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Nutritional and Biological Effects of Turmeric (*Curcuma longa*) Supplementation on Performance, Serum Biochemical Parameters and Oxidative Status of Broiler Chicks Exposed to Endosulfan in the Diets

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ABSTRACT

The present study was planned to evaluate the effects of turmeric (*Curcuma longa*) for protection against alterations resulted from exposure to endosulfan in broiler chicks. A total of 180 day old chicks were divided into 6 groups of 30 chicks with 3 replicates. First group was fed basal diet while the other five groups were fed basal diet supplemented with 5 g turmeric, 10 g turmeric, 30 mg endosulfan, 30 mg endosulfan plus 5 g turmeric and 30 mg endosulfan plus 10 g turmeric/kg diet during the experimental period. Growth performance, carcass traits, blood parameters, oxidative status and viability of the broilers chicks were used as criteria of response. The results showed that endosulfan significantly decreased the levels of Total Protein (TP), albumin (ALB), globulin (GLB), HDL-cholesterol, catalase (CAT), superoxide dismutase (SOD) activity and reduced glutathione (GSH) concentration but significantly increased albumin/globulin (A/G) ratio, total cholesterol (TCHO), LDL-cholesterol, triglyceride (TRG), malondialdehyde (MDA) concentration and hepatic transaminases (alanine amino-transferase, ALT and aspartate amino-transferase, AST) and exhibited different alterations to the hepatic structure in comparison with control and both turmeric groups. Dietary supplementation of turmeric at different levels could ameliorate these effects but not restored to control level. It is recommended that regular consumption of turmeric in the diet of broiler chicks provides a constant supply of potential antioxidants that could reduce these alterations.

Key words: Turmeric, nutritional supplementation, biological effects, endosulfan, performance, serum biochemical parameters, oxidative status, broiler chicks

INTRODUCTION

Pesticide-related adverse effects in humans, animals and birds have become a serious public health concern. Among all forms of chemical pesticides, organochlorines pesticides (OCPs) are considered to be the most hazardous with respect to environmental pollution, they are very persistent, non-biodegradable, add to the residue buildup in the food chain, cause eco-system

imbalances and result in various biological disorders (Garg *et al*., 2004a). In Egypt, all types of OCPs have been banned for agriculture and public health reasons. However due to its cheap price, easy to use and effective pest eradication, some kinds of them are still widely employed, coupled with a lack of law enforcement (Nasr *et al*., 2009). Endosulfan (C9H6Cl6O3S), a compound of the cyclodiene subgroup of OCPs, is used extensively worldwide in agriculture and horticulture as a contact and stomach insecticide and as an acaricide on field cereals, oil seeds, coffee, cotton, vegetables, potato, tea and fruit crops (Vorkamp *et al*., 2004). One of the major routes of exposure in non-target species is by ingestion of food contaminated with endosulfan residues as a result of application or bioaccumulation also via pulmonary and dermal routes. Its residues have been detected in a variety of different wild and domestic mammalian species, fish and in imported and locally raised chicken and bovine meat in Egypt (Aboul-Enein *et al*., 2010). The presence of residues in avian species suggests the plausibility of endosulfan to induce toxicopathological effects in these species (Garg *et al*., 2004b). Endosulfan produces oxidative stress by generation of free radicals and induces tissue lipid peroxidation (Comelekoglu *et al*., 2000).

Recently, turmeric (*Curcuma longa*) which is an extensively used spice, food preservative and coloring material has been found to possess biological actions and medicinal applications (Akbarian *et al*., 2012). Curcumin is the main component responsible for its biological activity but this plant also contains other components such as curcuminoids and polypeptides with biological action (Mesa and Ramirez-Tortosa, 2000). A number of studies have been conducted to evaluate its effect on the performance of broiler chicks (Hosseini-Vashan *et al*., 2012). However, information about the antagonistic effect of *Curcuma longa* on the toxicopathological alterations of endosulfan in broiler chicks is scarce. Therefore, the present experiment was conducted to investigate the attenuating role of turmeric on the possible endosulfan-induced adverse effects on the growth performance, carcass characteristics, blood biochemical parameters, oxidative status and pathological changes in liver of broiler chicks.

