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Full Length Research Paper

Antioxidant status, immune system, blood metabolites and carcass characteristic of broiler chickens fed turmeric rhizome powder under heat stress

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This experiment was conducted to evaluate the effects of dietary turmeric rhizome powder (TP) on performance, blood metabolite, immune system, antioxidant status, and relative weight of organs in pre and post heat stressed broilers. Two hundred and sixty-four (264) day-old male Arian broiler chicks were randomly allotted to three dietary treatments containing 0, 0.4 or 0.8% turmeric powder. Each diet was fed to four replicates of 22 birds each. Heat stress was applied for 5 h (33°C) from 28 to 42 days. Two birds from each replicate were randomly selected and blood samples were taken to collect the serum, plasma and whole blood. These were slaughtered to determine the relative weight of organs pre (28 days PHS) and after heat stress (42 days AHS). TP did not affect feed intake, body weight, feed conversion ratio (FCR), production index, and protein and energy efficiency ratio of broilers. Blood cholesterol and low density lipoprotein (LDL) decreased and blood high density lipoprotein (HDL) increased when fed TP in PHS and AHS birds. TP did not affect serum triglyceride, protein, antibody production against sheep red blood cell (SRBC), IgG, IgM and Newcastle vaccination (ND) in PHS and AHS. TP suppressed the enzyme activity of lactate dehydrogenase (LDH), aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) of heat stressed birds. The enzyme activity of creatine kinase (CK) in AHS and superoxide dismutase (SOD) in PHS were not affected by TP diets. TP diets increased blood activity of glutathione peroxidase (GPx) and SOD and decreased blood thiobarbituric acid reactive substances (TBARS) index. The H:L ratio, relative weight of bursa of fabircus and abdominal fat decreased in birds fed TP diets. TP diets did not alter percentage of bone Ash, and P of heat stress broilers; however, it increased bone Ca of heat stressed broilers. It can be concluded that the supplementation of TP to diets, decreased the activity of dehydrogenase enzyme, stressor index, and improved the antioxidant status without affecting performance and the immune system of heat stressed broilers.

Key words: Turmeric powder, immune and antioxidant system, blood metabolite, broiler.

INTRODUCTION

Oxidative reactions may develop food deteriorations. Numerous diseases including atherosclerosis and cancer were created by toxic substances formed in these reactions (Kansci et al., 1997; Zhou and Decker, 1999). Heat stress (HS) is the major cause of quality deterioration in meat and meat products (Sahin et al., 2006). Heat stress stimulates the metabolic oxidation capacity of skeletal muscle by increasing the release of

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corticosterone and catecholamines and initiates lipid peroxidation in cell membranes (Sahin et al., 2001; Mujahid et al., 2007). Chronic heat stress may decrease metabolic oxidation capacity due to a self-propagating scavenging system (Azad et al., 2010). The concentration of pro-oxidants and antioxidants in diets may influence the rate of lipid oxidation in meat and chicken products (Tichivangana et al., 1985; Ruiz et al., 1999). Therefore supplementation of antioxidant to diets may decrease the oxidative reaction in chicken products under heat stress condition (Flachowsky, 2000, 2002). Recently, many researches have been done about antioxidant properties of turmeric (Asai et al., 1999; Suvanated et al., 2011; Basavaraj et al., 2011). Turmeric is a medicinal herb native to the Asian that has a considerable content of curcumin (diferuloylmethane). The main antioxidant component in turmeric is curcumin that is a phenolic antioxidant. Curcumin prevents lipids from oxidation (Sreejayan et al., 1997). Turmeric powder is used as a food additive, preservative and coloring agent in Asian countries, including China and South East Asia. Turmeric has beneficial effects on many biological reactions including anti-inflammatory, antioxidant, anticarcinogenic, antimutagenic, anticoagulant, antifertility, antidiabetic, antibacterial, antifungal, antiprotozoal, antiviral, antifibrotic, antivenom, hypotensive and hypocholesteremic activities (Chattopadhyay et al., 2004). The performance parameters of broilers fed turmeric rhizome powder (TP) were improved (Suvanated et al., 2003; Zeinali et al., 2009). Birds fed Turmeric powder had lower feed intake and feed conversion ratio (FCR) (Wuthi-Udomler et al., 2000; Samarasinghe et al., 2003; Durrani et al., 2006). Emadi and Kermanshahi (2007b) reported an improvement in antibody response against sheep red blood cell (SRBC), IgG and IgM. However, no alterations in immune response to Newcastle vaccination of birds fed TP were observed (Mehala and Moorthy, 2008). The hemoglobin values of broilers fed 0.8 g/kg reduced but the erythrocytes and hematocrit were not affected by the concentration of TP in dietary treatment (Sugiharto et al., 2011). However, an increase in the value of hemoglobin and a reduction in red blood cell count of broilers fed TP were revealed (Emadi et al., 2007).

