TURMERIC (*Curcuma longa* Linn.) SUPPLEMENTATION AS AN ALTERNATIVE TO ANTIBIOTICS IN POULTRY DIETS

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ABSTRACT

Antibiotics have been used in non-therapeutic fashion as growth promoter for about 50 years in many parts of the world. It has been proven that supplementation of antibiotics in the diets reduces morbidity and mortality, as well as improve feed efficiency and overall growth performance of broiler chickens. However, the routine use of these antimicrobial growth promoters (AGPs) is being curtailed in view of threat to public health occurring through microflora that are developing resistance to antibiotics. This risk has driven European Union and other countries to withdraw authorization of in-feed antibiotics since 1997. Removal of AGPs resulted in substantial increase infections in poultry. As a consequence, the poultry industry needs to find alternatives to antibiotics in order to stem the effects of infection. One comparable alternative is natural sources of herbs and medicinal plants, which later known as phytobiotics. For the last 15 years, these alternatives have been increasingly claimed to increase enteric health, stimulate digestive system, and enhance growth performance. It was reported that turmeric (*Curcuma longa* Linn.) belongs to such class of medicinal plant and may be an alternative to antibiotics in poultry production. In this review, the responses of poultry to diets supplemented with turmeric on growth performance, egg production, health status, and carcass characteristic were briefly discussed.

Keywords: Turmeric, non-antibiotic feed additive, poultry production

ABSTRAK

SUPLEMENTASI KUNYIT (*Curcuma longa* Linn.) SEBAGAI ALTERNATIF PENGGANTI ANTIBIOTIK PADA PAKAN UNGGAS

Antibiotika telah dimanfaatkan sebagai pemacu pertumbuhan ternak selama lebih dari 50 tahun di berbagai negara. Fakta-fakta menunjukkan bahwa penggunaan antibiotika dalam pakan terbukti dapat mengurangi jumlah ternak yang sakit (morbiditas), menekan angka kematian (mortalitas), serta meningkatkan efisiensi pakan dan kinerja pertumbuhan ternak ayam broiler. Akan tetapi, penggunaan secara rutin yang tidak terkendali telah memicu munculnya kekhawatiran masyarakat akan berkembangnya mikroflora yang tahan terhadap antibiotika yang juga dipakai pada pengobatan manusia. Kekhawatiran ini telah memaksa pemerintah Uni Eropa serta berbagai negara lain untuk mencabut ijin penggunaan antibiotika dalam pakan unggas sejak tahun 1997. Peniadaan antibiotika dalam pakan ini ternyata justru berimbas pada meningkatnya penyakit-penyakit infeksi saluran pencernaan ternak unggas. Sebagai konsekuensinya, para pelaku industri peternakan terpaksa mencari alternatif lain sebagai pengganti antibiotika. Salah satu alternatif yang dapat diandalkan untuk menekan kasus infeksi ini adalah dengan suplementasi produk herbal dalam pakan, yang di kemudian hari dikenal sebagai fitobiotika. Pada kurun waktu 15 tahun terakhir ini telah terjadi peningkatan jumlah penelitian yang mengklaim bahwa alternatif alami ini dapat memperbaiki status kesehatan saluran pencernaan, menstimulasi sistem pencernaan, serta meningkatkan kinerja pertumbuhan ternak. Berbagai kajian ilmiah menunjukkan bahwa kunyit (*Curcuma longa* Linn.) sebagai salah satu tanaman obat dapat dipakai sebagai alternatif pengganti antibiotika dalam pakan unggas. Oleh sebab itu, di dalam kajian ini dibahas secara singkat respon positif ternak unggas terhadap suplementasi kunyit dalam pakan dengan menggunakan kinerja pertumbuhan, produksi telur, status kesehatan, serta penampilan karkas.

Kata kunci: Kunyit, aditif pakan non-antibiotika, produksi unggas

INTRODUCTION

Antibiotics have been used as antimicrobial growth promoters (AGPs) in animal feeds worldwide for many years to improve food safety by increasing animal health and reducing or removing certain exogenous pathogens. However, in order to avoid the possible risk of developing resistant pathogens, as well as to meet the public pressure for antibiotic-free animal products, the use of antibiotic in poultry diets was

totally banned in the European Community in January 2006. Nevertheless, apart from preventing the potential hazard, the absence of AGPs in the diet has resulted in health problems in poultry, including significant increase in infection (Casewell et al. 2003). Hofacre (2001) reported that the incidence of necrotic enteritis or Clostridial infection has engendered considerable complications related to animal welfare and resulted in severe economic losses in poultry industries. In order to reduce the disadvantages of sub- and clinical infections, the poultry and feed industries needs to find alternatives to AGPs. These alternatives are required to be generally recognized as safe for both animal and humans, environmentally friendly, applicable in the diets, and address organic livestock issue (Cabuk et al. 2006). Various alternatives of green additives have been studied in order to maximize the growth performance and product quality of poultry in the diets without antibiotics.