MATERIALS AND METHODS

The present study was carried out at Poultry Research Farm, Faculty of Veterinary Medicine, Zagazig University, Egypt. All the procedures were carried out according to the Local Experimental Animal Care Committee and approved by the ethics of Institutional Committee of Department of Forensic Medicine and Toxicology, Faculty of Veterinary Medicine, Zagazig University, Egypt.

Birds and experimental diets: A total of one hundred eighty day-old mixed sexes Hubbard broiler chicks, purchased from a local hatchery, were weighed on arrival and randomly assigned to one of 6 treatments with three replicates of 10 chicks based on a completely randomized design. The chicks were housed in conventional type cages with feed and water provided for *ad libitum* consumption and fed a diet formulated to meet nutrient requirements recommended commercially (Table 1). The lighting condition was 23 h light and 1 h darkness. Vaccination and medical program were done according to the different stages of age under supervision of a veterinarian.

Six starter and grower diets were formulated to provide a similar nutrient profile with the exception of using additives or a combined addition of these additives. The first group was fed a basal diet while the other five groups were fed basal diet supplemented with 5 g turmeric, 10 g turmeric, 30 mg endosulfan, 30 mg endosulfan plus 5 g turmeric and 30 mg endosulfan plus 10 g turmeric/kg diet during experimental period (five weeks). All the chicks were fed starter diets from 0-18 days of age and experimental grower diets from 19-35 days of age. The basal diet was

Table 1: Ingredient (g) and nutrient content of experimental diets (g kg^{-1})

	Days	
Parameters	Starter diet (0-18)	Grower diet (19-35)
Ingredient		
Yellow corn	605.10	666.20
Soybean meal 44%	260.00	203.10
Maize gluten meal 62%	80.00	80.00
Vegetable oil	15.00	12.00
Limestone	11.20	11.80
Di-calcium phosphate	17.50	16.00
Salt	3.00	3.00
Premix[1]	3.00	3.00
L-lysine	3.60	3.50
Dl-methionine	1.60	1.40
Total	100.00	100.00
Calculated composition[2]		
ME (kcal kg^{-1})	3050.00	3101.00
Crude protein	220.60	200.60
Calcium	9.50	9.20
Nonphytate P	4.50	4.10
Lysine	13.00	11.50
TSAA	9.50	8.80
Threonine	7.80	7.02
Tryptophan	2.20	1.90
Chemical analysis[3]		
Crude protein (%)	214.50	195.00
Ether extract (%)	24.20	24.80
Crude fiber (%)	30.80	28.00
Ca (%)	9.60	9.30
P total	6.75	6.50
Price per ton diet, L.E[4]	4037.00	3892.20

[1]Provides per kg of diet: Vitamin A: 12,000 I.U, Vitamin D3: 5000 I.U, Vitamin E: 130.0 mg, Vitamin K3: 3.605 mg, Vitamin B1 (thiamin): 3.0 mg, Vitamin B2 (riboflavin): 8.0 mg, Vitamin B6: 4.950 mg, Vitamin B12: 17.0 mg, Niacin: 60.0 m, D-Biotin: 200.0 mg, Calcium D-pantothenate: 18.333 mg, Folic acid: 2.083 mg, Manganese: 100.0 mg, Iron: 80.0 mg, Zinc: 80.0 mg, Copper: 8.0 mg, Iodine: 2.0 mg, Cobalt: 500.0 mg and Selenium: 150.0 mg [2]Calculated according to NRC (1994) [3]Chemical analysis according to AOAC (2006). [4]Calculated according to the price of feed ingredients when the experiment was started

analyzed for crude protein, ether extract, crude fiber, ash, calcium and phosphorus according to the procedures of the AOAC (2006). All chemicals including endosulfan (Technical grade, 98%) were obtained from Merck, India and Sigma (St. Louis, MO, USA).