Dietary TP may affect lipid metabolism in broiler chickens. The serum cholesterol and high density lipoprotein (HDL) increased and low density lipoprotein (LDL) and very low density lipoprotein (VLDL) cholesterol decreased in birds fed TP (Emadi et al., 2007). The concentration of serum total protein, albumin, glucose, globulin, total cholesterol, triglyceride, HDL, LDL and VLDL cholesterol were not affected by the supplementation of turmeric powder (Ashayerizadeh et al., 2009). Turmeric powder improved the liver function of broiler via decreasing the activity of alanine aminotransferase and alkaline phosphatase (Emadi and Kermanshahi, 2007a). Turmeric powder enhanced the antioxidant status of heat stressed broilers via improving the activity of glutathione peroxidase and superoxide dismutase and decreasing the concentration of malondialdehyde (MDA) (Zienali et al., 2011).

Turmeric powder may affect nutrient metabolism of broiler chicks. A higher relative weight of breast and thigh meat and lower relative weight of abdominal fat were reported in birds fed diets containing TP (Durrani et al., 2006; Emadi and Kermanshahi 2007b). The relative weight of abdominal fat decreased when birds fed diets contained up to 10 g TP/ kg diets (Al-Sultan, 2003; Emadi and Kermanshahi, 2003; Zeinali et al., 2009). Turmeric powder did not affect relative weight of heart, liver, and gizzard (Ashayerizadeh et al., 2009).

The purpose of this research was to investigate the effects of dietary turmeric powder (TP) on performance, blood metabolite, immune system, antioxidant status, and relative weight of organs in pre and post heat stressed broiler chickens.

MATERIALS AND METHODS

264 day-old male Arian broiler chicks were randomized into 36 floor pens (1.0 × 2.4 m). Feed (three times per day) and water were provided *ad libitum*. Birds were maintained on a photoperiod of 23:1. The corn-soybean meal basal diet (mash form) was formulated to meet or exceed the nutritional requirements of chicks from hatch to six weeks as recommended by the Arian catalog (Table 1). Dietary treatments were included the basal diet (control); basal diet supplemented with 0.4% TP; and basal diet supplemented with 0.8% TP were applied from 1 day. A completely randomized design was used with four replicates of 22 chicks. Birds were maintained under recommended environmental temperature of Arian strain committee from day 1 to 28. Heat stress was applied from 10:30 to 15:30 daily for all the birds from day 28 to 42. The daily temperature was gradually (within 2h) increased from 21 to 33± 1°C, and decreased to 21°C.

Data and sample collection

Chicks' weight and feed consumption were weekly recorded for each experimental unit. The feed: gain ratio was calculated (g feed: g gain). Daily mortality was recorded. The Energy efficiency ratio (EER; grams of weight gain × 100/total ME intake) and protein efficiency ratio (PER; grams of weight gain per gram of protein intake) and production index or European production factor (PI; 100*[(body weight*livability)/ (FCR* rearing period (day) were calculated. Two samples of 2 ml of blood were obtained from the wing vein of two birds from each replicate at days 28 and 42. These samples were used to provide the sera to study the antibody production against sheep red blood cell (SRBC) (Nelson et al., 1995) and Newcastle vaccination (ND), total protein and blood lipids. The activity of blood enzyme including lactate dehydrogenase (LDH), aspartate transaminase (AST), alanine transaminase (ALT), alkaline phosphatase (ALP), and creatine kinase (CK) were determined in plasma samples by auto analyzer spectrophotometer instrument (BioSystems S.A. Costa Brava 30, 08030 Barcelona, Spain). About 2 ml of blood was immediately placed in a heparinized tube which was kept in ice to provide the plasma and hemolysate for determination of malondialdehyde (MDA) and activity of antioxidant enzymes involved superoxide dismutase (SOD) and glutathione peroxidase (GPx), respectively