Turmeric (*Curcuma longa* Linn. or *C. domestica* Val.) is a rhizomatous herbaceous perennial herb of ginger family that is widely used and cultivated in the tropical and sub tropical regions of the world, such as in Pakistan, China, Indonesia, India, Malaysia, Jamaica, and Peru (Govindarajan and Stahl 1980). Linnaeus described turmeric as *Curcuma longa* and its taxonomic position is as follows:

Class : Liliopsida
Subclass : Commelinids
Order : Zingiberales
Family : Zingiberaceae
Genus : Curcuma
Species : *Curcuma longa*

(Chattopadhyay et al. 2004)

Curcuma longa is the domesticated species of turmeric, while the wild one is called C. *aromatic*. It belongs to the family Zingiberaceae that consists of hundreds species of plants, along with other noteworthy members like curcuma, ginger, white-turmeric, black-turmeric, wild-turmeric, mango-ginger, cardamom, siam-tulip (hidden-ginger), zedoary, and galangal. This medicinal plant possesses rhizomes and underground root-like stems (Araújo and Leon 2001) that had been originally used as a food additive in curries to improve the storage condition, appearance, flavour, palatability, and preservation of food (Jayaprakasha et al. 2005).

PHYTOCHEMICAL CONTENT OF TURMERIC

Turmeric rhizome contains the highest active compounds (phytochemicals) than other parts in turmeric plant. Rhizome is the portion of the plant that used medicinally as human remedies and non-medicinally as food (spice) or feed additives. Extraction process of the rhizome results in a dry yellow polyphenol-rich powder that is oil-soluble in its natural state (Khan et al. 2012). When compared with the synthetic antibiotics, phytochemicals in turmeric are known to be natural, less toxic, residue free, and are thought to be ideal as feed additives in animal diets (Wang et al. 1998).

Turmeric contains 6.3% protein, 5.1% fat, 3.5% minerals, 69.4% carbohydrates, and 13.1% moisture (Chattopadhyay et al. 2004). The active ingredients of turmeric rhizomes consist of volatiles and non-volatiles constituents. The major active substances in non-volatile are the colouring agent and are a rich source of phenolic compounds, such as curcumin (Roughley and Whiting 1973), demethoxycurcumin, bisdemethoxy-curcumin, and colourless metabolites tetrahydro-curcumin (Huang et al. 1995). The major active substances in volatile oil are curcuminoids (Toennesen 1992), ar-turmerone (Ferreira et al. 1992), zingiberene (Smith and Robinson 1981), turmerone (Baik et al. 1993), and curlone (Kiso et al. 1983). Curcumin (diferuloylmethane) is the main yellow bioactive component that has a wide spectrum of biological actions, including antioxidant, antibacterial, antifungal, antiprotozoal, antiviral, antiinflammatory, anti-carcinogenic, antihypertensive, and hypo cholesteremic activities (Bhavani Shankar and Sreenivasa Murthy 1979; Govindarajan and Stahl 1980; Masuda et al. 2001; Chattopadhyay et al. 2004; Chen and Huang 2009). It is estimated that 2-5% of turmeric is curcumin (Agarwal et al. 2001). Curcumin and curcuminoids posses antinematocidal (Kiuchi et al. 1993), antiinflammatory (Ammon et al. 1993), antioxidative (Osawa et al. 1995), anticoccidials (Allen and Fetterer 2002; Abbas et al. 2010), and immunomodulatory (Kumari et al. 2007; Yarru et al. 2009) properties. Araújo and Leon (2001) summarized the biological properties of curcumin and other phytochemicals as curcumin (antibacterial, antiviral, antioxidant, antiinflammatory, antitumor), arturmerone (anti-snakebite), methylcurcumin (antibacterial, anti-protozoal against *Leishmania amazonensis*), curcuminoids (antiprotozoal *Plasmodium falciparum* and *Leismania major*).

Volatile oil of turmeric has biological activities as antibacterial (Bhavani Shankar and Sreenivasa Murthy, 1979), antifungal (Banerjee and Nigam, 1978), and anti-inflammatory agents (Chandra and Gupta, 1972). Other bioactive compounds also exhibit beneficial effects, such as demethoxy curcumin (antioxidant), bisdemethoxy curcumin (antioxidant), and sodium curcuminate (anti-inflammatory).

RESPONSES ON GROWTH PERFORMANCE OF BROILER

Numerous reports have been published, advocating the beneficial effects of turmeric meal supplementation on growth performance of broiler chickens. Kumari et al. (2007) reported that turmeric meal supplementation at the rate of 1.0 g/kg improved growth performance of 42-d old Vencob broiler chickens. Al-Sultan (2003) observed that addition of turmeric meal at the rate of 5.0 g/kg increased body weight and feed conversion ratio of broiler chickens. In other study, Durrani et al. (2006) found that supplementation of 5.0 g/kg turmeric meal in the diets resulted in a significant improvement on body weight gain and feed efficiency without any adverse effects on mortality. Allen et al. (1998), Abbas et al. (2010), and Lee et al. (2010a) noted that turmeric meal supplementation alleviated growth-depression effect of Eimeria infection. Similarly, Yarru et al. (2009) reported positive effects of 5.0 g/kg turmeric meal supplementation in birds exposed to aflatoxin. Gowda et al. (2009) reported that feeding broiler chickens with diets containing 74 ppm curcuminoids from turmeric meal ameliorated the growth-depression effect of aflatoxin B1. Zainali et al. (2008) reported that dietary supplementation of 10.0 g/kg turmeric meal increased the body weight gain of (Ross x Ross) broiler chickens reared under the heat stress condition. In a recent study using Arbor Acre broiler chickens, Rajput et al. (2012) showed that supplementation on 0.2 g/kg pure curcumin - phytochemicals derived from turmeric - increased the body weight gain and reduced the FCR of broiler chickens.

