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Turmeric (*Curcuma longa* Linn.) as a phytogenic growth promoter alternative for antibiotic and comparable to mannan oligosaccharides for broiler chicks

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ABSTRACT

This work aimed at investigating the potential as a growth enhancer of different dietary concentrations of turmeric (*Curcuma longa* Linn.) as an alternative to oxytetracyline (OTC) as antibiotic and as comparable to mannan oligosaccharide for broiler chicks. A total of 252 Hubbard broiler chicks at one day of age were distributed randomly in a straight run experimental design among six treatments, each replicated seven times, with six unsexed chicks per replicate. The basal diet was administered without supplements (control group) or supplemented with turmeric at 0.5, 1, and 2 g/kg diet, or with mannan oligosacride (MOS) at 1 g/kg feed or with OTC at 50 mg/kg feed. Growth performance, carcass characteristics, meat quality traits, blood biochemical constituents, antioxidant status and red blood cell (RBCs) were investigated. Turmeric supplementation at 1 g/kg feed significantly improved feed conversion ratio (FCR) and European production index compared to the control group and MOS groups. The results indicated that turmeric can be used at 1 kg/t feed as a phytogenic feed additive as an alternative to OTC or MOS without negative effects on the productive and economic traits of broilers. There were no differences from using OTC and MOS, while there was an increase in the European production efficiency index and the broilers' health status.

KEY WORDS: Turmeric, Antibiotic, Prebiotics, Carcass traits, Meat quality, Blood biochemical, Blood biochemistry, Broiler.

RESUMEN

Este trabajo se realizó para investigar el potencial como promotor del crecimiento de diferentes concentraciones dietéticas de cúrcuma (*Curcuma longa* Linn.) como una alternativa a los antibióticos y oxitetraciclina y comparable a oligosacáridos mannan (MOS) para pollos de engorda. Un total de 252 pollos Hubbard de un día de edad se distribuyeron al azar en un diseño experimental de seis tratamientos, siete repeticiones y con seis pollos sin sexar por repetición. La dieta basal se administró sin suplementos (grupo control) o complementada con cúrcuma en dosis de 0.5, 1 y 2 g/kg de dieta, o con 1 g/kg de alimento de oligosacárido mannan, o con oxitetraciclina 50 mg/kg de alimento. Se evaluó el crecimiento, características de la canal, características de calidad de carne, constituyentes bioquímicos sanguíneos, estado antioxidante y glóbulos rojos. La suplementación de cúrcuma en 1 g/kg alimento significativamente mejoró la tasa de conversión alimenticia y el Índice de Producción Europea en comparación con el grupo control y grupo MOS. Los resultados indican que la cúrcuma puede usarse en 1 kg/t de alimento como una alternativa a oxitetraciclina o MOS sin efectos negativos sobre los rasgos productivos y económicos de pollos de engorda. No hubo diferencias de uso entre oxitetraciclina y MOS, mientras que con cúrcuma hubo un aumento en el índice de eficiencia de la producción europea y el estado de salud de los pollos.

PALABRAS CLAVE: Cúrcuma, Antibióticos, Probióticos, Calidad de canal, Calidad de carne, Química sanguínea, Pollos.

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INTRODUCTION

In the last few decades, antibiotic residuals and the development of bacterial strains resistant to antibiotics have become a problem[1] due to the addition of antibiotics in animal feed formulations[2,3,4]. However, the prohibition of the use of antibiotics in animal feed in Europe in 2006 to improve the safety and security of the food chain caused significant health problems in poultry, such as increasing the incidence of intestine necrotic enteritis and clostridia. These in turn caused major complications related to decreasing animal welfare and increasing economic losses[4,5]. Hence prebiotics, probiotics, synbiotics, herbs, spices and essential oils has been investigated as an alternative to antibiotics because of their antibacterial, antioxidant, digestive and metabolic enhancing effects[6].

Botanical compounds have been shown to be potential alternatives to antibiotics for poultry production[7,8,9]. Turmeric is a member of the Zingiberaceae family. It is mainly utilized in the food industry to enhance the palatability, preservation and appearance of food. Turmeric contains different bioactive compounds, such as curcumin, demethoxycurcumin, bisdemethoxycurcumin and tetrahydrocurcuminoids[10,11,12]. These bioactive compounds have antioxidant, anti-inflammatory and nematocidal activities[10,13,14,15], protective effects against mutagenicity and hepatocarcinogenicity induced by aflatoxin[2,16] and against coccidiosis[5,17,18]. In the literature, the effects of turmeric supplementation between 0 to 10 g/kg on chicken performance have been inconclusive. For example, broilers fed diets supplemented with turmeric at 5 g/kg feed exhibited improved performance but did not affect serum total protein, albumin, globulin, ALKP, ALT and AST enzymes[1,6,19]. On the other hand, turmeric powder did not significantly affect growth performance or the carcass yield of broiler chickens[9,12,20]. Turmeric powder at 0.6 and 0.9 g/kg alleviated the negative effect of aflatoxin B_1 on serum total protein, albumin and globulin, boosted antioxidant defense enzymes, e.g. catalase and superoxide dismutase, and decreased MDA[2]. The levels of liver enzymes (ALT and ALKP) were substantially reduced by feeding broilers turmeric powder at 5 g/kg[21].

