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Review Article

Essential Oils as a Feed Additive in Poultry Nutrition

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ABSTRACT

The increased awareness and concern over the antibiotic residues in animal and poultry products among the consumers made the hour a prime time to find an alternative to antibiotic growth promoters (AGPs) and it have increased a lot over the past decade. One such alternative is the essential oils (EOs) which are derived from various plants as secondary metabolites. Essential oil usage in animal feeding has been practiced for their role as antibacterial, antiviral, antifungal, antioxidant, digestive stimulant, immunomodulator, hypolipidemic agent and also heat stress alleviator. They had been successfully used as a dietary antibiotic replacer without residues. They not only act as an *in vivo* anti-oxidant for the animal but also exert its anti-oxidant action to prolong the shelf life of the feed in which it is incorporated and the meat which is obtained from the animal fed with essential oils. The lean meat produced by essential oil supplementation through the poultry diet reduces the risk of hyperlipidemia in the consumers. The results being favourable as an alternative to antibiotics, spur the researchers to exploit the role of essential oil mixtures as a feed additive. Nowadays, essential oils are used in the ruminant experiments as an agent to reduce the rate of methanogenesis thereby traffics the organic molecules for efficient energy synthesis. Hence, various studies have been carried out across the globe with possible combinations and cocktail of these oils or the crude extracts of their active principles to explore the multifaceted calibre of these feed additives. The expanding horizons in the research on essential oils are expected to pull the curtain down for the extensive use of antibiotics as feed additives. In the near future the role of essential oils in the poultry feeding will play a huge role in the industry development.

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INTRODUCTION

The dietary use of antibiotics has been practised for decades in animal production especially in commercial poultry production as a growth promoter. The need for the use of antibiotics to decrease the spread of disease (Waldroup et al., 2003) and as a growth enhancer is increasing day by day to sustain the growth of poultry production (Roura et al., 1992). The opportunistic pathogens that are normally inhabitant of the intestinal tract may reduce the growth rate and is related with the microbial load of the chicken's environment (Thomke and Elwinger, 1998). Antibiotics act on pathogenic intestinal bacteria that will produce toxins that harm the birds either in terms of livelihood or production performance. Antibiotics used in this way get accumulated in the tissues of birds leading to antibiotic resistance in human through food chain ultimately ending up in therapeutic failure (Levy and Marshall, 2004).

Many countries have banned the use of antibiotics in animal production as a feed additive. Hence the need of the hour is to find an alternative to antibiotics. Therefore, search for antibiotic alternatives have already been undergoing to control the enteric diseases (Fritts and Waldroup, 2003; Ayed et al., 2004) which is encouraged by the World Health Organization (Humphrey et al., 2002). The quest for the alternatives to antibiotics has been tried by many scientists like Langhout, (2000); Mellor, (2000); Wenk, (2000) and Humphrey et al., (2002). Humphrey et al. (2002) found that lactoferrin and lysozyme are having the antibacterial activity and can be used as an alternative to antibiotics in chickens as feed additive. Rectenly, Essential Oils (EOs) are found to have antibacterial property and also exhibiting antioxidant, antiinflammatory, anticarcinogenic, digestion–stimulating and hypolipidemic activities (Viuda–Martos et al., 2009, 2011). Considering the versatility of EOs, it can be used as growth promoters in animal production.

What are Essential Oils?

EOs are derived as a mixture of aromatic oily liquids obtained from plant materials such as flowers, buds, seeds, leaves, twigs, bark, herbs, wood, fruits and roots. They are fragrant volatile compounds, named after their origin (Oyen and Dung, 1999). The term '*essential*' was proposed by Paracelsus in his theory of '*quinta essentia*' who believed that this quintessence was the effective element in a medical preparation (Oyen and Dung1999) but the term '*volatile oil*' had been proposed in medieval pharmacy (Hay and Waterman, 1993). Essential oils

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were obtained by various methods like expression, fermentation or extraction but the method of steam distillation is the most commonly used method commercially. They are categorized as "generally recognized as safe" (GRAS), as endorsed by the Flavour and Extract Manufacturers Association (FEMA) and the Food and Drug Administration (FDA) from the U.S.A., and used in the food industry. The use of EOs in enhancing productivity gives promising results as growth and health promoter.