Some studies have reported that combinations of turmeric meal and other phytobiotics have beneficial effect to enhance the growth performance of broiler chickens. Al-Kassie et al. (2011) reported that supplementation of turmeric and cumin mixture in the diets at the rate of 5.0 g/kg resulted in a greater body weight gain and lower feed conversion ratio in 42-d old Arbor Acres broiler chickens. Other study (Sawale et al. 2009) have reported that dietary supplementation of layer diets with herbal-mineral mixture containing turmeric reduced the harmful effect of Ochratoxin A infection on body weight gain and feed efficiency. Improvement on the growth performance due to supplementation of turmeric meal in those studies might be attributed to the beneficial properties of phytochemicals in turmeric that posses antimicrobial, antifungal, and antioxidant activities in broiler chickens that may improve the bird utilisation of dietary nutrients (Osawa et al. 1995; Al-Sultan 2003; Radwan et al. 2008). On the other hand, there were reports to show that turmeric had the ability to stimulate the digestive system, such as stimulate the intestinal lipase, sucrose, and maltase activities (Platel and Srinivasan, 1996) as well as the secretion of pancreatic lipase, amylase, trypsin, and chimotrypsin enzymes (Platel and Srinivasan 2000). Recently, Rajput et al. (2012) showed that dietary supplementation of pure curcumin at the rate of 0.2 g/kg in a corn-soybean based diets increased villus length and width in the duodenum, jejunum, and caeca of 42 days old broiler chickens. Therefore, there is a possibility to suggest that improvement on the growth performance due to dietary turmeric meal in broiler chickens is attributed to the improved digestive system in the body.

However, some authors did not find beneficial effects on supplementing diets with turmeric meal at the rate of 0.5 g/kg (Akbarian et al. 2012), 1.0 g/kg (Rahmatnejad et al. 2009), 2.0 g/kg (Mehala and Moorthy 2008; El-Hakim et al. 2009), 5.0 g/kg (Gowda et al. 2008; Yarru et al. 2009), 10.0 g/kg (Al-Sultan 2003; Durrani et al. 2006; Abbas et al. 2010), or 30.0 g/kg (Abbas et al. 2010). In addition, supplementing drinking water with turmeric at the rate of 5.0 g per liter also did not influence body weight gain, daily feed intake, and feed conversion ratio of 21 d old Ross 308 broiler chickens (Sadeghi et al. 2012). The difference in responses of broiler chickens reported in those studies was due to the difference of the basal diets, rearing periods of the broiler or the other experimental details used in those studies, such as statistical design, dose supplementation, and breed of the birds.

RESPONSES ON EGG PRODUCTION AND QUALITY

There were evidences to show that dietary supplementation with turmeric meal stimulated egg production of laying hens. Supplementation of 5.0 g/kg turmeric meal in layer diets increased egg production, weight and mass, while supplementation of 10.0 g/kg increased the yolk weight and yolk index (Radwan et al. 2008). The authors suggested that supplementing layer diets with turmeric meal improved the environment in the uterus (specifically the site of calcium deposition) and consequently increased shell weight and thickness. In a study using a commercial product, supplementation of a herbo-mineral toxin binder product containing turmeric alleviated the adverse effect of Ochratoxin A infection on egg production (Sawale et al. 2009).

However, some studies found no effect of dietary supplementation with turmeric meal on egg production and quality. In a study using Single Comb White Leghorn layers, Moorthy et al. (2009) found that dietary supplementation of 1.0 g/kg turmeric meal did not influence hen house egg production as well as percent hen day egg production. Results in other studies showed that supplementation of turmeric meal

in the diets at 2.0 g/kg (Riasi et al. 2012) or 5.0 g/kg (Radwan et al. 2008) did not affect egg shell thickness or egg shell weight. In recent study, Malekizadeh et al. (2012) reported that supplementation of turmeric meal in the diet at the rate of 10.0 or 30.0 g/kg did not influence egg production, egg weight, and egg mass of single comb White Leghorn (W-36) laying hens. The dissimilarity results found in the egg traits may be caused by some differences in the experimental methods used in those studies.