Performance and carcass components: The birds were weighed individually at weekly intervals. Mortality was recorded daily. Total feed intake was measured per pen weekly. Feed intake (FI) and feed efficiency (FE) (weight gain/feed intake) were adjusted for mortality. Three birds of each group were sampled randomly for carcass evaluations at 35 days of age and slaughtered and weighed. Their feathers were plucked manually, eviscerated by hand. Whole carcass, abdominal fat pad (excluding the gizzard fat), empty gizzard and proventriculus, liver, heart, pancreas and spleen were excised and weighed individually. The carcass yields were calculated as a percentage of the pre-slaughter live body weights of broiler chickens. Blood was

obtained from sacrificed broilers in clean sterile tubes. Samples were let to coagulate and centrifuged at 3500 rpm for 15 min and serum was separated and stored in Eppendorf tubes at -20°C until analyzed.

Serum biochemistry: Total protein (TP), albumin (ALB), globulin GLB (TP-ALB), albumin/globulin (A/G) ratio, total cholesterol (TCHO), HDL-cholesterol, LDL-cholesterol (TCHO-HDL), triglyceride (TRG), aspartate aminotransferase (AST) and alanine aminotransferase (ALT) concentrations were determined spectrophotometrically using commercial diagnostic kits provided from Biodiagnostic Co. (Giza, Egypt).

Assay of antioxidant indices in liver: For antioxidant assays, liver samples were homogenized (10% w/v) in potassium phosphate buffer solution (pH 7.4) and then centrifuged at 3000 rpm for 15 min. The resulting supernatant was used to determine catalase (CAT) activity according to Aebi (1984) and superoxide dismutase (SOD) activity according to Nishikimi *et al.* (1972), reduced glutathione (GSH) concentration according to Ellman (1959) and lipid peroxidation (malondialdehyde, MDA) according to Ohkawa *et al.* (1979).

Histopathological investigation: Liver specimens were taken from chicks of different groups, weighed and fixed in 10% buffered neutral formalin solution. Five-micron thick paraffin sections were prepared, stained by hematoxylin and eosin for histopathological examination (Bancroft and Stevens, 1996).

Statistical analysis: The data were statistically analyzed using general linear models procedure adapted by SPSS for user's guide with one-way ANOVA. Duncan test within program SPSS was done to determine the degree of significance between means.

RESULTS

Performance and carcass components: The effect of dietary supplementation of turmeric or endosulfan on growth performance is presented in Table 2. The dietary treatments had significant ($p<0.05$) effects on the LBW and BWG during all experimental periods. The chicks fed turmeric 5 g kg^{-1} diet achieved the heaviest live body weight at all the studied ages, the opposite occurred in endosulfan group. Turmeric supplementation to diet containing 30 mg endosulfan significantly improved body weights at all ages compared to endosulfan diet.

The effect of dietary supplementation with endosulfan and turmeric on FI and FE is presented in Table 3. The results of experiment indicate that, FI and FE were significantly ($p<0.05$) affected by dietary treatments except FE during 21-35 days period. Where, the largest amounts of FI were observed by chicks consumed the diet containing 10 g turmeric compared to other treatments. On the contrary, the smallest amounts of FI were recorded for endosulfan group. Supplemental dietary turmeric to endosulfan diet led to an observable improvement of FI throughout the experiment. The birds receiving endosulfan during overall period had a significantly ($p<0.05$) higher FE compared to other groups.

