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Research Article

Effect of Curcumin as A Natural Feed Additive on Productive Performance and Immune Response of Broiler Chicks

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Abstract:

This research aimed to determine if broiler chick productivity improved by including curcumin in their diet as a feed additive. Three hundred and sixty-day-old Cobb broiler chicks were randomly split into six groups of three replicates, 20 chicks in each. For the first 14 days of age, birds fed on 3000 kcal ME/kg and 23% crude protein diet, then 3100 kcal ME/kg and 21% crude protein from days 14-28, and finally 3200 kcal ME/kg with 20% crude protein from days 28-85. This diet was used as a control for one of the six groups. Curcumin (at doses of 150, 200, 250, 300, and 350 mg/kg) was added to the diets of the remaining 5 groups. Body weights, weight gains, and feed conversion ratios of birds fed 250, 300, and 350 mg curcumin/kg diet were significantly higher than those of the control group. The percentage of surviving birds was also greater in the curcumin-fed group compared to the control. Lymphoid organ relative weights increased considerably in birds fed a curcumin diet. Serum total protein, albumin, and globulin levels were also significantly higher in the curcumin group than in the control. In contrast, serum concentrations of cholesterol, triglycerides, and total lipids were significantly lower. Hematological tests revealed an elevated percentage of packed cell volume in the blood and an elevated red and white blood cells count compared to the control group. In conclusion, 350 mg curcumin/ Kg of food can be safely utilized in broiler feeding with excellent effects on productive performance.

1. Introduction

The use of antibiotics as growth promoters in chicken diets has been restricted in recent years due to worries about antibiotic residues in animal tissues and the ensuing development of antibiotic-resistant microbial strains (Roe and pillai, 2003 and Saleha et al., 2009). Additionally, there has been a significant increase in awareness among chicken consumers concerning the potential health risks associated with using medicines in poultry farming. As a result, in some regions of the world, antibiotics cannot be used in animal feed (Simon, 2005). Recently, scientists have been exploring natural compounds like curcumin to find effective yet benign alternative possibilities. Animal and fish feed have benefited from turmeric's primary bioactive compound because of its immunostimulatory, antioxidant, antibacterial, and anti-inflammatory effects (Nonose et al., 2014 and Galli et al., 2018). Several studies conducted to investigate the effect of curcumin on the growth performance of birds Rahmani et al. (2017) found that mal Ross chicks fed either curcumin/nano curcumin-containing diet improved ($p \leq 0.05$) body weight and gain compared to those fed control diet. The daily body weight and weight gain of broiler birds (day-old male Ross chicks) fed diets supplemented with curcumin were statistically significantly greater than those of the control groups (Ayman et al., 2019). Yadav et al. (2020), Hafez et al. (2022), and Li et al. (2022) statistically observed superior growth performance in the curcumin groups compared to the control. On the other hand, Zhenglu et al. (2019) and Gabriela et al. (2020) found that the body weight and weight gain of groups that received 1,000 and 2,000 mg/kg curcumin were significantly ($P \leq 0.05$) lower than those in control. Arslan et al. (2017), Abdullahel et al. (2017), and Shohe et al. (2019) reported that turmeric supplementation either at 0.5 or 1.5% level reduced feed intake in broilers as compared to control. Abdullahel et al. (2017), Arslan et al. (2017), and Yesuf et al. (2017) reported that turmeric supplementation at 0, 0.5, 1.0, and 1.5% improved feed conversion efficiency in comparison to the control group. On the other hand, Shohe et al. (2019) found that the average feed conversion efficiency was considerably lower in the group fed (7.5 g turmeric powder /kg feed), followed by the groups fed (5 g turmeric powder/kg feed), and then the control group. Supplementing with 7.5 grams of turmeric was associated with a significant decrease in abdomenal fat compared to the placebo group and a corresponding increase in dressing percentage. On the other hand, Khwairakpam et al. (2016) found no significant difference in dressing percentage, cut-up parts weight, and broiler chicks' giblet due to turmeric powder supplementation. Rajput et al. (2013) found that the thymus's relative weight was slightly higher in birds fed the curcumin-containing diet than in the control group. Zhang et al. (2018) discovered no statistically significant differences ($P > 0.05$) between the control and dietary curcumin treatments in the absolute or relative weights of the liver, spleen, thymus, and bursa of Fabricius. Al-Noori et al. (2011) and Sugiharto et al. (2011) reported that haemoglobin (Hb) and packed cell volume (P.C.V) exhibited a significant (P<0.05) increase in broiler chicks as compared with control. While Abd Al-Jaleel (2012), Abdullahel et al. (2017), and Shohe et al. (2019) concluded that the inclusion of turmeric at different levels in feed showed no significant difference in PCV and (Hb) haemoglobin compared to the control. Hussein (2013) and Zhenglu et al. (2019) showed that adding turmeric powder to a broiler's diet resulted in lower levels of blood cholesterol and triglycerides than the control group. Arslan et al. (2017) reports indicated that supplementation with turmeric boosted antibody titers against ND and IBD, decreased blood total cholesterol, and elevated HDL-HDL-cholesterol while not affecting LDL-cholesterol or triglycerides at any dose. However, the optimal outcomes were achieved with a supplementation dosage of 1.5%. Ayman et al. (2019) and Fayiz et al. (2020) showed that blood total protein and globulin were higher in broilers fed either curcumin or nano-curcumin than those fed a control diet. The greatest serum albumin levels were found in the group given nano-curcumin (0.3 g/kg). They also found that feeding nano-curcumin reduced the amount of serum aspartate transaminase (AST). The serum ALT activity of the birds that were given either nano-curcumin or curcumin was significantly lower than that of the control groups. On the other hand, Abou-Elkhair et al. (2014) found that the concentrations of total protein, albumin, glucose urea, and total cholesterol in broiler chicks were not noticeably altered by supplementation with 0.5% turmeric powder.