Classification of Essential Oils

EOs are basically comprises two classes of compounds: Terpenes and Phenylpropenes. Terpenes are sub–divided based on the 5–carbon isoprene unit (building block) into mono, sesqui and diterpenes where the numbers of isoprene units are 2, 3 and 4 respectively, while the phenylpropenes consist of 6–carbon aromatic ring with a 3–carbon side chain (C_6–C_3 compounds). More than 1000 monoterpenes and 3000 sesquiterpenes are identified until today (Clegg et al., 1980; Cooke et al., 1998).

Essential Oil Synthesis

The terpenes and phenylpropenes are synthesized by mevalonic and shikimic pathways, respectively. Mevalonic acid (six carbons) that is formed by condensation of three acetate units by HMG–CoA reductase, is converted to 5–carbon isopentenyl pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP), which are the activated 5–carbon units of isoprene. IPP and DMAPP are then combined in a 1:1 molar ratio to generate 10–carbon geranyl pyrophosphate (GPP), the precursor of monoterpenes. The conversion of IPP to GPP produces the 15–carbon sesquiterpene compound, farnesyl pyrophosphate (FPP). Thymol and carvacrol are derived from GPP and classified as monoterpenoids or isoprenoids. β–ionone is derived from FPP and thus classified as either sesquiterpene or isoprenoid. Classification of essential oils is given in figure 1

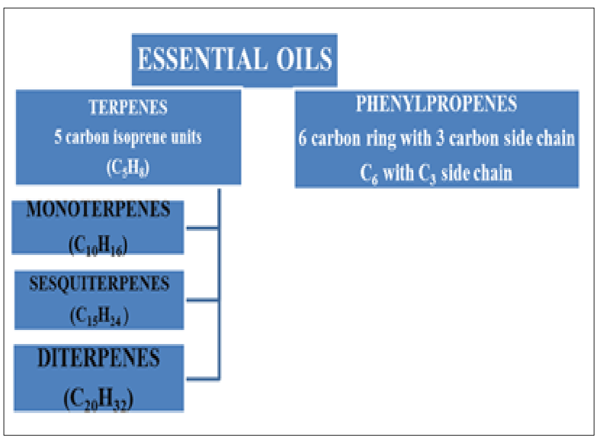

Figure 1: Classification of essential oils

The shikimic acid pathway produces the aromatic amino acid phenylalanine, the products of which are cinnamic acid and p–coumaric acid, occurring in trans–configuration (Seigler, 1998). Among the important phenylpropene compounds are eugenol, trans–cinnamaldehyde, safrole and also the pungent principles, capsaicin and piperine. These are classified as phenylpropenoids. The synthetic pathways and the related compounds are reviewed in more detail elsewhere (Loza–Tavera, 1999).

Properties of Essential Oils

Essential oils possess the characteristic odours that are specific to that oil. They exist either in liquid or volatile form at the ambient temperature. They are readily soluble in common organic solvents like ether, benzene, acetone, etc. Most of the EOs are lighter than water with specific gravity between 0.8 and 1.17 but the clove and cinnamon oils are heavier.

Uses of Essential Oils in Poultry Feeding

The EOs have wide range of activities in system like anti–bacterial, antioxidant, digestive stimulant, hypolipidemic, growth promoter, immunomodulator, antimycotic, antiparasitic, antitoxigenic, antiviral and insecticidal. But the most important uses of EOs are reviewed here. Beneficial activities of essential oils are summarized in figure 2

Figure 2: Benefits of essential oils

Antimicrobial Activity

The antimicrobial activities of EOs were exploited from the ancient period (Hammer et al., 1999). This property has kindled the interest of researchers to use it as an antibiotic alternative. The pure compounds have been shown to have antimicrobial effects in vitro (Cowan, 1999). Cinnamaldehyde derived from Cinnamon strongly inhibits *Clostridium perfringens* and *Bacteroides fragilis* and moderately inhibits *Bifidobacterium longum* and *Lactobacillus acidophilus* isolated from human faeces (Lee and Ahn, 1998). This property of selective inhibition of intestinal pathogenic bacteria can be exploited to balance the microbial population in the poultry intestine.

