.5% basil showed significantly ($P<0.05$) higher feed conversion ratio as compared with peppermint and control treatments; 1% basil significantly increased the final body weight of chicken broilers	Gurbuz et al., 2016
	3 g/kg basil significantly ($P<0.05$) improved body weight and reduced serum cholesterol compared with the control and fenugreek diets, but with no effect on carcass quality	Abbas, 2010
	3%, 4%, 5% basil revealed that significantly ($P<0.05$) increased body weight, body weight gain and feed conversion ratio in Hubbard chickens as compared with the control, and significantly ($P<0.05$) decrease feed intake compared with the control group.	Al-Kelabi, 2013
	200, 400 and 600 ppm basil essential oil with 150 ppm probiotic and 150 ppm antibiotic had no effect of broilers performances, but 200 ppm basil essential oil supplementation significantly ($P<0.05$) decreased abdominal fat	Riyazi et al., 2015a
	200, 400 and 600 ppm basil essential oil with 150 ppm probiotic (Protexin) and 150 ppm antibiotic (Avilamycin); used on Arian broilers significantly decreased the total bacteria counts ($P<0.05$), without affecting the colony-forming units of Lactobacilli	Riyazi et al., 2015b
	10 and 20 g/kg of basil powder and 0.5 and 1 g/kg basil essential oil on broilers diets significantly ($P<0.05$) improved body weight, economic efficiency and production index compared to control; also, significantly decreased serum triglycerides and cholesterol. All supplementations increased percentage of dressing and total edible parts compared with control.	Elnaggar & El-Tahawy, 2018.
	1% of basil in Cobb 500 broiler chickens increased ($P<0.05$) gizzard weight, total polyphenols content and the antioxidant capacity; lowered cholesterol content in breast meat muscles and altered the instrumental color and textural parameters.	Vlaicu et al., 2021
	0.5% basil in Cobb 500 chickens significantly ($P<0.05$) increased the antioxidant parameters and in MDA level with a significant controlling and prevention effect on Escherichia coli infection.	Kilany et al., 2018
	0.5% and 1.0% of basil powder in Ven Cobb broiler diets, improved ($P<0.05$) body weight gain, feed conversion efficiency and immune status by augmenting the T-cell mediated immune response.	Sheoran et al., 2017
Thyme	100 and 200 ppm essential oil, increased feed intake, body weight and FCR, dressing percentage, organs and decreased abdominal fat	Al-Kassie, 2009
	5 and 10 g/kg thyme powder and 0.5 and 1g/kg thyme essential oil on broilers diets significantly ($P<0.05$) improved body weight, economic efficiency and production index compared to control; also, significantly decreased serum triglycerides and cholesterol. All supplementations increased percentage of dressing and total edible parts compared with control.	Elnaggar & El-Tahawy, 2018
	300 mg oil increased only body weight in broilers diets	Al-Mashadani et al. 2011
	2% thyme increased body weight, organs development, decreased feed intake and mortality	El-Ghousein and Al-Beitawi 2009
	5g/kg increased body weight gain compared with antibiotic supplemented diet	Toghyani et al. 2010
	the addition of 0.5% of thyme powder to 1-day-old Cobb chicks for 35 days improved the immune status and antioxidant activities in broilers while the lipid peroxidation of meat was reduced	Ahmadian et al. 2020