Prebiotics are also possible alternatives, particularly mannan oligosaccharides (MOS) derived from *Saccharomyces cerevisiae*[22,23]. The mode of action of MOS involves supplying intestinal microflora by nutrients (as prebiotics) and inhibiting the attachment of pathogenic bacteria, i.e. *E. coli* and *Salmonella enteritidis,* to the intestinal mucosa by binding the mannose receptors on the type 1 fimbriae[22]*.* The positive effect of MOS on broiler performance was already reviewed[22].

Oxytetracyclines (OTC) are broad-spectrum bacteriostatic agents derived from the bacteria Streptomyces. Oxytetracyclines prevent bacteria from multiplying while the host animal's immune system deals with the original infection. The recommended dose is 5 to 50 g/t feed as a continuous feed additive. In the literature, oxytetracyclines have been used for the amelioration of the growth of broilers, but the

Table 1. Fatty acid (FA) composition as percentage of fatty acids and antioxidants indices of turmeric

Fatty acid	As a % of FA[1]	As a % of FA[2]
C6:0	0.166	---
C8:0	0.039	---
C10:0	0.347	---
Undecanoic acid, C11:0	0.099	---
Tridecanoic acid, C13:0	0.282	---
Myristic acid, C14:0	0.94	---
Pentadecenoic acid, C15:1	11.29	4.04
Palmtioleic C16:1	28.11	32.50
Palmitic acid, C16:0	8..60	9.76
Heptadecenoic C 17:1	19.15	20.98
Linolenic C 18.3	---	6.01
Linoleic acid, C18:2c	15.70	18.63
Oleic acid, C18:1	14.1	8.08
Stearic acid, C18:0	0.103	---
Arachidic acid, C20:0	0.16	---
SFA	10.73	9.76
MUFA	72.65	61.66
PUFA	15.70	24.64
UFA	89.35	86.30
SFA/UFA ratio	0.120	0.113
Antioxidant activity inhibition, %	60.38	---
Total phenolic compounds, mg/kg	14.25	---

[1] Represents the present sample of turmeric [2] according to Radwan[28], SFA= Saturated fatty acids, MUFA= Mono unsaturated fatty acids, PUFA= polyunsaturated fatty acids, UFA= Unsaturated fatty acids.

results have been contradictory[24,25]. Thus this research aims to investigate the growth promoting effect of turmeric *(Curcuma longa Linn.)* and to compare it to OTC and MOS on growth performance, carcass characteristics, meat quality, serum biochemical constituents and health status during the 1st through 35th days of age of broiler chickens.

MATERIAL AND METHODS

Source of turmeric, fatty acid profiles and antioxidant indices

Turmeric purchased from the local market in a powder form was used in this experiment. The chemical analyses of the experimental diets were according to AOAC[26], meanwhile, metabolizable energy value was calculated using the equation for vegetable/plant feedstuffs according to Janssen[27]. The fatty acids profile analysed according to Radwan[28] (Table 1) after the extraction of lipids[26]. The total phenolic contents according to Balinsky *et al*[29] and the antioxidant activity (%) inhibition, determined to Benzie *et al* methodology[30].

Chicks, diets and experimental design

A total of 252 Hubbard broiler chicks 1 d of age were used in this experiment. They were fed the experimental diets (Table 2) according to a two-phase feeding system, with a starter-grower diet from d 1 to 27 and a finisher diet from d 28 to 35. The chicks were distributed randomly in a complete randomized design among six treatments. Each was replicated seven times with six unsexed chicks per replicate. The basal diet was

Table 2. Diets composition and nutrient profiles of the experimental diets percentage as fed basis

