Effects of dietary supplement of turmeric powder *(Curcuma longa)* on blood biochemistry parameters and antioxidant activity in chickens

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Abstract

The present study was conducted with 288 one-day-old mixed broiler chicks (Ross 308) to investigate the effects of dietary supplementation with various levels of turmeric powder on blood constituents and antioxidant activity. The chicks were randomly assigned to eight dietary groups, which were given turmeric powder levels of 10, 12, 14, 16, 18 and 20 g/kg feed, and two control groups (positive and negative). Each dietary group contained six replicates with six birds each. The results showed that the concentrations of glucose, albumin, blood urea nitrogen and total bilirubin, and the enzyme activity of alanine aminotransferase decreased significantly in the serum of broiler chickens treated with turmeric powder compared with untreated chickens (control groups). However, there was no significant reduction in the concentration of serum creatinine or the enzyme activities of aspartate aminotransferase, alkaline phosphatase, lactate dehydrogenase and creatine kinase in serum. The activity of the gamma-glutamyl transferase enzyme did not change either. There was no significant increase in the concentrations of serum total protein and globulin in the groups treated with turmeric powder compared with control groups, except at weeks 2 and 4. The total antioxidant capacity in tissues (liver, heart and kidney) and serum was not affected significantly by turmeric powder. From these results it can be concluded that dietary turmeric powder had positive effects on the blood biochemistry parameters of broiler chickens, but that antioxidant activity was not improved.

Keywords: Broiler, enzyme activity, immune system, performance
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Introduction

Poultry feed represents 65% - 70% of overall poultry production costs, so the utilization of feed in broilers (Abd Al-Jaleel *et al*., 2012) should be improved. In the past, antibiotics were used in broiler feed as growth promoters through improved gut health and reduced cost of production, thus maximizing feed conversion efficiency. However, these antibiotics had indirect adverse effects on human health because of residues in chicken meat (Yang *et al*., 2009), and the increased resistance of certain microbes (Denli *et al*., 2003). Therefore, researchers have tended to use various types of medicinal plants as alternatives to antibiotics in the diet of broilers (Zhang *et al*., 2009). (Suppl.)

Turmeric is an important medicinal plant that is used as a dietary supplement in poultry feeding. In Southeast Asia, rhizomes of turmeric have been used extensively in traditional medicine and human food preparation in fresh and powdered form (Ammon & Wahl, 1991; Jayaprakasha *et al*., 2005; Akbarian *et al*., 2012). Curcumin (diferuloylmethane) is the most bioactive ingredient in turmeric. It represents 3% - 5% of the curcuminoids in turmeric rhizomes and is a strong phenolic antioxidant (Osawa *et al*., 1995; Stankovic, 2004; Jaggi Lal, 2012). The biological properties of the turmeric plant and its extracts have been described in numerous reports (Akram *et al*., 2010; Khan *et al*., 2012; Eevuri & Putturu, 2013; Nirisha *et al*., 2015). Its benefits in poultry nutrition include improving broiler performance parameters and endogenous digestive enzyme secretion, and activating immune responses and antimicrobial and antioxidant activities (Dorman & Deans, 2000; Burt, 2004; Khan *et al*., 2012).

Blood biochemistry parameters and antioxidant activity are important biomarkers of health status and nutrient metabolism in the body of an organism (Lokesh *et al*., 2012). Recent studies have evaluated the effects of turmeric powder on blood biochemistry parameters and antioxidant capacity in broiler chickens (Emadi *et al*., 2007; Gowda *et al*., 2009; Daneshyar, 2012; Hussein, 2013). However, the results have not

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been consistent. Therefore, the purpose of the current work was to investigate the influence of various levels of turmeric powder on the biochemical blood parameters and tissue antioxidant activity of broiler chickens.

