Journal of Medicinal Plants and By-products (2014) 1: 1-12

Review Article

Application of Medicinal Plants in Poultry Nutrition

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Article History: Received: 21 September 2013/Accepted in revised form: 31 May 2014

Abstract

Application of most antibiotic growth promoters as feed additives has been banned in a lot of countries due to cross-resistance against pathogens and residues in tissues. Therefore, scientists are searching for alternatives to antibiotics nowadays. Medicinal plant extracts are one of the alternatives that have anti-microbial and growth promoting effect on poultry. In this paper, the benefits of using of medicinal plants such as Garlic (*Allium sativum* L.), Cumin (*Cuminum cyminum* L.), Black Cumin (*Nigella sativa* L.), Wild Mint (*Mentha longifolia* L.), Pumpkin (*Cucurbita pepo* L.), Thyme (*Thymus vulgaris* L.), Cinnamon (*Cinnamomum zeylanicum* Nees), Chestnut (*Castanea sativa* Mill.) wood, Clove [*Syzygium aromaticum* (L.) Merr. & L.M.Perry], Yucca Schidigera, Alfalfa (*Medicago sativa* L.), Turmeric (*Curcuma longa* L.), Sumac (*Rhus coriaria* L.), Common mushroom [*Agaricus bisporus* (J.E.Lange) Emil J. Imbach], Grape (*Vitis vinifera* L.) seed, Goldthread (*Coptis chinensis* Franch.), Mulberry leaf (*Morus alba* L.), and Honeysuckle (*Lonicera japonica* Thunb. ex Murray) on poultry production are discussed.

Key words: Feed additive, Medicinal plant, Growth promotion, Poultry

Introduction

After the usage of most antibiotic growth promoters as feed additives have been banned by the European Union due to cross-resistance against pathogens and residues in tissues, scientists have searched for alternatives to antibiotics. In this view, aromatic plants and essential oils extracted from these plants are becoming more important due to their antimicrobial effects and the stimulating effect on animal digestive systems [1]. Useful antimicrobial phytochemicals can be divided into several categories: phenolics and polyphenols (simple phenols, phenolic acids, quinones, flavones, tannins, and coumarins), terpenoids and essential oils, alkaloids, and lectins and polypeptides [2]. The beneficial effects of botanical additives in poultry (broilers, layers, broiler breeders, and layer breeders) may arise from the positive effect on feed intake, digestive secretions, immune stimulation, antibacterial, coccidiostatical, antiviral or anti-inflammatory activity. In plant tissues, pH values are dependent on the presence of poly-carboxylic acids, phosphate salts, fiber and proteins [3]. The active constituents in the leaves, stem, seeds, roots and barks of these medicinal plants are highly effective to combat different diseases and improve the digestion that in turn could improve the performance of the recipients [4]. To differentiate the plant products used for veterinary purposes (prophylaxis and therapy of diagnosed health problems), phytobiotics were redefined by Windisch and Kroismayr [5] as plant derived products added to the feed in order to improve performance of agricultural livestock. With respect to biological origin, formulation, chemical description and purity, phytobiotics comprise a very wide range of substances and four subgroups may be classified: 1) herbs (product from flowering, non-woody and non-persistent plants), 2) botanicals

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(entire or processed parts of a plant, e.g., root, leaves, bark), 3) essential oils (hydro distilled extracts of volatile plant compounds), and 4) oleoresins (extracts based on non-aqueous solvents) [5]. Compared with synthetic antibiotics or inorganic chemicals, plant derived products have proven to be natural, less toxic, residue free, and are thought to be ideal feed additives in animal nutrition [6].The active compounds of phytobiotics are secondary plant constituents. Four factors may affect the effectiveness of phytobiotic additives: 1) plant parts and their physical properties, 2) source, 3) harvest time, and 4) compatibility with the other ingredient(s) in the feed [6], which can explain why 50% difference in body weight gain and 63% difference in feed conversion ratio could happen when different kinds of phytobiotics are used in chicken diet [7]. Among phytobiotics, essential oils (EO) have been applied in chicken feed in Europe and USA [8]. However, bird growth responses to EO supplementation are still controversial. No EO effects on growth performance were reported [9,10]; whereas improved growth performance were observed at different ages of birds fed certain EO-supplemented diet(s) [11,12]. In addition, the efficacy of dietary EO can be affected by intrinsic and extrinsic factors such as nutritional status of animals, infection, diet composition and environment [13,14]. A commercial preparation of essential oil components reduced fecal *C .perfringens* counts of broilers in a field study [15]. In addition, dietary supplementation of EO reduced the intestinal populations of *Escherichia coli* and increased digestive enzymes in either pancreas and/or intestinal mucosa [16]; however intestinal mucosal morphology was not affected by EO supplementation [17]. Therefore, the effects of medicinal plants supplementation on poultry production are reviewed in this paper.

