



Turmeric Powder: Potential Alternative to Antibiotics in Broiler Chicken Diets

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Abstract | The gradual increment of the human population resulted in an increased demand for animal protein in developing countries. To satisfy the need for animal protein, synthetic antibiotics were incorporated into broiler chickens' diets to stimulate growth and rapidly increase production performance. This is a significant problem since the resistance of antimicrobial can be derived from antibiotics' abusive usage. The antibiotic immunity is of great public health concern because the antibiotic-resistant bacteria linked with the animals may be infective to humans, easily transmitted through food chains to humans, and widely disseminated via animal waste in the environment. These can cause complex, which somehow prolonged human infections leading to higher healthcare costs and often death. There is an urgent need for the agricultural industry to develop strategies to substitute antibiotics for food-producing animals, especially poultry and livestock. Turmeric (*Curcuma longa* Linn.) is one of the many medicinal herbs promising agricultural products as natural feed additives in poultry diets. It is the primary source of phenolic compounds such as curcumin, bisdemethoxycurcumin, demethoxycurcumin, and tetrahydrocurcuminoids. Several trials of the utilization of turmeric in poultry have been conducted using the *in vitro* and *in vivo* methods, and it was found out that turmeric and its derivatives have antimicrobial properties. The use of turmeric powder as feed additives and supplements have been recommended as an alternative to antibiotics for broiler chicken production. The purpose of this review is to discuss the antimicrobial property of turmeric powder and its effect on broiler chicken in terms of performance and meat quality.

Keywords | *Curcuma longa*, Curcumin, Antimicrobial, Antioxidant, Meat quality

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INTRODUCTION

Poultry raising has undergone a paradigm shift in structure and activity, transforming itself into a major commercial enterprise from a mere backyard sector (Dalal and Kosti, 2018). It is very popular compared with some livestock industries such as swine and cattle because it enjoys a relative advantage on the ease in management, wide acceptance of its product, quick and higher returns to capital investment (Dumaup and Ampode, 2020). With the gradual increment of the human population, it is also expected that demand for poultry meat and its by-products will increase in the nearest future. Thus, to satisfy the demand

for poultry products, synthetic antibiotic growth promoters (AGPs) were incorporated into animal feed to stimulate growth, rapidly increase productivity, reduce the production cost, reduce feed efficacy, and minimize mortality preventing infections (Van den Bogaard and Stobberingh, 2000). This is a significant problem since the resistance of antimicrobial can be derived from antibiotics' abusive usage (Landers et al., 2012; WHO, 2012; Guil-Guerreiro et al., 2017). The abusive use of antibiotics had indirect adverse effects on human health because of residues in chicken meat, milk, and eggs (Guetiya-Wadoum et al., 2016). Moreover, antibiotic immunity is of great public health concern because antibiotic-resistant bacteria associ-

ated with the animals may be pathogenic to humans, easily transmitted through food chains to humans and widely disseminated via animal waste in the environment (Manyi-Loh et al., 2018). Hence, the use of antibiotics as a growth promoter was totally banned in the European Union since January 2006.

The worldwide ban on the use of synthetic antibiotics and the consumers augmented awareness triggered a need for natural and safe feed additives to obtain better production results of farm animals (Ortserga et al., 2008; Alagawany et al., 2016). Hence, the use of prebiotics, probiotics, essential oils, and the inclusion of various medicinal herbs into poultry diets as an alternative to synthetic antibiotics has been investigated to maximize poultry's production performance. These feed additives become poultry raisers' interest because of their potential as antioxidant, antibacterial, digestive, and metabolic enhancing effects (Durrani et al., 2006; Attia et al., 2017). The ideal antibiotic alternatives should have the same mechanism and beneficial effects as AGPs to ensure optimum production performance and increase nutrient availability (Lillehoj et al., 2018). The utilization of botanical compounds has been reported to be potential alternatives to antibiotics for poultry production (Nasir and Grashorn 2010; Nouzarian et al., 2011; Attia et al., 2017).