In the present study, carcass yields, abdominal fat and relative weights (organ weight, g/100 g of body weight) of broilers at 35 days were statistically influenced by the dietary treatments (Table 3). The highest values of carcass, dressing, liver, heart and spleen percentages were achieved by birds fed 5 g turmeric. Conversely, the birds fed endosulfan diet resulted in the lowest values of carcass, dressing, liver, heart, pancreas, spleen and proventriculus percentages. The

Table 2: Effect of treatments on growth performance and viability rate of broiler chicks

	Dietary treatments							
Parameters	Control	Turmeric (5 g)	Turmeric (10 g)	Endosulfan (30 ppm)	Endosulfan+ Turmeric (5 g)	Endosulfan+ Turmeric (10 g)	SEM[1]	p-value[2]
Body weights (g)								
0 day	45.95	45.89	45.74	45.79	45.86	45.81	0.25	0.990
21 days	717.01^{b}	719.28^{ab}	723.53^{a}	692.66^{d}	710.39^{c}	708.55^{c}	1.06	<0.001
35 days	1461.00^{b}	1479.29^{a}	1468.73^{ab}	1431.84^{c}	1461.37^{b}	1460.49^{b}	2.29	<0.001
Body weight gain (g)								
0-21 days	671.05^{b}	673.39^{ab}	677.79^{a}	646.87^{d}	664.53^{c}	662.74^{c}	0.62	0.033
21-35 days	743.99^{c}	760.01^{a}	745.20^{c}	739.18^{d}	750.98^{b}	751.94^{b}	1.55	0.012
Overall (0-35 days)	1415.04^{b}	1433.39^{a}	1422.99^{ab}	1386.05^{c}	1415.51^{b}	1414.67^{b}	2.29	<0.001
Cumulative feed intake (g)								
0-21 days	1110.40^{b}	1112.43^{b}	1120.73^{a}	1004.15^{d}	1103.08^{c}	1097.16^{c}	9.64	<0.001
21-35 days	1545.70^{b}	1540.76^{b}	1548.07^{a}	1496.55^{d}	1544.58^{b}	1518.04^{c}	6.99	<0.001
Overall (0-35 days)	2656.10^{ab}	2653.19^{b}	2668.08^{a}	2500.70^{d}	2647.66^{b}	2615.50^{c}	13.96	<0.001
FE (g gain: g feed)[3]								
0-21 days	0.60^{b}	0.60^{b}	0.60^{b}	0.64^{a}	0.60^{b}	0.60^{b}	0.01	0.022
21-35 days	0.49	0.49	0.48	0.49	0.48	0.49	0.01	0.112
Overall (0-35 days)	0.54^{c}	0.55^{b}	0.54^{c}	0.58^{a}	0.54^{c}	0.55^{b}	0.00	<0.001
Viability (%)	90.00^{a}	96.67^{a}	93.34^{a}	80.00^{b}	93.34^{a}	90.00^{a}	1.50	0.005

Values in the same row not sharing a common superscript differ significantly ($p<0.05$), [1]SEM: Standard error mean, [2]Overall treatment [3]FE: Feed efficiency: Weight gain: Feed intake

Table 3: Effect of treatments on carcass traits, relative weights of broilers chicks at the end of experiment

	Dietary treatments							
Parameters (%)	Control	Turmeric (5 g)	Turmeric (10 g)	Endosulfan (30 ppm)	Endosulfan+ Turmeric (5 g)	Endosulfan+ Turmeric 10 g	SEM[1]	p-value[2]
Carcass	72.56^{b}	75.80^{a}	70.23^{c}	52.00^{f}	68.16^{d}	65.17^{e}	1.760	<0.001
Dressing	76.67^{b}	80.06^{a}	74.80^{b}	56.24^{e}	72.21^{c}	69.13^{d}	1.770	<0.001
Liver	2.16^{c}	2.23^{a}	2.19^{b}	2.14^{d}	2.15^{d}	2.11^{e}	0.009	<0.001
Gizzard	1.35^{d}	1.45^{c}	1.84^{a}	1.57^{b}	1.32^{e}	1.27^{f}	0.045	<0.001
Heart	0.58^{a}	0.58^{a}	0.54^{c}	0.52^{d}	0.58^{a}	0.56^{b}	0.005	<0.001
Giblets	4.11^{c}	4.26^{b}	4.57^{a}	4.24^{b}	4.05^{d}	3.96^{e}	0.046	<0.001
Spleen	0.11^{b}	0.14^{a}	0.13^{a}	0.10^{c}	0.11^{b}	0.10^{c}	0.003	<0.001
Abdominal fat	1.76^{b}	1.24^{e}	1.68^{d}	1.80^{a}	1.71^{c}	1.68^{d}	0.040	<0.001
Pancreas	0.25^{a}	0.24^{ab}	0.24^{ab}	0.22^{c}	0.25^{a}	0.23^{b}	0.002	<0.001
Proventriculus	0.31^{c}	0.35^{b}	0.36^{a}	0.27^{d}	0.30^{c}	0.27^{d}	0.008	<0.001