Table 1. Composition of control diet and diets containing turmeric powder (TP) for starter (0-21 days) and grower (21-42 days) period in broiler chickens under heat stress.

Ingredient	Starter diet			Grower diet		
	Control	0.4% TP	0.8% TP	Control	0.4% TP	0.8% TP
Corn	61.35	61.35	61.30	69.37	69.12	68.95
Soybean	32.06	30.80	30.00	23.91	22.63	21.54
Gluten meal	2.6	3.50	4.00	3.10	4.05	4.90
Turmeric powder	0.00	0.40	0.80	0.00	0.40	0.80
Oyster shell	1.49	1.48	1.45	1.32	1.38	1.38
Dicalcium phosphate	1.43	1.40	1.36	1.26	1.25	1.25
Salt	0.40	0.40	0.40	0.35	0.35	0.35
Vit. Premix	0.25	0.25	0.25	0.25	0.25	0.25
Min. Premix	0.25	0.25	0.25	0.25	0.25	0.25
DL-methionine	0.13	0.13	0.13	0.14	0.13	0.14
L-lysine	0.04	0.04	0.05	0.13	0.19	0.20
Nutrient composition						
Metabolisable energy (kcal/kg)	2930	2933	2.932	3020	3020	3020
Crude protein %	21.51	21.51	21.49	18.98	18.97	18.97
Lysine (%)	1.16	1.15	1.15	1.02	1.03	1.03
Met +Cys (%)	0.88	0.88	0.88	0.81	0.82	0.83
Calcium (%)	0.96	0.95	0.96	0.89	0.89	0.89
Available phosphorous (%)	0.44	0.44	0.44	0.42	0.42	0.41

Supplied the following per kilogram of diet: Vit A, 25000 IU; Vit D, 5000 IU; Vit E, 12.5 IU; Vit K, 2.5 IU; Vit B1, 1mg; Vit B2, 8 mg; Vit B6, 3 mg; Vit B12, 0.015 mg; Folic acid, 0.025 mg; nicotinic acid, 17.5 mg; calcium pantothenate, 12.5 mg; Fe, 80 mg; Cu, 10 mg; Mn, 80 mg; Se, 0.15 mg; I, 0.35 mg.

(Satoh, 1978; Yagi, 1984). The GPx and SOD activity was measured using RANSEL and RANSOD kit (Randox Laboratories Limited, 55 Diamond Road, Crumlin, County Antrim, BT29 4QY, United Kingdom), respectively. The MDA concentrations in homogenates were measured by the method of Jo and Ahn (1998). The plasma MDA concentration was expressed as nmol/ml. At 40 days, 1 ml of whole blood was taken in heparinized capillary tubes for counting the blood cell count and determination of Heterophil :Lymphocyte (H:L) ratio.

At the days 28 and 42, two birds from each pen was selected, slaughtered, weighed and the organs such as breast, thigh, Gall bladder, spleen, bursa of fabricus, thymus, liver, heart and intestine were weighed. The percentage of ash, calcium and phosphorous of right tibia also were determined at 42 days.

Statistical analysis

Data were collected and analyzed as a completely randomized design using the general linear model of SAS software (SAS Institute Inc., 2002). The statistical differences between means were analyzed by Tukey's test ($P<0.05$). The percentage data were transformed using arcsine square root ($x + 1$) prior to statistical analysis.