The antimicrobial properties of 29 essential oils were evaluated against 59 microorganisms (Deans and Ritchie, 1987) and this property differs with the family it belongs, like Lavandin, Tea tree and Peppermint oils have shown a little or no antimicrobial property but Cinnamon, Oregano, Thyme have shown great antimicrobial activity, while Juniper shows an antifungal activity (Dorman and Deans, 2000, Royo et al., 2010).

The exact mechanism of antimicrobial activity is poorly understood. The cell membrane is the main site of action. It may be due to the change in the permeability of cytoplasmic membrane to hydrogen (H^+) and potassium (K^+) ions (Deans and Ritchie, 1987). Their hydrophobic nature makes them more active against Gram positive bacteria and the small molecular weight of these oils makes them active against Gram negative bacteria too (Deans and Ritchie, 1987).

Antimicrobial Action of Individual Essential Oils

1. Carvacrol and thymol causes disintegration of the membrane of bacteria and hence leading to the release of membrane–associated material from the cells to the external medium.
2. Terpenoids and Phenylpropanoids can penetrate the membrane of the bacteria due to their lipophilicity and reach the inner part of the cell.

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3. The antifungal activity of cinnamaldehyde (Kurita et al., 1979) due to its reaction with sulfhydryl groups which is necessary for the growth of the fungi. The formation of charge transfer complexes with electron donors in the fungal cell could lead to inhibition of cell division and thus interferes with cell metabolism.
4. It was also reported that cinnamaldehyde inhibits fungal cell wall synthesizing enzymes (Bang et al., 2000).
5. The combination of probiotics and essential oils inflicted a decrease of microbial load in the intestine.
6. Garlic oil has been shown to inhibit *E. coli* and *Salmonella* Typhimurium during in vitro studies (Ross et al., 2001).

Table 1 shows the In vitro studies on essential oils for its antimicrobial activity and minimum inhibitory concentration (mic,ppm).

Microorganisms	MIC values (ppm)			References
	Carvacrol	Cinnamadehyde	Thymol	
Escherichia coli	450	396	450	Helander et al., 1998
Escherichia coli	225	NT	225	Cosentino et al., 1999
Staphylococcus aureus	450	NT	225	Cosentino et al., 1999
Candida albicans	150	NT	150	Ali–shtayeh et al., 1997
Candida albicans	113	NT	113	Cosentino et al., 1999
Candida albicans	200	200	NT	Ferhout et al., 1999
Pseudomonas aeruginosa	500	NT	500	Ali–shtayeh et al., 1997
Pseudomonas aeruginosa	›900	NT	›900	Cosentino et al., 1999
Salmonella Typhimurium	150	396	150	Helander et al., 1998
Salmonella Typhimurium	225	NT	56	Cosentino et al., 1999
Streptococcus mutans	125	250	250	Didry et al., 1994
Streptococcus mitis	125	125	125	Didry et al., 1994

Table 1: Antibacterial activity and Minimum inhibitory concentration (MIC, ppm) of EOs
NT- Not tested

Blends of EOs could be used to control *Clostridium perfringens*; Thymol can inhibit the growth of S. Typhimurium and *E. coli* (Helander et al., 1998).

Hernandez et al. (2003) showed, in a study with live chickens, that a blend of the EOs of cinnamon, pepper, and oregano improved digestibility in chickens receiving supplemental feed compared with chickens fed a control diet without the blend. Several studies indicated that the use of EOs improved broiler feed conversion ratio (Windisch et al., 2008).

Thyme essential oil (TEO) fed to Japanese quail reduced the ileal *E. coli* and increased the *Lactobacillus* count (Figure 3) on 35 days of feeding (Khaksar et al., 2012).