One of the many medicinal herbs promising agricultural products as natural feed additives in poultry diets is Turmeric (*Curcuma longa* Linn.) from the Zingiberaceae family (Figure 1). In the Philippines, turmeric is commonly known as "luyang dilaw". It is a perennial plant with a short stem and large oblong leaves, and it bears ovate, pyriform, or oblong rhizomes, which are often branched and brownish-yellow in color (Daneshyar et al., 2011). It is primarily utilized to improve food palatability, enhanced food appearance, food preservation (Attia et al., 2017), traditionally used as medicine (Li et al., 2011), and one of the most popular dietary supplements in the world (Andrew & Izzo, 2017). Moreover, turmeric is one of the primary sources of phenolic compounds such as curcumin, bisdemethoxycurcumin, demethoxycurcumin, and tetrahydrocurcuminoids (Kiuchi et al., 1993; Al-Sultan, 2003; Sadeghi, 2012). These bioactive compounds are yellowish turmeric pigments and have antioxidative, anticarcinogenic, anti-inflammatory, nematocidal activities, and antihepatotoxic (Nishiyama et al., 2005). It also controls against coccidiosis (Allen et al. 2002), mutagenicity, and hepatocarcinogenicity induced by aflatoxin (Soni et al., 1997, Ahmadi, 2010; Attia et al., 2017). However, limited literature has been published on turmeric utilization as a natural growth promoter in broiler chickens. Thus, a review has been made to present turmeric's potential in broiler chicken production, nutrition, and health.

ACTIVE CHEMICAL COMPONENTS OF TURMERIC POWDER

Turmeric contains a high level of beneficial phenolic compounds (curcuminoids) and terpenoids (sesquiterpenes). The main curcuminoids of the rhizome are curcumin, demethoxycurcumin, and bisdemethoxycurcumin. Whereas ar-turmerone, α -turmerone, and β -turmerone are the major ketonic sesquiterpenes of turmeric essential oil. These compounds have been reported to have antibacterial, antioxidant, anti-inflammatory, antihepatotoxic, anticarcinogenic, and hypocholesterolemic activities (Nishiyama et al., 2005; Daneshyar et al., 2011; Li et al., 2011; Abou-Elkhair, 2014; Alagawany et al., 2016).



Figure 1: Fresh turmeric rhizome and powder
Photos by Keiven Mark B. Ampode and Arbaya M. Zacaria, College of Agriculture, Sultan Kudarat State University – Lutayan Campus

Curcumin is the major bioactive component of turmeric powder (Pawar et al., 2014), about 80% of the total curcuminoids (Ashraf and Sultan, 2017). It can reach up to 6.8-7.3% of the product as reported by Paul et al. (2016). Curcumin is hydrophobic phenol and is responsible for the turmeric's orange-yellow color (Tanzeela et al., 2015; Choudhury, 2019). The primary issue of curcumin is its poor absorption in the small intestine. Nevertheless, novel methods to increase its bioavailability and curcumin's efficacy in influencing the functionality and improving gut health may be associated with a concentration in the intestine due to its poor absorbability (Lopresti, 2018).

Prasad and Aggarwal (2011) reported that turmeric originated in India is considered the best in the world's curcumin content basis. However, the variation of curcumin content of turmeric from various states of India was observed by Geethanjali et al. (2016). This variation may affect the quality of the turmeric and its efficacy to animal performance (Table 1 and 2). Nonetheless, a prediction model was developed to quantify environmental factors for predicting and optimizing curcumin content for commercial cultivation (Abdul et al., 2016).

Table 1: Effect of turmeric powder on broiler performance and meat quality raised in normal condition