Ingredients/ profiles	Starter-grower diets 1-27 d of age (kg/t)				Finisher diets 28-35 d of age (kg/t)			
	0	0.5	1.0	2.0	0	0.5	1.0	2.0
Maize	508	507.5	507	506	600	599.5	599	598
Full fat soybean	80	80	80	80	100	100	100	100
Soybean meal	335	335	335	335	230	230	230	230
Vegetable oil blend	40	40	40	40	37	37	37	37
Turmeric powder	0.0	0.5	1.0	2.0	0.00	0.5	1.0	2.0
Sodium chloride	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Dl- methionine	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0
L-lysine	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Dicalcium phosphate	18.5	18.5	18.5	18.5	15.0	15.0	15.0	15.0
Limestone	10	10	10	10	10	10	10	10
Vit. + Min. mixture[1]	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Total	1000	1000	1000	1000	1000	1000	1000	1000
Calculated[2] and chemical composition[3] (g/kg)								
ME MJ/kg diet[2]	.1297	.1297	.1297	.1297	.1346	.1346	.1346	.1346
Dry matter[3]	897	895	898	896	895	897	898	891
Crude protein[3]	222	223	220	221	189	187	189	187
Calcium[2]	9.2	9.2	9.2	9.2	8.2	8.2	8.2	8.2
Inorganic phosphorus[2]	4.9	4.9	4.9	4.9	4.1	4.1	4.1	4.1
Methionine+cystine[2]	8.5	8.5	8.5	8.5	7.4	7.4	7.4	7.4
Lysine[2]	13.0	13.0	13.0	13.0	11.0	11.0	11.0	11.0
Crude fibre[3]	52.3	52.3	52.3	52.3	56.5	54.7	55.5	57.5
Crude fat[3]	88.3	88.3	88.3	88.3	89.1	87.1	88.1	89.3
Ash[3]	85.3	84.3	83.7	86.4	91.2	90.8	88.5	89.0

[1]Vit+Min mix. provides per kilogram of the diet: Vit. A, 12000 IU, vit. E (dl-α-tocopheryl acetate) 20 mg, menadione 2.3 mg, Vit. D3, 2200 ICU, riboflavin 5.5 mg, calcium pantothenate 12 mg, nicotinic acid 50 mg, Choline 250 mg, vit. B12 10 μg, vit. B6 3 mg, thiamine 3 mg, folic acid 1 mg, d-biotin 0.05 mg. Trace mineral (mg/ kg of diet): Mn 80 Zn 60, Fe 35, Cu 8, and Selenium 0.1 mg.

formulated to be isocaloric and isonitrogenous and to meet the nutrient requirements[31]. The basal diet was administered without the tested supplements (the control group) or supplemented with turmeric at 0.5 (T_0.5), 1 (T_1), and 2 (T_2) g/kg diet. The concentrations of turmeric supplementation was chosen based in previous studies[12,20,21] in which 0 to 10 g/kg was included in broiler diets with inconclusive results. The basal diet was also supplemented with mannan oligosaccharides (MOS; Alltech Inc., Nicholasville, KY, USA) at 1 g/kg diet or oxytetracycline (OTC) at 50 mg/kg diet. OTC is a broad-spectrum bacteriostatic agent derived from the bacteria Streptomyces. The recommended dose is 5 to 50 g/t feed as a continuous feed additive. Terramycin (OTC) is a registered trademark of Pfizer, Inc., USA. It is US FDA NADA (new animal drug application) #95-143, approved by the FDA 7870000 101-9010-07 and licensed to Phibro Animal Health Corporation for OTC HCl.

Broilers husbandry

Chicks were kept in battery brooders (40×45×60 cm) under similar managerial and hygienic conditions in semi-opened housing. Water and mash feeds were offered *ad libitum*. The brooding temperature was 34, 32 and 30 ºC during the 1st, 2nd and 3rd wk of age, respectively. During 21 to 35 d of age, the average ambient temperature and relative humidity (RH) were 30 ± 3 °C to 45 ± 4 %, respectively. The light-dark cycle was 23:1.

Data collection

Body weight was recorded at the 1st, 14th, 27th and 35th d of age; body weight gain, feed intake and the feed conversion ratio (FCR) were calculated for the periods 1-14, 1-27, and 1-35 d of age. At 35 d of age, seven chickens from each treatment representing all replicates were randomly taken and slaughtered to determine their carcass characteristics. In addition, the lymphoid organs, including the thymus, spleen and bursa of Fabricius, were removed and weighed. Meat quality traits (n= 7 samples/treatment) represented all replicates, such as chemical composition (dry matter, protein, lipid and ash) and physical characteristics (pH, colour of meat, water holding capacity [WHC] and tenderness) were carried out as previously reported[32].

At d 35 of age, seven blood samples were collected in both not-heparinized and heparinized tubes from each treatment represented all treatment replicates. The serum was separated by centrifugation at 1,500 xg for 10 min at 4 °C and stored at -18 °C until analysis. The selected serum biochemical profile such as serum total protein and albumin concentrations (g/dL), alanine amino-transferase (ALT) and aspartate aminotransferase (AST), (µ/L), alkaline phosphatase (ALKP) enzymes, total antioxidant capacity (TAC) as an indicator of antioxidant status, and malnodialdehyde (MDA as a biomarker for lipid peroxidation respectively were determined using commercial diagnostic kits (Diamond Diagnostics Company, Cairo, Egypt)[32,33]. Globulin concentration (g/100 mL) was calculated as the difference between total protein and albumin. Red blood cell (RBCs) characteristics, including haemoglobin (Hgb), packed cell volume (PCV), mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV) and mean corpuscular haemoglobin concentration (MCHC), were measured as previously cited[32,33]. Haemagglutination (HINDV) inhibition for New Castle disease virus was determined according to Snyder *et al*[34].

