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The Influence of Dietary Boron Supplementation on Performance, Some Biochemical Parameters and Organs in Broilers

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ABSTRACT

This study was performed to investigate the effect of adding boron (B) to broilers' diets on performance, some blood biochemical parameters and visual and histopathological examinations of organs in broilers. One hundred and forty four chicks were randomly assigned to 4 groups with 3 replicates. The broilers were fed commercial diets supplemented with 0 (control group) and 500, 750, 1000 mg kg^{-1} (diet) B from Boric Acid (BA) for 42 days. Live body weight, weight gain, food consumption and feed conversion ratio were recorded at weekly intervals. At the end of the experimental period (42 days of age), serum Aspartate aminotransferase (AST), Alanine aminotransferase (ALT), Gamma Glutamyl Transpeptidase (GGT), Alkaline Phosphatase (ALP), Creatine Kinase (CK), Lactate Dehydrogenase (LDH) enzyme activities and glucose, creatinine, total protein, albumin, globulin, triglyceride, total cholesterol, High Density Lipoprotein-cholesterol (HDL-C), Low Density Lipoprotein-cholesterol (LDL-C), calcium (Ca), phosphorus (P), magnesium (Mg) and B levels were determined. Performance parameters were affected negatively and significantly by B supplementation. Serum AST, ALT, CK, LDH activities and glucose, total protein, albumin, globulin, triglycerides, total cholesterol, LDL-C and Mg levels were significantly influenced by dietary B supplementation. Necrosis in muscle fibers was observed but no gross and microscopic changes were determined in liver, kidney and brain in histological examinations in B supplemented groups. In conclusion; add boron to broilers' diets at levels 500, 750 and 1000 mg kg^{-1} (feed) did not cause mortality or result in histopathological lesions except for muscles. On the other hand, it resulted in a significant decrease in performance and changed some biochemical parameters in broilers.

Key words: Biochemical parameters, boric acid, chicken, growth performance, tissue damage

INTRODUCTION

Boron (B) is an essential trace element for human, animals and higher plants and it is found in every part of the environment (McDowell, 1992; WHO, 1998; Laila and Adel, 2002; Tariq and Mott, 2007; Shaaban, 2010). However the exact metabolic and biochemical functions of B are not fully understood, it has been suggested that B have important effects on various metabolic and physiological systems (bone, mineral, lipid, energy metabolism, endocrine function etc.) of the in animal and human organism (Nielsen *et al*., 1988; Hall *et al*., 1989; Hunt and Herbel, 1991a, b; Kurtoglu *et al*., 2001, 2005; Gallardo-Williams *et al*., 2003;

Karabulut and Eren, 2006; Eren and Uyanik, 2007; Basoglu *et al.*, 2010). Boron, in the form of various inorganic borates, is widely distributed in low concentrations throughout nature and, used in industrial and domestic applications. It is used in the production of fibreglass, borosilicate glass, enamels, frits, glazes and as cosmetics, pharmaceuticals (as a pH buffer), boron capture therapy, insecticide, antiseptic and chemical preservative in food products (Woods, 1994; WHO, 1996, 1998; See *et al.*, 2010).

The oral toxicity of B is low (McDowell, 1992; WHO, 1998). On the other hand, B accumulation was shown in bone, muscle, adrenal tissue, brain, hypothalamus, liver, spleen, kidney, adrenals, lymph node, testis, seminal vesicles, prostate, large intestine and blood after exposure to high doses of B (Ku *et al.*, 1991; Sander *et al.*, 1991; Moseman, 1994; Tibbits *et al.*, 2000) in various animals. It is reported that disorders such as edema and inflammation in the skin around the nail and legs, depressed live weight gains and feed consumption, low haematocrit, haemoglobin, triglyceride, protein, phosphorus and ALP levels, riboflavinuria, paralysis in toe, disorder of calcium metabolism, osteoporosis with the decreasing of the parathyroid activity, inhibition of sperm production, testicular atrophy, disorder of the ovarium development, alopecia, dermatitis, hypertonia and even death were seen depending on the excessive intake of the B element in several animals (Nielsen *et al.*, 1988; Sander *et al.*, 1991; Treinen and Chapin, 1991; McDowell, 1992; Naghii and Samman, 1993; Ku and Chapin, 1994; WHO, 1996, 1998; Bustos-Obregon and Ricardo Hartley, 2008; See *et al.*, 2010). Geyikogglu and Turkez (2007) suggested that 3.375 and 4.5 mmol B kg^{-1} b.wt. (750 and 1000 ppm boric acid) caused decreased metabolite concentrations (glucose, glycogen, lactate and ATP) in muscle fibers as dependent on time in broiler chickens.