Breeds and Duration of Exposure	Methodology	Findings	Recommended TP Inclusion	References
1-day-old Ross-308 broiler, 42-days of trial	Total 350 chicks in seven dietary treatments: control, 0.2% TP, 0.4% TP, 0.6% TP, 0.8% TP, 1% TP, & 1000 ppm antibiotic (unnamed)	↑DHA fatty acid ↓TBARS in thigh meat, saturated fatty acids of breast meat in 0.8% & 1% TP. ↔TBARS in breast meat, saturated fatty acids of thigh meat	0.2-0.8%	Urusan and Bolukbasi 2020
1-day-old Ross broiler, 56-days of trial	Total 200 chicks in five dietary treatments: control, 0.25% TP, 0.5% TP, 0.75% TP, & 1% TP	↑ BWG & FCR in 1% TP compared other TP groups ↔ BWG, FCR & blood lipid profile in 1% TP and control	1%	Ekine et al. 2020
1-day-old Arbor-acre broiler, 29-days of trial	Total 108 chicks in three dietary treatments: control, 0.5% TP, & 1% TP	↑BWG in 1% TP ↓FI in 0.5% TP, FCR compared to control	1%	Daramola 2020
1-day-old broiler, 42-days of trial	Total 300 chicks in six dietary treatments: control, with antibiotic, 0.25% TP, 0.5% TP, 0.75% TP, & 1% TP	↑BWG, <i>Lactobacilli</i> count ↓FCR, <i>C. perfringens</i> counts ↔FI	0.5%	Ahlawat et al. 2018
1-day-old Cobb-500 broilers, 32-days of trial	Total 360 chicks in six dietary treatments: control, 0.5% TP, 0.75% TP, 0.5% ginger powder, 0.75% ginger powder, & 0.5% ginger powder + 0.5% TP	↑BWG, FCR, ↔FI, weight of offal, hematology	0.75%	Kafi et al. 2017
1-day-old Hubbard broiler, 25-days of trial	Total 252 chicks in six dietary treatments: control diet, 0.05% TP, 0.1% TP, 0.2% TP, 0.1% MOS & 50 ppm CTC	↑ EPEI in 0.1% TP ↓ FI in 0.2% TP; FCR in 0.1% & 0.2% TP ↔ BWG, MQ	0.1%	Attia et al. 2017
1-day-old male Ross 308 broiler, 42-days of trial	Total 200 chicks in four dietary treatments: control, 0.25% TP, 0.5% TP, & 0.75% TP	↑Protein (numerical) of thigh meat; ↓Blood triglyceride, saturated fatty acid of thigh meat ↔pH, Dry Matter, Ash, triglyceride of thigh meat	-	Daneshyar et al. 2011
1-day-old Vencobb broiler, 42-days of trial	Total 280 chicks in seven dietary treatments: control, 0.1% <i>Aloe vera</i> Powder, 0.2% <i>Aloe vera</i> Powder, 0.1% TP, 0.2% TP, 0.1% <i>Aloe vera</i> Powder + 0.1% TP, & 0.2% <i>Aloe vera</i> Powder + 0.2% TP	↓FCR at first week ↔BWG, FI, FCR	0.1%	Mehala and Moorthy 2008
1-day-old Ross broiler, 49-days of trial	Total 200 chicks in four dietary treatments: control, 0.25% TP, 5% TP, & 0.75% TP	↓Abdominal fat ↔ FI, BWG, FCR, CSCI	0.25%	Emadi and Kermanshashi 2006
1-day-old broiler, 35-days of trial	Total 160 chicks in four dietary treatments: control, 0.25% TP, 0.5% TP, & 1% TP	↑BWG, dressing percentage, thigh & breast weight in 0.5%, ↓FCR in 0.5%, FI compared to control ↔Offal weight	0.5%	Durrani et al. 2006

First Trial: 19-days old broiler, 28-days of trial	Total 180 chicks in six dietary treatment: control diet, 500 ppm virginiamycin, 200 ppm MOS, 0.1% TP, 0.2% TP, & 0.3% TP	↑Carcass weight compare to control	0.1%	Samarasinghe et al., 2003
Second Trial: 21-days old broiler, 28-days of trial	Total 144 chicks in three dietary treatments: 500 ppm virginiamycin, 200 ppm MOS, & 0.1% TP	↓FCR & coliform count compared to control ↔FI in 0.1% TP with other groups, BWG with virginiamycin & MOS groups		

Abbreviations: ↑ = increase; ↓ = decrease; ↔ = similar effect; - = no recommendation stated; BWG = Body Weight Gain; FI = Feed Intake; FCR = Feed Conversion Ratio; EPEI = European Production Efficiency Index; MQ = Meat Quality; CW = Carcass Weight; CSCI = Carcass Skin Color Index; TBARS = Thiobarbituric Acid Reactive Substance; TP = Turmeric Powder; MOS = Mannan oligosaccharide; CTC = Oxytetracycline; HSCAS = Hydrated Sodium Calcium Aluminosilicate

Table 2: Effect of turmeric powder on broiler performance and meat quality raised under challenge condition