Upon necropsy, the intestine was removed, thoroughly washed with a physiological saline (0.9% NaCl) solution, blotted on filter paper and then buffered with formalin 10%. The fixed specimens were processed using a conventional paraffin embedding technique. From the prepared paraffin blocks, 5 mm thick sections were obtained and stained with haematoxylin and eosin for light microscopic examination[35]. In order to determine the length of the villi, 5 villi were measured on each segment for all groups. The villi lengths were measured from their base upwards to the end of the villus. The morphometric measurements were taken in a binocular microscope equipped with a clear Nikon camera and coupled with an image-analysing system from Optika[36].

Statistical analysis

Data were analysed using the SAS software program[37], using a completely randomized design, considering the replicate as the experimental unit according to the following model:

$$Y_{i,j} = \mu + T_i + \varepsilon_{i(j)}$$

With $Y_{i,j}$ being any observation for which $X_1 = i$ (i and j denote the level of the factor and the replication within the level of the factor, respectively); μ= general location parameter; $T_{i=}$ is the effect of having treatment level I; εi(j)= is the random error.

Mean differences were tested by the Tukey's studentized test[37] using $P \leq 0.05$; although when P value was great than 0.05 and less than 10 was reported as trend. Before analysis, all percentages were converted to arc sin to normalize data distribution.

RESULTS

Chemical composition, fatty acids, antioxidant activity percentage inhibition and total phenolic compounds

Chemical composition of turmeric showed 89.7 % dry matter, 5.8 % crude protein, 4.7 % ether extract, 4.2 % ash 3.5 % crude fiber and 71.5 % nitrogen free extract and calculated ME value was found to be 3,664 kcal/kg turmeric. The results, as displayed in Table 1, describe the fatty acids content of turmeric, antioxidant activity inhibition and total phenolic compounds. The results indicate that linoleic acid is the dominant polyunsaturated fatty acid and palmitoleic acid is the dominant monounsaturated fatty acid. These indicate that turmeric is a good source of unsaturated fatty acids. The antioxidant activity inhibition and total phenolic compounds are 60.38 % and 14.25 mg/g, revealing a potential antioxidant activity.

Growth performance

Data for broiler performance are shown in Table 3. The results showed that different supplements did not significantly affect BWG of chickens during different experiment period except for a trend for greater ($P \leq 0.089$) growth of T_0.5, and the MOS groups during d 15-27 and T_0.5 and T_1 ($P \leq 0.095$) during the whole experimental period (d 1-35 of age) in comparison to the control group, T_2 group and OTC groups and the control group, T_2 group, MOS and the OTC groups, respectively.

Table 3. Growth performance of broiler chickens fed diets supplemented with different concentrations of turmeric, mannanoligosacchride and oxytetracycline

Criteria	Control	Curcumin g/ kg diet			MOS	OTC	SEM	*P*-value
		0.5	1	2				
Body weight and body weight gain, g								
Body weight at 1 d	46	46	48	47	45	46	1.01	0.524
BWG 1-14 d of age	386	352	376	341	377	347	13.9	0.139
BWG 15-27 d of age	837	954	882	829	905	836	34.1	0.089
BWG 28-35 d of age	495	527	580	565	510	599	40.1	.0401
BWG 1-35 d of age	1718	1833	1838	1735	1792	1781	34.2	0.095
Feed intake, g/chick/ period								
1-14 d of age	646^{a}	607^{ab}	560^{ab}	511^{b}	649^{a}	549^{ab}	23.6	0.001
15-27 d of age	1495^{abc}	1652^{a}	1465^{abc}	1416^{bc}	1597^{ab}	1316^{c}	52.8	0.001
28-35 d of age	994	1093	1072	1002	1045	1252	77.6	0.225
1-35 d of age	3135^{ab}	3352^{a}	3097^{ab}	2929^{b}	3292^{a}	3118^{ab}	73.3	0.005
Feed conversion ratio, kg feed/kg gain								
1-14 d of age	1.67^{ab}	1.72^{a}	1.49^{c}	1.50^{c}	1.72^{a}	1.58^{bc}	0.022	0.001
15-27 d of age	1.78^{a}	1.74^{ab}	1.66^{ab}	1.71^{ab}	1.77^{a}	1.59^{b}	0.038	0.012
28-35 d of age	2.01	2.09	1.85	1.74	2.04	2.19	0.109	0.076
1-35 d of age	1.82^{a}	1.83^{a}	1.68^{b}	1.69^{b}	1.84^{a}	1.75^{ab}	0.021	0.001
Survival rate and European production efficiency index (EPEI)								
Survival rate, %	100	100	100	100	100	100	0	ND
EPEI	262^{b}	279^{ab}	303^{a}	286^{ab}	271^{b}	282^{ab}	5.98	0.001

MOS= Mannoligaosacchride; OTC=Oxytiteracycline; BWG= Body weight gain; SEM= Standard error of means.