Boric acid is used in the poultry environment primarily to litter which could lead to accidental consumption of the chemical by poultry. Sander *et al.* (1991) reported that boric acid is highly efficient against cockroaches and darkling beetles determined in poultry houses. Several authors have investigated the effects of different doses of B up to 320 mg kg^{-1} supplementation to diet in broilers (Rossi *et al.*, 1990, 1993; Qin and Klandorf, 1991; Elliot and Edwards, 1992; Kurtoglu *et al.*, 2001, 2005; Fassani *et al.*, 2004; Geyikogglu and Turkez, 2007; Yildiz *et al.*, 2011; Bozkurt *et al.*, 2012) but there are no studies about the effects of higher doses than 320 mg kg^{-1} on performance and blood biochemical parameters in broilers. The determination of maximum tolerable doses of boric acid in broilers is also important. Therefore, this study was performed to investigate the effects of adding 500, 750 and 1000 mg kg^{-1} boron supplementation to diet on performance, some biochemical parameters and organs in broilers.

MATERIAL AND METHODS

Animals and experimental design: One hundred and forty four, day old, broiler chicks were used in this study. Chicks were randomly assigned to 4 groups with 3 replicates (12 chicks each). Chicks of each replicate were kept in separate floor pens with 24 h constant light schedule. The broilers were fed commercial diets (starter and grower) supplemented with 0 (control group) and 500, 750 and 1000 mg kg^{-1} (diet) B from boric acid (H_3BO_3, Carlo Erba) from 0-42 days as experimental period. Ingredients and chemical composition of the basal diet fed to broilers was shown in Table 1. Feed and water was supplied *ad libitum*. This study was approved by the Ethics Committee of University of Erciyes, Faculty of Veterinary Medicine, Approval number, 2004-45-59.

Measurements of performance: Live Body Weight (LBW), Body Weight Gain (BWG) and Feed Consumption (FC) were weekly recorded. Feed Conversion Ratio (FCR) was calculated by dividing feed consumption by live weight gain.

Table 1: Ingredients and chemical composition of basal diets fed to broilers

Ingredients (%)	Starter (1-30 day)	Grower (30-42 day)
Corn	30.00	40.60
Wheat	10.40	14.00
Sunflower meal (36% CP)	16.90	12.50
Soy meal (44% CP)	8.00	8.10
Full fat soybean	26.90	17.00
Vegetable oil	3.00	2.50
Limestone flour	0.90	0.90
Meat-bone meal	3.00	3.50
Salt	0.25	0.25
Vitamin-mineral[1]	0.25	0.25
Methionine	0.14	0.12
Lysine	0.09	0.11
Enzyme	0.10	0.10
Phytase	0.07	0.07
Chemical analyses (%)		
Dry matter	92.80	91.60
Crude protein	23.50	22.20
Crude ash	5.52	6.35
Crude cellulose	5.48	6.86
Crude fat	9.98	9.92
Calculated analyses (%)		
Lysine	1.30	1.10
Crude protein	24.00	21.00
Crude ash	6.90	6.03
Crude cellulose	6.40	5.20
Crude fat	10.60	7.90
Calcium	1.00	1.00
Phosphorus	0.73	0.75
Methionine	0.60	0.50
Metabolisable energy (kcal kg^{-1})	3100.00	3100 .00
Boron (mg kg^{-1})	0.221	0.23

CP: Crude protein, [1]Provided by per kg of diet: Vitamin A: 12000 IU, Vitamin D3: 1500 IU, Vitamin E: 30 mg, Vitamin K3: 5 mg, Vitamin B1: 3 mg, Vitamin B2: 6 mg, Vitamin B6: 5 mg, Vitamin B12: 0.03 μg, Nicotinamide: 40 mg, Vitamin C: 50 mg, Calcium D-pantothenate: 10 mg, Folic acid: 0.75 μg, Biotin: 0.075 μg, Choline chloride: 375 mg, Mn: 80 mg, Fe: 40 mg, Zn: 60 mg, Cu: 5 mg, I: 0.4 μg, Co: 0.1 μg, Se: 0.15 μg, Antioxidant: 10 mg