Breeds and Duration of Exposure	Methodology	Findings	Recommended TP Inclusion	References
1-day-old Cobb-500 broiler, 30-days of trial	Total 3000 chicks in six groups. Each group was divided into two subgroups fed either control or 0.2% TP diets	↓FCR, <i>C. perfringens</i> counts	0.2%	Ali et al. 2020
1-day-old Lohmann broiler, 35-days of trial	Total 392 chicks in four dietary treatments: control, 1% acidified TP, 1% acidified black pepper, 1% acidified TP + 1% acidified black pepper	↑Meat yellowness ↓FCR, abdominal fat, meat lightness, ↔FI, BWG, internal organs, meat redness in 1% TP & control groups	1%	Sugiharto et al. 2020
1-day-old male Cobb broiler, 35-days of trial	Total 672 chicks in 4x2 factorial design (TP level x <i>S. typhimurium</i> inoculation). Levels of TP: control, 1%, 2%, & 3%	↑FI, BWG, FCR, villus height, crypt depth, ↓FI & BWG in 3% TP; bacterial infection	1%	Nascimento et al. 2019
1-day-old Ross 308 broiler, 42-days of trial	Total 625 chicks in five treatments groups: thermoneutral control, heat-stressed control, heat-stressed 0.1% betaine, heat-stressed 0.2% TP, & heat-stressed 0.1% betaine + 0.2% TP	↑BWG, FI compared to heat-stressed control ↓FCR, Mortality rate, heterophil:lymphocyte ratio compared to heat-stressed control ↔BWG, FI, FCR in betaine & TP groups	0.2%	Akhavan-Salamat and Ghasemi 2016
1-day-old Ross 308 broiler, 42-days of trial	Total 200 chicks in four treatment groups under heat stress condition: control, 0.5% TP, 0.5% cinnamon, 0.25% TP + 0.25% cinnamon	↑BWG, FI ↓FCR, lipid peroxidation	0.5%	Baghban et al. 2016
1-day-old Hubbard broiler, 35-days of trial	Total 180 chicks in six dietary treatment: control, 0.5% TP, 1% TP, 30 mg endosulfan, 30 mg endosulfan + 0.5% TP, 30 mg endosulfan + 1% TP	↑FI, BWG, FCR, CW, detoxification ↓Mortality	0.5%	Alagawany et al. 2015

1-day-old Ross 308 broilers, 42-days of trial	Total of 288 chicks in eight dietary treatments: negative control, positive control (vaccinated with ND HB1 & Lasota, IB, & IBD), & positive control + different level of TP (1%, 1.2%, 1.4%, 1.6%, 1.8% & 2%)	↓BWG, FI, ↔FCR, antibody titer production, weight of lymphoid organs	-	Qasem et al. 2015
1-day-old male Ross 308 broiler, 42-days of trial	Total 250 chicks in five treatment groups: thermoneutral control, heat-stressed control, heat-stressed 0.5% TP, heat-stressed 0.5% cinnamon, & heat-stressed 0.25% TP + 0.25% cinnamon. Dietary treatments were given from 25 to 42 days	↑Dry matter of thigh meat, thigh pH ↓Meat lightness, lipid peroxidation ↔Meat redness & yellowness	0.5%	Kanani et al. 2013
1-day-old male Ross 308 broiler, 42-days of trial	Total 300 chicks in four dietary treatments: control, 0.33% TP,	↓FCR, abdominal fat, liver weight, blood triglyceride ↔FI, BWG, CW, antibody titer production	-	Nouzarian et al. 2011
1-day-old broiler, 42-days of trial	Total 90 chicks in six treatment groups infected with <i>Eimeria tenella</i> . Two control groups (infected & uninfected) & four treatment groups (1.2% salinomycin sodium, 1% TP, 2% TP, & 3% TP)	↓Bloody feces, oocyst excretion ↔FI, BWG, FCR in 3% TP, salinomycin & uninfected groups	3%	Abbas et al. 2010
1-day-old male Cobb broiler, 21-days of trial	Total 140 chicks in seven dietary treatments: control, 0.5% food grade TP, 0.5% HSCAS, 1 ppm aflatoxin B ₁ , 0.5% TP + 1 ppm aflatoxin B ₁ , 0.5% HSCAS + 1 ppm aflatoxin B ₁ , & 0.5% TP + 0.5% HSCAS + 1 ppm aflatoxin B ₁	↑FI, BWG, blood total protein & cholesterol, ↓Relative liver weight, liver peroxide ↔FCR	1% + HSCAS	Gowda et al. 2008

Abbreviations: ↑ = increase; ↓ = decrease; ↔ = similar effect; - = no recommendation stated; BWG = Body Weight Gain; FI = Feed Intake; FCR = Feed Conversion Ratio; EPEI = European Production Efficiency Index; MQ = Meat Quality; CW = Carcass Weight; CSCI = Carcass Skin Color Index; TBARS = Thiobarbituric Acid Reactive Substance; TP = Turmeric Powder; MOS = Mannanoligosaccharide; CTC = Oxytetracycline; HSCAS = Hydrated Sodium Calcium Aluminosilicate