^{a,b,c} Differences among means within a column within each factor not sharing similar superscripts are significant ($P<0.05$),

Feed intake during the different experimental periods was significantly affected by the different treatments. During d 1-14 of age, the T_2 group consumed significantly less feed than the control and MOS groups. During d 15-27 of age, the T_2 and OTC groups reduced feed intake in comparison to the T_0.5 group. In addition, OTC groups reduced feed intake in comparison to the MOS group. For the 1-35 d period, the T_2 group significantly decreased feed intake in comparison to the T_0.5 and MOS groups.

During most of the experimental periods, the different supplements significantly affected FCR. During d 1-14 of age, the T_1, T_2 and OTC groups significantly improved FCR in comparison to the other groups, but the T_1 and T_2 groups had more favorable effects than the OTC group as the difference between OTC and control group was not significant. During d 15-27 of age, the OTC group significantly improved FCR in comparison to most of the experimental groups except for the T-0.5, T_1 and T_2 groups. During d 28-35 of age, there was a trend for improved FCR of groups on T_1 and T_2 in comparison to the other experimental groups. For the whole period, the T_1 and T_2 groups significantly boosted FCR in comparison to the other groups except for OTC.

The survival rate was 100 % in the different experiment groups. The European Production Efficiency Index of the T_1 group was significantly higher than that of the control and MOS groups. Other groups exhibited intermediate values.

Carcasses characteristics and inner body organs

The results for carcass traits, relative weight of internal organs, chemical composition and physical parameters of meat are presented in Table 4. Most of the traits were significantly

Table 4. Carcass characteristics, inner body organs and meat quality of broiler chickens fed diets supplemented with different concentrations of turmeric, mannanoligosacchride and oxytetracycline

Criteria	Control	Curcumin g/kg diet			MOS	OTC	SEM	*P* value
		0.5	1	2				
Carcass characteristics and inner body organs								
Dressing,%	72.7^{a}	68.1^{b}	69.4^{ab}	69.9^{ab}	68.7^{ab}	66.6^{b}	0.951	0.006
Abdominal fat,%	0.759	0.715	0.670	0.634	0.544	0.673	0.091	0.654
Proventiculus,%	0.582^{a}	0.495^{ab}	0.379^{b}	0.532^{ab}	0.604^{a}	0.505^{ab}	0.056	0.010
Gizzard,%	1.38^{a}	1.32^{a}	0.889^{b}	1.25^{a}	1.11^{ab}	1.15^{ab}	0.079	0.005
Liver,%	2.36	2.23	2.16	2.25	2.34	2.48	0.111	0.422
Heart,%	0.540^{a}	0.352^{b}	0.430^{ab}	0.533^{a}	0.484^{ab}	0.450^{ab}	0.038	0.022
Pancreas,%	0.283	0.274	0.214	0.253	0.299	0.228	0.019	0.039
Intestinal,%	7.93	8.53	8.13	8.97	7.65	7.99	0.451	0.332
Intestinal villi length, µm	1261^{c}	1435^{b}	1406^{b}	1289^{b}	1255^{c}	1806^{a}	57.4	0.001
Spleen weight, %	0.102^{ab}	0.084^{b}	0.114^{ab}	0.091^{b}	0.162^{a}	0.088^{b}	0.014	0.008
Thymus weight, %	0.394^{a}	0.377^{ab}	0.335^{b}	0.481^{a}	0.307^{b}	0.340^{b}	0.078	0.004
Fabricius bursa weight, %	0.134^{ab}	0.117^{ab}	0.179^{a}	0.157^{ab}	0.159^{ab}	0.100^{b}	0.017	0.040
Chemical composition of meat,%								
Dry matter	25.1	24.9	25.0	25.0	24.9	24.9	0.064	0.215
Crude protein	19.2	19.1	19.3	19.0	18.9	19.1	0.101	0.086
Lipids	4.72	4.75	4.58	4.73	4.81	4.64	0.071	0.294
Ash	0.973	0.993	0.990	0.987	0.983	0.990	0.012	0.879
Physical characteristics of meat								
pH	5.93	6.08	6.01	6.00	6.02	5.98	0.079	0.862
Color, optical density	0.197	0.210	0.212	0.203	0.209	0.209	0.094	0.864
Tenderness cm^{2}/g	9.82	10.02	10.19	10.26	9.86	10.26	0.066	0.579
WHC, cm^{2}/g	17.48	18.25	17.48	17.92	17.82	17.98	0.059	0.315

SEM= Standard error of means, MOS= Mannoligaosacchride, OTC=Oxytiteracycline, pH= hydrogen power; WHC= Water holding capacity.