RESULTS

Performance and blood metabolite

Broilers fed turmeric powder (TP) had similar body weight gain, feed intake, feed conversion ratio, production index (european efficiency factor (EEF), energy efficiency ratio and protein efficiency ratio as the control, before (28 days) and after heat stress (42 days) (Table 2). Compared to the control diets, chicks fed 8 g/kg TP had significantly lower concentration of blood cholesterol and LDL and had higher HDL in PHS and AHS conditions (Table 3). Blood triglyceride and total protein were not significantly different among birds fed the experimental diets. The activity of lactate dehydrogenase (LDH), aspartate transaminase (AST), alanine transaminase (ALT), alkaline phosphatase (ALP), and creatine kinase (CK) in blood of broiler chicks fed control and turmeric powder under heat stress are shown in Table 4. The activity of ALP, AST, ALT and LDH decreased in chicks fed 8 g/kg TP compared to the control groups and there was a significant difference in the activity of ALP between the two levels of TP. The blood enzyme activity of CK did not differ among experimental diets in heat stressed broiler.

Antioxidant status

The antioxidant parameters including blood activity of Glutathione peroxidase (GPx) and Superoxide dismutase (SOD) and plasma thiobarbituric acid reactive substances

Table 2. Effect of dietary turmeric powder (TP) on performance parameters of broiler chickens in pre (28 days) and post (42 days) heat stress.

Parameter	Control	0.4% TP	0.8%TP	SEM	Pr>F
Pre Heat stress(28 days)					
Body weight (g:bird)	1116.67	1053.60	1062.87	20.54	0.1170
Feed intake(g:bird)	1562.96	1604.58	1566.97	34.42	0.6544
FCR (g:g)	1.403	1.523	1.473	0.043	0.1929
Production index(PI)(g:g:d)	2.818	2.413	2.518	0.116	0.0847
EER (g:100 kcal)	19.44	17.408	17.998	0.612	0.1055
PER (g:g CP)	2.880	2.600	2.685	0.088	0.1256
Heat stress (42 days)					
Body weight (g:bird)	2080.78	1955.71	1981.71	27.76	0.0528
Feed intake(g:bird)	3591.1	3659.5	3668.1	96.90	0.7735
FCR (g:g)	1.725	1.878	1.860	0.049	0.1069
Production index(g:g:d)	2.7425	2.3775	2.2850	0.121	0.0563
EER (g:100 kcal)	14.545	13.668	13.550	0.662	0.5336
PER (g:g CP)	2.2975	2.175	2.155	0.101	0.5786

[a,b,c], Row with no common superscript differ significantly (P<0.05).

Table 3. Effect of dietary turmeric powder (TP) on blood lipid and total protein of broiler chickens in pre (28 days) and post (42 days) heat stress.

Diet	Cholesterol		Triglyceride		LDL		HDL		Total protein	
	28 days	42 days	28 days	42 days	28 days	42 days	28 days	42 days	28 days	42 days
Control	153.67[a]	123.50[a]	76.33	96.47	47.00[a]	52.33[a]	55.33[b]	60.27[b]	3.53	3.567
0.4%TP	136.60[ab]	109.00[b]	84.00	91.80	39.68[b]	44.38[ab]	67.67[a]	72.13[a]	3.77	4.033
0.8% TP	131.00[a]	101.47[b]	94.72	88.73	37.67[b]	39.72[b]	69.00[a]	72.73[a]	3.40	3.533
SEM	4.056	4.061	5.402	1.813	1.401	1.972	2.802	2.380	0.205	0.167
Pr>F	0.0179	0.0226	0.1311	0.0612	0.0075	0.0108	0.0252	0.0167	0.4832	0.1374

[a,b,c] Column with no common superscript differ significantly (P<0.05).

Table 4. Effect of dietary turmeric powder (TP) on activity of blood enzymes of broiler chickens under heat stress (42 days).