Therefore, the present study aimed to investigate the effects of curcumin as a natural feed additive on broiler chicks' productive and immune response.

2. Materials and Methods

At one day old, 360 Cobb chicks were randomly split into 6 groups of 3 replicates, with 20 chicks in each duplicate, and placed in sterile floor pens. For the first 14 days of life, the animals were fed a beginning meal of 3000 kcal ME/kg and 23% crude protein, then a diet of 3100 kcal ME/kg and 21% crude protein from days 14-28, and finally a diet of 3200 kcal ME/kg with 20% crude protein from days 28-35 (finisher period).

Table (1): Composition and calculated analysis of the experimental basal diets:

Ingredients	Periods		
	Starter diet %	Grower diet %	Finisher diet %
Yellow corn	56.5	59.8	58.64
Soybean meal (44 %)	28.3	25.5	30.80
Corn gluten meal (62 %)	10.00	8.5	2.52
Vegetable oil	1.5	2.5	4.88
Di-calcium phosphate	1.7	1.7	1.16
Limestone	1.2	1.2	1.30
Dl-Methionine	0.1	0.1	0.1
L-lysine	0.1	0.1	_
Salts (Nacl)	0.3	0.3	0.3
Premix	0.3	0.3	0.3
Total	100.00	100.00	100.00
Calculated analysis :			
Crude protein (CP %)	23.06	21.1	20.05
Metabolizable energy (kcal/kg)	3010	3106	3200
Ether extract (EE %)	2.773	2.846	2.50
Crude fiber (CF %)	3.554	3.409	3.50
Calcium (%)	1.143	0.949	0.90
Available phosphorus (%)	0.469	0.463	0.35
Lysine(%)	1.148	0.981	1.00
Methionine (%)	0.55	0.520	0.43
Methionine + cystine (%)	0.855	0.789	0.77

Until the animals reached the age of 35 days, one of the six experimental groups was fed this diet as a control, while the other five groups were given the same basal diet plus varying doses of curcumin (150, 200, 250, 300 and 350 mg/Kg diet). All of the chicks in the experiments were raised with the same level of care and were given access to food and water at will. The chicks' weight, feed intake, and conversion efficiency were recorded each week to determine how well they responded. Four chicks from each group were bled at 35 days old. After centrifuging the serum at 3000 rpm for 15 minutes, the serum was collected. Total lipid concentration was measured in serum samples (Frings and Dunn, 1970), cholesterol (Allain et al., 1974), and triglyceride (Fossati and Prencipe, 1982) utilizing store-bought kits for the analysis. Albumin and total serum protein concentrations were determined calorimetrically (Doumas et al., 1971).

The concentration of serum globulins was calculated by subtracting the concentration of albumins from the concentration of total proteins for a direct comparison. In the end, we scalded, de-feathered, and gutted four chicks from each group as a sacrifice. Weights of abdominal fat pads, visceral organs, and lymphoid tissues were recorded with data on the number of dressings produced. Tissue samples included the heart, gizzard, liver, and thymus. After detaching the neck and feet from the carcass, we weighed it and divided that number by the sum of the live BW of birds times 100 to get the carcass yield %. Using input-output analysis of the ratios under test, we could determine their cost-effectiveness, assuming all other costs would remain the same. Analysis of variance in the SAS software was used for the statistical analyses (1996). For post hoc comparisons, we used the Duncan multiple range test (Duncan, 1955) to establish the statistical significance of differences between groups. When comparing means, a value of ($p \leq 0.05$) was taken to indicate statistical significance.

3. Results and discussion

Tables 2 and 3 show curcumin's effects on broiler chicks' growth performance. The initial body weights of the chicks in each group (39.94, 40.0, 39.86, 39.9, 39.86, and 39.85) were all statistically similar, indicating that the birds were randomly assigned to the treatment groups. Table (2) shows that during the starting phase, the weekly live weight of broiler chicks was significantly influenced by nutritional interventions. By the end of the study period, the T5 and T6 diet groups' body weight had increased by 6.9 and 7.4 %, respectively, compared to the basal diet group. The T3 and T4 diet groups' body weight had increased by 3.6 and 4.8%, respectively. In addition, at the end of 4 weeks of age and growth period, birds fed dietary T5, and T6 recorded the heaviest weight by 7.2% and 9.2% compared to those fed control basal diet, followed by birds fed dietary T3 and T4 by 4.1% and 5.4%. Weights at 5 weeks of age were as follows: 2304.2 g for birds fed diet T3, 2335.6 g for birds given diet T4, 2372.3 g for birds fed diet T5, and 2410.2 g for birds fed diet T6. Compared to the control group, birds on the T2 diet gained much less weight (2271.6) during feeding. At all events, at the end of the finisher and experimental periods (35day of age), chicks fed dietary T5 and T6 yielded a significantly heavier body weight by 6.8% and 8.6%, followed by 4.9% and 5.2% of those fed dietary T3 and T4 compared to the control group, respectively.