Sample collection and analysis: Blood samples were taken from V. brachialis of the animals (12 broilers from each group, 4 animals per replicates) at the end of the experimental period. Sera were separated by centrifugation at 3000 rpm for 10 min after 1 h incubation at room temperature and stored at -20°C until the analysis. Sera were analysed by a spectrophotometer (Shimadzu UV Model 1208) using commercial kits for AST, ALT, GGT, ALP, CK, LDH activities, glucose, creatinine, total protein, albumin, Ca, P, Mg (Biolabo, France), triglycerides, total cholesterol, HDL-C and LDL-C (AMP, Austria) levels. The serum globulin concentrations were calculated by subtracting the albumin values from the total protein values. Chemical composition of the diet was analysed by the method of AOAC (1984). Boron levels in sera and in basal diet were determined by ICP (Inductively coupled plasma atomic emission spectrometer; AES Varion Vista Model, Sydney, Australia). Twelve chicks from each group were killed by neck dislocation and gross visual

examination of organs was made during the necropsy procedure to determine tissue damage and liver, kidney, brain and muscle samples were preserved in buffered formalin for histopathological evaluations. Tissue samples were embedded in paraffin, sectioned (5-6 μm), stained with hematoxylin and eosin (H and E) and then examined with light microscope (Luna, 1968).

Statistical analysis: Statistical analyses of data were performed by SPSS 15.0 version for Windows. One-way analysis of variance (ANOVA) was used for the differences between groups. When the F values were significant, Duncan's Multiple Range Test was performed. All data were expressed as Mean±SEM. Results are considered as significant when the p-value was less than 0.05.

RESULTS AND DISCUSSION

In the present study, no mortality was seen in B supplemented groups as indicated by Hoffman *et al.* (1991) who supplemented diet of ducklings with 1000 mg kg^{-1} B. This can be attributed to the doses used in this study, as 500, 750 and 1000 mg kg^{-1} B were tolerated by the broilers because of B is absorbed rapidly and virtually completely from gastrointestinal tract and rapidly excreted (McDowell, 1992; WHO, 1998).

As shown in Table 2 and 3, LBW and BWG ($p<0.001$) were decreased significantly in 500, 750 and 1000 mg kg^{-1} B groups compared with control group. In regard to B treated groups, there was a significant decrease in LBW which was B-doses dependent. Feed consumption ($p<0.05$) was depressed insignificantly by 500 and 750 mg kg^{-1} B and significantly by 1000 mg kg^{-1} B. Similar results were obtained in broilers fed 300 (Rossi *et al.*, 1993) and 320 mg kg^{-1} B (Rossi *et al.*, 1990), in ducklings fed 1000 mg kg^{-1} B (Hoffman *et al.*, 1991) and layer (Wilson and Ruszler, 1996, 1998; Eren *et al.*, 2004) fed 400 mg kg^{-1} B. Feed efficiency ($p<0.01$) was negatively affected by 1000 mg kg^{-1} B as indicated by Rossi *et al.* (1990) who supplemented the diet of broiler chicks with 320 mg kg^{-1} B. Decreased LBW and BWG that observed in B treated groups may be resulted from the reduction feed intake.

Our results showed that decreases were determined in serum total protein in 750 and 1000 mg kg^{-1} B groups, albumin in all of the B groups ($p<0.01$) and globulin ($p<0.05$) levels in 1000 mg kg^{-1} B group compared with control group in the present study (Table 4). This result is in agreement with the findings of Hoffman *et al.* (1991) who reported that plasma protein concentration decreased in the presence of 1000 mg B kg^{-1} feed in ducklings. The decreases in protein levels may attribute to the decrease in feed consumption and thus the decrease of the

Table 2: Effect of adding different levels of boron to broilers' diet on live body weight (LBW)

	B (mg kg^{-1} diet)			
Weeks	0	500	750	1000
0	42.76±0.78	43.09±0.72	43.09±0.64	42.78±0.67
1	131.38±2.95^{ab}	124.50±2.09^{b}	128.63±1.74^{b}	112.46±1.77^{c}
2	316.67±8.22^{a}	271.67±7.18^{b}	288.25±6.52^{b}	218.88±4.46^{c}
3	610.00±14.86^{a}	493.13±10.97^{b}	524.58±12.81^{b}	368.87±10.21^{c}
4	930.38±19.60^{a}	803.57±13.65^{b}	776.08±22.20^{b}	525.73±16.18^{c}
5	1316.42±29.23^{a}	1130.27±24.56^{b}	1046.25±34.03^{c}	695.81±21.37^{d}
6	1800.00±43.18^{a}	1553.09±40.35^{b}	1391.00±45.24^{c}	889.40±29.17^{d}