Garlic (*Allium sativum*)

Garlic (*Allium sativum*) is well known as a spice and herbal medicine for the prevention and treatment of many diseases. The major active ingredients of garlic are allicin, ajoene, S-allyl cystine. It was found that garlic has antimicrobial activity [18], it decreases serum and liver cholesterol [19] and it improves productive performance of broiler chicks [20]. Olobatoke and Mulugeta reported significant increases of 0.81 mm in albumen height and 2.71 in haugh unit of fresh eggs at 3% Garlic powder (GP) addition ($P < 0.05$). At 5% GP supplementation, egg and albumen weights increased significantly by 2.06 and 1.84 g, respectively, compared with the control group. Egg production decreased significantly at 5% GP following a decrease in feed consumption. Similarly, log bacterial count in feces showed a dose-dependent reduction as dietary GP increased. Organoleptic evaluation of eggs from treated birds revealed a strong garlic flavor in eggs from 5% GP group compared with the control and 3% GP groups. The results of their study suggested that dietary GP improved egg weight and albumen quality with a strong garlic flavor at high dietary levels [21]. Choi *et al*. evaluated the effects of supplementing diets with garlic powder and Alpha-tocopherol on performance, serum cholesterol levels, and meat quality of chickens. A total of 300 one-d-old broiler chicks were assigned to 5 diet treatments (0, 1, 3, and 5% garlic powder and 3% garlic powder + 200 IU of Alpha-tocopherol/kg) with 3 replications of 20 birds for 35 d. There were no significant differences in broiler performance among the treatments. Increasing the levels of garlic powder and applying garlic powder plus -tocopherol significantly decreased total and low-density lipoprotein cholesterol and increased high-density lipoprotein cholesterol in the broiler blood ($P < 0.05$). They stated that dietary garlic powder or garlic powder plus tocopherol supplementation increased unsaturated fatty acid, total unsaturated fatty acid, and total unsaturated fatty acid: total saturated fatty acid ratios. They suggested that 5% garlic powder or 3% garlic powder plus 200 IU of -tocopherol antioxidant properties were effective for enhancing of lipid and color stability [22].

Black Cumin (*Nigella sativa* L.)

Black cumin seeds (*Nigella sativa* L.) are one of the most popular medicinal plants. The composition and properties of cumin seeds have been fairly investigated [23, 24]. They reported that cumin seeds, or their extracts have anti-microbial, anti-histaminic, anti-tumor, anti-hypertensive and anti-flammatory effects. Harzallah and associates reported that the main active components of black cumin seeds are thymoguinone, thymol and carvacrol which are pharmacologically active substances [25]. Toghyani *et al*. reported that dietary black cumin seed extract did not affect the body weight, feed consumption and carcass characteristics of chickens [26]. However, Khan *et al*. reported that chickens fed diets supplemented with 2.5 or 5.0% black cumin seed had significantly greater body weight gain than those fed with the

1.25% BCS diet or negative control. They also reported that birds getting 2.5 and 5% black cumin seed in the diet showed an increase (P<0.05) in serum total protein than the 1.25% or control group [27]. Sogut *et al*. reported that Supplementation of ground black seeds to the broiler chickens diet caused a significant (P< 0.01) decrease in feed intake of the birds [28].

Cumin (*Cuminum cyminum* L.)