Materials and Methods

Turmeric was purchased commercially as dried roots. The roots were ground into a powder, which was weighed and added to the basal diet as 10, 12, 14, 16, 18 and 20 g/kg of feed**.**

The experiment involved 288 one-day-old commercial mixed sex broiler chicks (Ross 308). They were obtained from a local hatchery, and placed in electrically heated battery cages in a closed house. The chicks were weighed on arrival (average weight 46 ± 0.42 g) and allocated according to a completely randomized design into eight groups of six replicates of six chicks each according to the limited levels of turmeric powder, plus a positive control group (+C) and a negative control group (-C), which included vaccinated birds and unvaccinated birds that received a basal diet without turmeric powder, respectively. This experiment included the +C and -C control groups because immune responses to the Newcastle Disease (ND), Infectious bronchitis (IB), Infectious Bursal Disease IBD vaccines were published previously (Qasem *et al*., 2015).

All the chicks were fed a commercial starter diet (215 g crude protein (CP)/kg from 1 to 21 days old (starter phase), followed by a finisher diet (185 g CP/kg) up to the end of the experiment (22 to 42 old) (finisher phase), as shown in Table 1. The experimental birds were given the feed in mashed form throughout the period. Feed and water were provided ad libitum. The temperature was set at 33 ºC in the first week and gradually decreased to 25 ºC by the end of the third week. Thereafter, the temperature was kept constant. Artificial lighting was used 24 hours a day throughout.

Table 1 Composition of the basal diets (%)

Nutrient	Basal diet	
	Starter (1 - 21 days)	Finisher (22 - 42 days)
ME, MJ/kg	12.13	12.55
Crude protein (CP), g/kg	215	185
Crude fat, g/kg	25	30
Calcium, g/kg	10	9
Available phosphorus, g/kg	4.2	4.0
Sodium, g/kg	1.5	1.5
Lysine, g/kg	12	10
Methionine, g/kg	5.0	4.5
Meth + cystine, g/kg	8.5	8.0

Composition of vitamins and minerals in the premix (per kg of diet): vitamin A, 12 000 IU; vitamin D, 5 000 IU; vitamin E, 60 mg; vitamin C 100 mg; vitamin K, 4 mg; vitamin B_1, 3 mg; vitamin B_2, 8 mg; vitamin B_6, 5 mg; vitamin B_{12}, 0.03 mg; niacin, 40 mg; folic acid, 2 mg; pantothenic acid, 15 mg; biotin, 0.2 mg; choline, 900 mg; cobalt, 0.5 mg; copper, 8 mg; iodine, 2 mg; iron, 35 mg; manganese, 90 mg; selenium, 0.2 mg; zinc, 70 mg.
ME: metabolisable energy.

Twelve blood samples of 2 mL each were collected weekly (at 7, 14, 21, 28, 35 and 42 days old) from the wing veins of 12 birds from each group using 3 mL syringes with 25 gauge needles. The samples then stood for 2 hours at room temperature where-upon the serum samples were centrifuged at 3000 x *g* for 5 minutes at 4 ºC and stored in Eppendorf tubes at −20 ºC until they were analysed. Glucose (GL364), total protein (TP245), albumin (AB362), blood urea nitrogen (BUN 020-150), creatinine (CR510), total bilirubin (BR2802) and the activity of blood enzymes, including alanine transaminase (ALT, EC 2.6.1.2) (AL1205), aspartate transaminase (AST: EC 2.6.1.1) (AS1204), alkaline phosphatase (ALP: EC 3.1.3.1) (AP307), lactate dehydrogenase (LDH EC 1.1.1.27) (LA401), creatine kinase (CK EC 2.7.3.2) (CK113) and gamma-glutamyl transferase (GGT EC 2.3.2.2) (GT2750) were assayed in the serum samples using a reagent kit (Randox Laboratories Ltd, Crumlin, Co. Antrim, UK) and spectrophotometer (semi-automated analyser, UDICHEM 310, Basildon, Essex, UK). To determine the total antioxidant capacity (TAC) in the liver, kidney and heart tissues, five birds at 21 and 42 days old were selected randomly from each group and weighed, slaughtered through the jugular vein in the neck. The organs (liver, kidney and heart) were removed and immediately stored at −80 ºC (Gowda *et al*., 2009) until testing. A TAC assay of serum was also tested at 21 and 42 days old. The testing procedure for the TAC assay of the tissues and serum was based on the assay kit manufacturer's instructions (Cayman Chemical Company, Ann Arbor, Mich., USA). The data were analysed with a general linear model (GLM) and a completely randomized design (SAS, 2000). The level of significance was set at P <0.05. Significant differences between mean values were assessed using Duncan's test (SAS, 2003).