RESPONSES ON HEALTH STATUS OF BROILERS

Turmeric also has beneficial effects on blood parameters in broiler chickens. Fat metabolism studies using male Wanjiang Yellow (Zhongze et al. 2008) and Arbor Acres (Zhongze et al. 2007; Zhongze 2009) broiler chickens showed that dietary supplementation of turmeric meal at the rate of 0.35 g/kg consistently stimulated the activity of hormone sensitive lipase (HSL) and increased the content of high-density lipoprotein (HDL) in the serum. Dietary supplementation of turmeric meal in the studies also reduced the total cholesterol concentration, total triglycerides, as well as the very low-density lipoprotein (VLDL) content in the blood serum. A study by Kermanshahi and Riasi (2006) showed that 0.5-1.5 g/kg turmeric meal supplementation decreased level of triglyceride, total cholesterol, HDL-cholesterol, and increased level of low-density lipoprotein-cholesterol (LDL-cholesterol) in the blood of Hy-Line W-36 laying hens. Riasi et al. (2012) reported that turmeric has a strong property to change the serum lipid profile in laying hens. Dietary supplementation of 0.5 g/kg turmeric meal in the study reduced the serum triglyceride, total and LDL-cholesterol and increased the serum HDL-cholesterol of Hy-Line W-38 laying hens. Emadi et al. (2007) reported that 2.5 g/kg turmeric meal supplementation in the diet increased the total cholesterol and HDL-cholesterol, while 5.0 g/kg supplementation increased haemoglobin and reduced LDL-cholesterol, very low-density lipoprotein-cholesterol (VLDL-cholesterol), and red blood cells of male Ross broiler chickens at 42 days of age. Malekizadeh et al. (2012) reported that 10.0-30.0 g/kg turmeric meal supplementation reduced total cholesterol in the blood serum of Single Comb White Leghorn (W-36) laying hen. Al-Sultan (2003) reported a significant improvement in both erythrocyte and leukocyte when the diets of broiler chicken was supplemented with 10.0 g/kg turmeric meal, while Sugiharto et al. (2011) reported a significant increased in erythrocyte following 600 mg/kg live body weight turmeric meal supplementation in the drinking water of broiler chickens. Antony et al. (1999) suggested that these improvements were attributed to the presence of curcumin in turmeric rhizome.

Other study using (Ross x Ross) male broiler chickens (Gowda et al. 2009) showed that dietary inclusion of 222 mg/kg curcuminoids from turmeric ameliorated the adverse effects of aflatoxin B1 on serum chemistry in terms of total protein, albumin and γ-glutamyl transferase activity. In that study, the depression in antioxidant functions caused by aflatoxin B1 was also mitigated by 222 mg/kg curcuminoids inclusion in the diets. In a study using cumin and turmeric mixture, Al-Kassie et al. (2011) reported that supplementation of 2.5 g/kg herbal mixture reduced blood cholesterol and mortality of Arbor Acres broiler chickens. The improvement in the serum lipid profile supports previous study by Chattopadhyay et al. (2004) and Srinivasan (2005) that turmeric has hypolipidemic and hypocholesterolemic properties.

Turmeric contains active compounds that beneficially stimulate bile secretion and bile flow which can support health of the liver. As noticed by Emadi and Kermanshahi (2007b), supplementation of turmeric meal in the diets at the rate of 2.5-7.5 g/kg reduced the concentrations of alkaline phosphatase (ALP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), and lactate dehydrogenase (LDH) in the blood of broiler chickens. Reductions of these enzymes are important as the accumulation of these enzymes in the liver are related to toxicity. In more recent study, Malekizadeh et al. (2012) showed that supplementing diets with 10.0-30.0 g/kg turmeric meal reduced the ALT and AST in blood serum of single comb white leghorn (W-36) laying hens. In other studies using broiler chickens, dietary supplementation of turmeric meal reduced ALT (Akbarian et al. 2012) and alkaline phosphatase (ALP) activities in the blood serum (Emadi and Kermanshahi 2007a; Emadi and Kermanshahi 2007b), which can be indication of better function of liver. Curcumin has also been reported to be able to enhance the concentration of catalase (Pulla Reddy and Lokesh 1994), as well as the expression of hepatic superoxide dismutase (Cheng et al. 2005) and glutathione peroxidase (Yarru et al. 2009), the enzymes that known to have a close relationship with the antioxidant status of the body. These results were consistent with the result in Dias et al. (2006) study and showed beneficial properties of phytochemicals in turmeric as antioxidant and hepato-protective agents in poultry (Osawa et al. 1995; Araújo and Leon 2001; Maheshwari et al. 2006; Shukla and Singh 2007). These efficacies of phytochemicals in turmeric might be the reason why this additive supports the health status of poultry.

RESPONSES ON IMMUNOMODULATORY SYSTEM

Response of broiler chickens due to dietary turmeric supplementation on immunomodulatory system has been evaluated in some studies. Kurkure et al. (2000) reported that dietary supplementation of 0.5 g/kg turmeric ameliorated the harmful effect of aflatoxin B1 on the body immune system, showing the humoral immune-stimulatory potential in poultry. In this study, the authors demonstrated alleviation on the humoral response against Newcastle disease virus in cockerels induced aflatoxicosis. The number of lymphocytes in lymphoid organs was partially repaired following turmeric administration. Results in mycotoxicosis study (Sawale et al. 2009) showed that turmeric ameliorated the deleterious effects of ochratoxin A on haematobiochemical and body immune system of laying hens. The haemagglutination titre of the birds was increased when the diets were supplemented with 1.25 g/kg herbomineral toxin binder containing turmeric. In other study using (Ross x Ross) broiler chickens, Lee et al. (2010b) demonstrated immunomodulatory properties of turmeric against parasitic infection. Serum antibody level against a microneme protein 2 from *Eimeria tenella* (EtMIC2) was significantly higher in birds fed diets supplemented with turmeric. EtMIC2 is an apical complex protein which plays an important role in host cell invasion of Eimeria parasites. It has a putative function in parasite adhesion to the host cell and plays an important role in inhibiting sporozoite invasion of host cell (Sasai et al. 2008).