Cumin (*Cuminum cyminum* L.) is an annual plant of the Umbelliferae family. Cumin is an important medical herb in Asia and has antioxidant, anticholesterol and antimicrobial properties. The inhibitory effect of the cumin extract on *E.coli* 0:157 was demonstrated *in vitro* [29]. According to Shetty *et al.* (1994), fungi and yeast were more sensitive to cumin essential oil as compared to bacteria [30]. Cumin not only increased activity and excretion content of bile acids but also increased pancreas and small intestine digestive enzymes such as amylase, tripsine, chymotripsine and lipase in rats [31-34]. The oral consumption of cumin seed (1.25%) significantly decreased gastrointestinal transit time (GTT) and increased retention time in rats [35]. Aami-Azghadi *et al.* reported that Fermacto and various levels of cumin essential oil did not influence the relative organ weights, carcass yields, fat digestibility, gastrointestinal transit time, humoral immune response and blood cell enumeration, but increased (*P*<0.05) serum triglyceride and VLDL concentrations of broiler chickens [36].

Wild Mint (*Mentha longifolia* L.)

Wild Mint (*Mentha longifolia*) known as horse or habek mint is often used in the domestic herbal remedy, being valued especially for its antimicrobial, antiseptic, antispasmodic, choleretic, carminative and central nervous system stimulant properties and its beneficial effects on the digestion [37]. The major compounds are carvone (67.3%), limonene (13.5%), 1, 8-cineole (5.4%), menthone (2.9%), linalool (2.8%), isomenthone (1.2%), that exhibit strong antibacterial and antioxidant activities [38]. Al-Ankari *et al.* reported the beneficial effect of wild mint on broiler productive performance [39]. However, Toghyani *et al.* and Ocak *et al*. did not observe any positive effect of dry peppermint on broilers performance and carcass traits [40, 41].

Pumpkin Oil (*Cucurbita pepo* L.)

Cucurbita pepo is a member of the family of *Curcubitaceae* which also includes *C. maxima, C. mixta* and *C. moschata. C. pepo* (flutted pumpkin) is ovoid in shape with a curved green shell. Inside the shell is a flat, round, yellow and white seed enclosed in a husk. These seeds are chewable and sweet with a nutty flavor. Besides having important edible uses and another as an industrial food additive, *C. pepo* also has medicinal uses, including anthelmintic as well as a natural laxative. In addition, it has been widely applied in the treatment of benign prostatic hyperplasia in men, obesity, skin problems and irritable bladder (enuresis) in children [42]. Hajati *et al.* reported that supplementation diets with 5.00 g kg^{-1} DM pumpkin oil in corn-soybean meal-wheat based diet can be profitable because it reduced broiler chicken's mortality and it had not any adverse effect on bird's performance. Also, pumpkin oil supplementation reduced blood fat of broiler chickens [43].

Thyme (*Thymus vulgaris* L.)

Thyme (*Thymus vulgaris* L.) is a popular medicinal plant mostly grown in Mediterranean regions and is among the herbal plants which have received increased attention due to its antioxidant and antibacterial properties. The herb has also been reported to have anti-bacterial activities against a wide range of pathogenic microbial organisms [44]. The major components of thyme essential oil are thymol and carvacrol, which have both been shown to possess potent antioxidant properties [45]. In addition, these phenolic compounds exhibit considerable antimicrobial and fungicidal activities [46]. Thymol was used to inhibit oral bacteria [47]. Furthermore, Cross *et al*. [11], Allen *et al*. [48] and Denil *et al*. [49] reported the beneficial effects of thyme in poultry production. Ground thyme has been shown to inhibit the growth of *S. typhimurium* when added to media [50]. The essential oil of the thyme has been shown to inhibit the growth of the *E. coli* in media [51]. Thymol has been reported to stimulate digestive secretions such as salivary amylase in humans, and bile acids, gastric, pancreatic enzymes (i.e. lipase, amylase, and proteases), and intestinal mucosa in rats [52]. Hashemipour *et al*. reported that feed supplementation with thymol + carvacrol enhanced performance, increased antioxidant enzyme activities, retarded lipid oxidation, enhanced digestive enzyme activities, and improved immune responses of broiler chickens [53].

Cinnamon (*Cinnamomum zelyanicum* Nees.)

