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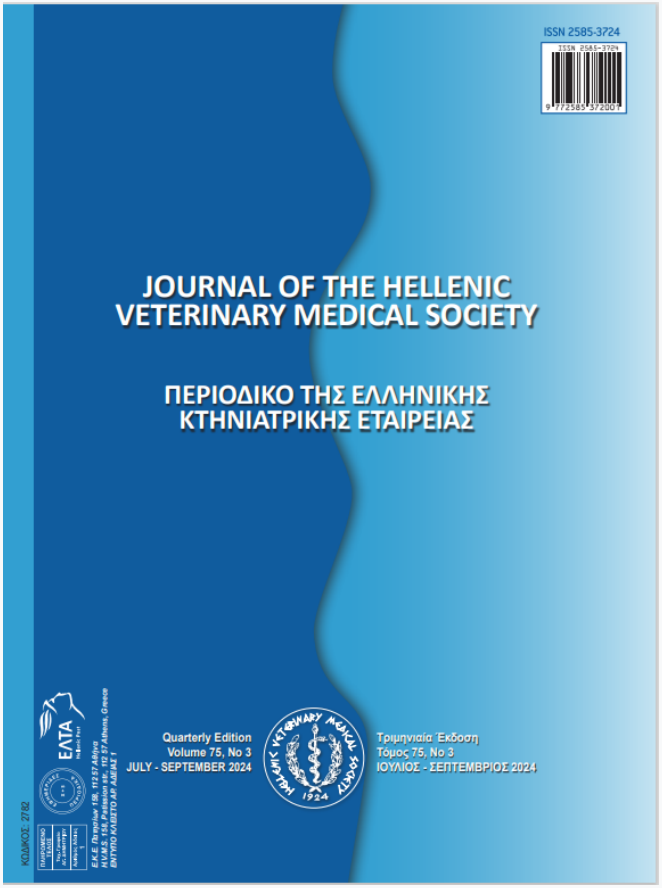

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Effect of different levels of turmeric (*Curcuma longa*) on productivity in broiler chickens

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ABSTRACT: This research was conducted to evaluate the effect of different levels of turmeric powder on the performance, blood parameters, immunity, intestinal morphology, carcass characteristics, cecum microbial flora, fatty acid profile and sensory evaluation of breast meat of broiler chickens. A completely randomized design was used including four levels of turmeric powder (250, 500, 750 and 1000 mg/kg diet) and a control treatment (without turmeric), in 5 replications. Based on obtained results, different levels of turmeric had significant effect on performance, carcass characteristics, blood parameters, immunity, intestinal morphology, cecal microbial flora, fatty acid profile, and the sensory evaluation of breast meat ($P<0.05$). Body weight, feed intake and feed conversion ratio (FCR) at the end of the period were significant in the treatments that received turmeric powder ($P<0.05$). Survival percentage, produced body weight per square meter, and final profit was also significant ($P<0.05$). Relative weight of abdominal fat, villus height and villus height/ crypt depth of the small intestine were significant in the treatments receiving turmeric powder ($P<0.05$). By adding turmeric powder to the diet of broiler chickens, the microbial population of the cecum also became significant ($P<0.05$). The concentration levels of uric acid, total cholesterol, glucose, HDL, albumin and liver enzymes alkaline phosphatase and ALT were significant in the birds receiving turmeric powder ($P<0.05$). Turmeric powder in the diet of broilers also had a significant effect on chondroitinic acid, linoleic acid and total polyathenoids ($P<0.05$). Turmeric powder was significant on the lactobacilli microbial population ($P<0.05$). Fat content, juiciness, crispyness, chewability, elasticity, mouthfeel and general acceptance were significantly improved ($P<0.05$). In this research, the treatment receiving 500 mg of turmeric powder per kg had the greatest effect on the measured characteristics of broiler chickens. It can be concluded that the addition of the powder of these medicinal and aromatic plants to the diet of broiler chickens has beneficial effects on the carcass characteristics and meat quality.

Keywords: fatty acid; blood plasma; abdominal cavity; triglyceride; feed conversion ratio; *Curcuma longa*

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INTRODUCTION

Currently, with the rapid increase in population and consequent ever-increasing need for food, especially protein, meeting the nutritional needs of the human population is of the greatest importance in human society (Lishianawati *et al.,* 2021). In recent years, poultry meat as a source of animal protein has become increasingly important in human nutrition as it is becoming more competitive day by day in relation to other consumed meats and their products (Augusty´nska *et al.,* 2022). It is predicted that the world population will reach 9.15 billion people by 2050 (Costantino *et al.,* 2018) and therefore, due to the increase in demand for animal protein, there is a need to improve the production level of this sector. With the increase in population and the increase in the demand for white meat, expansion of the poultry industry would seem to be necessary to meet the need (Amini *et al.,* 2015). Among the problems in broiler breeding is the poor performance of breeding units (Anonymous. 2014). This in turn is related to the correct way of feeding, strain selection, flock density, sensitivity of the flock to pathogens and metabolic disorders, optimal capacity of the rearing unit, appropriate slaughter age and other management and economic aspects (Hughes. 2012). Food is perhaps the most well-known and effective means of improving the immune system of birds in response to various diseases (Wang and Xiong, 2019). Usually, a significant challenge that arises during the different stages of poultry breeding is that the nutrients in the diet are not used for bird growth but are diverted to different metabolic paths (Bozhko *et al.,* 2021; Ormian and Tobiasz-Salach, 2022). For example, by using amino acids, there is a large increase in the number of lymphocytes, acute phase proteins and also antibodies (Shahidi *et al.,* 2021).

There are novel reports on positive effects of feed additives in human (Liu *et al*., 2023; Chuai *et al*., 2023; Zhen *et al*., 2024; Liang *et al*., 2024) and animals (Seidavi *et al*., 2017; Movahhedkhah *et al*., 2019; Chand *et al*., 2021). Stressful factors can cause hormonal changes, decrease in feed intake, metabolic changes in nutrition and also problems in the bird's immune system (Alagawany *et al.,* 2019). By stimulating the immune system with a foreign protein, an antibody reaction against this protein can be observed. The strength of this antibody is used as an indicator of the ability of the humoral system in animal immunological and ecological research (Wang *et al*., 2015). Stress will not allow the bird to express all its potential in growth, feed conversion ratio and egg production (Al-Sultan *et al.,* 2019). However, turmeric can reduce the negative effects of stress and inflammation on the growth performance of broilers (Kanani *et al*., 2016; Candra and Putri, 2020) and laying hens (Giannenas *et al*., 2022).