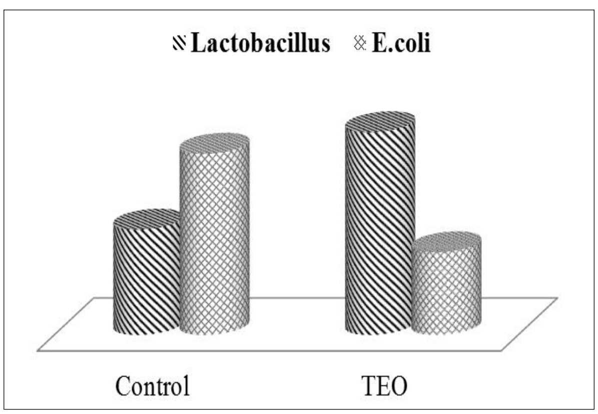

Figure 3: Ileal Count of J. quail fed with Thyme essential oil (TEO)

Essential oils in addition to its antimicrobial activity also possess various activities like antioxidant property (Krause and Ternes, 1999; Botsoglou et al., 2002a), hypocholesterolemic activity (Yu et al., 1994; Case et al., 1995; Craig, 1999), flavouring agent and also has digestive stimulant properties (Langhout, 2000; Williams and Losa, 2001).

Antioxidant Activity of Essential Oils in the Biological System

Essential oils have good antioxidant role in biological system. EOs acts as effective free radicals scavenger (Youdim and Deans, 1999 and 2000). EOs influences the *in vivo* antioxidant defense systems such as SOD, glutathione peroxidase and Vit E. Oregano essential oil possesses high antioxidant activity (Cervato et al., 2000; Dorman et al., 2003) and enhances oxidative stability of fat–containing animal products like meat and eggs by compensating the increased degree of unsaturation (Bauer et al., 2001; Botsoglou et al., 2002b)

In Vitro Studies

Economou et al. (1991) assessed the antioxidative properties of various extracts of plant oils like oregano, thyme, marjoram, spearmint, lavender and basil which was added to lard kept at 75 °C. He assessed the antioxidant property by their effectiveness in stabilizing the lard and found out that extract containing Oregano (Raza et al., 2009) was the most effective followed by thyme, dittany, marjoram and lavender. Studies of Schwarz et al. (1996) reported that compounds like β–cymene–2, 3–diol, thymol and carvacrol (Baratta et al., 1998) were found in thyme showed strong antioxidant properties.

Farag et al. (1989) carried out a study to find out the relationship between the antioxidant property of the essential oils and its chemical composition, and found that the high antioxidant activity of thymol is due to its phenolic OH groups acting as hydrogen donors to the peroxy radicals which are produced during the lipid oxidation and thereby reduce the hydroxyl peroxide formation.

In Vivo Studies

The antioxidant effect of essential oils in broiler chicken has been reported by the studies of Lopez–Bote et al. (1998); Botsoglou et al. (2002a, b). Botsoglou et al. (2002b) found that Oregano essential oils exert its antioxidant property on the cell membrane of meat and abdominal fat. EOs acts as effective free radical scavengers and enhances the *in vivo* antioxidant systems – superoxide dismutase, glutathione peroxidase and vitamin E. Botsoglou et al. (1997) found that lower concentration of malonaldehyde in chicken egg yolk feed with thyme and related it to the transfer of antioxidant components but its effect

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disappeared soon after the stop of supplementation. Thymol and carvacrol have antioxidant activity on egg and chicken meat when supplemented in the feed (Lee and Marshall, 2004).

Phenols in olive oil are effective non–tocopherol antioxidants (Baldioli et al., 1996), have antioxidative property (Papadopoulos and Boskou, 1991), free radical scavenging ability (Visioli et al., 1998), act as a specific antioxidant on bio-membranes (Saija et al., 1998) and inhibit the low density lipoprotein oxidation (Wiseman et al., 1996; Visioli et al., 1998).