ANTIBACTERIAL PROPERTY OF TURMERIC POWDER

Turmeric and its derivatives have proven to have an antimicrobial property based on *in vitro* and *in vivo* trials. Reduction of *Escherichia coli* counts was observed by Ahlawat et al. (2018) by supplementing turmeric powder at 0.5% of the diet. A study by Nascimento et al. (2019) reported that 1% turmeric powder in the diet inhibits intestinal colonization of *Salmonella typhimurium* in infected chicks. Necrotic enteritis induced by *Clostridium perfringens* causes high mortality and problem in performance in poultry (Caly et al., 2015). Furthermore, coccidiosis caused by protozoan is one of the predisposing factors of necrotic enteritis (Adhikari et al., 2020). A recent study by Ali et al.

(2020) reported that dietary supplementation of turmeric powder at 0.2% was found to have an effective reduction of *C. perfringens* counts in the gut of broiler chicken. Additionally, protozoan under genus *Eimeria* can be controlled by turmeric powder (Abbas et al., 2010; Gogoi et al., 2019). The findings conclude that turmeric powder can be used to prevent necrotic enteritis and other intestinal diseases.

The reduction of bacterial counts might be due to the antimicrobial properties of the active components of turmeric. In vitro trials confirmed that curcumin is effective in controlling *Streptococcus pyogenes*, *S. aureus*, *Acinetobacter iwoffii*, *Enterococcus faecalis*, *Pseudomonas aeruginosa*, *Salmonella*

enteritica, *E. coli*, *Bacillus subtilis*, and *Klebsiella pneumoniae* (Infante et al., 2014; Gunes et al., 2016; Adamczak et al., 2020). Boeder et al. (2018) reported that turmeric extract with high curcumin content have better anti-mycoplasma (*M. hominis*, *M. capricolum*, *M. genitalium*, and *M. pneumoniae*) activity. Furthermore, *M. gallisepticum* which is the causative agent of chronic respiratory disease, can be controlled by combining nanoparticles of turmeric, zedoary, and garlic extracts (Handharyani et al., 2020).

The essential oil from turmeric can inhibit the growth of *E. coli*, *P. aeruginosa*, *Bacillus cereus*, *Bacillus coagulans*, *Bacillus subtilis*, and *S. aureus*, and *Staphylococcus epidermitis* (Negi et al., 1999; Goncalves et al., 2019; Kumar et al., 2020). Essien et al. (2015) discussed that the turmeric essential oil's significant antibacterial activity might be attributed to turmerone level. However, Marliyana et al. (2019) reported that pure ar-turmerone does not have antibacterial activity against *S. aureus* ATCC 25923, *E. coli* ATCC 25922, *Klebsiella pneumoniae* ATCC 13883, and *P. aeruginosa* ATCC 27853. The authors stress that the essential oil's antibacterial activity might be due to the compounds' synergism instead of the pure compounds.

The antibacterial mechanisms of curcumin were reviewed by Zheng et al. (2020) and Kai et al. (2020). The authors discussed that it destroys bacteria by inhibiting the bacteria's quorum-sensing system, downregulation of bacterial gene expression, inhibition of SOS-induced responses, inhibition of cell division, and interfering protein synthesis by RNA disruption, disruption of the cell membrane, and induction of reactive oxygen species.

TURMERIC POWDER VERSUS ANTIMICROBIAL GROWTH PROMOTER

Numerous studies recommending turmeric and its derivatives to use as an alternative to AGP in broiler chickens have shown significant improvement or similar performance with that of antibiotics. Attia et al. (2017) found significant improvement in feed conversion ratio (FCR) and European production index of Hubbard broiler when fed with 0.1% turmeric powder from day 1 to day 35 compared to control diet (no turmeric powder), a diet with 0.05% and 0.2% turmeric powder, a diet with 0.1% mannan oligosaccharide (MOS), and diet with 50 ppm oxytetracycline (CTC). Samarasinghe et al. (2003) found no significant difference in feed intake, weight gain, and FCR between broiler chicken fed 0.1% turmeric powder, 200 ppm MOS, and 500 ppm virginiamycin. The author added, 0.2-0.3% turmeric powder improved protein and energy utilization. Ahlawat et al. (2018) compared the broiler chickens' performance fed different levels (0.25%, 0.5%, 0.75%, and 1%) of turmeric powder and unnamed antibiotics. The authors observed a significant difference in