The numerous essential oils found in cinnamon are primarily cinnamaldehyde and cinnamyl acetate, cinnamyl alcohol, eugenol, and carvacrol [54,55-56], which have been shown to have strong antibacterial activity [57], and antioxidation activity [58,59]. Previous research showed that Cinnamon oil and it's constituents (cinnamaldehyde and eugenol) had antibacterial activity against *Escherichia coli, Pseudomonas aeruginosa, Enterococus faecalis, Staphylococcus aureus, taphylococcus epidermis, Salmonella Sp.* and *Parahemolyticus* [60]. Besides, it has inhibitory properties against *Aspergillus flavus* [61]. Sang-Oh *et al*. studied diets supplemented with three levels of cinnamon powder (3, 5, and 7 %) on meat quality and growth performance of broiler chickens. They reported that chicken meat quality and growth performance in broiler chickens fed diets containing cinnamon powder increased significantly ($P < 0.05$) when compared to the control group. However, the TBARS of the meat of chickens fed diets containing cinnamon powder decreased significantly ($P < 0.05$) when compared to the control group. They suggested that the cinnamon powder can improve the shelf life and quality of chicken meat with maximizing the productivity of broiler chickens [62].

Chestnut (*Castanea sativa* Mill.) Wood

A commercial product, Silva feed ENC (ENC), a purified natural extract of sweet chestnut (*Castanea sativa*) wood, rich in hydrolyze-able tannins such as castalagin, has been proposed for poultry feeding. Graziani *et al*. who evaluated the in-vitro antimicrobial activity of this product, observed a positive effect on different bacterial strains, such as *Escherichia coli, Bacillus subtilis, Salmonella enterica serovar Enteritidis, Clostridium perfringens, Staphylococcus aureus,* and *Campylobacterjejuni* [63]. Previously, similar findings were obtained by Li and Song who used a natural extract of chestnut shell. Moreover, in practical conditions, some breeders have suggested that dietary use of ENC can improve broiler chicken performance and reduce mortality [64]. Schiavone *et al.* reported that when chicks were fed ENC from 14 to 56 d of age, the ENC had a positive effect on average daily gain in the first 2 wk of addition, whereas this effect was not evident in the last 2 wk compared with the control group. Similar trends were also shown for daily feed intake. Overall, the chicks fed 0.20% ENC had better growth performance than the control group. Carcass analysis showed no gross lesions in organs and no significant differences in thigh and breast composition among groups. Noteworthy is the fact that the ENC treated groups had less total litter nitrogen. Chicks fed with 0.15 and 0.20% ENC showed a significant difference in total litter nitrogen compared with the control group. No significant difference in nitrogen balance was observed, and the addition of 0.20% ENC seemed to have a positive influence on chick feeding [65].

Clove (*Syzygium aromaticum* (L.) Merr. & L.M.Perry)

Clove extract is commonly used in the food industry because of its special aroma and natural safety. In addition, the essential oil from clove also exhibited strong antibacterial properties. Antiseptic, appetite and digestion stimulant [66], strong antimicrobial and antifungal [67], analgesic and anti-inflammatory [68], anesthetic [69], anti-inflammatory and anticarcinogenic [70], antiparasitic [71] and antioxidant [72] activities of clove and its ingredients have been reported. Isabel and Santos investigated the effects of organic acid salts (calcium propionate and calcium formate) and plant extracts (a blend of clove and cinnamon essential oils) on growth performance and carcass quality characteristics of broilers. They reported that clove and cinnamon essential oils showed a potential advantage over calcium propionate and calcium formate for improving feed conversion ratio and percentage of breast weight [73]. Dalkilic and Guler reported that Clove extract has the positive effects on performance and digestion process and it is natural and safety feed additive, so that 400 ppm supplementation of clove extract to diets can be considered as an alternative natural growth promoter for poultry instead of antibiotics [74].

Yucca Schidigera

Yucca schidigera is a major source of natural saponins that inhibit the development of protozoa by interaction with the cholesterol present on the parasite cell membrane, thus resulting in parasite death [75]. Several studies with saponins have demonstrated their positive effects on improved nutrient absorption by increasing intestinal permeability *via* membrane depolarization [76]. Based on the emulsifying properties (stabilizing water or oil emulsions) and the intense effect of

making monoglycerides more soluble [77], dietary supplementation of saponins will result in the emulsification of oil fats, promoting their digestion. Saponins can also affect the absorption of vitamins and minerals. In rats, for example, they reduce the absorption of Fe [78]. Oral administration of saponins is also correlated to improved animal resistance to field infections (nonspecific immunity), suggesting an immuno-modulatory effect [79].

Alfalfa (*Medicago sativa* L.)