Due to limitations on the use of antibiotics in poultry diets, alternative supplements such as medicinal plants, including turmeric, have become a focus of consideration. For example, turmeric powder added to the diet has the best effects on productivity and immune response. Hleap-Zapata *et al.,* (2020) showed that the active ingredient of turmeric as a feed supplement was curcumin and its various derivatives such as demethoxycurcumin, bisdemethoxycurcumin and tetrahydrocurcuminoid. Herbal supplements can improve growth performance, carcass characteristics and immune status in broiler chickens (Demirhan. 2020). The use of turmeric in the diet increases the activity of antioxidant enzymes such as superoxide dismutase, catalase and glutathione peroxide in the liver and reduces the amount of lipid peroxidation by removal of free radicals (Isroli *et al.,* 2017).

Turmeric is widely used worldwide in traditional medicine and has a wide range of biological effects. The positive relationship of curcumin with the secretion of trypsin, chymotrypsin, amylase and lipase enzymes in the intestinal tract of broiler chickens has been proven (Xie *et al.,* 2019). In one study, the effects of turmeric intake in the diet on the stress, immune, antioxidant and inflammatory responses of the common carp (*Cyprinuscarpio*) during exposure to copper were significant (Rajabiesterabadi *et al.,* 2020). The phenolic nature of curcuminoid is effective in suppressing the growth of bacterial pollutants (Febrianta *et al.,* 2021). There are many nutrients in turmeric that beneficial to human health. Among the important nutrients in turmeric are vitamin C, vitamin B6, iron and potassium (de Carvalho *et al.,* 2020). Because turmeric is rich in a chemical compound called curcumin, it improves insulin resistance in diabetic patients, neutralizes excess insulin in the blood, and as a result prevents fatigue caused by low blood glucose and decreases appetite and weight (Rhayat *et al.,* 2017).

The effectiveness of turmeric on the stomach and digestive system are due to its antioxidant properties. Turmeric can aid digestion and improve conditions such as heartburn, pain or inflammation and stomach ulcers, Helicobacter pylori infection, loss of appetite, diarrhea, gas, irritable bowel syndrome (IBS), inflam-

matory bowel diseases such as Crohn's. and ulcerative colitis (Adegoke *et al.,* 2018). In a study conducted on rats, it was shown that the inhibitory effect of curcumin sodium at 3 mg per kg in habited lipooxygenase and cyclooxygenase (Ahlawat *et al.,* 2018). Administering curcumin to humans changes the ratio of beneficial to pathogenic bacteria by increasing the population of lactobacilli, bifid and butyrate-producing bacteria and decreasing the number of enterococci and enterobacteria (Zam, 2018).

Studies have shown that adding turmeric powder to duck diet reduces the pH of duck meat (Feng *et al.,* 2017). Also, in another study, good results were obtained by using 7.5% of micro-encapsulated turmeric powder for pickling poultry meat. In this study, turmeric powder was effective as a good natural agent to inhibit the growth of aerobic bacteria and increase the shelf life of minced meat stored in the refrigerator (Demirhan. 2020). The study conducted on the crispiness and softness of meat with the addition of turmeric powder showed that the effect of turmeric was significant and the hardness of the meat was less compared to other treatments that did not receive turmeric powder (Rahman *et al.,* 2021). Similar results were obtained in the research of Abd El-Hack *et al.,* (2021).

The results of the studies conducted by (Hoseini *et al.,* 2015) indicated that there was no difference in the conversion coefficient of diets containing 0.1 and 0.2% turmeric compared to the control group. The results of the research (Rajput *et al.,* 2013) also showed improvement of the use of metabolic energy due to the addition of curcumin to the poultry diet. In research results by Ahmed *et al.,* (2018), no significant difference in the percentage of chest and thigh muscles with the intake of turmeric was observed. They expected the use of turmeric powder to improve growth and the feed conversion ratio. In this research, the average weight gain of the treatment containing 0.5% turmeric in the final period was numerically higher than the control treatment. In a study on the effect of adding turmeric on the qualitative characteristics of duck meat, the curcuminoid content of turmeric was considered to be 2.5 to 5.4%. Existing studies on the effect of turmeric on the intestinal morphology, the characteristics of the microbial flora and the fatty acid profile of the breast meat of broiler chickens are rare, possibly because preparing turmeric powder is not easy. In order to reduce the negative effects of using large amounts of turmeric powder in feeding broiler chickens, the present research tested lower concentrations of turmeric powder in the diet of broiler chickens. The most important goals of this study were to investigate performance, blood parameters, immunity, intestinal morphology, carcass characteristics, cecum microbial flora, fatty acid profile, and taste sensation of breast meat of Ross 308 strain broilers. In fact, the purpose of this study was to determine the most appropriate and safe level of added turmeric powder in the broiler chicken diet in order to improve the performance of broiler breeding units.

MATERIALS AND METHODS

The experiment with 5 treatments at four levels of dry turmeric powder (250, 500, 750 and 1000 mg/kg ration) and the control treatment (without turmeric) was carried out in 5 replicates in Zanjan, Iran in 2022. In each experimental unit, 10 broiler chickens of Ross 308 strain were used, and a total of 250 chickens (10×5×5) were used. The area of each experimental unit was 1 square meter. The experimental units were divided in such a way that the least environmental stress was imposed on the experimental birds. After preparing the pens, chickens were randomly divided into experimental units after weighing. The average weight of each experimental unit was recorded. Turmeric powder was obtained from Barij Essens Company (Kashan, Iran).

The experimental period was 6 weeks (42 days) and water and feed intake were free. Addition of commercial additives was avoided in the rations. The feed ration was prepared according to the recommendation of the Aviagen (2019) and provided to the chickens *ad libitum*. The composition of the basic ration and its nutritional characteristics are shown in Table 1 and Table 2, respectively. Turmeric powder was not used in the control treatment. Turmeric powder was prepared from its rhizome as follows. First, turmeric rhizomes were washed and dried in an oven at 55^{o}C for 12 hours and then ground. The powder obtained was stored in a glass container with a lid.

The temperature of the hall was 31^{o}Cin the first week, and then it was reduced by two degrees a week until it reached a constant temperature of 25^{o}C. The humidity of the hall was 55% and the lighting program was set to 23 hours of light and one hour of darkness. The chicken vaccination program and other rearing management conditions were carried out according to the Aviagen (2019) catalogue for Ross 308 strain chickens.