Supplementing with turmeric in one's diet has been shown to have a statistically significant effect on initial growth. The body weight gains of birds fed dietary T4, T5, and T6 were 5.5%, 7.7%, and 8.1% higher than those fed a control diet during the starting period. T2 diet-fed birds gained about as much weight as the controls. The present findings also revealed, as shown in Table (2), that dietary interventions substantially impacted weight increase during the introductory phase. In comparison, birds fed diets T5 and T6 had larger gain values of 1240.6 and 1269.6 g, followed by birds fed diets T3 and T4 with gain values of 1204.2 and 1220.4 g, and finally, the control group with a gain value of 1155.6 g. No statistically significant differences existed between the birds given a basal diet with turmeric and the control group after 5 weeks. Throughout the experimental periods, it can be summarized that total body weight increase improved by 2.3%, 3.8%, 5.3%, 7.0%, and 8.7% of birds fed dietary T2, T3, T4, T5, and T6 compared to those fed control basal diet, respectively. The antinutritional elements provided in turmeric were ineffectual, allowing curcumin to be successfully used as a feed supplement to broiler diets. This led to an increase in both live body weight and weight gain. The results confirmed other studies by Hafez et al. (2022) reported that curcumin's antioxidant properties reduce free radicals and may improve broiler growth. Also, the growth-promoting effect of curcumin may be related to the improvement of digestive enzyme activities (Jiang et al., 2016), immunity (Ming et al., 2020 ; Yonar et al., 2019), and the ability to anti-stress (Akdemir et al., 2017). The present results were in harmony with the findings by Herawati (2010), Elmakki et al. (2013), Sethy et al. (2016), Shohe et al. (2019), and Hafez et al. (2022) reported that broiler-fed curcumin containing diets caused a significant increase in body weight and weight gain.

Dietary interventions significantly affected total feed consumption (g/brid) during the starting and developing periods. During the starting period, birds on the control diet had a feed intake value of 460.9 g, followed by those on diets T2, T3, T4, and T5 with values of 453.5 g, 451.1 g, 453.7 g, and 452.5 g, respectively. In contrast, birds fed dietary T6 had the lowest consumption values (434.2 g/bird). Also, at the lowest ($P \leqslant 0.05$), total feed intake during the growth period was 1682.2g and 1672.1g of birds fed dietary T5 and T6, followed by 1688.8 and 1691.0 g/bird, of those fed dietary T3 and T4, respectively. as opposed to the 1860.8 g of the control birds. During the finishing period, the same pattern was seen, with birds fed the control diet and T2 recording the highest consumed values (1374.7 and 1372.0 g/bird, P0.05), followed by birds fed the T3 and T4 diets (1361.1 and 1355.6 g/bird, P0.05), and finally birds fed the T6 diet (1342.3 g/bird, P0.05) and the control diet (1374.7 g/bird, P0.05). The total feed intake during the trial (from age 1 to 5 weeks) was considerably lower at higher curcumin concentrations. The birds on the control basal diet devoured 3696.5 gm, followed by those on the T3 and T4 diets at 3612.6 and 3501.1 g/bird, respectively. In contrast, birds fed dietary T5, and T6 had the lowest levels, 3486.6 and 3448.5 g/bird compared to control, respectively. T5 and T6 birds ate 6.02 and 7.2% less than they did on the control basal diet, respectively; similarly, birds fed treatments 2, 3, and 4 ate 2.3%, 5.58, and 2.1% less than they did on those diets.