Values in the same row not sharing a common superscript differ significantly ($p<0.05$) [1]SEM: Standard error mean, [2]Overall treatment p-value

abdominal fat percentage of the endosulfan group was found to be significantly ($p<0.05$) higher than that in the other groups. Gizzard and giblets values were statistically ($p<0.05$) increased by birds fed diet with supplemented 10 g turmeric compared to other treatments.

Serum biochemistry: The effect of endosulfan and turmeric exposure on serum biochemical parameters of broiler chicks is illustrated in Table 4. Supplementation of diet with both low and high level of turmeric did not change the concentration of serum ALT and AST in comparison with control group. On contrary, serum ALT and AST concentrations were significantly increased in

Table 4: Effect of treatments on serum biochemical parameters and oxidative status in liver of broilers chicks at 35 day

	Dietary treatments							
Parameters	Control	Turmeric (5 g)	Turmeric (10 g)	Endosulfan (30 ppm)	Endosulfan+ Turmeric (5 g)	Endosulfan+ Turmeric (10 g)	SEM[1]	p-value[2]
Biochemical								
Total protein (g dL^{-1})	4.74^{b}	4.94^{b}	5.53^{a}	3.12^{e}	3.90^{d}	4.34^{c}	0.19	<0.001
Albumin (g dL^{-1})	2.27^{c}	2.34^{b}	2.51^{a}	1.89^{f}	1.99^{e}	2.10^{d}	0.05	<0.001
Globulin (g dL^{-1})	2.46^{bc}	2.60^{b}	3.01^{a}	1.23^{e}	1.91^{d}	2.24^{c}	1.40	<0.001
A/G Ratio	0.92^{bc}	0.90^{bc}	0.83^{c}	1.55^{a}	1.04^{b}	0.95^{bc}	0.06	<0.001
Triglycerides (mg/100 mL)	64.25^{d}	59.35^{e}	57.51^{e}	114.24^{a}	81.61^{b}	77.85^{c}	4.71	<0.001
Total cholesterol (mg dL^{-1})	77.75^{c}	67.65^{c}	61.09^{c}	153.28^{a}	102.98^{b}	96.62^{b}	7.66	<0.001
HDL (mg dL^{-1})	46.55^{ab}	47.15^{ab}	50.37^{a}	18.41^{d}	29.93^{c}	42.23^{b}	2.84	<0.001
LDL (mg dL^{-1})	18.63^{c}	17.15^{c}	16.66^{c}	37.36^{a}	24.55^{b}	21.91^{bc}	1.81	<0.001
ALT (IU mL^{-1})	9.75^{d}	9.76^{d}	8.38^{d}	19.11^{a}	13.75^{b}	11.71^{c}	0.88	<0.001
AST (IU mL^{-1})	45.27^{d}	45.73^{d}	44.41^{d}	125.50^{a}	101.91^{b}	85.78^{c}	7.72	<0.001
Oxidative status								
SOD (U g^{-1} tissue)	28.32^{c}	42.65^{b}	50.49^{a}	10.87^{f}	16.98^{e}	22.77^{d}	3.38	<0.001
Catalase (nmol g^{-1} tissue)	70.13^{a}	67.46^{a}	69.78^{a}	19.83^{c}	35.98^{b}	47.29^{b}	4.81	<0.001
GSH (ng g^{-1} tissue)	16.29^{b}	18.94^{a}	19.31^{a}	3.39^{e}	6.79^{d}	11.29^{c}	1.47	<0.001
MDA (ng g^{-1} tissue)	50.46^{c}	29.29^{d}	25.38^{d}	125.48^{a}	75.39^{b}	54.88^{c}	8.27	<0.001

Values in the same row not sharing a common superscript differ significantly ($p<0.05$) [1]SEM: Standard error mean, [2]Overall treatment p-value

birds feed on diet supplemented with endosulfan compared to control group. Co-treatment of diet containing endosulfan with turmeric 10 g was more valuable in decreasing ALT and AST concentrations than 5 g, however their values were still higher than control.