^{a,b,c} Differences among means within a column within each factor not sharing similar superscripts are significant (P<0.05).

affected by the treatments with the exception of the relative weight of the abdominal fat, liver, pancreas (although F value was significant P≤0.039 for only pancreas) and intestine. Dressing percentage significantly decreased due to T_0.5 and OTC supplements in comparison to the control group. It was found that the T_1 group significantly decreased proventriculus in comparison to the control and MOS groups, and also decreased rate of gizzard in comparison with the control, T_0.5 and T_2 groups. The heart percentage was significantly lower in the T_0.5 group than in the control and T_2 groups. Most supplemented groups, except the MOS group, significantly increased intestinal villi length in comparison to the control one, with the OTC group displaying the greatest effect.

Lymphoid organs such as the spleen, thymus and Fabricius bursa were significantly affected by the dietary supplementations. The MOS group exhibited significantly greater spleen weight than the T_0.5, T_2 and OTC groups. The thymus percentage was greater of the control and T_2 groups than those of the other groups except for T_0.5 group. The Fabricius bursa of the T_1 group was significantly higher than that of only the OTC group.

Meat quality

Table 4 shows the content of the dry matter, protein, lipids and ash of the meat, as well as the physical traits such as pH, color, WHC and tenderness. These traits were not significantly affected by the different supplementations, but there was a trend ($P \leq 0.086$) for higher CP of T_1 group than that of MOS group.

Blood biochemical, liver leakage, antibody titer and red blood cells characteristics

The blood serum biochemical components are shown in Table 5. Different supplements significantly affected serum total protein, globulin, ALKP, ALT, AST, AST/ALT ratio, HI NDV and TAC. It was found that the T_0.5, MOS and OTC groups had a significant increase in the total protein in

Table 5. Serum biochemical, liver leakage markers, antioxidant indices and red blood cell parameters of broiler chickens fed diets supplemented with different concentrations of turmeric, mannanoligosacchride and oxytetracycline

Criteria	Control	Curcumin g/kg diet			MOS	OTC	SEM	*P* value
		0.5	1	2				
Serum protein metabolites								
Total protein, g/dL	6.18^{ab}	6.30^{a}	5.73^{c}	5.93^{bc}	6.40^{a}	6.40^{a}	0.066	0.001
Albumin, g/dL	3.30	3.27	3.12	3.12	3.07	3.07	0.103	0.628
Globulin, g/dL	2.88	3.02	2.60	2.80	3.33	3.32	0.143	0.032
Albumin to globulin ratio	1.16	1.083	1.24	1.14	0.928	0.942	0.087	0.051
Liver leakage and antibody markers								
Alkaline phosphatase, U/L	9.25^{c}	10.75^{bc}	12.75^{a}	11.25^{ab}	11.75^{ab}	11.00^{abc}	0.431	0.008
ALT, U/L	63.0^{a}	62.0^{a}	62.3^{a}	61.8^{a}	60.8^{a}	58.8^{b}	0.512	0.001
AST,U/L	54.3^{a}	50.0^{b}	52.3^{ab}	52.0^{ab}	52.3^{ab}	53.3^{ab}	0.731	0.017
AST/ALT ratio	0.862^{ab}	0.806^{b}	0.840^{b}	0.843^{b}	0.863^{ab}	0.909^{a}	0.014	0.003
HINDV, Log^{2}	4.37^{b}	5.48^{ab}	6.73^{a}	5.62^{ab}	5.15^{ab}	4.12^{b}	0.325	0.013
Antioxidant indices								
TAC, mmol/l	416^{b}	439^{a}	434^{a}	422^{b}	431^{a}	431^{a}	1.43	0.001
MDA, µmol/l	10.8	11.3	11.0	11.3	10.8	11.3	0.471	0.920
Red blood cell parameters								
RBCs, (10^{6}/mm^{3})	1.58	1.70	1.67	1.62	1.72	1.70	0.039	0.071
Hgb, g/dL	11.8^{a}	10.8^{ab}	11.8^{a}	10.8^{ab}	10.3^{b}	11.3^{ab}	0.271	0.004
PCV,%	32.0^{ab}	32.2^{ab}	33.2^{a}	32.8^{a}	31.2^{b}	32.2^{ab}	0.381	0.008
MCV, µm^{3}/RBC	205^{a}	190^{ab}	200^{a}	200^{a}	181^{b}	190^{ab}	4.65	0.006
MCH, pg	74.4^{a}	63.0^{cd}	70.2^{ab}	65.4^{bcd}	60.0^{d}	67.0^{bc}	1.61	0.001
MCHC,%	36.2^{a}	32.8^{b}	34.8^{ab}	32.6^{b}	32.8^{b}	34.8^{ab}	0.721	0.002

MOS= Mannoligaosacchride; OTC=Oxytiteracycline; SEM= Standard error of means; ALT= Alanine amino transferase; AST= Aspartate amino transferase; HINDV=haemagglutination inhibition for new castle disease virus; TAC= Total antioxidant capacity; MAD= Malnodialdehyde; Hgb=Hemoglobin; PCV= Packed cell volume; MCV= Mean cell volume; MCH= Mean cell hemoglobin; MCHC= Mean cell hemoglobin concentration.