Information on how curcumin in the diet affects feed intake and feed conversion ratio is shown in Table (3). Dietary interventions significantly affected total feed intake (g/brid) throughout the starter and growth periods. The control diet group had a feed intake value of 460.9 g throughout the starting period, while the dietary groups T2, T3, T4, and T5 all recorded values of 453.5, 451.1, 453.7, and 452.5 g, respectively. Conversely, birds on a diet T6 had the lowest consumption values (434.2 g/bird). Also, the total feed intake of birds fed dietary T5 and T6 was the lowest, coming in at 1682.2g and 1672.1g, while that of birds fed dietary T3 and T4 was the highest, at 1688.8g and 1691.0 g/bird, respectively. When compared to the 1860.8 g of the control birds. Similar results were seen during the finisher period, with birds fed the control diet and T2 recording the highest consumed values (1374.7 and 1372.0 g/bird, P0.05), followed by birds fed the T3 and T4 diets (1361.1 and 1355.6 g/bird, P0.05), and finally birds fed the T6 diet (1342.3 g/bird, P0.05) and the control diet (1354.7 g/bird, P0.05). Throughout the experiment (from age 1 to age 5), the higher the curcumin content of the meal, the lower the animals' overall feed intake. The control baseline diet birds ate the most at 3696.5 gm, followed by the T3 and T4 diet birds at 3612.6 and 3501.1 g/bird. Birds on diets T5 and T6 had the lowest levels compared to the control group, at 3486.6 and 3448.5 g/bird, respectively. T5 and T6 birds consumed 6.02 and 7.2% less, respectively, compared to the control basal diet, which was statistically significant. The feed conversion ratio throughout the starter and finisher phases did not change significantly ($P>0.05$) when curcumin was included in the diet (Table 3). There were notable variations across the experiment, not just the growing phase. The feed conversion ratio of groups fed diets containing curcumin levels improved significantly during the entire growth period. However, compared to the control group, birds in the T2, T3, T4, T5, and T6 feeding groups who were given curcumin diets fared better. At the end of the trial, the group fed dietary T6 had the highest feed conversion ratio (1.54), followed by those fed dietary T2, T3, T4, and T5 (1.61, 1.56, 1.56, and 1.56). Those given a control basal diet had the worst result (1.69). Feed conversion ratios increased by 5% to 9.7% in birds fed dietary T2 and T6 containing curcumin, compared to control. One or more of the following may have contributed to the large increase in viability and feed conversion ratio seen in birds fed curcumin levels containing diets: increased live body weight, decreased feed intake, nutritional balancing, complementary effects, and increased nutrient utilization. Broilers fed a meal enriched with curcumin throughout the study period may have better-absorbed fats because their stomach acids and bile were more active. The present results confirmed by Shohe et al. (2019) reported that improving feed conversion might be better performance of body weight, weight gain, and feed intake. All these benefits are recorded by feeding curcumin for a longer time, enhancing the absorption of nutrients in the advanced stage (Nawab et al., 2019). Besides, the upregulation of pancreatic lipase and increased trypsin, amylase, and chymotrypsin improved intestinal maltase and sucrose activities (Salah et al., 2019). The present results were in harmony with the findings by Abd Al-Jaleel (2012), Hussein (2013), and Rajput et al. (2013), who reported that feed conversion was significantly ($p\leq0.05$) in broiler birds fed curcumin-containing diets compared to control.

Mortality rate:

Table 4 displays the relative rates of mortality and survival. According to the results, the survival rate of chicks fed a diet containing curcumin increased significantly, from 95% to 100% for birds fed Dietary T6, 98% to 100% for broilers fed Dietary T5, 96% to 100% for broilers fed ford Dietary T3 and T4, and 95% to 96% for those fed Dietary T2 and the control basal diet, respectively. Curcumin's antimicrobial, antifungal, antiprotozoal, and antiviral properties may explain why birds fed a diet rich in turmeric have a higher survival rate (Chen and Haung, 2009). In this regard, Shohe et al. (2019) observed that birds whose diets included turmeric powder had a higher percentage of survivors compared to those whose diets did not contain the spice.

Carcass traits of broiler chicks:

Table 4 shows how the levels of turmeric in the broiler chicks' diets affected their carcass characteristics. Casket weight, forequarter, and total edible portion percentages were all changed by diet. However, there were no statistically significant differences between the groups when comparing the back, heart, liver, gizzard, and abdomen fat percentages in broiler chickens ($P>0.05$). The percentage of carcass weight for birds fed diets T3, T4, T5, and T6 was higher than for birds fed the control diet (75.53 vs. 77.4 vs. 76.43 vs. 77.23), followed by birds fed diet T2 (73.4 vs. 71.84), and finally by birds fed diet T2 (48.13 vs. 45.7). T3, T4, T5, and T6 diets resulted in total edible part increases of 4.9%, 7.77%, 5.82%, and 6.9%, respectively, compared to the control baseline diet. The enhancement of relative carcass weight or total edible parts may be related to raising the ratio of netting to live body weight due to better feed utilization without belly fat formation. In keeping with the present finding, other authors have found a considerable increase in carcass yield percentages when supplementing the diet with curcumin compared to the control diet (Durrani et al., 2006 and Arslan et al., 2017).

Table (2): Effect of dietary curcumin level supplementation on body weight and weight gain of broiler chicks during the experimental period:

Age/week	Curcumin levels						Sig
	T1 (control)	T2 (150 mg/kg)	T3 (200 mg/kg)	T4 (250 mg/kg)	T5 (300 mg/kg)	T6 (350 mg/kg)	
Initial body weight	39.9±0.06	40.0±0.05	39.9±0.06	39.9±0.05	39.7±0.06	39.9±0.06	NS
Body weight at 2-week Starter period	424.0±3.94[d]	433.2±4.45[cd]	440.7±5.66[bc]	451.0±4.80[ab]	454.0±4.81[ab]	456.0±4.85[a]	**
Body weight at 4-week Growing period	1580.3±11.64[d]	1621.8±19.45[cd]	1644.9±17.83[c]	1639±19.20[ab]	1694.6±14.33[ab]	1725.7±17.17[a]	**
Body weight at week 5 Finisher period	2220.5±17.80[d]	2271.6±25.62[cd]	2304.2±27.97[bc]	2334±32.30[ab]	2372.3±18.58[ab]	2410.2±29.47[a]	**
Total body weight gain during the starter period	384.8±3.93[d]	393.2±4.45[c]	400.8±5.67[bc]	405.8±4.94[b]	414.3±4.79[ab]	416.1±4.85[a]	**
Total body weight gain during the grower period	1155.6±12.29[d]	1188.5±19.17[cd]	1204.2±18.61[c]	1220.4±17.22[bc]	1240.6±15.12[ab]	1269.6±16.89[a]	**
Body weight gain during the finisher period	640.1±21.98	649.7±25.45	659.2±29.54	669.4±29.54	677.6±20.85	684.5±32.72	NS
Total body weight gain from 0-5 weeks of age	2180.6±17.80[d]	2231.6±25.62[cd]	2264.3±27.97[bc]	2295.7±29.48[bc]	2332.6±18.58[ab]	2370.3±29.47[a]	**

a, b, & c: No significant difference (P>0.05) exists between any two means within the same row with the same superscript letter.
Sig = significant Ns= non-stop significant *= (p≤0.05) **= (p≤0.01)

Table (3): Effect of dietary curcumin levels supplementation on feed intake and feed conversion ratio of broiler chicks during the experimental period:

Age/week	Curcumin levels						Sig
	T1 (Control)	T2 (150 mg/Kg)	T3 (200 mg/kg)	T4 (250 mg/kg)	T5 (300 mg/kg)	T6 (350 mg/kg)	
Total feed intake during the starter period	460.9±8.13[b]	453.5±2.25[b]	451.1±3.46[b]	453.7±1.73[b]	452.5±3.26[b]	434.2±5.08[a]	*
Total feed intake during the growing period	1860.8±2.28[d]	1787.1±0.50[c]	1688.8±1.44[b]	1691.0±4.73[b]	1682.3±4.14[ab]	1672.0±4.72[a]	**
Total feed intake during the finisher period	1374.7±0.89[d]	1372.0±1.520[d]	1361.1±1.48[c]	1355.6±2.33[b]	1351.6±1.66[b]	1342.3±0.88[a]	*
Feed intake during the overall experimental period	3696.5±9.530[d]	3612.6±3.330[c]	3501.1±6.32[b]	3500.4±5.33[b]	3486.6±1.28[b]	3448.5±1.96[a]	*
Feed conversion during the starter period	1.19±0.033	1.15±0.008	1.15±0.002	1.16±0.011	1.16±0.014	1.12±0.019	NS
Feed conversion during the grower period	1.60±0.012[b]	1.50±0.019[a]	1.42±0.026[a]	1.42±0.038[a]	1.42±0.049[a]	1.40±0.021[a]	*
Feed conversion during the finisher period	2.14 ±0.031	2.12±0.012	2.10±0.05[6]	2.08±0.080	2.08±0.092	2.06±0.092	NS
Feed conversion overall during the experimental period	1.69±0.002[c]	1.61±0.013[b]	1.56±0.011[ab]	1.56±0.018[ab]	1.56 ±0.034[ab]	1.54±0.024[a]	*

a, b, & c: No significant difference (P>0.05) exists between any two means within the same row with the same superscript letter.
Sig = significant Ns= non-stop significant *= (p≤0.05) **= (p≤0.01)

Table (4): Effect of dietary curcumin levels supplementation on the mortality rate of broiler chicks:

Item	Curcumin levels					
	T1 (control)	T2 (150 mg/kg)	T3 (200 mg/kg)	T4 (250 mg/kg)	T5 (300 mg/kg)	T6 (350 mg/kg)
Total mortality	3	3	2	2	1	-
Viability %	95.00	95.00	96.66	96.66	98.30	100

Lymphoid organsrelative weight:

Table 5 shows the typical relative weights of lymphoids, which are primarily responsible for the immune response in birds. The bursa of Fabricius, thymus, and pancreas of broiler chicks that were given a diet grew significantly. Burse prevalence was highest in birds fed diet T6, then 0.073, 0.08, 0.081, and 0.094% in birds fed diets T2, T3, T4, and T5, and finally 0.06% in birds provided the control diet. The thymus weight % was 0.575 in the T5 and T6 diet groups, 0.50 in the T2 and T3 diet groups, 0.373 in the T4a diet group, and 0.310 in the control diet group. Furthermore, compared to control-fed chickens, T6-fed birds had significantly bigger pancreases (0.455%) and spleens (0.183%) than T4- and T5-fed birds (0.315%) and control-fed birds (0.230%). These results may indicate the good health status of chicks fed dietary curcumin supplementation. Bennett and Stephens (2006) revealed that the presence or absence of bursa indicates the general health of birds. The bursa of sick or stressed birds is small, while that of a healthy, productive bird is huge. Bursa size is a biological indicator of how successfully flocks are managed and how disease threats are mitigated. Turmeric immune activators in broiler contain several substances, including the coloring material, which is a rich source of phenolic compounds like curcumin, and thymus, spleen, and choicely bursa weight changes as a result of curcumin supplementation in the diet (Roughley and Whiting, 1973).