Diet	LDH	AST	ALT	CK	ALP
Control	1175.3[a]	234.07[a]	22.59[a]	5561	2421[a]
0.4%TP	942.3[ab]	224.75[ab]	17.58[b]	4812	1809[b]
0.8% TP	752.0[b]	211.53[b]	17.54[b]	4890	1051[c]
SEM	94.45	3.356	1.043	191.16	88.178
Pr>F	0.052	0.0034	0.0111	0.0483	0.0001

[a,b,c,] Column with no common superscript differ significantly (P<0.05). LDH, Lactate dehydrogenase; AST, aspartate aminotransferase; ALT, alanine aminotransferase; CK, creatine kinase; ALP, alkaline phosphatase.

(TBARS) in birds fed TP diets in pre (28 days) and post (42 days) heat stress are shown in Table 5. The activity of superoxide dismutase (SOD) increased in chicks fed 8 g/kg TP compared to the control diet before heat stress applied, however, the activity of SOD were not affected in heat stressed birds fed TP. The blood activity of Glutathione peroxidase increased when chicks were fed turmeric powder as compared to the control at pre and post heat stressed birds. Compared to the control groups, chicks fed 4 and 8 g/kg TP had significantly lower plasma concentration of MDA at pre and post heat stress conditions.

Immune system

Immune system status of broiler chicks fed dietary control

Table 5. Effect of dietary turmeric powder (TP) on antioxidant parameters of broiler chickens in pre (28 days) and post (42 days) heat stress.

Diet	SOD		GPx		TBARS	
	28 days	42 days	28 days	42 days	28 days	42 days
Control	155.09[b]	171.20	123.56[c]	183.12[b]	0.736[a]	0.760[a]
0.4%TP	170.68[ab]	175.61	169.63[a]	219.17[a]	0.594[b]	0.529[b]
0.8% TP	182.16[a]	183.72	175.12[a]	227.02[a]	0.525[b]	0.508[b]
SEM	4.196	6.091	4.940	6.648	0.036	0.021
Pr>F	0.0045	0.3777	0.0001	0.0026	0.0075	0.0001

[a,b,c], Column with no common superscript differ significantly (P<0.05). SOD, Superoxide dismutase; GPx, glutathione peroxidase; TBARS, thiobarbituric acid reactive substances.

Table 6. Effect of dietary turmeric powder(TP) on immune system of broiler chickens in pre (28 days) and post (42 days) heat stress.

Diet	SRBC		IgM		IgG		Newcastle		H:L
	28 days	42 days	28 days	42 days	28 days	42 days	28 days	42 days	42 days
Control	5.33[b]	6.17	3.63	2.34	1.70	3.83	5.33	6.00	0.786[a]
0.4%TP	6.33[ab]	6.80	4.33	1.97	2.00	4.83	6.33	6.33	0.638[b]
0.8% TP	6.67[a]	7.11	4.63	2.44	2.03	4.67	6.00	6.69	0.598[b]
SEM	0.333	0.498	0.316	0.298	0.245	0.332	0.430	0.438	0.0292
Pr>F	0.0458	0.2500	0.0685	0.422	0.3031	0.1551	0.3170	0.5787	0.0088

[a,b,c], Column with no common superscript differ significantly (P<0.05). SRBC, Sheep red blood cell; H:L, heterophil: lymphocyte.

and turmeric powder pre and post heat stress are shown in Table 6. The antibody production against SRBC, IgM, IgG and Newcastle titre were not significantly different among dietary treatments with the exception of the SRBC titer enhanced in birds fed TP before heat stress. The ratio of heterophil: lymphocyte (H: L) in blood of heat stressed broiler chicks fed 4 or 8 g TP/kg diets decreased. The dietary TP did not affect hematocrit and hemoglobin (data not shown).

Carcass and bone characteristics

Effect of dietary turmeric powder on relative weight of some organs (Bursa of Fabricus, spleen, abdominal fat) in pre (28 days) and post (42 days) heat stress and bone characteristics of heat stressed broiler chickens are shown in Table 7. The relative weight of bursa of fabricus increased when fed 8 gTP/ kg diets birds, but no significant differences were observed in birds fed experimental diets under high ambient temperature. Compared to the control, chicks fed 8 g/ kg TP had significantly lower relative weight of abdominal fat in PHS and AHS conditions. Other relative weight of organs including relative weight of breast, thigh, intestine, liver, pancreas, bile, thymus, spleen, and heart revealed no significant differences among dietary treatments pre and post heat stress (data not shown). The bone characteristics including percentage of ash, calcium (Ca) and phosphorous (P) are also shown in Table 7. The highest percentage of tibia bone calcium was revealed in chicks fed 8 g/kg TP, but the percentage of ash and P was not significantly different among the dietary treatments.