Results and Discussion

The effects of turmeric on the serum glucose in broiler chicken blood, which was collected weekly, are presented in Table 2. Serum glucose concentration decreased significantly (P <0.05) in the treatment groups that received high levels of turmeric powder (18 and 20 g/kg of diet) compared with the control groups (positive and negative controls) at weeks 2 and 4. During the other weeks of the experiment, the reduction of serum glucose was non-significant in all the treatment groups compared with the control groups.

Table 2 Effect of various levels of dietary turmeric powder on serum glucose concentration (mg/dL) of broiler chickens

TP (g/kg)	Age (weeks)						Overall mean (0 - 42 days)
	1	2	3	4	5	6	
10	190.2	178.5^{ab}	200.7	207.3^{ab}	206.7	206.5	198.3^{ab}
12	191.0	184.5^{ab}	197.3	207.3^{ab}	203.2	209.8	198.8^{ab}
14	186.8	176.8^{ab}	198.0	198.8^{b}	198.0	208.2	194.3^{ab}
16	150.3	182.7^{ab}	196.8	204.3^{b}	205.3	207.5	191.2^{ab}
18	162.8	174.0^{b}	196.3	203.0^{b}	201.8	192.8	187.2^{b}
20	175.0	171.5^{b}	193.7	202.8^{b}	196.8	188.3	188.0^{b}
+C	191.5	194.3^{a}	205.2	230.0^{a}	212.3	215.0	208.1^{a}
-C	180.0	193.5^{a}	206.5	228.5^{a}	210.8	211.7	206.3^{a}
SEM	16.51	5.34	6.18	7.75	5.34	7.13	4.08
P-value	0.57	0.02	0.81	0.03	0.39	0.13	0.01

TP (g/kg): turmeric powder levels added to diet.
+C: the positive control group (vaccinated and untreated with turmeric powder).
-C: the negative control group (unvaccinated and untreated with turmeric powder).
SEM: standard error of the mean for the treatment effect.
a-b: values in the same column with different superscripts differ significantly (P <0.05).

There were no significant differences between the dietary treatment groups and the control groups in total protein in all weeks except week 4, when all groups fed supplemented diets had significantly (P <0.05) higher serum total protein concentrations than the control groups, as shown in Table 3. At weeks 2 and 4, the various levels of turmeric powder added to the diet significantly lowered (P <0.05) serum albumin concentration of broiler chickens compared with the positive and negative control chickens (Table 4). However, serum globulin levels increased significantly when compared with negative control chickens at the same time, as listed in Table 5.

There was a significant (P <0.05) decrease in the serum BUN concentration of broilers treated with turmeric powder at weeks 1, 3, 5 and 6 compared with the control groups, as shown in Table 6. However, serum creatinine concentration was not significantly different between the dietary groups. In addition, serum total bilirubin concentration did not change significantly except at weeks 1, 2 and 4, when the concentration was significantly lower (P <0.05) in chickens fed various levels of turmeric powder compared with the control groups (Table 7).