Table 1. Percentage feed ingredients of diets used during the starter (1st-21st days of age) and grower (22nd-42nd days of age) periods

Ingredient (%)	Starter period (1st-21st days of age)	Growth period (22nd-42nd days of age)
Corn	56.20	60.57
Soybean Meal	34.95	30.40
Soybean Oil	2.50	3.40
Meat meal	3.00	1.50
DL-methionine	0.30	0.20
L-lysine	0.05	0.00
L-Threonine	0.03	0.00
Ca 22%, P 18%	0.90	1.50
CaCO3	0.95	1.30
KHCO3	0.05	0.03
NaCl	0.32	0.45
Vitamin and mineral mixture[1]	0.65	0.55
Empty space (sand + Turmeric powder)	0.10	0.10
Total	100	100

1Vitamin A: 5,000 IU/g; vitamin D3: 500 IU/g; vitamin E: 3 mg/g; vitamin K3: 1. 5 mg/g; vitamin B2: 1 mg/g; calcium pantothenate:4 mg/g; niacin: 15 mg/g; vitamin B6: 13 mg/g; Cu: 3 mg/g; Zn: 15 mg/g; Mn: 20 mg/g; Fe: 10 mg/g; K: 0. 3 mg/g

Table 2. Nutritional composition (calculated) of basal diets used in the experiment

Ingredient	Starter period (1st-21st days of age)	Growth period (22nd-42nd days of age)
Metabolizable energy(kcal/kg)	3030	3200
Crude protein (%)	24.0	22.0
Lysine(%)	1.45	1.24
Methionine (%)	0.65	0.55
Methionine+ Cysteine (%)	1.00	0.90
Threonine (%)	1.85	0.85
Tryptophan (%)	0.35	0.27
Arginine (%)	1.65	1.50
Isoleucine (%)	1.08	0.95
Valine (%)	1.50	1.05
Leucine (%)	2.00	1.85
Calcium (%)	1.08	0.90
Available Phosphorus (%)	0.45	0.45
NaCl (%)	0.23	0.23
Potassium (%)	1.05	0.92
Dietary cation-anion balance (mEq/kg)	270.15	240.55
Choline (g/kg)	1.45	1.35
Linoleic acid (%)	1.20	1.25
Crowd Fiber (%)	3.70	3.60
Ether extract (%)	6.75	8.55

Measurement of performance

Evaluation of performance traits including body weight gain, feed intake, feed conversion ratio, and body weight gain were calculated at the end of each period.

Economic performance, including weight at the end of the period, retention percentage, production of live chicken meat per square meter, total cost, income per square meter, profit per square meter were measured for each experimental unit separately. To calculate the income, the price of each kg of live chicken was considered to be 1.33 dollars. Also, the costs of feeding and buying day-old chicks were considered equal to 80% of the total costs of poultry farming.

Measurement of carcass components

Carcass measurement was done according to the

standard method (Saraei *et al.,* 2014). In short, at the end of the test periodto determine the carcass traits, three chickens with a weight close to the group average were selected from each repetition and killed after 4 hours of starvation. Then live weight, full weight, full stomach carcass weight, empty stomach carcass weight, breast weight, thigh weight, wing weight, abdominal fat weight, pancreas weight, heart weight, gizzard weight, together with the weights of the stratum corneum, spleen, thymus, bursa of fabricius, duodenum, jejunum, ileum and cecum were determined. All chickens were weighed before slaughter. The weight of carcass components was measured with a digital scale (AND company, model FX300 GD, Japan) with an accuracy of 0.001 grams. Then, the weight ratio of each component of the carcass was obtained by dividing the weight of each component by the weight of the empty carcass.

Measurement of blood constitutes organs related immunity

Measurement of blood plasma components was done using a standard method (Jahanpour *et al.,* 2013; Shabani *et al.,* 2015). In short, on the 42nd day of breeding broiler chickens, three chickens were randomly selected from each experimental unit and after taking blood from the wing vein, three blood samples were mixed with each other and the pooled sample was immediately sent to the laboratory to determine glucose level, total cholesterol, triglyceride, very low density lipoprotein, high density lipoprotein, low density lipoprotein, the ratios of total cholesterol to high density lipoprotein and low density lipoprotein to high density lipoprotein. The levels of albumin and the liver enzymes alkaline phosphatase and ALT were also determined. Pars Azmoun diagnostic kits (Tehran, Iran) were used to measure these blood parameters. The principle of all of the above measurements was colorimetric. Due to the fact that blood serum proteins are composed of albumins and globulins (fibrinogen remains in the clot and does not enter the serum), the concentration of globulin in each of the blood serum samples was obtained from the difference in the concentration of total protein and albumin of the same sample. Weights of organs related to immunity recorded based on Seidavi *et al*., (2014).

Measurement of intestinal morphology

At the end of the experiment, different parts of the intestine were separated from one chicken from each repetition. Three pieces of 1 cm were prepared from the ileum, the samples were washed in normal saline solution and then fixed in 10% formalin. Then, after embedding in paraffin, cross-sections with a thickness of 5 microns were prepared and stained with hematoxylin-eosin. In the next step, the parameters of villi height, crypt depth, epithelium thickness, villus length, ratio of villus length to crypt depth were measured using an optical microscope (Olympus model BX-51M, United States of America).

Measurement of carcass fatty acid profile

To determine the fatty acid profile of the carcass, one broiler from each treatment was slaughtered. 10 grams of breast fat was extracted from the slaughtered carcass. First, the tissue samples were thoroughly mixed with 100 ml of methanol: chloroform solution (2:1) for about 3-4 hours. After that, the samples were filtered and mixed with 25 ml saturated sodium chloride solution in a separating funnel. In the next step, the chloroform phase containing the fat was filtered through filter paper soaked in potassium sulfate. The washed and filtered sample was dried under vacuum in a rotary evaporator until only fat remained. After this step, 10 mg of isolated fat was mixed well with 2 ml of potassium hydroxide, 2 ml of normal methanol and 7 ml of n-hexane, before the resulting samples were centrifuged for 10 minutes. after which the sample was stood for 5 minutes to separate its upper phase. Then, about one microliter of the supernatant phase was injected into a gas chromatography device (Rei NorAzma, Shimadzu model, Japan), and the amounts of fatty acids were calculated as a percentage (Levkut *et al.,* 2017).