DISCUSSION

The data revealed that supplementation of TP until 8 g/Kg did not have influence on performance parameters. Similar findings about no alteration in performance parameters of broiler fed TP were reported by researchers (Gowda et al., 2008; Mehala and Moorthy, 2008; Yarru et al., 2009). However, broiler chicks fed dietary turmeric powder had a higher body weight gain, energy efficiency ratio, yield of production and lower FCR than the basal diet (P<0.05) (Suvanated et al., 2003). Therefore, TP has a low effect on performance parameters of broilers, because the taste of TP may reduce feed intake.

Turmeric powder affects blood lipid metabolisms. This study revealed higher blood HDL cholesterol for broiler fed 8 gTP/kg diets in PHS and AHS. The same findings were reported by Emadi et al. (2007) and Ashayerizadeh et al. (2009). However, some researches did not significantly alter the cholesterol, HDL, LDL, TG and total protein in broiler fed TP (Namagirilakshmi, 2005; Mehala and Moorthy, 2008; Basavaraj et al., 2011). These differences may be due to the concentration of curcumin in turmeric, because it affects the metabolism of

Table 7. Effect of dietary turmeric powder (TP) on relative weight of organs broiler chickens in pre (28 days) and post (42 days) heat stress and bone parameters of broiler under heat stress

Diet	Bursa of Fabrcius		Spleen		Abdominal fat		Bone		
							Ca	P	Ash
	28 days	42 days	28 days	42 days	28 days	42 days	42 days	42 days	42 days
Control	0.504[a]	0.255	0.360	0.276[b]	2.71[a]	3.61[a]	38.79[b]	17.76	40.73
0.4%TP	0.438[ab]	0.242	0.349	0.325[ab]	1.90[b]	3.09[ab]	43.36[ab]	17.80	41.55
0.8% TP	0.346[b]	0.237	0.377	0.355[a]	1.25[b]	2.57[b]	44.44[a]	17.48	42.20
SEM	0.027	0.014	0.026	0.013	0.169	0.178	1.254	0.421	1.343
Pr>F	0.0087	0.6808	0.7529	0.0074	0.0030	0.0082	0.0064	0.8453	0.920

[a,b,c], Column with no common superscript differ significantly (P<0.05).

cholesterol. Curcumin reduces plasma LDL and VLDL significantly and liver cholesterol content along with an increase of plasma α-tocopherol level in rat, suggesting *in vivo* interaction between curcumin and α-tocopherol that may decrease cholesterol levels (Kamal-Eldin et al., 2000). Lowering cholesterol effects may be mediated by the stimulation of hepatic cholesterol-7- hydroxylase activity because the digestibility of TG was not affected by curcominoid supplementation (Asia et al., 1999; Babu and Srinivasan, 1997). Therefore, minimum curcumin will have effect on the activity of this enzyme.

Enhanced levels of serum ALT, AST and LDH are used as indicators of liver damage (Ozaki et al., 1995). The activity of other blood enzymes including LDH, ALT, AST, and ALP were suppressed by the supplementation of TP to heat stressed broiler diets. Curcumin reduced the activity of ALT, AST and LDH in iron injected broilers (Reddy and Lokesh, 1996). The activity of ALP decreased in chicks fed 4 and 8 g/kg TP compared to the control groups and there was a significant difference in the activity of ALP between the two levels of TP. Basavaraj et al. (2011) reported no alteration in ALP of broilers fed TP. Lower activity of dehydrogenase enzyme could indicate better liver function in heat stressed birds.