body weight gain at 0.5-75% and a significant difference in FCR at 0.5%. Moreover, Abbas et al. (2010) found a similar coccidiostatic effect with that of salinomycin sodium (0.024% of the diet) when 3% turmeric powder is added to the diet of *Eimeria tenella* infected broiler chicken. The nano-curcumin of turmeric was effective in controlling *Eimeria* species (Gogoi et al., 2019). The findings reported in those studies conclude that turmeric powder can replace certain antibiotics as a growth promoter, giving better or at least similar performance.

EFFECT ON FEED INTAKE

Feed intake is a very critical and influential gauge in determining the performance of broiler chicken. Therefore, it is vital to determine the effect of feed ingredients on the animal's feed intake. Published studies regarding turmeric's impact on the feed intake of broilers vary from one experiment to another. Emadi and Kermanshashi (2006) reported 0.25-0.75% turmeric powder did not affect the feed intake of Ross broiler. This agrees with Mehala and Moorthy (2008) result where Vencobb broiler fed with 0.1-0.2% turmeric powder did not influence feed intake. Also, Ahlawat et al. (2018) did not find a significant effect of 0.25-1% turmeric powder in feed intake. However, Dar-amola (2020) found a reduction of feed intake of broiler chicken (Arbor-acre) at 0.5% turmeric powder. Moreover, Qasem et al. (2015) reported adverse effects of turmeric powder in feed intake at a higher dose (1-2% into the diet of Ross 308 broiler chicken).

Turmeric powder might improve feed intake when broiler chicken is under stress conditions. Akhavan-Salamat and Ghasemi (2016) reported an improvement in feed intake in Ross 308 broilers fed 0.2% turmeric powder raised under heat stress conditions. A similar finding was observed by Baghban et al. (2016) and Sadeghi and Moghaddam (2018) at 0.5% turmeric powder. Cobb-500 broiler raised in humid subtropical climate had better feed intake fed 0.75% turmeric powder diet.

Turmeric can also alleviate the adverse effect of toxic contaminants in the diet. Alagawany et al. (2015) reported Hubbard broiler chicken exposed to endosulfan (30 ppm) increased feed intake fed 0.5-1% turmeric powder diet. Also, Cobb x Cobb broiler exposed to 1 ppm aflatoxin slightly improved the performance and feed intake when turmeric powder is given at 0.5% (Gowda et al., 2008). Gholami-Ahangaran et al. (2015) reported that aflatoxin's toxic effect in the liver is mitigated by turmeric powder. Furthermore, Yarru et al. (2009) found that turmeric powder changes the expression of certain genes (antioxidant, biotransformation, and immune system) in the liver of chicken fed aflatoxin.

An infection such as coccidiosis can adversely affect broiler chicken feed intake (Christaki et al., 2004). However, the *Eimeria tenella* infected chicken fed with 3% turmeric powder in the diet would eat the same amount of non-infected chicken (Abbas et al., 2010). Nascimento et al. (2019) reported that 3% turmeric powder in the diet adversely affected the feed intake even the chicken was inoculated with *Salmonella typhimurium*. The findings revealed that the inclusion of 1% was the effective dose without negatively affecting the feed intake.

EFFECT ON FCR AND BODY WEIGHT GAIN

Numerous studies evaluated the effect of turmeric powder on the growth performance of broiler chicken. The variation of the findings might be due to several factors such as basal diets, growing duration, statistical design, breeds of broiler, the dosage of turmeric powder (Dono, 2013), and variation of the amount of active components (Li et al., 2011). Kafi et al. (2017) observed improvement in harvest weight and FCR of Cobb-500 broilers when the commercial feed was supplemented with 0.75% turmeric powder. A recent study by Ekine et al. (2020) reported that 1% inclusion of turmeric powder in a corn-soybean-based diet improved body weight gain and FCR of Ross broiler chicken without significant effect in blood Aspartate aminotransferase, Alanine transaminase, and lipid profile. Thirty-five days-old broilers supplemented with 0.5% turmeric powder improved body weight gain, FCR, dressing percentage, breast yield, and thigh yield (Durrani et al., 2006). Daramola (2020) reported an improvement in FCR and body weight gain of Arbor-acre broiler fed 0.5-1% sundried turmeric powder. However, Nouzarian et al. (2011) only found significant improvement of performance parameters in FCR when 0.33-1% oven-dried turmeric powder replaced corn in basal diet and fed to male Ross 308 broilers. An adverse effect of turmeric powder in body weight gain was observed by Qasem et al. (2015) when turmeric powder was given at 1-2% of the diet of vaccinated Ross 308 broiler chicken, however, the FCR was not affected.