Turmeric has also been proven to have ability to stimulate the expression of genes which are involved in antioxidant and immune system of broiler chickens. Using a quantitative real-time PCR technique, Yarru et al. (2009) showed that 5.0 g/kg turmeric meal supplementation had beneficial effects on the stimulation of genes expression that involved in antioxidant function [cytochrome P450 1A1 and 2H1 (CYP1A1 and CYP2H1)] and genes expression that involved in the immune system [interleukins 6 and 2 (IL-6 and IL-2)] in broiler chickens. Lee et al. (2010b) reported that when compared to the control group, birds with turmeric administration had significantly higher level of transcripts encoding pro-inflammatory cytokine IL-1β in the duodenum. The levels of transcript encoding IL-6, IL-15 and IFN-γ in that study were also higher in turmeric treated birds. In a study with mice, Chuchill et al. (2000) showed that curcumin treatment increased the number of mucosal CD4 (+) T and B cells, suggesting that curcumin modulates lymphocyte-mediated immune functions. These improvements could be attributed to activity of curcumin as immunostimulant agent (Antony et al. 1999; Yadav et al. 2005; Gautam et al. 2007).

RESPONSES ON CARCASS TRAITS OF BROILERS

Dietary supplementation with turmeric may have beneficial effects on the carcass traits of broiler chickens as it contains beneficial phytochemicals, like curcumin, ar-turmerone, methylcurcumin, and other active compounds. Dietary supplementation of curcumin meal at the rate of 0.35 g/kg reduced the abdominal fat content, subcutaneous fat thickness, intermuscular fat width, and liver fatness of male Wanjiang Yellow (Zhongze et al. 2008) chickens. In later study, Zhongze (2009) reported that percentage of abdominal and liver fat weight as well as subcutaneous fat thickness of Arbor Acres and Wangjiang Yellow broiler chickens were reduced following 0.25-0.35 g/kg curcumin supplementation. Samarasinghe et al. (2003) noted that 3.0 g/kg turmeric meal supplementation reduced the fat content and improved carcass quality of broiler chickens. Using a higher level of supplementation (5.0 g/kg), Durrani et al. (2006) showed beneficial effects of dietary turmeric meal supplementation to reduce fat content, increase carcass quality and dressing percentage, as well as to increase the breast, thigh, and giblet weight of broiler chickens. Dietary supplementation of turmeric meal in that study also had favourable effect to reduce the cost per chick ratio.

However, some studies did not find any significant effect of turmeric supplementation at the rate of 1.0 g/kg (Rahmatnejad et al. 2009) or 2.0 g/kg (El-Hakim et al. 2009) on carcass production. Al-Sultan (2003) reported no difference found in the crude protein content in breast and thigh muscles following turmeric meal supplementation in the broiler diets.

TOXICOLOGICAL EFFECTS OF TURMERIC

Turmeric is well known to have a property as a safe, natural, and residue free phytobiotics (Wang et al. 1998). The World Health Organization declared turmeric and its yellow coloring agent (curcumin) as safe to be used in human food and animal feed (WHO 1987). In human and animal studies so far turmeric is considered to have low toxicity (Alia et al. 2006), hence this yellow additive is secure and ideal for poultry. There is no publication as yet that have reported harmful effects of turmeric meal in poultry diets when used at low to moderate concentrations.

Consumption of excessive dosage of turmeric is not recommended because it may induce hepatotoxic effect as noted in studies using mice (Kandarkar et al.

1998) and rats (Deshpande et al. 1998). In particular, Al-Sultan and Gameel (2004) recommended not supplementing broiler diets with more than 50.0 g/kg turmeric meal as it may contribute to induction of parenchymal and portal infiltration of mononuclear cells and hyperaemia of portal vessels.

CONCLUSION

Available literatures indicate that turmeric (*Curcuma longa*) may be a useful alternative to antibiotics in poultry production system due to its wide safety margin and its efficacies to promote growth performance. The enhancement in growth performance might be attributed to the improved enteric health status, digestive system, immunomodulatory system, and nutrient and energy utilization. However, so far little work has been done to suggest its mode of action in poultry. Therefore, to optimize the efficacy of turmeric meal supplementation in poultry diets, future researches should focus more on the mechanism of action, optimum dose of supplementation, as well as the duration of application.

REFERENCES

Abbas RZ, Iqbal Z, Khan MN, Zafar MA, Zia MA. 2010. Anticoccidial activity of *Curcuma longa* L. in broilers. Braz Arch Biol Technol. 53:63-67.

Agarwal M, Walia S, Dhingra S, Khambay BPS. 2001. Insect growth inhibition, antifeedant and antifungal activity of compounds isolated/derived from *Zingiber officinale* Roscoe (ginger) rhizomes. Pest Manag Sci. 57:289-300.

Akbarian A, Golian A, Kermanshahi H, Gilani A, Moradi S. 2012. Influence of turmeric rhizome and black pepper on blood constituents and performance of broiler chickens. Afr J Biotechnol. 11:8606-8611.

Al-Kassie GAM, Mohseen AM, Abd-Al-Jaleel RA. 2011. Modification of productive performance and physiological aspects of broilers on the addition of a mixture of cumin and turmeric to the diet. Res Opin Anim Vet Sci. 1: 31-34.

Al-Sultan SI. 2003. The effect of *Curcuma longa* (turmeric) on overall performance of broiler chickens. Int J Poult Sci. 2:351-353.

Al-Sultan SI, Gameel AA. 2004. Histopathological changes in the livers of broiler chicken supplemented with turmeric (*Curcuma longa*). Int J Poult Sci. 3:333-336.