^{a,b,c} Differences among means within a column within each factor not sharing similar superscripts are significant ($P<0.05$).

comparison to the other groups except for the control group. The latter group had also greater total protein than T_1 group. Differences in serum globulin were not significant among different means of groups. ALKP was significantly higher for the groups supplemented with T_1, T_2 and MOS in comparison to the control group; the T_1 group showed the greatest effect and T_0.5 and OTC exhibited intermediate values.

The antibiotic supplemented group had significantly decreased ALT in comparison to the other groups, while the T_0.5 group had significantly decreased AST in comparison to only the control group. In addition, the AST/ALT ratio of the turmeric groups was significantly lower than that of the OTC group. HINDV was the highest of T_1 group while the lowest was from the control and OTC groups. Most of supplemented groups except that T_2 group had significantly higher TACs than that of the control group, with the T_0.5 group exhibiting the greatest TAC. There were no significant differences in MAD among the different groups.

The different treatments had a significant effect on most of the hematological traits except for RBCs ($P \leq 0.071$). Hgb, PCV, MCV, MCH and MCHC were the lowest in the MOS group, while Hgb, PCV, MCV of the T_1 group had the highest values. MCH and MCHC were the highest in the control group but did not significantly differ from the T_1 group.

DISCUSSION

The present results indicate that turmeric is a potential source of nutrients, poly-unsaturated fatty acids and antioxidants[38], and T_1 improved growth performance and the European production efficiency index. This indicates that 1 g/kg turmeric is adequate as an alternative growth promoter that could replace OTC and have a better impact on productive performance than MOS for both FCR and the European production index.

The potential effect of turmeric on growth performance and the production index of broilers are in line with those reported elsewhere[11,20,39]. The aforementioned authors concluded that turmeric supplementation at the rate of 1 to 10 g/kg improved growth performance of broiler chickens without adverse effects on mortality. In addition, turmeric supplementation at 5 g/kg feed improved the growth of chickens exposed to aflatoxins[40,41], and alleviated the negative influences of Eimeria infection[18,19,42] and of heat stress[39]. These potential effects of turmeric could be attributed to its curcuminoids (3 to 5 %, as found in turmeric powder), bisdemethoxy curcumin and demethoxy curcumin, the principle active compounds in turmeric[43]. These compounds show a wide spectrum of biological activities including antioxidant, antibacterial, antifungal, antiprotozoal, antiviral, anticoccidial and anti-inflammatory properties, digestion- and absorption-enhancing effects, and protection effects against coccidiosis and toxins[5,19,44]. Turmeric also improves liver and bile functions through increased bile secretions, protects the stomach from ulcers and reduces liver toxins. These improvements can enhance digestion, metabolic processes and nutrient utilisation for growth through stimulation of protein synthesis by the chicken enzymatic system[6,11]. Turmeric has been observed to enhance the intestinal lipases, amylase, trypsin and chymotrypsin secretions[45]. This is similar to our findings regarding the increase in the length and width of villi in the intestinal, which are also similar to other findings[45]. Therefore, the improvement in the growth performance due to turmeric supplementation to broilers' diets can be partly attributed to improving the ecology and function of the digestive tract of chickens. On the other hand, turmeric did not show constant effects on growth performance as had been reported[21]. No significant positive effect of turmeric powder at between 3.03 and 10 g/kg diet on the growth performance of broiler chickens[9,12]. This inconsistency in the reviewed results can be attributed to the different qualities of feed, breeder and age of the broilers, statistical design, doses of turmeric and the sanitary and environmental conditions. The improved production index by 15.6 % due to inclusion of turmeric powder at 1 g/kg is in the range cited in the literature of 1.5 %[39] and 11.8 %[6] when turmeric was supplemented at 5 g/kg feed.

Turmeric, particularly at 1 g/kg feed, induced adaptive changes in the different body organs. The decreased proventriculus and gizzard and increased intestinal villi length indicated enhanced digestive function that can explain the increased performance, meat protein and somewhat

decrease in meat lipid of the broilers on the T_1 treatment. On the other hand, turmeric at 1 and 2 g/kg diet had no negative effects on carcass traits. Meat quality is an important concept in broiler production nowadays and improved postharvest quality and shelf life is essential[32]. The present findings indicate that turmeric is a beneficial feed additive due to phytochemicals, such as curcumin, AR-turmerone, methylcurcumin and other active compounds that could improve carcass quality and reduce spoilage[1,5]. This increase in the quality of the carcass traits of broilers could be attributed to its antimicrobial effect, which improves the shelf life of the carcasses[1,6,11].