Endosulfan significantly decreased the levels of TP, ALB, with highly significant reduction in GLB and HDL level but significantly increased the A/G ratio, TCHO, LDL-cholesterol and TRG. Supplementation of diet with 10 g turmeric to basal diet or endosulfan containing diet has a high potential to restore all these biochemical measurements to be near control values more than 5 g.

Assay of antioxidant indices in liver: The data in Table 4 show that hepatic SOD and CAT activity as well as GSH concentration were significantly ($p<0.05$) decreased in endosulfan fed group while MDA concentration was significantly elevated in comparison with control group. Supplementation of basal diet with turmeric alone (5 or 10 g kg^{-1} diet) could equally improve the oxidative status in the liver of chicks; where they resulted in significant increase in GSH concentration than control group besides keeping the catalase activity from reduction and significantly decreased MDA concentration. Meanwhile, 10 g turmeric was more efficient than 5 g in increasing the SOD activity. Treatments of the diet containing endosulfan with 10 g turmeric resulted in significant increase SOD activity and GSH concentration and significantly decreased MDA concentration. The 10 g turmeric could also significantly increase SOD activity and GSH concentration and significantly decreased MDA concentration than 5 g turmeric in hepatic tissue of endosulfan group. Moreover, turmeric at 5 or 10 g significantly increased the catalase activity in the same group. But the two added levels (5 or 10 g kg^{-1}) could not restore the oxidative status of the liver to normal values.

Histopathological investigation: The liver of control and turmeric groups showed normal hepatocytes and sinusoidal architectures (Fig. 1a). However, the liver of endosulfan group