Polysavone is a natural extract of alfalfa (*Medicago sativa L.*), and contains polysaccharides (18.63%), triterpenoid saponins (5.58%), and flavonoids (5.89%). Plant polysaccharides definitely possess an immunomodulating effect in many ways, and they regulate the balance of the neuro-endocrine immune network [80, 81, 82, 83].The immune-enhancing function of alfalfa polysaccharides has been studied in broiler chickens and swine in China [84, 85]. Saponins are compounds found in a number of plants. Previous studies had suggested that alfalfa saponins may prevent hypercholesterolemia, reduce egg production, and depress growth in mammals and birds [86, 87, 88]. Ilsley *et al*. reported that quillaja saponins may potentiate an immune response in the weaned piglet but have a detrimental effect on the utilization of feed [89]. Flavonoids isolated from plants are used in the treatment of certain physiological disorders in humans, and some flavonoids exhibit unusual hormonal activities as estrogens when fed to livestock. Plant flavonoids are likely to be exploited as animal hormones and as antimicrobial, antiinflammatory, and antitumor compounds in the future [90].

Turmeric (*Curcuma longa* L.)

Safe, natural phytobiotics such as turmeric (*Curcuma longa*) are being suggested as alternatives due to its anti-bacterial, anti-viral, coccidiostatic and other beneficial properties. Turmeric, a medicinal plant native to the Asian subcontinent, is known to possess antimicrobial and antioxidant properties. The powder of dried roots and rhizomes of turmeric is used as one of the spices in Indian curries and other cuisine. The curcuminoids, yellowish pigments present in turmeric powder, have shown protective effects against AFB1 [91]. Gowda *et al*. noted the inclusion of 5g/kg turmeric improved weight gain in chicks fed a diet containing the most biologically active aflatoxin B1 [92]. Daneshyar *et al*. examined the effect of the dietary supplementation of turmeric rhizome powder (TRP) on plasma lipoprotein concentrations, and the meat quality and fatty acid composition of the thigh muscle of the broilers. They reported that supplementation of TRP in broiler chickens diets decreased the concentrations of saturated fatty acids and triglycerides in thigh meat and subsequently improved the meat quality [93]. Shivappa Nayaka *et al*. studied the efficiency of inclusion of *Azadirachta indica* (8g/kg diet), turmeric (2 g/kg diet), vitamin E (0.2 g/ kg diet) and their combinations on humoral immune response against Newcastle virus and cell mediated immune response of broiler chicks. They reported that inclusion of *Azadirachta indica*, turmeric and Vitamin E significantly improved the cell mediated immune response in broilers either alone or in combination. However, combinations containing turmeric and vitamin E had better results compared to *Azadirachta indica* fed and control diet fed broilers [94].

Sumac (*Rhus coriaria* L.)

Various tanniniferous plants, including sumac (*Rhus coriaria* L.), have been known to contain naturally occurring compounds with antimicrobial activities [95,96,97]. Sumac grows wild in the region extending from the Ca-nary Islands to the Mediterranean and south eastern Anatolian region of Turkey. The ground spice is used as a condiment and sprinkled over kebabs, grilled meats, soups, and some salads. In folk medicine, it is used for treatment of indigestion, anorexia, diarrhea, hemorrhages, and hyperglycemia [96-98]. The main compounds in sumac are hydrolyzable tannins and substantial amounts of flavonoids. It has been demonstrated that gallotannins in sumac leaves are decomposed by heating above 50 °C [99]. Golzadeh *et al*. investigated the effects of sumac fruit (*Rhus coriaria* L.) powder (SFP) on performance, plasma concentrations of total cholesterol (TC), triglyceride (TG), high density lipoprotein (HDL-c), low density lipoprotein (LDL-c), very low density lipoprotein (VLDL-c) and plasma fasting blood sugar (FBS), as well as proportional abdominal fat. They reported that dietary supplementation of SFP reduces the blood TC, VLDL-c and FBS concentrations, which can be related to decreased activity of HMG-CoA reductase and α-amylase activities. The higher abdominal fat weights of the SFP-fed birds are

possibly related to changes of energy storage towards fat deposition [100]. Sharbati Alishah *et al*. studied the effect of different levels of sumac fruit powder, 0 (Z-SFP), 0.25 (L-SFP), 0.50 (M-SFP) and 1% (H-SFP) along with 100 mg/kg alpha tocopherol acetate (VE) on performance and blood antioxidant status of broiler chickens under heat stress condition. They reported that although dietary SFP consumption improves the performance of broiler chickens during the starter period under heat stress, it does not affect the performance during the grower period or the blood antioxidant indices at week 6 of age [101].