The efficacy of turmeric was also tested in a challenging environment. For example, Ross broiler raised under heat stress conditions and fed with 0.5% turmeric powder in the diet had better body weight gain which was correlated to better feed intake (Baghban et al., 2016). Furthermore, Akhavan-Salamat and Ghasemi (2016) reported that Ross 308 fed with 0.2% turmeric powder gives similar performance to provided with 0.1% betaine in the diet. Recently, Ali et al. (2020) reported that Cobb-500 broilers fed with 0.2% turmeric powder improved FCR. Also, the mortality rate was reduced due to the reduction of *Clostridium perfringens* count in the gut.

The improvement of broiler chicken performance might be due to turmeric powder's antioxidant content (Hewlings and Kalma, 2017) and enhancement of antioxidant enzyme activity (Sadeghi and Moghaddam, 2018). It also reduces lipid peroxidation during stress condition, improvement in intestinal morphology (Sugiharto, 2020) which improve nutrient utilization, improvement in immune status (Isroli et al., 2017), antimicrobial properties (Nascimento et al., 2019; Ali et al., 2020) and improvement in gut ecology (Ahlawat et al., 2018).

EFFECT ON MEAT QUALITY

Food and Agriculture Organization (2014) defined meat quality based on its compositional quality, palatability, and nutritional quality. Supplementation of turmeric powder in the diet of broiler chicken was found to affect meat quality. Daneshyar et al. (2011) reported that supplementation of turmeric powder improves the meat quality of broiler chicken by increasing the crude protein and reducing triglycerides and saturated fatty acids of the meat. Urusan and Bolukbasi (2020) reported that 0.2-0.4% turmeric powder in the diet increased the DHA content of the breast, and the inclusion of 0.6-0.8% decreased saturated fatty acids in thigh and breast meat. Kanani et al. (2013) reported that Ross 308 raised under heat stress conditions enhanced meat pH and color. Sugiharto et al. (2020) found the same result where broiler fed with 1% acidified turmeric powder had a lower meat lightness value compared to the control. Slightly high yellow pigmentation of the skin and low abdominal fat of the carcass was observed. Partovi et al. (2020) discussed that the changes in meat lightness are linked to the oxidation of phospholipid of the meat, which contributed to pH reduction. Turmeric contains curcuminoids, which are natural antioxidants (Pashtetsky et al., 2019) and are deposited in the skin and tissue when supplemented in the diet causing slight yellow pigmentation of the meat (Johanna et al., 2018). The meat's oxidation defense is improved by the amount of curcuminoid (Zhang et al., 2015; Partovi et al., 2019).

CONCLUSION

The incorporation of Phytogetic feed additives as an alternative to synthetic antibiotics is gaining popularity in recent years. It is usually incorporated into farm animals' diets to enhance flavor and palatability, resulting in improved production performance. Turmeric is one of the many medicinal herbs promising in agricultural products as feed additives in broiler diets. It contains a high level of beneficial phenolic compounds and terpenoids, and the main curcuminoids of the rhizome are curcumin, demethoxycurcumin, and bisdemethoxycurcumin. Turmeric powder has been recommended as an alternative to synthetic antibiotics without adverse effects on broiler chickens'

growth performance, health, and economic traits. Also, turmeric powder as a feed supplement into broiler diets improves the chicken meat crude protein content and reduces triglycerides and saturated fatty acids. Moreover, the bioactive compounds in turmeric showed a broad spectrum of biological activities, including antibacterial, antiviral, anticoccidial, antiprotozoal, digestion absorption-enhancing effects, protection against toxins, and coccidiosis. The various effects of turmeric in broiler chickens might be due to the different levels of Curcumin incorporated into the diet. Thus, standardization of turmeric powder based on Curcumin level is recommended for commercialization.

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AUTHORS CONTRIBUTION

The authors contributed equally to this review paper.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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