Despite the absence of a significant effect of turmeric in this study on the relative weight of abdominal fat, liver and intestines, there was a numerical decease in percentage abdominal fat of 11.7 % and 16.5 % and in liver of 8.5 and 4.7 % due to turmeric supplementation at 1 and 2 g/kg, respectively. The positive effect of turmeric in abdominal fat and liver could be attributed to its negative influence on liver fatty acid synthesis as manifested by an increase in meat CP and the decrease in meat lipid of T_1 group. In literature, liver triacylglycerol and plasma triacylglycerol in the VLDL fraction and liver cholesterol significantly decreased, but the activity of hepatic acyl-CoA oxidase increased[9,46]. In addition, turmeric at a rate of 3 g/kg feed reduced the meat fat content and increased the carcass quality of broilers[11,47,48].

In partial agreement with the present results, turmeric supplementation at 5 g/kg feed did not significantly affect percent dressing, liver, gizzard and heart, but significantly increased the proventriculus[6]. In addition, turmeric at the same dose significantly increased percent dressing, weight of the breast and thigh, but did not affect percent liver, heart and gizzard[6]. In other studies, turmeric supplementation did not significantly affect the weight of the carcass, heart, pancreas or intestine[9], gall bladder[11], the ready-to-cook carcass, liver, pancreas, heart, gizzard, proventriculus, abdominal fat and length of the entire small intestinal, duodenum, jejunum and ileum[12]. However, turmeric decreased the abdominal fat and liver percentages[9,11] and increased percentage of the entire small intestinal and the ileum weight[12].

The effect of turmeric, MOS and OTC on meat quality are in partial agreement with those reported elsewhere[11], who showed that curcuma longa did not affect crude protein or extracts of breast and thigh meat as well as organoleptic tests (smell, flavour, colour and tenderness).

Lymphoid organs, antibody level, antioxidant status and blood metabolites are a good markers of health status of the animal. The impact of turmeric concentrations on lymphoid organs indicates that different concentrations of turmeric did not affect spleen, thymus and Fabricius bursa percentages, but MOS increased percent spleen and decreased thymus and did not significantly affect Fabricius bursa and 28-d HINDV titer in comparison with the control and antibiotic groups. In the literature, the inclusion of turmeric powder increased the spleen weight and did not affect the Bursa and thymus weight index[11], spleen and bursa of Fabricius[9,12] and relative weight of the spleen, bursa or thymus[20]. These results reveal that turmeric is a safe phytogenic feed supplement for chickens and may enhance their immune response as measured by specific antibody titres, as reviewed by others[5].

The changes in serum metabolites indicate that, except for the decrease in serum total protein, turmeric supplementation at different doses did not affect serum albumin, globulin and albumen to globulin and indices of hepatocellular leakage (ALT, AST and AST/ALT). There were, however, numerical decreases in the AST and AST/ALT ratio, which show a potential decease in hepatocellular leakage markers that could be attributed to the significant increase in TAC (antioxidants index) of broilers fed turmeric supplemented-diets. Similarly, serum ALT and AST were not affected by turmeric powder[49]. In addition, turmeric powder at 0.6 and 0.9 alleviated the negative effect of aflatoxin B_1 on serum total protein, albumin and globulin, boosted antioxidant defence enzymes, e.g. catalase and superoxide dismutase, and decreased MDA[2]. The levels of liver enzymes (ALT and ALKP) were substantially reduced by feeding broilers turmeric powder[22]. On the other hand, turmeric at 5 g/kg feed did not affect serum total protein, albumin, globulin, ALKP, ALT and AST enzymes[20].

The increase in the Hgb and PCV of broilers supplemented with turmeric at 1 g/kg feed indicates an improvement in health status. This can be attributed to the antioxidant capacity of turmeric and its digestive-enhancing effect that

may improve iron absorption. Similar results were reported by for RBCs[11] and for PCV[12]. Also, found that turmeric improved the health status of broilers[20]. In accordance with the present results, no mortality up to 35 d of age in broilers was observed when turmeric was supplemented at 0.5 % in the broiler diet[6], and less mortality was observed at 0.1 % inclusion[39].

It was found that turmeric at 1 g/kg feed had effects comparable to MOS and OTC on growth, dressing percentage and lymphoid organs, and was better by 8.7 % than MOS for FCR. The lower feed utilization of the MOS group might have been due to their lowest villi length. OTC induced the highest increase in intestinal villi, with no difference in FCR and production index from the turmeric groups. The effect of OTC seems to be related to the anti-inflammatory action of OTC rather than to its antibiotic effect[26,50,51]. On the other hand, MOS and OTC increased serum total protein compared to the intermediate and highest turmeric doses. These results indicated that turmeric had antibiotic-like effects due to its antimicrobial and anti-inflammatory effects.

CONCLUSION AND IMPLICATIONS

Turmeric can be used at 1 kg/t feed as a phytogenic feed additive as an alternative to OTC or MOS without negative effects on the productive and economic traits of broilers. There were no differences from using OTC and MOS, while there was an increase in the European production efficiency index and the broilers' health status.

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