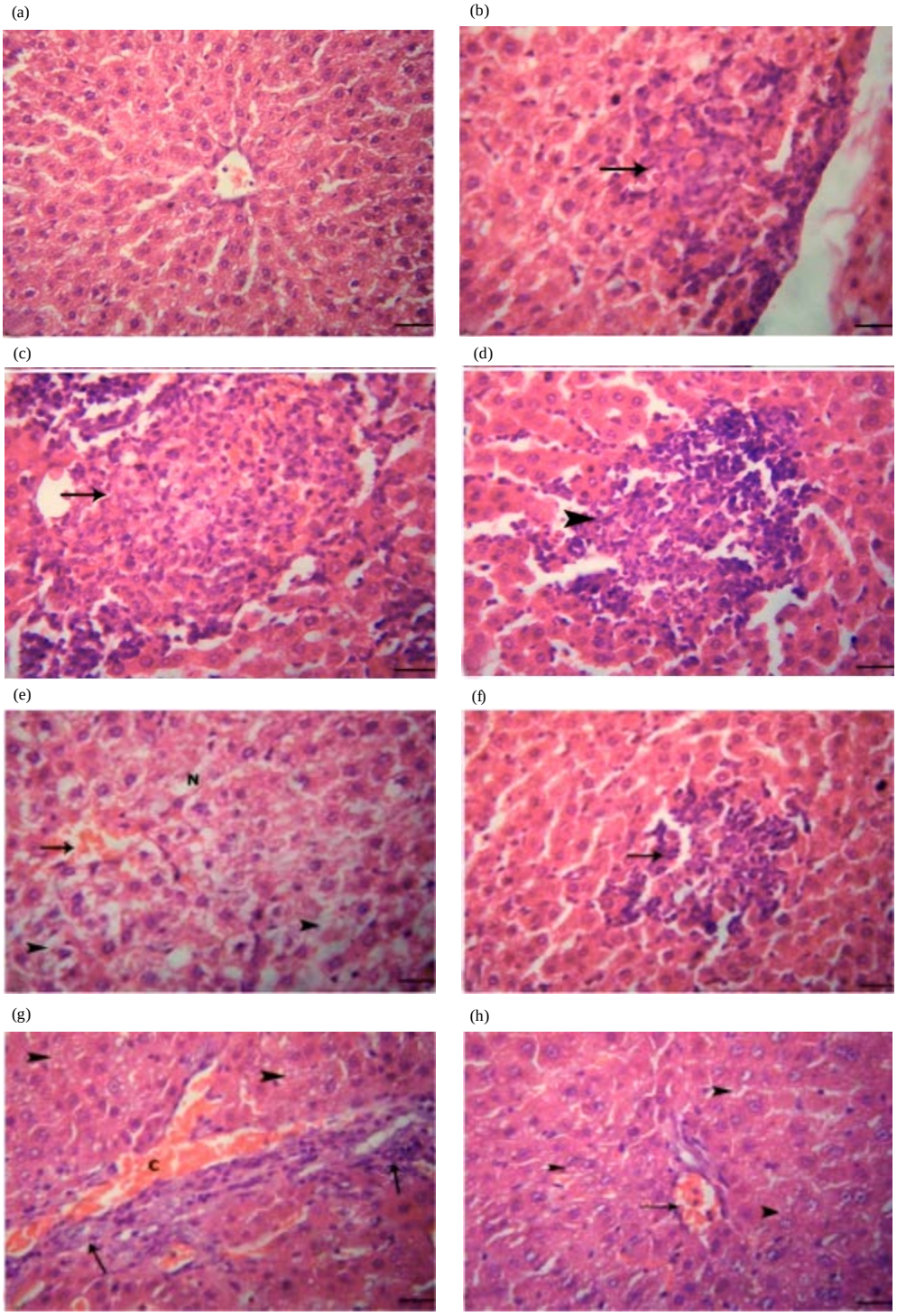

Fig. 1(a-h): Photomicrographs of liver sections of control and experimental groups (H and E×Scale bar = 20 μm). (a) Control and (b-d) Turmeric, endosulfan, (e-f) Endosulfan plus turmeric (5 g kg^{-1}) and (g-h) Endosulfan plus turmeric (10 g kg^{-1})

revealed multiple areas of coagulative necroses represented by pyknosis and karyolysis and infiltrated with round cells (Fig. 1a). Severe hydropic degeneration was noticed particularly around the portal areas. The hepatocytes were enlarged with large nuclei (megalohepatocytes). The portal areas showed severe congestion in the hepatoportal blood vessels and heavily infiltrated with mononuclears (Fig. 1c). Focal replacements of the hepatic parenchyma with aggregations of round cells predominately lymphocytes and macrophages (Fig. 1d). The liver of endosulfan plus turmeric (5 g kg^{-1}) group showed hydropic degeneration, individual cell necrosis and few extravasated erythrocytes (Fig. 1e) and small area of coagulative necrosis infiltrated with lymphocytes (Fig. 1f). The liver of endosulfan plus turmeric (10 g kg^{-1}) group showed congestion of hepatoportal blood vessels in addition to biliary and oval cells hyperplasia (Fig. 1g) with microvesicular steatosis and congestion (Fig. 1h).