Essential Oil as Flavouring Agent

Essential oils are used as flavouring agent in human foods. Carvacrol can be used in non alcoholic beverages up to the level of 26 ppm and in baked goods up to 120 ppm (Furia and Bellanca, 1975). Cinnamaldehyde can be used as low as 8 ppm in ice cream products and as high as 4900 ppm in chewing gum (Furia and Bellanca, 1975). Thymol and beta–ionone are also used as flavouring agents in foods. The characteristic flavour of essential oils can be used to standardize the diet so that there is no alteration in feed intake post weaning in piglets. Specific effects of flavours on chicken performance have not received much attention because poultry may not acutely respond to flavour when compared to pigs (Moran, 1982). With the limited literature, there is evidence (Deyoe et al., 1962) that flavours could affect feed intake. On the other hand, the effects of flavours on poultry performance are regarded as negligible (Moran, 1982). Hence the aspect of essential oil as flavouring agent in poultry nutrition needs to be assessed.

Essential Oils on Digestive Processes

There are studies that dietary essential oils addition could improve the digestion process (Mellor, 2000), the reason behind the use of spices and herbs (from which essential oils are derived) in food (Pradeep and Geervani, 1994). They enhance the trypsin and amylase enzyme activity (Jang et al., 2007). The pungent principles in essential oils like curcumin, capsaicin and piperine have been found to stimulate the digestive enzyme activities of both intestinal mucosa and also in pancreas (Platel and Srinivasan, 2000). Studies have shown that the spices or its active components increased the bile salt secretion (Sambaiah and Srinivasan, 1991). Cinnamaldehyde increased the bile secretion in the rat (Harada and Yano, 1975). The pungent principles capsaicin, piperine and cinnamaldehyde share their synthetic pathways (shikimic pathway). Lee et al. (2003) reported that cinnamaldehyde in diet had a role in the digestion process while thymol is not involved in these processes. Kreydiyyeh et al. (2000) observed that there was an increase in the absorption of glucose in the intestine of rats when they were fed with anise oil.

Role of Essential Oils in Lipid Metabolism

Craig (1999) reported that the herbs and its essential oils have a role in cholesterol lowering activity and by doing so they provide protection against cancer. The hypocholesterolemic effect of lemongrass oil is due to the inhibition of hepatic 3–hydroxy–3–methylglutaryl coenzyme A (HMG–CoA) reductase activity which is a key regulatory enzyme in cholesterol synthesis (Elson et al., 1989, Cooke *et al.*, 1998, Crowell, 1999).

Case et al. (1995) reported in poultry, a 5% inhibition of HMC–CoA reductase activity will lead to lowered serum cholesterol by 2%. Qureshi et al. (1988) fed cockerels with limonene at 25 to 100 ppm for a period of 26 days and found that the hepatic HMG–CoA reductase activity as well as the serum cholesterol show a dose–dependent decrease, however, the hepatic fatty acid synthetase activity remained unaffected. Dietary essential oils like borneol, cineole, citral, geraniol, menthone, menthol, fenchone and β–ionone suppresses the hepatic HMG–CoA reductase activity (Yu et al., 1994). Middleton and Hui (1982) reported that the inhibitory action of essential oils on hepatic HMG–CoA reductase is independent of the diurnal cycle of the enzyme and of hormones like insulin, glucocorticoids, triiodothyronine and glucagon. Study by Gopi et al. (2012) reported a significant reduction in the serum cholesterol level of broiler fed with cinnamon powder at 250 and 500 ppm (97.43 and 94.87 mg/dl *vs* 116 mg/dl). The broilers showed a dose dependent reduction in serum cholesterol levels.