Measurement of cecal microbiota

In order to determine the microbial population of the cecum of chickens, on the 42nd day of each repetition, two birds whose weight was close to the average of the group were selected and killed after weighing. After opening the abdominal cavity, the cecum was separated with sterile scissors and its contents were emptied from the last two centimeters into sterile microtubes. The contents from two birds from each replicate were pooled and the bacterial population determined. The samples which included lactobacillus, *E. coli*, coliform, bifidobacterium and the entire population of anaerobic bacteria were stored at -70°C until required. To determine the various bacterial types, the following culture media were used: lactobacillus bacteria -MRS-agar (DeMan-Rogosa-Sharpe agar), *E. Coli* bacteria -EMB-agar (eosine methylene

blue agar), coliform bacteria (MacConkey agar). For counting bifidobacterium and the total population of anaerobic bacteria, a special culture medium was used. Finally, the colonies related to each culture medium were counted as Colony Forming Units (CFU) in one gram of sample and the CFU data was converted into log10 form. The data obtained were then used for statistical analysis.

Measurement of sensory traits of meat

In this experiment, one half of breast muscle (1 chicken per replicate) was used to evaluate meat sensory traits. For this purpose, the samples were cooked in special containers without spices and oil for 40 minutes. Then, 6 judges were invited to check the fatiness, juiciness, crispiness, colour, fragrance, chewability, elasticity, mouthfeel and general acceptance. An evaluation scale of 1 to 5 was used to score the samples.

Statistical analysis

The experiment was conducted with 5 treatments of5 replicates based on a balanced completely randomized design (CRD). Data were arranged with Excel (2010) software and analyzed using SAS (2010) statistical software with Proc GLM procedure. Duncan's multiple range test was used to compare the means. The statistical model of the plan was as follows:

$$Yijk=\mu+Ai+Eij$$

In the above relationship, (Yijk) is the value of each observation, (μ) is the average, (Aj) is the effect of turmeric powder, and (Eij) is the error effect.

RESULTS

The results obtained include performance results in Tables 3, 4, characteristics of carcass components in Table 5, blood plasma parameters in Tables 6, 7, fatty acids in Table 8, small intestine morphology in Table 9. Immunity data are presented in Table 10, cecal microbial flora in Table 11 and taste characteristics in Table 12.

The results of statistical analysis of the data showed that the effect of turmeric powder on the performance of broiler chickens (Table 3) was significant ($P<0.05$). Body weight gain and feed intake in the initial period, and growth and feed conversion ratios in the growth period were significant. Also, the results showed that the body weight gain, feed intake and the feed conversion ratio at the end of the rearing period

Table 3. Effect of turmeric powder on body gain (g/chick/day), feed intake (g/chick/day), and feed conversion ratio (g/g) of Ross 308 broilers at starter (1st-21st days of age), growth (22nd-42nd days of age) and whole (1st-42nd days of age) periods*

Treatments		Starter			Growth			Whole		
		BWG	FI	FCR	BWG	FI	FCR	BWG	FI	FCR
Turmeric powder (mg/kg)	Control(0)	48.80^{c}	62.14^{c}	1.27	79.56^{b}	171.37	2.15^{a}	64.18^{c}	116.75^{b}	1.82^{a}
	250	52.75^{ab}	66.65^{ab}	1.26	83.02^{a}	171.59	2.06^{b}	67.89^{ab}	119.12^{b}	1.75^{b}
	500	54.42^{a}	69.28^{a}	1.27	82.67^{a}	173.96	2.10^{ab}	69.52^{a}	121.62^{a}	1.75^{b}
	750	52.32^{ab}	66.72^{ab}	1.27	79.93^{b}	171.01	2.14^{ab}	66.12^{bc}	118.87^{b}	1.79^{b}
	1000	51.08^{bc}	65.58^{b}	1.28	79.44^{b}	171.08	2.15^{a}	65.26^{c}	118.33^{b}	1.81^{a}
SEM		0.57	0.64	0.01	0.47	0.46	0.01	0.46	0.45	0.01
P-Value		0.01	0.01	0.99	0.01	0.22	0.07	<0.0001	0.01	0.02

* Means within each column without superscript or with at least one common superscript do not differ significantly at P>0.05.
SEM: Standard Error of Means; BWG: Body weight gain; FI: Feed intake; FCR: Feed conversion ratio

Table 4. Effect of turmeric powder on the economical parameters of Ross 308 broilers at 42nd days of age*

Treatments		BWG(g)	Survival (%)	PBW (kg/m^2)	Cost ($/m^2)	Income ($/m^2)	Profit ($/m^2)
Turmeric powder (mg/kg)	Control(0)	2695.73^{c}	95.06^{c}	26.95^{c}	34.45^{c}	35.85^{c}	1.40^{c}
	250	2851.25^{ab}	96.16^{b}	28.51^{ab}	35.16^{b}	37.92^{ab}	2.76^{ab}
	500	2920.13^{a}	97.38^{a}	29.20^{a}	35.82^{a}	38.83^{a}	3.01^{a}
	750	2777.25^{bc}	95.20^{c}	27.77^{bc}	35.09^{bc}	36.93^{bc}	1.84^{bc}
	1000	2741.17^{c}	95.52^{bc}	27.41^{c}	34.95^{bc}	36.45^{c}	1.50^{c}
SEM		19.56	0.21	0.19	1.27	0.26	0.19
P-Value		<0.0001	0.0001	<0.0001	0.01	<0.0001	0.01

* Means within each column without superscript or with at least one common superscript do not differ significantly at P>0.05.
SEM: Standard Error of Means; PBW: Produced body weight

(42 days) were significant (P<0.05). The most beneficial effect of turmeric powder was observed at a level of 500 mg/kg.

The statistical results from the analysis of broiler performance data in (Table 4) showed that the effect of turmeric powder on body weight gain at the end of the period, survival percentage, meat production per square meter, total cost, total income and final profit was significant (P<0.05). Once again, the best results were obtained with an experimental treatment level of turmeric powder at500 mg/kg (P<0.05).