DISCUSSION

The present study was conducted to evaluate the protective role of turmeric in broiler chicks exposed to endosulfan in diets. Endosulfan predominantly increases the mortality rate than control (Ganeshwade *et al*., 2012). This may be due to the severe physiological stress of endosulfan at cellular level. The significant reduction in the FI of endosulfan group in the present study may be attributed to either biological effect of endosulfan or due to low palatability of the treated feed (Prakash *et al*., 2009) which reflected on the and BW and BWG. Similar results have been reported in quails (Qamar *et al*., 2012). Contrary to the present findings, endosulfan did not affect the BW of broiler chicks (Garg *et al*., 2004a). Dietary supplementation of turmeric to basal diet or endosulfan diet exhibited a significantly positive effect on FI, BWG and FCR and other carcass characteristics as well as mortality rate which is in accordance with Hussein (2013). These positive effects might be due to turmeric anti-inflammatory, antioxidant and antibacterial activities. Thus, turmeric could limit the growth and colonization of numerous pathogenic and non-pathogenic species of bacteria in the chicken's gut and balanced gut microbial ecosystems leading to better feed utilization.

Liver is the principle organ that detoxifies endosulfan to endosulfan ether; this will damage the liver cells and produce hepatotoxicity. This could explain the increased level of ALT and AST in endosulfan group and the reduced concentrations of total proteins and albumin, this came in accordance with Nawaz *et al*. (2010).

Endosulfan remarkably reduced the serum globulin and resulted in elevated A/G ratio which may be due to its effect on rough endoplasmic reticulum, the site of globulin synthesis (De los Reyes and More, 1979). Turmeric supplementation improved the levels of TP, ALB and GLB and restored the liver functions (AST and AST) suggesting the hepatoprotective effect of turmeric. Similar reports in lab animals were obtained by Nandan and Vipin (2014). Endosulfan significantly increased TCHO, LDL-cholesterol and TRG and decreased HDL concentrations compared to the all other groups. The disturbance in the lipid profile may be attributed to increased synthesis and accumulation of cholesterol in liver and/or impaired biliary function. Turmeric supplementation resulted in improving the lipid profile of both control and endosulfan groups. This was in agreement with Hosseini-Vashan *et al*. (2012) who clearly demonstrated that turmeric could eliminate lipids from body.

The present study showed that endosulfan resulted in alteration in the all the studied oxidative stress markers in comparison with other treatment groups. Similar results were obtained by Mahran (2013). However, endosulfan increased the activities of antioxidants (Rastogi *et al*., 2014).

The changes in oxidative indices observed in this study suggest that reactive oxygen species are involved in endosulfan-induced toxicity *in vivo* and this support the opinion of Banerjee (1999), these radicals can react with all biological macromolecules i.e., lipids, protein, nucleic acid and carbohydrates. Antioxidant enzymes counteract the insecticide-induced oxidative stress resulting in their consumption (Waheed and Mohammed, 2012). In addition to oxidative damage, endosulfan led to depletion of GSH which resulted in increased level of lipid peroxidation (MDA). It seems that turmeric supplementation both at 5 and 10 g to control and endosulfan diet was effective in enhancing the antioxidant ability of birds which appeared to lower the mortality. Turmeric is a rich source of beneficial phenolic compounds, the curcuminoids having strong antioxidant activity (Balasubramanyam *et al*., 2003). Reddy and Lokesh (1994) found that curcumin supplementation inhibited lipid peroxidation in rat liver microsomes, erythrocyte membranes and brain homogenates. Moreover, it lowers the susceptibility of Low Density Lipoprotein (LDL) cholesterol to oxidation (Mesa and Ramirez-Tortosa, 2000). Thanks to high ROS scavenging capacity of curcumin returning to the presence of π-conjugation in curcumin makes it more hydrophobic which promotes its localization in the lipid bilayer membrane and lipid solubility. This allows the reaction of curcumin with the lipid peroxyl radical and it acts as a chain terminating antioxidant (Sankar *et al*., 2010).

The abovementioned picture of endosulfan toxicity observed in this study came in harmony and confirmed by the extensive damage and structural abnormalities in hepatic tissues induced by endosulfan. The pathological changes in the liver following endosulfan exposure have also been reported in quails (Qamar *et al*., 2012). The pathological alterations observed after endosulfan were remarkably reduced by turmeric supplementation, suggesting its hepato-protective effects.

CONCLUSION

The turmeric supplementation is a promising approach for improving the growth performance and oxidative status in broiler chicks exposed to endosulfan.

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