The antibody production against SRBC, IgM, IgG and Newcastle titre was not significantly different among dietary treatments. Haemagglutination inhibition titre against Newcastle disease revealed no significant difference ($P < 0.01$) among the treatment groups (Suvanated et al., 2003; Mehala and Moorthy, 2008). The ratio of heterophil: lymphocyte (H: L) in blood of broiler chicks fed 4 g/kg TP decreased compared to the control groups at heat stress condition. Reduction in the ratio of H:L indicate that the stress index in broilers under heat stress was reduced. Similar finding was reported by Suvanated et al. (2003) at 28 and 42 days of age of broilers. The hemoglobin and hematocrit values of broilers fed up to 8 g/kg were not affected and the same results were reported by Basavaraj et al. (2011) and Sugiharto et al. (2011).

Increase in the activity of antioxidant enzymes such as SOD and GPx was revealed in chicks fed TP as compared to the control under heat stress. SOD "metalloprotein enzyme" is the first enzyme contributed in the antioxidant defense system. GPx "seleno enzyme" catalyses the reaction of hydroperoxides with reduced glutathione to form glutathione disulphide (GSSG). Therefore, elevated concentration of these enzymes may improve the steady state of antioxidant system of broilers. The TBARS index or the concentration of plasma MDA is another index for evaluating antioxidant systems. Chicks fed 4 and 8 g/kg TP had significantly lower plasma concentration of MDA at pre and post heat stress conditions. Suvanated et al. (2003) reported that the supplementation of turmeric that corresponded to 90 ppm curcuminoid had a trend to decrease MDA. These findings show that TP diets reduce the oxidative reactions in the body of broiler chicks and the rate of MDA production and TBARS index. It could improve the meat quality via the reduction of free radical and peroxide radical.

The relative weight of organs including relative weight of breast, thigh, intestine, liver, pancrease, bile, thymus, spleen, and heart revealed no significant differences among dietary treatments pre and post heat stressed birds. These findings were approved by the last reports (Emadi and Kermanshahi 2006; Ashayerizadeh et al., 2009; Basavaraj et al., 2011). However, Durrani et al. (2006) reported higher relative weight for breast and thigh meat in broiler fed TP, but relative weight of other organs were the same for our results.

Compared to the control, chicks fed 8 g/kg TP had significantly lower relative weight of abdominal fat in PHS and AHS conditions. The abdominal fat decreased at high levels of turmeric powder (Al-Sultan, 2003; Emadi and Kermanshahi, 2006; Samarasinghe et al., 2003; Zeinali et al., 2009). However, Sugiharto et al. (2011) reported no alteration in relative weight for abdominal fat of broilers fed TP. These differences may be due to the strain, the composition of diets or percentage of curcominoid in diets. The relative weight is not acceptable for consumer. Lower relative weight of abdominal fat is an index for evaluating broiler meat. Therefore, TP could be supplemented to broiler diets for

reducing abdominal fat.

The highest percentage of bone Ca was revealed in legs of chicks fed 4 g/kg TP, but the percentage of ash and P were not significantly different among the dietary treatments. Basavaraj et al. (2011) reported no alteration for ash in broilers fed TP, but lower percentage of phosphorous and calcium was observed in 0.15 % of TP and no effect was found at 0.3 % TP.

Conclusion

Supplementation of turmeric powder to broiler diets as antioxidant components could improve the antioxidant status; liver function via reduction in the activity of dehydrogenases enzyme, reduction in the stressor index and abdominal fat deposition of heat stressed broilers without affecting the performance.

Abbreviations

TP, Turmeric rhizome powder; **PHS,** pre heat stress; **AHS,** after heat stress; **FCR,** feed conversion ratio; **HDL,** high density lipoprotein; **LDL,** low density lipoprotein; **SRBC,** sheep red blood cell; **AST,** aspartate aminotransferase; **ALT,** alanine aminotransferase; **ALK,** alkaline phosphatase; **CK,** creatine kinase; **GPx,** glutathione peroxidase; **SOD,** superoxide dismutase; **TABRS,** thiobarbituric acid reactive substances; **ND,** Newcastle vaccination; H:L, heterophil: lymphocyte.

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