The results of analysis of variance in (Table 5) show the effects of turmeric powder on empty stomach carcass weight, the ratio of empty stomach to full carcass weight, the ratio of breast weight to full carcass, the fat ratio of abdominal area to full carcass, the weight ratio of wings to the carcass and viscera were all significant (P<0.05). Here however, the effect of turmeric powder at the lower level of 250 mg/kg had the greatest effect on the carcass weight of empty stomach and viscera (P<0.05). But the use of turmeric powder at 500 mg/kg showed the greatest effect on

Table 5. Effect of turmeric powder on carcass components of Ross 308 broilers at 42nd days of age*

Treatments		DBW (g)	FACW (g)	EACW (g)	RWEAF (%)	RWB (%)	RWD (%)	RWAF (%)	RWW (%)	RWH (%)	Viscera (g)
Turmeric powder (mg/kg)	Control(0)	2344.40	2066.91	1664.21^{a}	80.65^{a}	33.33^{ab}	32.15	3.57^{a}	4.69^{ab}	0.59	8.52^{b}
	250	2353.59	2195.46	1653.46^{a}	75.40^{ab}	30.07^{b}	28.85	2.41^{ab}	4.39^{b}	0.59	9.33^{a}
	500	2284.94	2106.65	1602.68^{ab}	76.11^{ab}	35.54^{a}	32.94	2.07^{b}	5.01^{a}	0.61	9.22^{a}
	750	2290.05	2077.59	1599.10^{ab}	77.05^{ab}	32.22^{ab}	29.57	2.39^{ab}	4.52^{b}	0.64	9.07^{ab}
	1000	2287.12	2090.41	1538.81^{b}	73.66^{b}	33.33^{ab}	30.73	2.46^{ab}	4.31^{b}	0.57	9.18^{a}
SEM		16.40	17.08	14.34	0.85	0.74	0.63	0.08	0.08	0.02	0.09
P-Value		0.52	0.11	0.03	0.09	0.04	0.21	0.03	0.03	0.89	0.06

* Means within each column without superscript or with at least one common superscript do not differ significantly at P>0.05.
SEM: Standard Error of Means; DBW: Defeather body weight; FACW: Full abdomen carcass weight; EACW: Empty abdomen carcass weight:RWEAF: Relative weight empty abdominal of full abdominal; RWB: Relative weight of breast; RWD: Relative weight of drumsticks; RWAF:Relative weight of abdominal fat; RWW: Relative weight of wings; RWH: Relative weight of heart

Table 6. Effect of turmeric powder on plasma constitutes (lipids and glucose) of Ross 308 broilers at 42nd day of age*

Treatments		Glucose (mg/dl)	Triglycerides (mg/dl)	Total cholesterol (mg/dl)	Uric acid (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
Turmeric powder (mg/kg)	Control(0)	186.47^{c}	54.71	153.06^{c}	3.47^{b}	73.19^{a}	90.62
	250	191.86^{b}	53.31	153.91^{c}	3.95^{ab}	65.87^{b}	89.42
	500	198.37^{ab}	54.24	159.60^{bc}	4.65^{a}	64.98^{b}	87.33
	750	197.70^{ab}	57.14	164.22^{ab}	4.06^{ab}	66.84^{b}	89.69
	1000	200.17^{a}	54.31	171.09^{a}	3.73^{b}	68.15^{ab}	88.63
SEM		7.88	4.28	6.52	7.05	2.43	0.85
P-Value		0.01	0.80	0.01	0.05	0.06	0.66

* Means within each column without superscript or with at least one common superscript do not differ significantly at P>0.05.
SEM: Standard Error of Means; LDL: Low Density Lipoproteins; HDL: High Density Lipoproteins

Table 7. Effect of turmeric powder plasma constitutes (enzymes, proteins and uric acid) of Ross 308broilers at 42nd day of age*

Treatments		Alkalinephosphatas (U/L)	AST (U/L)	ALT (U/L)	TP (g/dl)	Albumin (g/dl)	Globulin (g/dl)
Turmeric powder (mg/kg)	Control(0)	7.48^{ab}	298.29	527.15	4.10	0.96^{b}	1.44
	250	7.96^{a}	297.93	548.87	3.91	1.03^{ab}	1.37
	500	7.46^{ab}	297.89	541.80	3.85	1.09^{ab}	1.43
	750	6.95^{b}	297.89	535.34	3.77	1.04^{ab}	1.60
	1000	7.38^{b}	293.45	560.95	3.71	1.15^{a}	1.65
SEM		0.26	8.05	10.76	20.87	0.12	0.05
P-Value		0.01	0.30	0.11	0.42	0.07	0.13

* Means within each column without superscript or with at least one common superscript do not differ significantly at P>0.05.
SEM: Standard Error of Means; AST: Aspartat amino transferase; ALT: Alanin amino transferase; TP: Total protein

Table 8. Effect of turmeric powder on free fatty acid profile (mgKOH/g) of Ross 308 broilers at 42nd day of age*

Treatments	Turmeric powder (mg/kg)				
Items/mgKOH/g	Control(0)	250	500	750	1000
Myristic acid (C14:0)	0.27	0.32	0.31	0.35	0.29
Pentadecanoic acid (C15:0)	0.13	0.11	0.11	0.10	0.10
Palmitic acid (C16:0)	18.16	19.72	21.02	18.83	19.72
Heptadecanoic acid (C17:0)	0.16	0.14	0.15	0.13	0.12
Stearic acid (C18:0)	4.97	4.34	4.68	4.57	3.78
Arachidic acid (C20:0)	0.12	0.11	0.11	0.10	0.09
Heneicosanoic acid (C21:0)	0.56	0.56	0.59	0.48	0.50
Behenic acid or Docosanoic acid (C22:0)	0.28	0.31	0.27	0.30	0.30
Total SFA	24.68	25.63	27.27	24.87	24.52
Myristoleic acid (C14:1)	0.41	0.43	0.49	0.47	0.49
Pentadecylic acid (C15:1)	6.66	7.17	5.79	6.47	6.70
Palmitoleic acid (C16:1)	1.53	1.26	1.29	1.33	1.33
Heptadecenoic acid (C17:1)	0.06	0.08	0.07	0.08	0.07
Oleic acid (C18:1, n-9)	36.49	40.13	39.39	39.33	39.46
Elaidic acid (C18:1t)	0.08	0.07	0.07	0.08	0.07
Gondoic acid or Eicosenoic acids (C20:1)	1.03^{b}	1.51^{a}	1.23^{ab}	1.16^{ab}	1.28^{ab}
Erucic acid or Docosenoic acid (C22:1)	0.29	0.27	0.30	0.24	0.28
Total MUFA	46.58	50.94	48.67	49.20	49.71
Linoleic acid (C18:2, n-6)	19.98^{b}	20.00^{b}	20.83^{ab}	19.43^{b}	23.64^{a}
Trans octadecadienoic acid (C18:2t)	0.11	0.16	0.15	0.12	0.15
Total PUFA, n-6	20.09^{b}	20.16^{b}	20.98^{ab}	19.55^{b}	23.79^{a}
Dihomo-gamma linoleic acid (C20:3)	0.80	0.85	0.77	0.85	0.86
Total PUFA, n-3	0.80	085	0.77	0.85	0.86
Total PUFA, n-6/total PUFA, n-3	25.64	23.73	27.26	23.25	28.39
UFA	63.80	66.51	58.91	62.54	59.56
UFA/SFA	2.58	2.61	2.17	2.54	2.43