Table 3 Effects of various levels of dietary turmeric powder on serum total protein concentration (g/dL) in broiler chickens

TP (g/kg)	Age (weeks)						Overall mean (0 - 42 days)
	1	2	3	4	5	6	
10	2.83	2.70	3.44	3.20^{a}	3.24	2.71	3.02
12	2.87	2.62	3.41	3.28^{a}	3.20	2.29	2.94
14	2.49	2.71	3.32	3.14^{a}	2.95	2.42	2.84
16	2.87	2.85	3.44	3.13^{a}	2.97	2.56	2.97
18	3.01	2.91	3.62	3.17^{a}	2.99	2.68	3.06
20	2.78	2.95	3.47	3.15^{a}	3.11	2.84	3.05
+C	2.96	2.76	3.43	2.76^{b}	2.90	2.79	2.91
-C	2.84	2.70	3.32	2.75^{b}	2.88	2.75	2.87
SEM	0.13	0.09	0.11	0.12	0.13	0.15	0.07
P-value	0.18	0.11	0.56	0.02	0.41	0.16	0.19

TP (g/kg): turmeric powder levels added to diet.
+C: positive control group (vaccinated and untreated with turmeric powder).
-C: negative control group (unvaccinated and untreated with turmeric powder).
SEM: standard error of mean for treatment effect.
a-b: values in the same column with different superscripts differ significantly (*P* <0.05).

Table 4 Effects of various levels of dietary turmeric powder on serum albumin concentration (g/dL) in broiler chickens

TP (g/kg)	Age (weeks)						Overall mean (0 - 42 days)
	1	2	3	4	5	6	
10	1.61	1.73^{ab}	1.82	1.70^{ab}	1.90	1.58	1.72^{ab}
12	1.57	1.60^{b}	1.81	1.51^{b}	1.81	1.28	1.63^{b}
14	1.54	1.58^{b}	1.58	1.52^{b}	1.81	1.46	1.58^{b}
16	1.57	1.53^{b}	1.78	1.56^{b}	1.93	1.43	1.63^{b}
18	1.46	1.51^{b}	1.80	1.46^{b}	1.70	1.50	1.57^{b}
20	1.41	1.54^{b}	1.76	1.51^{b}	1.77	1.46	1.57^{b}
+C	1.65	1.77^{ab}	1.86	1.90^{a}	1.80	1.59	1.76^{ab}
-C	1.74	1.85^{a}	1.95	1.94^{a}	1.83	1.61	1.82^{a}
SEM	0.09	0.10	0.07	0.09	0.06	0.07	0.04
P-value	0.11	0.01	0.22	0.01	0.12	0.60	0.01

TP (g/kg): turmeric powder levels added to diet.
+C: positive control group (vaccinated and untreated with turmeric powder).
-C: negative control group (unvaccinated and untreated with turmeric powder).
SEM: standard error of mean for treatment effect.
a-b: values in the same column with different superscripts differ significantly (*P* <0.05).

Activities of three serum enzymes only, namely ALT, CK and DHL, were affected (*P* <0.05) by supplementation of turmeric powder to the basal diet in broiler chickens at weekly intervals. The results are presented in Tables 8, 9 and 10. Table 8 shows that the diets supplemented with 16, 18 and 20 g/kg of turmeric powder significantly (*P* <0.05) reduced the enzyme activity of ALT in the serum of broiler chickens at weeks 1 and 2 compared with those fed control diets. In Tables 9 and 10, the activities of CK and LDH enzymes were significantly (*P* <0.05) lower in chickens that received 16, 18 and 20 g/kg dietary turmeric powder in comparison with control groups at weeks 1 and 4, respectively. However, the data of the activities of AST, ALP and GGT enzymes did not reveal significant effects for various dietary levels of turmeric powder at the weekly points.

Table 5 Effects of various levels of dietary turmeric powder on serum globulin concentration (g/dL) in broiler chickens

TP (g/kg)	Age (weeks)						Overall mean (0 - 42 days)
	1	2	3	4	5	6	
10	1.22	0.97[ab]	1.62	1.51[a]	1.34	1.13	1.30[ab]
12	1.31	1.02[ab]	1.59	1.78[a]	1.39	1.02	1.31[ab]
14	0.95	1.13[a]	1.74	1.62[a]	1.14	0.96	1.25[ab]
16	1.30	1.33[a]	1.65	1.57[a]	1.04	1.14	1.34[ab]
18	1.55	1.40[a]	1.83	1.71[a]	1.29	1.18	1.49[a]
20	1.37	1.41[a]	1.71	1.64[a]	1.35	1.38	1.48[a]
+C	1.31	0.99[ab]	1.58	0.86[b]	1.10	1.20	1.17[ab]
-C	1.10	0.85[b]	1.37	0.80[b]	1.05	1.15	1.05[b]
SEM	0.10	0.12	0.13	0.11	0.17	0.17	0.07
P-value	0.06	0.01	0.21	0.01	0.19	0.61	0.01