Values (Mean±SEM) within each row with different superscripts differ significantly at $p<0.001$

Table 3: Effect of adding different levels of boron to broilers' diet on feed consumption (FC) (g), body weight gain (BWG) (g) and feed conversion ratio (FSR) (g feed g^{-1} LBW)

		B (mg kg^{-1} diet)				
Days	Parameters	0	500	750	1000	p-value
1-7	FC	141.73±5.25	146.50±9.44	155.83±4.71	149.25±16.50	-
	BWG	88.62±3.28^{a}	81.41±2.85^{a}	87.04±0.91^{a}	69.69±0.75^{b}	**
	FCR	1.60±0.08	1.80±0.09	1.79±0.07	2.14±0.24	-
8-14	FC	298.05±3.12^{a}	309.29±19.71^{a}	320.42±8.47^{a}	241.63±16.08^{b}	*
	BWG	185.37±8.09^{a}	147.16±6.46^{b}	158.12±7.95^{b}	106.41±3.12^{c}	***
	FCR	1.61±0.07^{a}	2.10±0.05^{b}	2.04±0.13^{b}	2.27±0.09^{b}	**
15-21	FC	482.45±4.25^{a}	405.07±98.56^{ab}	434.00±9.12^{ab}	326.61±64.22^{b}	*
	BWG	293.25±7.01^{a}	221.51±23.40^{b}	236.33±15.77^{b}	149.29±5.32^{c}	**
	FCR	1.65±0.04	1.98±0.71	1.86±0.17	2.22±0.52	-
22-28	FC	665.73±6.67	751.14±85.03	672.17±74.05	764.84±68.01	-
	BWG	320.38±24.72^{a}	325.97±23.83^{a}	251.50±29.17^{a}	154.39±21.68^{b}	**
	FCR	2.11±0.18^{b}	2.32±0.31^{b}	2.80±0.61^{b}	5.31±1.31^{a}	*
29-35	FC	813.91±1.63^{a}	689.51±67.49^{ab}	641.75±23.19^{ab}	527.90±95.11^{b}	*
	BWG	386.04±41.67^{a}	310.35±35.13^{ab}	270.17±27.09^{b}	170.29±5.03^{c}	**
	FCR	2.16±0.23	2.28±0.30	2.43±0.29	3.07±0.46	-
36-42	FC	1179.63±10.49^{a}	954.71±136.17^{ab}	927.50±50.75^{ab}	720.61±118.82^{b}	*
	BWG	483.58±67.93^{a}	427.32±41.17^{ab}	354.07±9.95^{b}	194.78±4.75^{c}	**
	FCR	2.54±0.35^{b}	2.22±0.10^{b}	2.62±0.07^{ab}	3.70±0.61^{a}	**
1-42	FC	3581.49±0.07^{a}	3256.24±149.96^{a}	3151.67±49.43^{ab}	2730.84±261.92^{b}	*
	BWG	1757.24±46.13^{a}	1513.73±77.01^{b}	1357.23±82.18^{b}	844.84±18.08^{c}	***
	FCR	2.04±0.05^{b}	2.16±0.09^{b}	2.35±0.19^{b}	3.23±0.26^{a}	**

Values (Mean±SEM) within each row with different superscripts differ significantly at *p<0.05, **p<0.01 and ***p<0.001

amount of protein which absorbed through small intestine. Serum B level was increased ($p<0.001$) in B treatment groups compared to the control group and this effect was B-doses dependent in this study (Table 4). In spite of, feed consumption of 1000 mg B treated group was reduced by (-16.15%) compared to the 500 mg B group and by (-13.36%) compared to the 750 mg B group, the serum B concentration was higher in the 1000 mg treated group compared to the other two B levels. This effect attributed to the increase of B absorption from intestine to the blood because increase B level in this group by 100 and 50% compared to the other two B levels, respectively.

As shown in Table 4, serum AST activity was highly significant decreased ($p<0.01$) in all groups fed diets supplemented with different levels of B and this effect was B-doses dependent and ALT enzyme activity was decreased ($p<0.001$) in a like manner with the AST but the significant was with the 750 and 1000 mg B only. Whereas significant increases in CK enzyme activity ($p<0.01$) with 750 and 1000 mg B doses and LDH enzyme activity ($p<0.05$) with 500, 750 and 1000 mg B doses were observed in B treated groups than the control group. It was reported that serum AST activity was decreased by 100, 200 and 400 mg kg^{-1} B supplementation in laying hens (Eren and Uyanik, 2007). The AST activity in rats (Hunt and Herbel, 1991a) and both AST and ALT activities in mice (Ince *et al*., 2011) were also decreased by B in previous studies. The decreases in AST and ALT enzyme activities by B supplementation in this study may result from the protective effects of the B on normal liver metabolism (Hunt and Herbel, 1991a; Ince *et al*., 2011). Skeletal muscle contains high activities of CK and LDH. Cell injury with subsequent leakage of the enzymes is the most common cause of their increased activities. Serum CK and LDH enzymes are