Alia BH, Marrif H, Noureldayemc SA, Bakheitd AO, Blunden G. 2006. Biological properties of curcumin: a review. NPC 1:509-521.

Allen PC, Danforth HD, Augustine PC. 1998. Dietary modulation of avian coccidiosis. Int J Parasitol. 28:1131-1140.

Allen PC, Fetterer RH. 2002. Recent advances in biology and immunobiology of Eimeria species and in diagnosis and control of infection with these coccidian parasites of poultry. Clin Microbiol Rev. 15:58-65.

Ammon HPT, Safayhi H, Mack T, Sabieraj J. 1993. Mechanism of antiinflammatory actions of curcumine and boswellic acids. J Ethnopharmacol. 38:105-112.

Antony S, Kuttan R, Kuttan G. 1999. Immunomodulatory activity of curcumin. Immunol Investig. 28:291-303.

Araújo CAC, Leon LL. 2001. Biological activities of *Curcuma longa* L. Memórias do Instituto Oswaldo Cruz. 96:723-728.

Baik KU, Jung SH, Ahn BZ. 1993. Recognition of pharmacophore of ar-turmerone for its anticancer activity. Arch. Pharmac. Res. 16:254-256.

Banerjee A, Nigam SS. 1978. Antimicrobial efficacy of the essential oil of *Curcuma longa*. Indian J Med Res. 68:864-866.

Bhavani Shankar TN, Sreenivasa Murthy V. 1979. Effect of turmeric (*Curcuma longa*) fractions on the growth of some intestinal and pathogenic bacteria *in vitro*. Indian J Exp Biol. 17:1363-1366.

Cabuk M, Bozkurt M, Alcicek A, Akbas Y, Kucukyilmaz K. 2006. Effect of a herbal essential oil mixture on growth and internal organ weight of broilers from young and old breeder flocks. South Afr J Anim Sci. 36:135-141.

Casewell M, Friis C, Marco E, McMullin P, Phillips I. 2003. The European ban on growth-promoting antibiotics and emerging consequences for human and animal health. J Antimicrob Chemother. 52:159-161.

Chandra D, Gupta SS. 1972. Anti-inflammatory and anti-arthritic activity of volatile oil of *Curcuma longa* (Haldi). Indian J Med Res. 60:138.

Chattopadhyay I, Biswas K, Bandyopadhyay U, Banerjee RK. 2004. Turmeric and curcumin: Biological actions and medicinal applications. Curr Sci. 87:44-53.

Chen HW, Huang HC. 2009. Effect of curcumin on cell cycle progression and apoptosis in vascular smooth muscle cells. Br J Pharmacol. 124:1029 – 1040.

Cheng H, Liu W, Ai X. 2005. Protective effect of curcumin on myocardial ischemia reperfusion injury in rats. Zhong Yao Cai J Chin Med Mater. 28:920-922.

Churchill M, Chadburn A, Bilinski RT, Bertagnolli MM. 2000. Inhibition of intestinal tumors by curcumin is associated with changes in the intestinal immune cell profile. J Surg Res. 89:169-175.

Deshpande SS, Lalitha VS, Ingle AD, Raste AS, Gadre SG, Maru GB. 1998. Subchronic oral toxicity of turmeric and ethanolic turmeric extract in female mice and rats. Toxicol Lett. 95:183-193.

Dias MC, Spinardi-Barbisan ALT, Rodrigues MAM, De Camargo JLV, Terán E, Barbisan LF. 2006. Lack of chemopreventive effects of ginger on colon carcinogenesis induced by 1, 2-dimethylhydrazine in rats. Food Chem Toxicol. 44:877-884.

Durrani FR, Ismail M, Sultan A, Suhail SM, Chand N, Durrani Z. 2006. Effect of different levels of feed added turmeric (*Curcuma longa*) on the performance of broiler chicks. J Agric and Biol Sci. 1:9-11.

El-Hakim ASA, Cherian G, Ali MN. 2009. Use of organic acid, herbs and their combination to improve the utilization of commercial low protein broiler diets. Int J Pou. Sci. 8:14-20.

Emadi M, Kermanshahi H. 2007a. Effect of turmeric rhizome powder on immunity responses of broiler chickens. J Anim Vet Adv. 6:833-836.

Emadi M, Kermanshahi H. 2007b. Effect of turmeric rhizome powder on the activity of some blood enzymes in broiler chickens. Int J Poul Sci. 6:48-51.

Ferreira LAF, Henriques OB, Andreoni AAS, Vital GRF, Campos M, Habermehl GG, De Moraes VLG. 1992. Antivenom and biological effects of ar-turmerone isolated from *Curcuma longa* (Zingiberaceae). Toxicon. 30:1211-1218.

Gautam SC, Gao X, Dulchavsky S. 2007. Immunomodulation by curcumin. The Molecular Targets and Therapeutic Uses of Curcumin in Health and Disease. 595:321-341.

Govindarajan VS, Stahl WH. 1980. Turmeric-Chemistry, technology, and quality. Crit Rev Food Sci Nut. 12:199-301.

Gowda NKS, Ledoux DR, Rottinghaus GE, Bermudez AJ, Chen YC. 2008. Efficacy of turmeric (*Curcuma longa*), containing a known level of curcumin, and a hydrated sodium calcium aluminosilicate to ameliorate the adverse effects of aflatoxin in broiler chicks. Poult Sci. 87:1125-1130.