Essential Oils in Meat Type Chickens

The essential oils as single or mixture may be used as a growth promoter in broiler production. Many studies have shown positive effects of dietary essential oil on body weight. Supplementing the dietary essential oils (Cross et al., 2002, 2007; Bampidis et al., 2005) would stimulate the growth performance of broilers. Higher body weight gain was observed in broilers fed with peppermint diet (Lovkova et al., 2001). The essential oils act as digestibility enhancer, optimizing the gut microbial ecosystem, stimulates the secretions of digestive enzymes and improves the growth performance in poultry (Lovkova et al., 2001; Williams and Losa, 2001; Cross et al., 2007). Ocak et al. (2008) supplemented a mixture of herbal essential oils to broilers and found a significant reduction in feed intake which was also observed in the study performed by Lee et al. (2003). When broilers were fed with essential oil mixture at levels of 24 and 48 mg/kg diet there was better feed conversion ratio and the mortality was reduced when fed with 0.2% of peppermint and thyme diets separately than groups fed with control diets during the 42 days growth period (0.00 and 0.00 *vs* 2.88% respectively). Denli et al. (2004) observed improved feed efficiency when the broiler quails were fed with thyme essential oils. They reported that the improvement in feed efficiency and feed intake achieved with essential oil mixture could be due to its positive effects on nutrient digestibility as reported by Langhout (2000a); Alcicek et al. (2003); Hernandez et al. (2004); Lee et al. (2003) interpreted that essential oil and their mixture could positively affect the intestinal microflora and thus digestion. Fotea et al. (2004) observed best average body weight of 2484g at the age of 42 days and 4% improvement in feed efficiency when broilers fed with 1.0% Oregano oil. Essential oils mixture of 200 ppm of oregano, anise oil, clove, rosmarin and tumeric plant have shown improvement in the growth performance of live broilers (Jamroz and Kamel 2002; Al–Sultan Zhang et al., 2003 2005). Gopi et al. (2012) reported that there was improvement in body weight gain in broilers fed with cinnamon powder at the rate of 500 ppm and 250 ppm (2109 and 1982 *vs* 1947 g). The feed efficiency was significantly better in supplemented group compared to control group (1.79 and 1.83 *vs* 2.03).

Thymol and carvacrol, from thyme and oregano respectively, have demonstrated biological properties such as antimicrobial, antioxidant and antiseptic activities (Lee and Ahn, 1998). Although evidence of the underlying mechanisms is still lacking by which dietary EO affect growth performance, dietary supplementation of EO has a beneficial effect on intestinal microflora (Helander et al., 1998) and digestive enzymes (Lee et al., 2003; Jang et al., 2007). Total and specific activities of trypsin in the pancreas were significantly ($P<0.05$) greater in blend EO at 50mg/kg. Total activity of maltase in the proximal region was much greater ($P<0.05$) in birds fed with 50 ppm of EO than those fed with basal diet or the diets containing antibiotics and 25 ppm of EO (Jang et al., 2007).

The efficacy of EO on growth performance in poultry is not consistent as it was supplemented to the diets at the levels of 20–200 mg EO/kg diet. Botsoglou et al. (2004) reported that supplementation of essential oils to diet had no beneficial effect on body weight. Similar observation was also made by Hernandez et al. (2004) who found that the addition of two

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plant extract to the diet had no effect on body weight and also Madrid et al. (2003) carried out studies on the blend of oregano, cinnamon and pepper essential oil on broiler performance. Hernandez et al. (2004) and Botsologlu et al. (2004) found that the addition of plant extracts to the diet had no beneficial effect on feed conversion ratio.

Cross et al. (2007) reported that dietary thyme had a different effect when used as herb or oil on weight gain and body mass. Essential oils or the main components of the essential oil did not affect the body weight gain or feed efficiency in broilers (Cross et al., 2002, 2007; Demir et al., 2003; Botsoglou et al., 2004; Hernandez et al., 2004; Bampidis et al., 2005).

The body weight of broilers fed with curcumin at the level of 0.1% was significantly ($p<0.05$) more (2273.39 ± 52.97) when compared to the control (1947.83 ± 41.39) and turmeric powder (2151.89 ± 55.16) fed groups (Mehala and Moorthy, 2008 and Moorthy and Edwin, 2010). The feed intake was significantly ($p<0.05$) more in curcumin (4504.76 ± 90.66) and turmeric powder (4256.65±93.04) supplemented groups than control (3954.22 ± 83.24). AL–Sultan (2003) observed improved feed consumption and increased average body weight in broilers fed with turmeric supplemented diets. Feed conversion ratio did not differ significantly.