TP (g/kg): turmeric powder levels added to diet.
+C: positive control group (vaccinated and untreated with turmeric powder).
-C: negative control group (unvaccinated and untreated with turmeric powder).
SEM: standard error of mean for treatment effect.
a-b: values in the same column with different superscripts differ significantly (*P* <0.05).

Table 6 Effects of various levels of dietary turmeric powder on concentration of blood urea nitrogen (BUN) (mg/dL) in broiler chickens

TP (g/kg)	Age (weeks)						Overall mean (0 - 42 days)
	1	2	3	4	5	6	
10	7.97[ab]	12.62	13.70[ab]	15.16	11.16[b]	11.76[ab]	12.06[bc]
12	7.26[ab]	12.67	13.7[ab]	15.88	10.87[b]	12.23[ab]	12.11[bc]
14	6.07[b]	11.78	12.67[b]	14.67	9.46[b]	10.42[b]	10.84[c]
16	5.71[b]	11.82	13.32[ab]	14.62	10.08[b]	10.18[b]	10.95[c]
18	5.83[b]	11.70	12.78[b]	13.82	8.93[b]	10.33[b]	10.56[c]
20	5.57[b]	10.30	12.17[b]	13.52	10.65[b]	9.82[b]	10.34[c]
+C	9.31[a]	14.60	17.55[a]	16.73	15.32[a]	15.37[a]	14.81[a]
-C	9.74[a]	13.72	17.35[a]	15.32	15.24[a]	14.56[a]	14.31[ab]
SEM	0.57	0.97	0.94	1.05	0.85	0.89	0.55
P-value	0.01	0.10	0.01	0.45	0.01	0.01	0.01

TP (g/kg): turmeric powder levels added to diet.
+C: positive control group (vaccinated and untreated with turmeric powder).
-C: negative control group (unvaccinated and untreated with turmeric powder).
SEM: standard error of mean for treatment effect.
a-b: values in the same column with different superscripts differ significantly (*P* <0.05).

Table 7 Effects of various levels of dietary turmeric powder on serum total bilirubin concentration (mg/dL) in broiler chickens

TP (g/kg)	Age (weeks)						Overall mean (0 - 42 days)
	1	2	3	4	5	6	
10	0.340[ab]	0.323[ab]	0.192	0.220[ab]	0.173	0.175	0.232[ab]
12	0.260[b]	0.222[b]	0.186	0.195[b]	0.162	0.168	0.177[b]
14	0.293[b]	0.216[b]	0.182	0.202[b]	0.140	0.147	0.185[b]
16	0.276[b]	0.324[ab]	0.184	0.193[b]	0.162	0.175	0.203 [ab]
18	0.268[b]	0.267[ab]	0.173	0.200[b]	0.150	0.154	0.198[b]
20	0.283[b]	0.229[b]	0.166	0.177[b]	0.157	0.155	0.192[b]
+C	0.371[a]	0.348[a]	0.195	0.278[a]	0.176	0.195	0.261[a]
-C	0.361[a]	0.350[a]	0.193	0.271[a]	0.184	0.183	0.251[a]
SEM	0.021	0.032	0.025	0.023	0.018	0.020	0.017
P-value	0.02	0.01	0.97	0.02	0.78	0.65	0.12

TP (g/kg): turmeric powder levels added to diet.
+C: positive control group (vaccinated and untreated with turmeric powder).
-C: negative control group (unvaccinated and untreated with turmeric powder).
SEM: standard error of the mean for the treatment effect.
a-b: values in the same column with different superscripts differ significantly (P <0.05).