Gowda NKS, Ledoux DR, Rottinghaus GE, Bermudez AJ, Chen YC. 2009. Antioxidant efficacy of curcuminoids from turmeric (*Curcuma longa* L.) powder in broiler chickens fed diets containing aflatoxin B-1. Br J Nutr. 102:1629-1634.

Hofacre CL. 2001. Necrotic enteritis, currently a billion dollar disease: is there anything new on the horizon? In: Lyons TP and Jacques KA, editors. Science and Technology in the Feed Industry. Proceedings of Alltech's 17th Annual Symposium, Nottingham (UK): Nottingham University Press. p. 79-86.

Huang MT, Ma W, Lu YP, Chang RL, Fisher C, Manchand PS, Newmark HL, Conney AH, You M. 1995. Effects of curcumin, demethoxycurcumin, bisdemethoxy curcumin and tetrahydrocurcumin on 12-O-tetradecanoylphorbol-13-acetateinduced tumor promotion. Carcinogenesis 16:2493-2497.

Jayaprakasha GK, Jagan Mohan Rao L, Sakariah KK. 2005. Chemistry and biological activities of *C. longa*. Trends Food Sci and Technol. 16:533-548.

Kandarkar SV, Sawant SS, Ingle AD, Deshpande SS, Maru GB. 1998. Subchronic oral hepatotoxicity of turmeric in mice--histopathological and ultrastructural studies. Indian J Exp Biol. 36:675-679.

Kermanshahi H, Riasi A. 2006. Effect of turmeric rhizome powder (*Curcuma longa*) and soluble NSP degrading enzyme on some blood parameters of laying hens. Int J Poult Sci. 5:494-498.

Khan RU, Naz S, Javdani M, Nikousefat Z, Selvaggi M, Tufarelli V, Laudadio V. 2012. The use of turmeric (*Curcuma longa*) in poultry feed. World's Poult Sci. J. 68:97-103.

Kiso Y, Suzuki Y, Oshima Y, Hikino H. 1983. Stereostructure of curlone, a sesquiterpenoid of *Curcuma longa* rhizomes. Phytochemistry 22:596-597.

Kiuchi F, Goto Y, Sugimoto N, Akao N, Kondo K, Tsuda Y. 1993. Nematocidal activity of turmeric: Synergistic action of curcuminoids. Chem Pharm Bull. 41:1640-1643.

Kumari P, Gupta MK, Ranjan R, Singh KK, Yadava R. 2007. *Curcuma longa* as feed additive in broiler birds and its patho-physiological effects. Indian J Exp Biol. 45:272-277.

Kurkure NV, Pawar SP, Kognole SM, Bhandarkar AG, Ganorkar AG, Kalorey DR. 2000. Ameliorative effect of turmeric (*Curcuma longa*) in induced aflatoxicosis in cockerels. Indian J Vet Pathol. 24:26-28.

Lee K, Lillehoj HS, Siragusa GR. 2010a. Direct-fed microbials and their impact on the intestinal microflora and immune system of chickens. J Poult Sci. 47:106-114.

Lee SH, Lillehoj HS, Jang SI, Kim DK, Ionescu C, Bravo D. 2010b. Effect of dietary curcuma, capsicum, and lentinus on enhancing local immunity against *Eimeria acervulina* infection. J Poult Sci. 47:89-95.

Maheshwari RK, Singh AK, Gaddipati J, Srimal RC. 2006. Multiple biological activities of curcumin: a short review. Life Sci. 78:2081-2087.

Malekizadeh M, Moeini MM, Ghazi S. 2012. The effects of different levels of ginger (*Zingiber officinale* Rosc) and turmeric (*Curcuma longa* Linn) rhizomes powder on some blood metabolites and production performance characteristics of laying hens. J Agric Sci Technol. 14:127-134.

Masuda T, Maekawa T, Hidaka K, Bando H, Takeda Y, Yamaguchi H. 2001. Chemical studies on antioxidant mechanism of curcumin: Analysis of oxidative coupling products from curcumin and linoleate. J Agric Food Chem. 49:2539-2547.

Mehala C, Moorthy M. 2008. Production performance of broilers fed with *Aloe vera* and *Curcuma longa* (turmeric). Int J Poult Sci. 7:852-856.

Moorthy M, Saravanan S, Mehala C, Ravi S, Ravikumar M, Viswanathan K, Edwin SC. 2009. Performance of single comb white leghorn layers fed with *Aloe vera*, *Curcuma longa* (turmeric) and probiotic. Int J Poult Sci. 8:775-778.

Osawa T, Sugiyama Y, Inayoshi M, Kawakishi S. 1995. Antioxidative activity of tetrahydrocurcuminoids. Biosci Biotechnol Biochem. 59:1609-1612.

Platel K, Srinivasan K. 1996. Influence of dietary spices or their active principles on digestive enzymes of small intestinal mucosa in rats. Int J Food Sci Nutr. 47:55-59.

Platel K, Srinivasan K. 2000. Influence of dietary spices and their active principles on pancreatic digestive enzymes in albino rats. Food/Nahrung 44:42-46.