	supplementation at lower levels, 0.2–0.8%, produced benefits in weight gain and immune status	Hassan, & Awad 2017
	0.04% thymol increased intestinal populations of Lactobacillus and Escherichia coli have increased in broilers	Nouri, 2019
	1% of thyme in Cobb 500 broiler chickens increased ($P<0.05$) gizzard weight, total polyphenols content and the antioxidant capacity; lowered cholesterol content in breast meat muscles and altered the instrumental color and textural parameters.	Vlaicu et al. 2021
	No effect on performances	Dahal and Farran et al. 2011.
	70 mg/kg diet of thyme in Ross-308 broilers increased abdominal fat pad	Ocak et al., 2008
Sage	2.5 or 5.0- and 7.5-mL sage extract / kg were included in the diets of Alectoris chukar partridges, no effect was found in performances, carcass development or blood parameters.	Yurtseven et al., 2008
	5.000 ppm extract from sage, thyme, and rosemary in broilers diet had no differences in feed intake, feed conversion or organs development, however improved apparent fecal digestibility of dry matter and ether extract	Hernandez et al., 2004
	1% of sage in Cobb 500 broiler chickens increased ($P<0.05$) gizzard weight, total polyphenols content and the antioxidant capacity; lowered cholesterol content in breast and thigh meat muscles and altered the instrumental color and textural parameters.	Vlaicu et al., 2021 Vlaicu et al., 2022
	50, 100, and 150 mg/kg of essential oils of oregano, sage, rosemary, and pepper increase in serum levels of lipase, uric acid, urea, and aspartate aminotransferase however it is suggested that they may cause kidney and liver impairment, with no effect on performances.	Traesel et al., 2011
	0.05% or 0.1% sage oil improved weight gain, feed conversion ratio and immunity status, while decreased the serum cholesterol, triacylglycerol and abdominal fat	Kishawy et al., 2016
	100, 200, 300 and 400 ppm of essential oil in Ross 308 broiler diets resulted in no differences among treatments for body weight gain, feed intake and feed conversion ratio; decreased serum cholesterol, triglycerides and low-density lipoprotein; significantly ($P < 0.05$) enhanced the immunity response with additional significant ($P < 0.05$) bactericidal effect for Escherichia coli.	Rasouli et al., 2020
	0.5% of sage powder used in Ross 308 broilers significantly ($P \leq 0.05$) increased body weight and reduced feed conversion ratio; 0.2% of sage powder increased the immunity titers against Newcastle disease and avian influenza viruses; plasma cholesterol, triglyceride, and low-density lipoprotein (LDL) concentration were reduced and high-density lipoprotein (HDL) concentration was increased significantly	Farhadi et al., 2020

Basil, thyme and sage plants and their essential oils as antioxidants in broiler meat

The antioxidant activity of herbal plants and their essential oils is another biological property of great interest, due to their ability of scavenging free radicals which may play an important role in preventing some diseases (i.e., cancer and heart diseases) caused by free radicals. The content of active substances and the chemical composition of herbal plants and their extracts in the final products may vary widely depending on the plant parts used, geographical origins, and harvesting season as mentioned early. It has also been suggested that the benefits of the use of essential oils of plants is often variable because it depends on all the constituents working together, however, plenty of studies have indicated the antioxidant activity of their usage (Miguel, 2010). The potential effect of herbal plants from the Labiatae family containing phenolic compounds on improving the oxidative stability of poultry meat (Kilany et al., 2018; Ahmadian et al., 2020; Vlaicu et al., 2021) was previously investigated. The use of 1% of basil, thyme or sage in broilers diet was very effective on improving the antioxidant activity in breast meat of broilers (Vlaicu et al., 2021). Significant improvements were also reported on meat quality at 0.5% or 1% levels of basil inclusion (Kilany et al., 2018). The addition of 0.5% of thyme powder to broilers for 35 days improved the antioxidant activities in meat by reducing the lipid peroxidation of meat (Ahmadian et al., 2020). Gheisar et al. (2015) reported that the thiobarbituric acid reactive substances (TBARS) value of breast meat was significantly reduced by the herbal plants blend containing thyme, oregano and rosemary. It was also reported that thymol reduced the oxidation of fatty acids indicated by the lower malondialdehyde level in meat (Placha et al., 2014). It can be concluded that these significant improvements regarding the antioxidant activity of *Labiatae* family plants on broilers meat may be due to their contents of phenolic compounds.

CONCLUSIONS

This review concludes the fact that plant cultivars vary in their nutrient concentrations. This variability in chemical composition, minerals, antioxidant compounds and fatty acids can be attributed to the moment of harvest, climate genotype and storage conditions, temperature, light, soil type and other conditions, which further could lead to different results when tested on chickens' meat quality. There are many advantages of using plants than antibiotics. The future of using plants and essential oils in animal feeding will in great measure depend on the knowledge of chemical structure, their value and characteristics of herbal plants or their extracts physiological needs and well-being of animal, and, above all on consumer's preferences and expectations. As a consequence of the reduced number of cows but an increased milk yield, milk production has continuously increased, except the year 1995 when it recorded the lowest level.

The North Eastern region is traditionally suitable for cow rearing, due to its pastures and meadows, the important number of cow livestock and possibilities to produce ecological milk.

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