Table 9. Effect of turmeric powder on small intestine (ileum) morphometry of Ross 308 broilers at 42nd day of age*

Treatments		Villus height(μm)	Villus width (μm)	Crypt depth (μm)	Villus height/crypt depth
Turmeric powder (mg/kg)	Control(0)	1237.5^{ab}	163.45	334.82	3.69^{b}
	250	1680.50^{a}	190.08	308.64	5.44^{a}
	500	1503.6^{ab}	168.14	297.64	5.13^{ab}
	750	1560.7^{a}	122.95	328.07	4.79^{ab}
	1000	1189.7^{a}	154.95	317.13	3.75^{b}
SEM		61.98	7.68	6.88	0.26
P-Value		0.01	0.10	0.41	0.07

* Means within each column without superscript or with at least one common superscript do not differ significantly at P>0.05.
SEM: Standard Error of Means

Table 10. Effect of turmeric powder on bursa, spleen and thymus of Ross 308 broilers at 42nd day of age*

Treatments		Bursa (%)	Spleen (%)	Thymus (%)
Turmeric powder (mg/kg)	Control(0)	0.14^{b}	0.13	0.32
	250	0.18^{b}	0.16	0.28
	500	0.23^{a}	0.12	0.26
	750	0.16^{b}	0.12	0.19
	1000	0.15^{b}	0.14	0.27
SEM		0.01	0.01	0.02
P-Value		0.01	0.18	0.11

* Means within each column without superscript or with at least one common superscript do not differ significantly at P>0.05.
SEM: Standard Error of Means

Table 11. Effect of turmeric powder oncecum microflora of Ross 308 broilers at 42nd day of age*

Treatments		Total bacteria (log cfu/g)	*Escherichia coli* (log cfu/g)	Coliforms bacteria (log cfu/g)	*Lactobacillus* bacteria (log cfu/g)
Turmeric powder (mg/kg)	Control(0)	8.56	7.39	7.38	6.79^{b}
	250	8.33	7.46	7.12	6.95^{b}
	500	8.65	8.80	6.92	9.22^{a}
	750	8.26	7.69	7.39	6.37^{b}
	1000	8.84	7.65	8.13	6.28^{b}
SEM		0.11	0.20	0.21	0.29
P-Value		0.53	0.16	0.48	0.01

* Means within each column without superscript or with at least one common superscript do not differ significantly at P>0.05.
SEM: Standard Error of Means; cfu: colony forming unit

Table 12. Effect of turmeric powderon sensory quality of broiler meatof Ross 308 broilers at 42nd day of age*

Treatments		Fat content	Juiciness	Crispiness	Colour	Fragrance	Chewability	Elasticity	Mouthfeel	General Acceptance
Turmeric powder (mg/kg)	Control(0)	2.80^{ab}	2.96^{b}	2.96^{ab}	3.46	2.63	3.46^{a}	3.06^{bc}	3.06^{b}	3.36^{ab}
	250	2.60^{ab}	2.96^{b}	2.86^{ab}	3.24	2.77	2.73^{a}	2.50^{d}	2.76^{b}	3.13^{bc}
	500	2.33^{b}	2.53^{b}	2.43^{b}	2.90	2.73	2.66^{b}	2.63^{dc}	2.76^{b}	2.82^{c}
	750	2.86^{ab}	2.63^{b}	3.00^{a}	3.06	2.76	2.90^{b}	3.16^{ab}	3.06^{b}	3.20^{bc}
	1000	3.13^{a}	3.60^{a}	3.16^{a}	3.10	3.10	3.60^{b}	3.56^{a}	3.63^{a}	3.76^{a}
SEM		0.09	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.07
P-Value		0.04	0.01	0.05	0.17	0.44	0.01	0.01	0.01	0.01

* Means within each column without superscript or with at least one common superscript do not differ significantly at P>0.05.
SEM: Standard Error of Means

the ratio of breast weight to full carcass, the fat ratio of abdominal area to full carcass and the weight ratio of wings to full carcass (P<0.05).

At 42 days, the results of the analysis of the variance of blood tests showed (Tables 6, 7) that the effect of turmeric powder on the concentration of glucose, triglyceride, total cholesterol, uric acid and HDL was significant (P<0.05). The highest levels of glucose, cholesterol, ALT and albumin were found in the use of turmeric powder at a level of 1000 mg/kg. The results also showed that in 42 days of rearing, the effect of turmeric powder at a rate of 250 mg/kg diet was significant too (P<0.05).

The results of the fatty acids profile at 42 days (Table 8) showed that the use of turmeric powder at a level of 250 mg/kg had the greatest change in the amount of gondoic or 11-eicosenoic acids (C20:1). Also, an effect of turmeric powder at a level of 1000 mg/kg on the profile of fatty acids was also observed.

The results of variance analysis showed an effect upon the morphology of the ileum part of the small intestine at 42 days old (Table 9). The use of 250, 500 and 1000 mg/kg of turmeric powder in the diet had the greatest effect on the height of ileum villi (P<0.05). The statistical results showed that when we supplemented 250 mg, the ratio of height to depth of creep was significant (P<0.05).

The results of variance analysis of the data of immune glands at 42 days showed (Table 10), turmeric powder was significant on the bursa of the Fabricius gland (P<0.05). Turmeric powder at a level of 500 mg/kg showed the greatest effect (P<0.05).

The results of statistical variance analysis obtained from the data of microbial flora from the cecum of broilers showed (Table 11) that the effect of turmeric powder on the lactobacilli microbial population was significant (P<0.05). However, the effect of turmeric powder on the overall microbial population was not significant (P<0.05). The experimental treatment that received 500 mg/kg of turmeric powder showed the highest microbial population of lactobacilli.

Statistical results from the analysis of variance and statistical data analysis of the sense of taste are presented in Table 12. These results show that the fat content, juiciness, crispiness, chewability, elasticity, mouthfeel and general acceptance were significant (P<0.05). In this research, turmeric powder at a level of 1000 mg/kg had the greatest effect on all but the

chewability of the breast meat which showed the best performance at a rate of 250 mg/kg.