Table 8 Effects of various levels of dietary turmeric powder on serum ALT enzyme activity (IU/L) in broiler chickens

TP (g/kg)	Age (weeks)						Overall mean (0 - 42 days)
	1	2	3	4	5	6	
10	6.93[ab]	5.88[ab]	7.67	7.57	7.95	7.25	7.21[ab]
12	6.93[ab]	6.97[a]	7.04	7.08	7.11	5.94	6.84[bc]
14	5.50[ab]	6.53[ab]	6.99	7.26	6.77	6.80	6.64[bc]
16	4.91[ab]	4.65[ab]	5.90	7.49	7.24	5.79	6.00[bc]
18	3.95[b]	4.28[b]	6.39	6.56	6.56	6.93	5.72[c]
20	5.13[b]	4.83[ab]	5.73	6.23	5.81	6.32	5.73[c]
+C	7.87[a]	7.06[a]	7.56	8.56	8.12	7.47	7.77[a]
-C	7.80[a]	7.09[a]	7.81	8.63	7.43	7.83	7.76[a]
SEM	0.73	0.55	0.79	0.75	0.66	0.59	0.29
P-value	0.001	0.001	0.43	0. 29	0.28	0.19	0.01

TP (g/kg): turmeric powder levels added to diet.
+C: positive control group (vaccinated and untreated with turmeric powder).
-C: negative control group (unvaccinated and untreated with turmeric powder).
SEM: standard error of the mean for the treatment effect.
a-b: values in the same column with different superscripts differ significantly (P <0.05).

The current results are consistent with those of other investigators. Gowda *et al*. (2009) found that 444 mg curcumin/kg significantly reduced serum glucose concentration, while the activities of GGT and AST enzymes did not differ significantly in the serum of curcumin-fed broiler chickens compared with control birds. Ahmadi (2010) indicated that serum glucose levels were significantly lower in broiler chickens fed 0.3 g turmeric powder/kg as a dietary supplement and that this effect was owing to better utilization of glucose. It is possible that turmeric powder increases the activity of glucose transporters, which are a family of transmembrane proteins that help to carry glucose across the plasmalemma (Kumari *et al*., 2007).

Table 9 Effects of various levels of dietary turmeric powder on serum creatine kinase activity (U/L) in broiler chickens

TP (g/kg)	Age (weeks)						Overall mean (0 - 42 days)
	1	2	3	4	5	6	
10	1673^{ab}	1677	1320	1672	1521	1891	1626
12	1679^{ab}	1560	1212	1674	1754	1692	1595
14	1429^{bc}	1564	1181	1659	1792	1958	1597
16	1445^{bc}	1307	1247	1533	1683	1641	1476
18	1355^{b}	1457	1081	1573	1426	1807	1450
20	1372^{b}	1369	1282	1655	1280	1805	1460
+C	1714^{a}	1537	1350	1711	1668	2088	1672
-C	1704^{a}	1565	1203	1656	1434	1968	1589
SEM	81.5	123.5	120.9	129.4	147.6	140.1	59.0
P-value	0.02	0.49	0.83	0.98	0.19	0.36	0.06

TP (g/kg): turmeric powder levels added to diet.
+C: positive control group (vaccinated and untreated with turmeric powder).
-C: negative control group (unvaccinated and untreated with turmeric powder).
SEM: standard error of mean for treatment effect.
a-b: values in the same column with different superscripts differ significantly (P <0.05).

Table 10 Effects of various levels of dietary turmeric powder on the serum lactic dehydrogenase concentration activity (IU/L) of broiler chickens

TP (g/kg)	Age (weeks)						Overall mean (0 - 42 days)
	1	2	3	4	5	6	
10	2027	2146	1732	1370^{a}	1658	1686	1770^{ab}
12	1963	2036	1624	1538^{a}	1565	1851	1763^{ab}
14	1912	1998	1688	1666^{a}	1564	1512	1723^{ab}
16	2083	2102	1886	1117^{b}	1630	1489	1717^{ab}
18	1943	1953	1691	1070^{b}	1551	1648	1643^{b}
20	1868	1782	1681	1063^{b}	1566	1641	1600^{b}
+C	2225	2073	1834	1526^{a}	1767	1993	1903^{a}
-C	2085	1972	1818	1520^{a}	1695	1919	1835^{ab}
SEM	141.8	115.5	157.1	88.3	165.0	135.8	66.6
P-value	0.70	0.48	0.93	0.01	0.98	0.10	0.04