Pulla Reddy Ach, Lokesh BR. 1994. Effect of dietary turmeric (*Curcuma longa*) on iron-induced lipid peroxidation in the rat liver. Food Chem Toxicol. 32:279-283.

Radwan N, Hassan RA, Qota EM, Fayek HM. 2008. Effect of natural antioxidant on oxidative stability of eggs and productive and reproductive performance of laying hens. Int J Poult Sci. 7:134-150.

Rahmatnejad E, Roshanfekr H, Ashayerizadeh O, Mamooee M, Ashayerizadeh A. 2009. Evaluation the effect of several non-antibiotic additives on growth performance of broiler chickens. J Anim Vet Adv. 8:1670-1673.

Rajput N, Muhammah N, Yan R, Zhong X, Wang T. 2012. Effect of dietary supplementation of curcumin on growth performance, intestinal morphology and nutrients utilization of broiler chicks. J Poult Sci. 50:44-52.

Riasi A, Kermanshahi H, Mahdavi AH. 2012. Production performance, egg quality and some serum metabolites of older commercial laying hens fed different levels of turmeric rhizome (*Curcuma longa*) powder. J Med Plants Res. 6:2141-2145.

Roughley PJ, Whiting DA. 1973. Experiments in the biosynthesis of curcumin. J Chem Soc Perkin Trans 1. 20:2379-2388.

Sadeghi GH, Karimi A, Padidar Jahromi SH, Azizi T, Daneshmand A. 2012. Effects of cinnamon, thyme and turmeric infusions on the performance and immune response in of 1-to 21-day-old male broilers. Rev Bras Ciên Avíc. 14:15-20.

Samarasinghe K, Wenk C, Silva KSFT, Gunasekera JMDM. 2003. Turmeric (*Curcuma longa*) root powder and mannanoligosaccharides as alternatives to antibiotics in broiler chicken diets. Asian-Australasian J Anim Sci. 16:1495-1500.

Sasai K, Fetterer RH, Lillehoj H, Matsuura S, Constantinoiu CC, Matsubayashi M, Tani H, Baba E. 2008. Characterization of monoclonal antibodies that recognize the *Eimeria tenella* microneme protein MIC2. J Parasitol. 94:1432-1434.

Sawale GK, Gosh RC, Ravikanth K, Maini S, Rekhe DS. 2009. Experimental mycotoxicosis in layer induced by ochratoxin A and its amelioration with herbomineral toxin binder 'Toxiroak'. Int J Poult Sci. 8:798-803.

Shukla Y, Singh M. 2007. Cancer preventive properties of ginger: A brief review. Food Chem Toxicol. 45:683-690.

Smith RM, Robinson JM. 1981. The essential oil of ginger from Fiji. Phytochemistry 20:203-206.

Srinivasan K. 2005. Spices as influencers of body metabolism: An overview of three decades of research. Food Res Int. 38:77-86.

Sugiharto, Isroli, Widiastuti E, Prabowo NS. 2011. Effect of turmeric extract on blood parameters, feed efficiency and abdominal fat content in broilers. J Indonesian Trop Anim Agric. 36:21-26.

Toennesen HH. 1992. Chemistry of curcumin and curcuminoids. In: Ho CT, Lee C, Huang MT. eds. Phenolic Compounds in Food and their Effect of Health, Vol. 1: Analysis, Occurrence and Chemistry. ACS Symposium Series No. 506. Washington, DC (USA): American Chem. Soc. p. 143-153.

Wang R, Li D, Bourne S. 1998. Can 2000 years of herbal medicine history help us solve problems in the year 2000. In Lyons TP, Jacques KA. eds. Biotechnology in the Feed Industry. Proceedings of Alltech's 14th Annual Symposium, Nottingham (UK): Nottingham University Press. p. 273-291.

WHO. 1987. Principles for the safety assessment of food additives and contaminants in food. World Health Organization (WHO), International Programme on Chemical Safety (IPCS), in cooperation with the Joint WHO/FAO Expert Committee on Food Additives (JECFA). Geneva, Switzerland. World Health Organization No. 70.

Yadav VS, Mishra KP, Singh DP, Mehrotra S, Singh VK. 2005. Immunomodulatory effects of curcumin. Immunopharmacol Immunotoxicol. 27:485-497.

Yarru LP, Settivari RS, Gowda NKS, Antoniou E, Ledoux DR and Rottinghaus GE. 2009. Effects of turmeric (*Curcuma longa*) on the expression of hepatic genes associated with biotransformation, antioxidant, and immune systems in broiler chicks fed aflatoxin. Poult Sci. 88:2620-2627.

Zainali A, Riasi A, Kermanshahi H, Ziaei H. 2008. Effect of selenium and (or) turmeric rhizome powder on growth performance of broiler chickens reared under heat stress condition. 1st Mediterranean Summit of WPSA, Advances and Challenges in Poult Sci Greece. p. 790-792.

Zhongze H, Yuanqing H, Like W, Aiyou W. 2007. Effect of curcumin on metabolism of fat for broilers. J Anhui Sci Technol Univ. 6:001.

Zhongze H, Like W, Aiyou W. 2008. Effect of curcumin on fat metabolism in Wanjiang Yellow chickens. Cereal Feed Ind. 4:012.

Zhongze H. 2009. Effect of curcumin on fat deposition and its mechanism in different breeds chickens. Anhui Agric Sci Bull. 15:107.