Common mushroom (*Agaricus bisporus* (J.E.Lange) Emil J. Imbach)

Mushrooms are nutritionally functional foods containing compounds with antimicrobial activity. Moreover, they are rich sources of natural antibiotics. Rowan *et al*. reported that numerous bioactive polysaccharides from medicinal mushrooms appear to enhance innate and cell-mediated immune responses and exhibit antitumor or antivirus responses in animals and humans. Guo *et al*. investigated several mushroom and herb polysaccharides, as alternatives for an antibiotic, on growth performance of broilers, and found *Lentinula edodes* to be a significant growth promoter in broilers [81]. The bioactive polysaccharides and polysaccharide-bound proteins from mushrooms are able to modulate many important immune cells because of their structural diversity and variability of the macromolecules [102]. In addition, they suggest that mushroom polymers (β-glucans) may trigger the stimulation of different immune cells in animals and humans by binding to a specific cellular receptor known as complement receptor type 3. Willis *et al*. noted enhanced beneficial bifidobacteria production from mushroom extract (*L. edodes*) given to broiler chickens [103]. Ergothioneine has been identified and quantified in various genera of mushrooms as the main anti-oxidant compound [104], whereas the phenolic antioxidants, variegatic acid and dibiviquinone, are also found in mushrooms [105]. The antioxidant activity of mushrooms has been documented *in vitro* as a radical activity scavenger [106] and *in vivo* as a cellular protector against oxidative damage in rat liver microsomes [107, 108]. *Agaricus bisporus* mushroom is also considered as a good source of selenium [109]. Consumption of *A. bisporus*, which is the most widely investigated edible mushroom, has been shown to retard the development of free radicals [110]. Willis *et al*. conducted an experiment to examine the effect of four mushrooms (Shiitake, Reishi, Cordyceps, Oyster) separate and combined *via* Fungus Myceliated Grain on male broiler chicks' performance after an Eimeria challenge at 14 days of age. They reported that Shiitake was superior and Cordyceps at the level of 5 percent decreased body weight gain of birds. They also stated that Cordyceps may reduce oocyst shedding [111]. Willis *et al*. studied the effect of four medicinal mushrooms *via* fungus myceliated grain (FMG) at three levels on production performance, blood parameters and natural coccidiosis oocyst excretion in floor reared broiler chickens. Three hundred day-old female broiler chickens were weighed and randomly assigned to nine different treatment groups. The four mushrooms utilized were Shiitake (*Lentinus edodes*), Reishi (*Ganoderma lucidum*), Oyster (*Pleurotus ostreatus*) and Cordyceps (*Cordycepss inensis*). Each mushroom was supplemented at a 5 and 10% inclusion level into a basal meal ration, and compared to a control ration containing no mushrooms. They stated the ability of certain mushrooms to influence body weight of broiler chickens and show some immune enhancement *via* the bursa of Fabricius [112].

Polyphenolic compounds

These medicinal herbs are good sources of polyphenols, which are widely distributed in plants and exhibit various antioxidant properties [113-114]. From a medical point of view, polyphenolic compounds have great importance against coronary heart disease and exhibit antioxidant and anti-tumor properties [115-116]. These biological functions are assumed to result from the radical-scavenging properties of polyphenolic compounds [117].

Grape seed (*Vitis vinifera* L.)