TP (g/kg): turmeric powder levels added to diet.
+C: the positive control group (vaccinated and untreated with turmeric powder).
-C: the negative control group (unvaccinated and untreated with turmeric powder).
SEM: standard error of mean for the treatment effect.
a-b: values in the same column with different superscripts differ significantly (P <0.05).

In addition, Kumari *et al*. (2007) recorded significantly higher levels of serum total protein and globulin of broiler birds fed a diet treated with turmeric powder at a rate of 1 g/kg, while the serum albumin level was lower (P <0.05). Al-Norii *et al*. (2011) found a significant increase in serum total protein concentration in broiler chickens that received a diet containing turmeric powder at levels of 0.5% and 1%. However, Emadi *et al*. (2007) suggested no significant effect on total protein and albumin concentrations in broiler chickens treated with the levels of 0.25%, 0.5% and 0.75% of turmeric powder at 21 days old. In another study by Emadi & Kermanshahi (2007) the same levels of turmeric powder decreased ALT and ALP enzyme activities in the serum of broiler chickens. Additionally, Arshami *et al*. (2013) found that LDH enzyme activities decreased significantly with increasing doses of turmeric powder in the diets of laying hens (5, 15 and 25 g/kg). However, CK enzyme activity was not significantly (P <0.05) different from that found in the control groups. Hosseini-Vashan e*t al*. (2012) reported significant reductions in the activities of ALT, AST and ALP enzymes in broiler chickens fed 0.4% and 0.8% turmeric powder under heat stress, whereas the serum CK enzyme was not affected.

In contrast, the results of some studies were different from the findings of the current study. Emadi & Kermanshahi (2007) stated that the serum activities of AST and LDH enzymes increased in broiler chickens fed turmeric powder at rates of 2.5 and 5 g/kg of the basal diet. Ahmadi (2010) reported that 0.3 g/kg of turmeric powder had no significant effect on serum total protein, albumin, globulin, ALT and AST enzymes compared with the control group.

Similarly, there were no significant differences in total protein, albumin and glucose in laying hens treated with 5, 15 and 25 g/kg of turmeric powder (Arshami *et al*., 2013). Namagirilakshmi (2005) reported that serum glucose was not significantly affected by turmeric powder added to broiler feed at levels of 0.25, 0.5, 0.75 and 1 g/kg. Kumari *et al*. (2007) and Mehala & Moorthy (2008) reported that the activity of some liver enzymes, such as ALT, AST, ALP and LDH, and glucose concentrations did not change with the dietary inclusion of turmeric powder in all the treated broiler chicken groups that were analysed. Additionally, certain biomarkers in the serum of rabbits (Basavaraj *et al*., 2011) and rats (Al-Nazawi & El-Bahr, 2012), including ALT, AST and ALP enzymes and uric acid, creatinine, globulin and total protein, were not affected by dietary supplementation with turmeric powder.

The present study showed significant increases in total protein and globulin at different weeks of the experiment, revealing high activity in the liver as a result of the curcumin component in turmeric powder (Kumari *et al*. 2007; Yousef *et al*., 2010). Serum globulin concentration was calculated as the difference between total protein and albumin concentrations. Therefore, it increased significantly in the treatment groups with turmeric powder, compared with the negative control group at the second week, and positive and negative control groups for the fourth week of the experiment, as shown in Table 5. Higher (P <0.05) serum globulin level demonstrated that chickens of treated groups had potential for better humoral immune (HI) levels, because the higher HI titre of treated groups was recorded in some weeks of the experiment (Qasem *et al*., 2015). On the other hand, serum albumin values of all groups (Table 4) were considered within the normal range of Ross 308 broilers (Abdi-Hachesoo *et al*., 2011), so decreased serum albumin level in the second and fourth weeks had no adverse effects on the healthy status of birds (Kumari *et al*., 2007).