DISCUSSION

In this experiment, the results related to the effect of different levels of turmeric powder on average body weight gain, average feed intake, feed conversion ratio, and economic performance including weight at the end of the period, survival percentage, meat production per square meter, total cost, total income, and final profit was significant. Here, the most beneficial effect of turmeric powder was at a level of 500 mg/kg in keeping with the results of studies conducted by Shahidi *et al.,* (2021) and Hoseini *et al.,* (2015) who showed no difference in the feed conversion ratio of diets containing 100 and 200 mg/kg of turmeric compared to the control group and of Naderi *et al.,* (2014) who showed that adding 250 mg/kg of turmeric to the feed of broilers significantly improved body weight gain and feed conversion ratio compared to the control treatment. Differences in the results of different studies are probably due to differences in the level of turmeric used, climatic conditions or diet composition. In the current study, the use of turmeric powder in the experimental treatment that received a level of 500 mg/kg had a beneficial effect on the final weight, the feed intake, the feed conversion ratio and the survival percentage of broiler chickens at the end of the period, so that more meat was produced at a final profit of some $3.01. The results of research by Rajput *et al.,* (2013) indicated an improvement in the use of metabolic energy due to the addition of curcumin to poultry diet. Curcuminoids, a significant percentage or turmeric, have antioxidant activity (El-Demery *et al.,* 2016). In the current research, the beneficial effect of curcumin in improving the use of metabolic energy increased the growth and survival of broiler chickens, and this factor contributed to the secretion mechanism of digestive system enzymes in the digestion and absorption of nutrients.

Turmeric powder had a significant effect on the percentage of empty stomach carcass weight, percentage of breast weight, percentage of fat in abdominal, percentage of wing weight and percentage of viscera weight compared to live weight ($P<0.05$). In the present study, turmeric powder at both 250 and 500 mg/kg showed the greatest effect on the ratio of breast weight, abdominal fat, empty stomach carcass weight, viscera and wing weight to full carcass compared to the control group. In research by Shirani *et al.,* (2019) it was shown that the active ingredients in medicinal plants can also reduce abdominal fat by modulating the transport of fatty acids and hence inhibiting the synthesis of adipose tissue. Also, Rajput *et al.,* (2013) and Al-Sultan *et al.,* (2019) in similar studies showed that the abdominal fat percentage decreased on the addition of turmeric to poultry diets. These researchers attributed the decrease in abdominal fat percentage to the improvement of fat metabolism due to the addition of turmeric to the diet. In the work reported by Olfati *et al.,* (2018), turmeric powder increased bile production and improved fat digestion. Ahmed *et al.,* (2018) revealed a significant difference in the percentage of chest and thigh muscles with turmeric intake. In line with the results of the current research, Hoseini *et al.,* (2015) also did not observe a significant difference in the percentage of chest muscles with the intake of turmeric. By contrast, in the research of Akhavan *et al.,* (2016), a diet containing 10 mg/kg of turmeric compared to the control, increased the percentage of breast weight. In a study, Bagban *et al.,* (2016) showed that adding 500 or 1000 mg/kg of turmeric powder to the diet can improve the quality of the carcass. In the recent experiment, it is possible to improve performance with reducing carcass fat. Abdominal contents and breast meat was improved due to the beneficial effect of turmeric powder on intestinal acidity and it caused the release of digestive enzymes and had a positive effect on the absorption of nutrients. And finally led to an increase in weight at the end of the period. These results were with those who they found that broiler chickens fed with turmeric at a level of 500 mg/kg were compatible. In our experiment, treatments that received turmeric powder at 500 mg/kg showed a lower abdominal fat percentage than the control group.

The effect of turmeric powder on the concentration of glucose, triglyceride, total cholesterol, uric acid, HDL and the liver enzyme alkaline phosphatase was also significant ($P<0.05$). In the current research, the highest level of glucose concentration was in the treatment where 1000 mg/kg of turmeric powder was used. Hosseini-Vashan *et al.,* (2016) showed that turmeric powder at a level of 400 and 800 mg/kg increased the level of HDL and decreased total cholesterol, LDL, LDH, AST, ALT and ALP in the plasma of broilers under heat stress. Further, Boroumand *et al.,* (2018) showed that turmeric powder at a level of 500 mg/kg decreased the plasma level of ALT, lactate dehydrogenase (LDH) and uric acid in broilers under heat stress. Gholami *et al.,* (2020) found in their study that an increase in blood glucose due to environmental

changes caused an increase in glucocorticoids in the body and Ashour *et al*., (2020) showed that curcumin increased the excretion of bile acids and stimulated secretion of lipase, amylase, trypsin and chymotrypsin enzymes. In the current experiment, the addition of turmeric powder to the diet probably controlled the environmental stress and this factor also had a positive effect on the economic performance of experimental treatments receiving turmeric powder.

In the present study, the use of turmeric powder at a level of 250 mg/kg caused the greatest change in the amount of gondoic acid or 11-eicosenoic acid (C20:1) ($P<0.05$). Further, the beneficial effect of turmeric powder at a level of 1000 mg/kg on the profile of fatty acids was observed, the greatest effect being on linoleic acid and total polyunsaturated fatty acids (Akl *et al.,* 2020). Palmitic acid (C16:0) often increases blood cholesterol levels, while linoleic acid (C18:2, n-6) has the opposite effect on blood cholesterol. Shirani *et al.,* (2019) showed that turmeric may reduce the deposition of abdominal fat by increasing the expression of acyl-CoA oxidase, the main enzyme of the beta oxidation process. In our research, the use of 500 mg/kg of turmeric powder reduced the area of abdominal fat. This reduction may be due to the beneficial effect of turmeric's bioactive component (curcumin) on increasing the amount of linoleic acid. The results of this research are consistent with the results of our experiment. In the present experiment, abdominal fat was reduced by increasing bird catabolism and lipogenesis and lipolysis, such as acetyl coenzyme A.