Table 4: Effect of adding different levels of boron to broilers' diet on some serum enzyme activities and metabolite levels in broilers (Mean±SEM)

	B (mg kg^{-1} diet)				
Parameters	0	500	750	1000	p-value
Enzyme activity (IU L^{-1})					
AST	265.24±13.44^{a}	227.94±9.78^{b}	221.63±13.58^{bc}	188.50±10.69^{c}	**
ALT	20.01±3.02^{a}	16.11±2.09^{ab}	10.78±2.78^{b}	3.91±0.78^{c}	***
GGT	22.39±1.15	22.67±1.47	21.64±1.31	23.69±3.11	-
ALP	1445.36±112.86	1710.39±43.92	1600.42±103.57	1435.17±127.35	-
CK	1412.78±172.28^{b}	1613.71±116.50^{b}	2103.75±173.10^{a}	2202.65±204.05^{a}	**
LDH	2502.70±645.09^{b}	4132.53±404.98^{a}	4108.19±238.73^{a}	4189.91±198.69^{a}	*
Metabolite (mg dL^{-1})					
Glucose	225.50±10.08^{a}	190.89±9.51^{b}	183.16±9.21^{b}	183.93±12.03^{b}	*
Creatinine	0.39±0.02	0.49±0.09	0.34±0.02	0.39±0.04	-
T. protein (g dL^{-1})	4.38±0.17^{a}	4.10±0.09^{ab}	3.81±0.11^{bc}	3.61±0.16^{c}	**
Albumin (g dL^{-1})	1.67±0.06^{a}	1.44±0.04^{b}	1.37±0.03^{b}	1.50±0.07^{b}	**
Globulin (g dL^{-1})	2.71±0.15^{a}	2.67±0.07^{a}	2.45±0.11^{ab}	2.11±0.17^{b}	*
Triglycerides	69.86±4.43^{a}	79.28±2.77^{a}	79.06±4.69^{a}	52.29±2.26^{b}	***
T. cholesterol	173.33±5.45^{a}	165.36±5.35^{a}	161.13±5.66^{a}	145.31±4.17^{b}	**
HDL-C	86.02±3.19	89.63±3.40	86.17±3.02	84.90±3.41	-
LDL-C	52.75±1.84^{a}	21.06±1.33^{b}	15.61±0.99^{c}	15.85±0.87^{c}	***
Ca	6.88±0.34	6.82±0.18	6.74±0.21	6.24±0.26	-
P	6.32±0.23	5.82±0.18	5.65±0.16	5.84±0.11	-
Mg	2.06±0.03^{a}	2.03±0.02^{a}	1.98±0.02^{a}	1.52±0.08^{b}	***
B (ppb)	2.40±0.23^{c}	28.80±2.62^{b}	46.35±2.86^{a}	50.48±3.38^{a}	***

Values (Mean±SEM) within each row with different superscripts differ significantly at *p<0.05, **p<0.01 and ***p<0.001, n = 12

useful diagnostically for identifying skeletal muscle disease (Meyer and Harvey, 1998), therefore, the increases in serum CK and LDH activities may be due to muscle damage characterised by necrosis in muscle fibers in B supplemented groups (Fig. 1-3) in the present study. On the other hand, no significant differences in serum GGT and ALP activities, creatinine, HDL-C, Ca and P levels were found between control and B treatment groups (Table 4) and no gross and microscopic changes were observed in histological examinations in liver, kidney and brain.

Boric acid supplementation has induced changes in serum glucose and lipid profiles (Table 4). In compared with control, serum glucose level was gradually and significantly decreased ($p<0.05$) in B groups. There was no change in glucose level among B treated groups. The decrease of serum glucose levels with supplementation of B consistent with the result of the studies that tested B in broiler (Hunt, 1989), in laying hens (Eren and Uyanik, 2007), in rats (Hunt and Herbel, 1991a), in dogs (Basoglu *et al*., 2000) and the decreases in serum glucose levels may be result of the binding of B to hydroxyl groups of α-glucose (Hunt, 1989; WHO, 1998) in the present study. Decreased total cholesterol significantly ($p<0.01$) in all B treated groups and triglycerides ($p<0.001$) in 1000 mg kg^{-1} B supplemented group and LDL-C ($p<0.001$) in all of the B treated groups levels may indicate that B is a hypolipidemic agent in this study. Our findings are in agreement with that of the previous studies in rat (Hall *et al*., 1989), rabbit (Basoglu *et al*., 2010) and laying hens (Eren and Uyanik, 2007).