Urea synthesis in the liver is the major source of nitrogen excretion into the blood and is filtered by the kidney. In the current study, decreased (P <0.05) serum BUN concentration of groups that received turmeric powder was possibly attributed to a lower rate of urea synthesis in the liver or a higher rate of urea excretion in the kidney under the effects of turmeric powder (Srimal, 1997; Amin & Abdou, 2012). The weekly reduction of BUN may be attributed to curcumin, which can improve the activity of kidney nephrons and thus increase the filtration of urinary metabolites from the blood of treatment groups (Srimal, 1997), particularly those that received high levels of turmeric powder. In addition, the data of the concentrations of total bilirubin and ALP enzymes in the serum of treated and untreated chickens were very high in the first week and then decreased gradually with age. These results were expected, because bilirubin and ALP enzyme activity are related to growth and bone formation and have physiological roles in general metabolic activity (Rizvi *et al*., 2008). The liver is rich in certain enzymes, such as ALT, AST and LDH, and damage often results in abnormally heightened concentrations of these enzymes in the blood (Kaplan *et al*., 2003). In the current study, decreases in the activities of liver ALT, AST and LDH enzymes and serum BUN and creatinine in treating birds were evidence that turmeric powder in these concentrations can safely be included in the basal diets of broiler chickens. It had no negative effects on biomarkers of liver and kidney function.

The incompatibility between these findings and certain previous reports might be the result of several factors. For example, the turmeric plant powders used in these studies could have had different concentrations of bioactive substances, which depend on the plant species, soil type, harvest season and processing methods (Jaggi Lal, 2012). There were no significant (P >0.05) differences among the dietary groups in the TAC of broiler tissues, including the heart, kidney and liver, at weeks 3 and 6. Similarly, serum TAC of the experimental birds at weeks 3 and 6 was not significantly influenced (P >0.05) by the dietary levels of turmeric powder.

The oxidation process in birds increases when they are exposed to chronic stressors, such as diseases, mycotoxins and heat. The curcumin in turmeric powder is known to be a good antioxidant, and its effectiveness can increase in stressful conditions (Shiyou Li, 2011). In the present study, the broiler chickens were not under stress, so the findings disagreed with some earlier reports. For example, Gowda *et al*. (2008; 2009) reported that total antioxidant and superoxide dismutase (SOD) activities in chickens were improved by the addition of turmeric powder (0.5%) and curcuminoids (222 mg/kg) to a diet that contained 1 mg aflatoxin B1/kg. In addition, Ayoub *et al*. (2009) found that turmeric powder (0.5% and 1%) in the diet had a protective effect against oxidant factors and increased glutathione concentrations in ducks treated with aflatoxin in their feed. In another experiment, turmeric rhizome powder was added at various concentrations (0.3, 0.6 and 0.9 g/kg feed) to the diet of broiler chickens. The powder decreased free radical production in chicken groups treated with aflatoxin B1 (Ahmadi, 2010). Moreover, Hosseini-Vashan *et a*l. (2012) stated that the activities of antioxidant enzymes (glutathione peroxidase and SOD) increased in heat-stressed broiler chickens that received turmeric powder as a feed additive.

Conclusion

Under the conditions of this experiment, it could be concluded that the biochemical constituents of the blood of broiler chickens were affected positively by the inclusion of turmeric powder in the diet. However, antioxidant activity was not improved. So, more studies are needed to explain how turmeric powder affects the metabolism of broiler chickens. The authors recommend similar experiments under field conditions.

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Authors' Contributions

MA and SI designed, conducted the growth trial and MA, MS and AR collected the samples from the birds. MA, MS and AR did the statistical analyses. MA and SI wrote the manuscript and submitted the manuscript.

Conflict of interest declaration

There is no conflict of interest.

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