In the present study, turmeric powder at a level of 250 mg/kg showed the greatest effect on the ratio of height to depth of creep and at a level of 250, 500 and 1000 mg/kg.It showed a uniform effect on the height of the villi in the ileum of the small intestine. In their research, Iqbal *et al.,* (2020) showed that intestinal villi are the primary site for nutrient absorption. Therefore, longer villi should represent more surface area, which in turn should increase nutrient absorption capacity. The improvement of the intestinal mucosal structure in response to ingested turmeric powder, may increase the population of beneficial bacteria that can produce antibacterial compounds thereby competing with harmful pathogens such as coliforms. Also, in a separated study, Mody *et al.,* (2020) showed that the improvement in small intestine morphometry changes may result from the maintenance of intestinal health caused by the stimulation of digestive enzyme secretion, thus improving the utilization of nutrients. Soumeh *et al.,* (2019) showed that feeding broilers with turmeric powder may stimulate the secretion of mucus in the intestine, which can act as a dynamic protective surface and prevent pathogens from adhering to intestinal epithelial cells. Turmeric powder improves overall growth. This improvement may result from an increase in the structural integrity of the intestinal epithelium, which plays an important role in nutrient digestion, absorption, and overall gut health. In the present study, the use of turmeric powder in the diet probably improved the gastrointestinal microbiota population and intestinal morphology more effectively, which indicates the synergistic effects between the presence of the turmeric bioactive (curcumin) and the beneficial bacteria of the gastrointestinal tract.

The results of this study show that the use of turmeric powder at a rate of 500 mg/kg has the greatest effect on the activity of the thymus gland compared to the other treatments. The beneficial effects of turmeric powder on bird performance may occur through changing the intestinal environment and increasing the immunity of beneficial stomach microorganisms, improving the function of the thymus gland. Jazi *et al.,* (2018) showed in a research study, competitive action reduces harmful bacteria and stimulates the immune system. Also, de Carvalho *et al.,* (2020) in a separate research study showed that by adding *Curcuma longa* powder at arate of 500 or1000 mg/kg to the diet of lambs, it improved the immune system and significantly increased the body weight of the lambs. In the current research, the improvement of the immune system and the increase in survival were probably due to the addition of turmeric powder to the diet. The statistical reasoning and positive results of this research are clear in the experimental treatment where the intake of turmeric powder was at a level of 500 mg/kg.

In the present study, the addition of turmeric powder increased the number of lactobacilli. Kahkhaie *et al.,* (2019) showed that turmeric reduces intestinal microbes and acts as an antibacterial, antioxidant and anti-inflammatory agent. The bioactive component of turmeric is curcumin (diferroyl methane), which causes a wide range of biological effects (Akter *et al.,* 2019). He *et al.,* (2018) showed that turmeric play a role in reducing the overall microbiota, increasing the number of lactobacillus in the intestine and improving the microbial ecology of the intestine. Also, Apperson and Cherian (2017) showed that the intestinal microflora can be improved by changing the acidity of the

intestine and by increasing the concentration of lactic acid, reducing the activity of harmful bacteria such as salmonella and *E. coli* and improving the population of lactobacilli. The addition of turmeric powder in the present study probably increased the number of lactobacilli and controlled *E. coli* and increased the release of digestive enzymes and thus improved the absorption of nutrients.

In the present study, the effect of different levels of turmeric powder on the fat content, juiciness, crispiness, chewability, elasticity, mouth feel and general acceptance was significant ($P<0.05$). Turmeric powder at a level of 1000 mg/kg had the greatest effect on the taste characteristics. The ability to chew breast meat showed the best performance in the treatment with turmeric powder at a rate of 250 mg/kg. Hady *et al.,* (2016) showed that turmeric powder has an effect on the activation of fatty acids. Essential fatty acids are not synthesized by the body, and their levels in broilers are determined by dietary intake and the degree of oxidation in tissues. Risdianto *et al.,* (2019) suggested that the level of organic acids may increase with the addition of turmeric powder and be effective in preventing the destruction of myoglobin in muscle tissues, thus reducing paleness and increasing redness of meat. The results of the study by Theshla *et al.,* (2019) showed that meat hydration in broilers can be affected by diet. The results of the present study are consistent with the results of other researchers. Also, the same researchers reported in another study that the crispiness and color of broiler chicken breast meat was affected by diets containing a mixture of turmeric powder. Rastad (2020) announced in that turmeric powder may delay the oxidation of myoglobin and prevent the denaturation of muscle protein in the meat of broiler chickens and finally change the chewability and elasticity of the meat thereby improving the taste. Sugiharto (2017) stated that the levels of 200, 400, 600 and 800 mg/kg of turmeric improved the digestion and metabolism of broiler chickens and therefore the production of hemoglobin in the tissue increased. And finally, it produced broiler chicken meat with of better quality and acceptability. Also according to Sugiharto *et al*., (2020), the addition of turmeric powder to the diet of broiler chickens may increase the deposition of pigment in the meat, especially the yellow pigment, and cause a change in the color of the meat. In the upcoming research, the improvement in meat quality in terms of taste characteristics referred to above may be due to the beneficial effect of turmeric powder on the digestion and metabolism, hemoglobin production in the tissue, pigment deposition and delayed oxidation of myoglobin in the meat tissue of broiler chickens.

The present study was conducted to investigate the effect of turmeric powder on carcass characteristics, the weight of the visceral organs, immunity and sensory evaluation of broiler chickens. Medicinal and aromatic plants have been used in cooking and treatment for years. Phytogenic growth stimulants have a beneficial effect on gut health for optimal performance. Due to their natural nature, compared to industrial additives, these components are free of residues and are environmentally friendly, and without side effects, they are ideal for animals and humans. These components have anti-microbial, anti-parasitic, insecticidal, anti-fungal, anti-viral and anti-toxic effects that improve feed digestibility. Since the increasing world population is continuously increasing the need for animal products, poultry production plays a very important role in the economic development (and well-being) of society. Proper nutrition is the most important way to live a healthy life. Chicken meat has valuable nutrients, including protein, for human nutrition and also confers a source of income for society in many developing and underdeveloped countries. Therefore, in order to achieve the goal of using raw materials to achieve maximum economic and social benefits, it is necessary to use additives that have an effective role in reducing natural hazards and increasing performance. All feed production has some degree of environmental impact, which largely depends on the production method. Because they use water and land, eating foods that are made with fewer resources is better for the planet because they do not significantly contribute to greenhouse gas emissions and are environmentally friendly. The use of turmeric powder in poultry feed makes it possible to limit or cease to use some industrial additives to reduce stress, improve performance and meat quality in broiler chickens. To this end in the present study, two good results were obtained: improved performance and greater compatibility with the environment.

CONCLUSION

It is concluded that use of turmeric powder at a level of 500 mg/kg in the diet of broiler chickens increases body weight and feed intake and improves the feed conversion ratio thereby increasing profit. It can also be concluded that the addition of this additive to the diet of broilers has a significant effect on the carcass components and bursa of Fabricius. Also, this additive had significant effect on the fat content, juici-

ness, crispiness, elasticity, chewability, mouthfeel and general acceptance of the breast meat.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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