Grape seed proanthocyanidin extract (GSPE) has been widely used as a human food supplement for health promotion and disease prevention. Proanthocyanidin is a naturally occurring polyphenolic antioxidant widely distributed in fruits, vegetable, nuts, seeds, flowers, and barks [118, 119]. The monomer structure of Proanthocyanidins is (epi) catechin or (epi) gallocatechin linked with C4 to C8 or C4 to C6 bonds [120]. Flavan-3-ol usually condensed into oligomeric and polymeric compounds with the degree of polymerization from 2 to 11, which was

known as condensed tannin according to the definition given by Bate-Smith and Swain [121]. During the last decade, experimental and clinical studies demonstrated that proanthocyanidin has variable pharmacological and nutraceutical benefits including improvement of ischemic cardiovascular disease, prevention of atherosclerosis, anticancer effects as well as antibacterial, antiviral, and antifungal activities [122, 123, 124]. The beneficial effects of proanthocyanidins were considered due to their free radical scavenging capability, which are 20 fold superior to other well-known antioxidants (e.g., vitamin C, vitamin E, or β-carotene). Tannins are therefore an integral part of the human diet over thousands of years. Avian protozoa, such as Eimeria, are one of the leading causes of poultry disease, and responsible for major economic losses in the poultry industry by increasing mortality and reducing growth rates [125]. The generation of proinflammatory mediators, together with the oxidative and nitrous oxide species, contributed principally to inflammatory injury and diarrhea. As occurred mostly in the case of parasite infection, the enzymatic antioxidant system of chicken, including superoxide dismutase (SOD) and catalase (CAT), was significantly decreased when infected with *Eimeria tenella* [126]. Changes in concentrations of serum NO and carotenoid was also detected with chicken coccidiosis [127], which suggested that the unbalanced oxidant/antioxidant status is likely to be important in the progress of the disease [126]. Therefore, substances that generate oxidative stress [e.g., artemisnin [128] or have antioxidant properties, such as n-3 fatty acids, γ-tocopherol, curcumin, and green tea extracts, demonstrated certain coccidiastat effects [81, 129]. The common approaches used in the last decade for the control of avian coccidiosis relied heavily on anticoccidial feed additives, which increased the resistance of the parasite to the traditional coccidiocidal pharmaceuticals and consequently led to the ban of chemotherapeutic methods. Therefore, there is an increasing demand for new antioxidant and immunological prophylaxis. Brenes *et al.* reported that the supplementation of grape seed extract (contained 45.5% extractable polyphenols) up to 3.6 g/ kg did not change the growth performance (0 to 3 weeks and 3 to 6 weeks of age) [130]. However, Hughes *et al.* [131] and Lau and King [132] reported a growth depression with the use of grape seed extract containing 90.2% of total phenolics, expressed as gallic acid equivalent, and incorporated in the diet at 30 g/ kg.

Goldthread (*Coptis chinensis* Franch.)

Goldthread (*Coptis chinensis* Franch.) is one of the famous traditional medicinal herbs because of its significant functions of antibiosis. Berberine, the major active component in goldthread, is an isoquinoline derivative alkaloid and is widely used in the treatment of calf diarrhea and in the clinical treatment of diabetes [133]. Liu *et al*. added a mixture of three dietary medicinal herb extracts (mulberry leaf: Japanese honeysuckle: goldthread =48.5: 48.5:3.0) to layer hen's diet. They reported that internal quality of the egg including weight, shell color, albumen height, yolk color, shell weight, shell thickness, and haugh units was not different among the dietary treatments. They also stated that dietary medicinal herb extracts may slightly enhance the oxidative stability of eggs [134].

Mulberry leaf (*Morus alba* L.)

Mulberry leaf (*Morus alba* L.) is widely cultivated in the Far East and has been reported to have many biological activities, such as antioxidants [135], antimicrobial [136], antifungal, anti-allergic [137], and hypoglycemic activities [138]. Jang *et al.* studied the anti-oxidative potential and quality of the breast meat of broiler chickens fed a dietary medicinal herb extract mix (consisting of mulberry leaf, Japanese honeysuckle, and goldthread at a ratio of 48.5:48.5:3.0). They reported that dietary medicinal herb extract mix increased the anti-oxidative potential and overall preference of breast meat during cold storage [139].

Honeysuckle (*Lonicera japonica* Thunb. ex Murray) Japanese honeysuckle (*Lonicera japonica* Thunb. ex Murray) has been used as a folk remedy for anti-inflammation and as an antidote for liver diseases. The major bioactive compounds of Japanese honeysuckle are lu- teolin, inositol, saponin, tannin, ginnol, and glycoside [140].

In conclusion, herbal additive can be used in organic poultry nutrition to improve birds' health and productivity and also farmers can use certain herbal additives to enrich birds' products (i.e. meat, egg) with natural antioxidants and antimicrobial compounds in order to combat with human cancer and infectious diseases.

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