Immune response:

The immune system is the body's initial line of defense against pathogens. The effects of curcumin supplementation on Hemagglutination inhibition of tiger in broiler chicks are shown in Table (6). (HIT). The HIT of NDV, H5N1, and H9N2 OF broiler chicks fed varying amounts of curcumin-containing diets differed significantly from those fed control diets. Antibody titers against NDV were highest in the birds fed T6, followed by those fed T5 and T4, and finally the birds fed T2 and T3. In contrast, those given a basal control diet had a value of only 4. Curcumin supplementation of the diet raised H5N1 and H9N2 antibody titers. Antibody response to H5N1 was highest in birds given diets of T6, T5, and T4, followed by 4.96 and 5.02 in birds given diets of T3 and T2, and lowest in birds given diets of control (3.53). Antibody titers to H9N2 were 7.83 and 7.26 in birds fed food T6 and T5, respectively, and 5.96 and 6.16 in birds fed dietary T3 and T4, compared to 4.63 in the control group.

Hematological parameter of broiler chicks:

Table 7 displays information on the effects of dietary curcumin levels on several hematological characteristics. The red blood cell count, packed cell volume percent, and hemoglobin levels of birds administered dietary curcumin were significantly greater than those of birds fed a control diet. Curcumin significantly enhanced red blood cell count in birds fed dietary T2, T3, T4, T5, and T6 by 16.4%, 21.1%, 18.8%, 20.8%, and 31.4%, respectively, compared with a control group. White blood cell count was also substantially higher in the groups fed dietary T4, T5, and T6 compared to the control group, with increases of 6.3%, 8.4%, and 15.7%, respectively. Birds on diets T2 and T3 had count values that were statistically similar to the control group. According to Nirmalan and Robinson (1971), the value of RBCs and WBCs count ranged between (2.13×10^6 - 2.8×10^6 /ml) and (28.6×10^3 - 33.1×10^3). The present results were within the physiological limits mentioned above, indicating the beneficial supplementation of curcumin to the broiler diet. Moreover, PCV % values were increased by 5.4%, 7.8%, 7.1%, and 10.2% for broiler birds fed dietary T3, T4, T5, and T6 compared to control, respectively. In contrast, the PCV% value of birds fed dietary T2 was statistically equal to those fed a control diet. The present data showed.

Also, the highest P≤0.05) hemoglobin values (32.5 and 31.3%) were recorded for birds fed dietary T6 and T5, followed by (29.8 and 30.0%) of groups fed dietary T3 and T4. In contrast, the lowest values were (26.9% and 27.9%) of those fed dietary control and T2, respectively. The improvement may be due to enhanced absorption of iron and protein in turmeric-supplemented birds (Kumari et al., 2007). It is well known that iron plays an important role in hemoglobin and red blood cell biosynthesis to prevent anemia and is essential for metabolic enzyme biosynthesis such as cytochromes, superoxide dismutase, and glutathione reeducates (El-Khimsawy, 1985; Bartove and Menner, 1996; Mohamed, 1998 and Badway, 1998). Generally, all values of hematological parameters observed in this study are within the normal ranges reported by several authors (Dukes, 1975 and Awoniyi et al., 2000). The present results confirmed by others, Al-Noori et al. (2011) carried out a study to determine the effects of curcumin longa powder on some blood parameters of broiler chickens; they found that Haemoglobin (Hb) and packed cell volume exhibited a significant increase (p≤0.05) compared with control.

Moreover, Sugiharto et al. (2011) and Sethy et al. (2016) reported that broilers supplemented with turmeric extract enhanced the production of hemoglobin in broilers. The increment in white blood cell count may be attributed to increased thymus gland weight in the present study and/or Increased zinc concentration in turmeric and the diets. These results, confirmed by Mohamed (1998), explained that zinc is considered a vital element in the development of the thymus gland, which is responsible for the division, maturation, and differentiation of lymphocytes to be immunologic competent T-lymphocyte responsible for cellular Immunity in birds.

Table (5): Effect of dietary curcumin levels supplementation on carcass characteristics of broiler chicks at the end of experimental periods:

Item (Relative to LBW):	Curcumin levels						Sig
	T1 (control)	T2 (150 mg/kg)	T3 (200 mg/kg)	T4 (250 mg/kg)	T5 (300 mg/kg)	T6 (350 mg/kg)	
Carcass, %	71.83±1.06[c]	73.40±0.92[bc]	75.53±0.36[ab]	77.40±0.80[a]	76.43±1.86[ab]	77.23±1.12[a]	**
Front part, %	45.70±0.64[b]	45.30±0.35[b]	48.13±0.70[a]	49.53±0.71[a]	48.20±1.15[a]	48.60±0.75[a]	**
Back part, %	26.13±0.54	28.10±0.60	27.40±1.01	27.86±0.60	28.23±0.78	28.63±0.38	NS
Heart, %	0.43±0.005	0.43±0.005	0.42±0.017	0.43±0.005	0.43±0.008	0.43±0.015	NS
Liver, %	2.50±0.057	2.50 ±0.173	2.48 ±0.111	2.43 ±0.202	2.50±0.1000	2.40 ±0.057	NS
Gizzards, %	2.25±0.028	2.20±0.115	2.40±0.057	2.21±0.044	2.14±0.030	2.24±0.045	NS
Total edible part %	77.00±0.997[c]	78.53±0.956[bc]	80.84±0.364[ab]	82.48±0.771[a]	81.50±1.871[ab]	82.30±1.196[a]	*
Abdominal fat %	0.966±0.066	0.906±0.052	0.886±0.072	0.916±0.101	0.863±0.040	0.850±0.125	NS

[a, b, & c]: No significant difference (P>0.05) exists between any two means within the same row with the same superscript letter.
Sig = significant Ns= non-stop significant *= (p≤0.05) **= (p≤0.01)

Table (6) Effect of dietary curcumin levels supplementation on lymphoid organs relative weight percentage of broiler chicks:

Item	Curcumin levels						Sig
	T1 (control)	T2 (150 mg/kg)	T3 (200 mg/kg)	(T4 250 mg/kg)	T5 (300mg/kg)	T6 (350 mg/kg)	
Bursa relative weight, %	0.060±0.0057[b]	0.073±0.0011[b]	0.080±0.0005[b]	0.081±0.0017[b]	0.094±0.0026[b]	0.141±.0.0282[a]	**
Thymus relative weight, %	0.310±0.0404[d]	0.363±0.0218[cd]	0.373±0.0272[cd]	0.423±0.0296[bc]	0.500±0.0288[ab]	0.575±.0.0086[a]	**
Pancreas relative weight,%	0.230±0.0230[c]	0.250±0.0173[c]	0.240±0.0115[c]	0.315±0.0028[b]	0.365±0.0259[b]	0.455±0.0259[a]	**
Spleen relative weight, %	0.107±0.0003[d]	0.183±0.0033[a]	0.133±0.0088[bc]	0.120±0.0057[c]	0.130±0.0057[c]	0.147±0.0043[b]	*

[a, b & c]: No significant difference (P>0.05) between any two means within the same row with the same superscript letter.
Sig = significant Ns= non-stop significant *= (p≤0.05) **= (p≤0.01)

Table (7): effect of dietary curcumin levels supplementation on the immune response of broiler chicks :

Age/week	Curcumin levels						Sig
	T1 (control)	T2 (150mg/kg)	T3 (200mg/kg)	T4 (250mg/kg)	T5 (300mg/kg)	T6 (350mg/kg)	
Log^2 NDV	400±0.057[d]	5.03±0.202[c]	5.56±0.233[bc]	5.96±0.260[ab]	6.50±0.288[a]	6.60±0.321[a]	**
Log^2 H5N1	3.53±0.290[d]	4.96±0.260[c]	5.20±0.115[bc]	6.03±0.290[ab]	6.20±0.404[a]	6.40±0.208[a]	**
Log^2 HgN2	4.63±0.185[c]	5.23±0.120[c]	5.96±0.317[b]	6.16±0.166[b]	7.26±0.266[a]	7.83±0.166[a]	**

[a, b, & c]: No significant difference (P>0.05) exists between any two means within the same row with the same superscript letter.
Sig = significant Ns= non-stop significant *= (p≤0.05) **= (p≤0.01)

Table (8): Effect of dietary curcumin levels supplementation on some hematological parameters of broiler chicks:

Item	Curcumin levels						Sig
	T1 (control)	T2 (150 mg/kg)	T3 (200 mg/kg)	T4 (250 mg/kg)	T5 (300 mg/kg)	T6 (350 mg/kg)	
R.B.C,s×10^6 /ML	2.13±.002[c]	2.48±0.007[b]	2.58±0.02[b]	2.53±0.08[b]	2.56±0.01[b]	2.80±0.05a	*
W.B.c×10^3 /ML	28.6±019[c]	28.7±0.19[b]	29.1±0.23[c]	30.4±0.7[b]	31.0±1.15[b]	33.1±0.39a	*
PCV%	29.4±0.68[b]	30.6±0.72[b]	31.0±0.88[ab]	31.7±0.57[ab]	31.5±.01[ab]	32.4±.0.85a	*
Hemoglobin %	26.9±0.14[e]	27.9±0.16[d]	29.8±1.8[c]	30.0±0.18[c]	31.3±0.01[b]	32.5±0.02a	*

[a, b, & c]: No significant difference (P>0.05) exists between any two means within the same row with the same superscript letter.
Sig = significant Ns= non-stop significant *= (p≤0.05) **= (p≤0.01)

Table (9): Effect of dietary on some biochemical parameters of serum blood for broiler chicks:

Item	Curcumin levels						Sig
	T1 (control)	T2 (150 mg/kg)	T3 (200 mg/kg)	T4 (250 mg/kg)	T5 (300 mg/kg)	T6 (350 mg/kg)	
Total Lipids (mg/dl)	296.1±3.6[a]	286.0±15.9[ab]	273.1±0.5[ab]	262.2±1.5[c]	258.1±2.9[c]	252.1±2.0[c]	**
Cholesterol (mg/dl)	191.2±2.2[a]	187±0.7[ab]	182.0±0.4[b]	173.3±1.6[c]	164.1±2.6[d]	154.2±1.8[e]	**
Triglycerides (mg/dl)	109.3±0.4[a]	107.2±0.4[ab]	105.1±0.4[ab]	100.3±0.4[c]	98.3±0.4[d]	99.4±0.6[d]	**
High-density lipoprotein (mg/dl)	38.7±0.2[a]	38.2±0.3[a]	36.1±0.3[b]	35.8±.3[b]	35.8 ±0.7[b]	35.2±1.8[b]	**
Low-density lipoprotein (mg/dl)	130.1±2.1[a]	129.1±0.9[a]	122.3±0.3[b]	118.2±1.8[b]	108.3±2.1c	99.4±1.7[d]	**
Total protein (mg/dl)	3.3 ±0.02[d]	3.4±0.02[d]	3.4 ±0.02 [d]	3.5 ±0.03[c]	3.6 ±0.02[b]	3.9 ±0.01[a]	**
Albumin(mg/dl)	1.19±0.009 [e]	1.25±0.019[d]	1.25±0.008[c]	1.32±0.017[c]	1.4 ±0.022[b]	1.49 ±0.013[a]	**
Globulin (mg/dl)	2.11±0.02 [d]	2.15±0.01[c]	2.15 ±0.02[c]	2.18 ±0.02[bc]	2.22 ±0.01[b]	2.41 ±0.02[a]	**

[a, b & c]: No significant difference (P>0.05) between any two means within the same row with the same superscript letter.
Sig = significant Ns= non-stop significant *= (p≤0.05) **= (p≤0.01)

Biochemical traits

Serum biochemical parameters have been used to indicate birds' nutrition and physiological status, as presented in Table (8). The concentration of serum total lipids, cholesterol, triglycerides, high-density lipoprotein, and low-density lipoprotein were significantly (P≤0.05) decreased by turmeric levels containing diet. Total lipids decreased by 8.4%, 12.9%, 14.7%, and 17.5% of birds fed dietary T3, T4, T5, and T6 compared to the control group. Also, the concentration of cholesterol and triglycerides in blood serum were significantly (P≤0.05) decreased by 2.2%, 5.1%, 10.3%, 16.5%, 24.0% and 1.9%, 3.4%, 9.0%, 11.2%, 10.0%, of birds fed dietary T2, T3, T4, T5 and T6 compared to control, respectively. Birds fed dietary T3, T4, T5, and T6 reduced (P≤0.05) the concentration of HDL and LDL in serum by 7.2%, 8.1%, 8.1%, 9.9%, and 6.4%, 10.1%, 20.1%, 30.9%, compared with those of the control, respectively. The highest (P≤0.05) concentration of total protein was 3.9 mg/dl of birds fed dietary T6, followed by 3.4%, 3.41%, 3.5%, and 3.6% mg/dl of those fed dietary T2, T3, T4 and T5 versus 3.3 mg/dl of group fed control diet. Total protein was significantly (P≤0.05) increased by 6.1%, 9.1%, and 18.2% of groups fed dietary T4, T5, and T6 compared to the control. While the albumin values increased by 5.0%, 5.0%, While the albumin values increased by 5.0%, 5.0%, 10.9%, 17.6%, and 25.2% of groups fed dietary T2, T3, T4, T5, and T6 relative to control, respectively. The reduction in total lipids cholesterol, triglyceride, and high-density lipoprotein or density lipoprotein levels may be due to at least in part; it possibly involves the combination of bioactive compounds in turmeric, such as short chine fatty acids and fiber fermentation by intestinal flora the decline may also, be due to the reduction in cholesterol absorption by the no digestible polysaccharides such as B-(13) glucans and the interaction of cholesterol with bile acids, which reduces their reabsorption into the enter hepatic circulation and causes the livers to divert cholesterol to bile acid production, thus reducing the cholesterol concentration in the blood (Chewing, 1996). The increased concentration of serum total protein, albumin, and globulin may be related to good utilization of dietary protein due to curcumin supplementation. These results align with the findings of Durrani et al. (2006), who stated that turmeric supplementation was beneficial regarding weight gain feed utilization and hypolipidemic. These results were confirmed by Hafez et al. (2022), who reported increases in serum concentration of protein albumin and globulin as a result of supplementation of curcumin in the broiler diet. Also, Hussein (2013) reported that turmeric powder supplementation in a broiler diet reduced serum concentration of cholesterol and triglycerides compared with control. Other findings by Fallah and Mirzaei (2016) observed that broilers receiving different levels of turmeric powder had lower uric, total cholesterol, HDL, LDL, and triglycerides concentrations as compared to the control group.

4. Conclusion

In conclusion, 350 mg curcumin/ Kg of food can be safely utilized in broiler feeding with excellent effects on productive performance.

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