The serum glutathione peroxidase (mg/ml) and ascorbic acid (mg/ml) contents were better in turmeric powder and curcumin fed groups compared to the control group. Chattopadhyay et al. (2004) and Holovska et al. (2003) observed increase in plasma antioxidant enzyme levels due to the supplementation of antioxidants in the diet of broilers. Rezaei–Moghadam et al. (2012) has also reported that supplementation of turmeric increases serum antioxidant levels. The immune status of the birds as assessed by RD titre values ($\log_2$) was found to be better in essential oil supplemented at 0.1% (7.0) and essential oil supplemented at 0.2% (6.75) groups as compared to control group (6.6). Madpouly et al. (2011) reported that turmeric powder in poultry rations enhances the immune response. Jamroz et al. (2005) also demonstrated increased pancreatic and intestinal lipase activity in broilers diets fed with added plant extract.

Essential Oils in Egg Laying Chickens

Supplementation of a diet with a mixture powder of garlic and thyme assisted in improving performance of laying hens and egg quality traits (Ghasemi et al., 2010). Plant extracts and spices as single compounds or as mixed preparations can play a role in supporting both performance and health status of animals (Alcicek et al., 2003; 2004; Cabuk et al., 2006). Essential oil addition significantly increased egg production than the addition of the antibiotic. Essential oils significantly reduced the incidence of broken/cracked eggs. An essential oil mixture was the only additive to significantly improve feed efficiency compared to the control. Dietary supplementation with essential oil mixture also improved ($P < 0.01$) feed efficiency. A similar result was observed by Ather (2000), who reported that the addition of essential oils of a polyherbal feed additive to a broiler breeder diet showed better average egg production compared to their control. Deying et al. (2005) found that a diet supplemented with herbal medicine (*Ligustrum lucidum* and *Schisandra chinensis*) significantly improved egg production and feed efficiency of laying hens. Botsoglou et al. (2005) was unable to find any significant effect on either on the egg production nor the feed efficiency on dietary addition of rosemary, oregano and saffron to the layers.

The performance of laying hens during the summer season can be maintained with dietary inclusions of essential oil mixtures. The results with essential oils during summer season have anti–heat stress effects (Liu–Fengtlua et al., 1998). Summer stress leads to drop in egg production, more egg breakage and mortality. To alleviate heat stress in poultry during summer season herbs such as tulsi, ashwagandha, amla, curry leaf, garlic and turmeric powder were evaluated in broiler chicken birds. Among the various herbal preparations screened, amla followed by ashwagandha (*Withania somnifera*) were found to increase the body weight, immune status, serum antioxidant levels and general health of the commercial broiler birds (Vasanthakumar et al., 2012a). The inclusion of essential oil mixture at the rate of 24 mg/kg diet significantly improved egg production, feed efficiency and reduced the percentage of cracked/broken eggs (Cabuk et al., 2006).

The preliminary findings by author with fenugreek seeds improved the semen quality in broiler breeder birds and thereby significant improvement in hatchability is expected. Further studies are in progress both in broilers and breeder hens to derive concrete results.

CONCLUSION

The antimicrobial activities of essential oils have been well documented while its toxicological effects are seen only at very high doses. The antioxidant and hypocholesterolemic effects have been studied in chickens. The characteristic flavour and stimulation of digestive process of essential oils might play role in poultry performance, however, it requires further studies. The hypolipidemic and immunomodulatory properties of these oils are gaining more interest among the poultry industrialists. The antioxidant property of these oils provides an effective protection against the drip loss during the prolonged low temperature storage which increases the acceptance among the consumers and reduces the loss for the meat processors. To conclude, the essential oils in the poultry diet could be used as an alternative to antibiotics, growth performance and value added products – low cholesterol meat, tenderness, green eggs, etc. Its role in improving the keeping quality and durability of raw as well as processed meat and nutraceutical property is also gaining importance. In the near future, it is expected that essential oils will play a huge role in the poultry industry development.

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