Boron has an essential function that regulates parahormone activity (McDowell, 1992) and therefore, effects Ca, P, Mg and cholecalciferol metabolisms (McDowell, 1992, Miljkovic *et al*., 2004; Kurtoglu *et al*., 2001, 2005) and it has been shown to prevent bone demineralization and affect

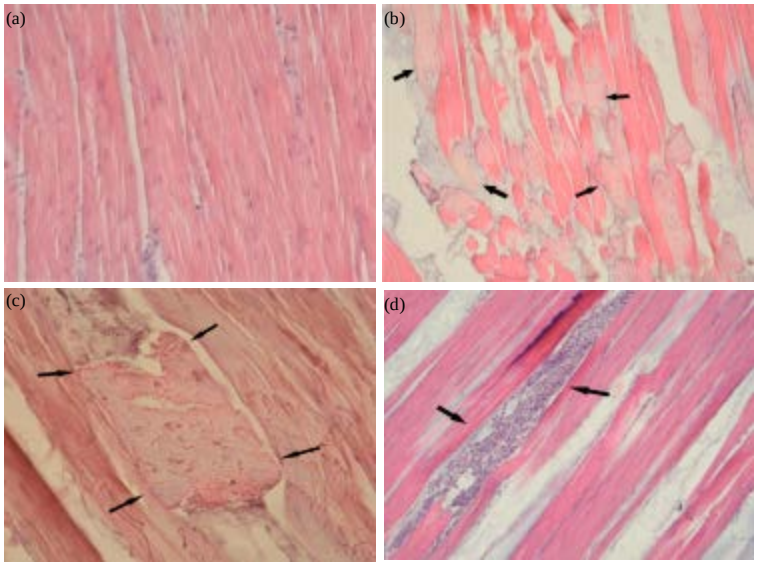

Fig. 1(a-d): Broiler muscles with (a) Normal appearance in control group, (b) Homogeneous pink-coloured necrotic areas (arrows), (c) Breakdown of muscle fiber depending on necrosis (arrows) and (d) Foci of mononuclear cell infiltration in necrotic areas between in muscle fibers (arrows), H and E, x400

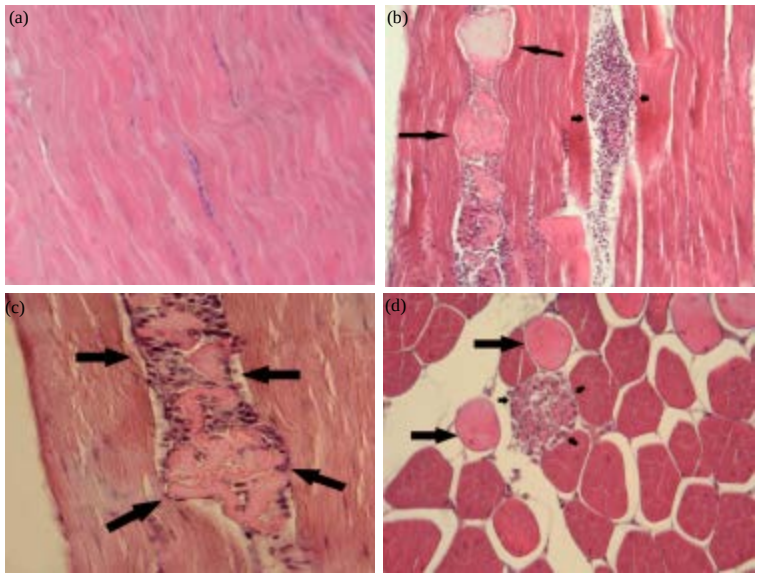

Fig. 2(a-d): Broiler muscle with (a) Normal appearance, control group, (b) Necrosis of muscle fibers (large arrows) and mononuclear cell infiltrations (small arrows), (c) Mononuclear cells in necrotic area of muscle fibers (arrows) and (d) Necrotic areas (large arrows) and mononuclear cell infiltrations (small arrows) in transverse cross section of muscle fibers, H and E, x200

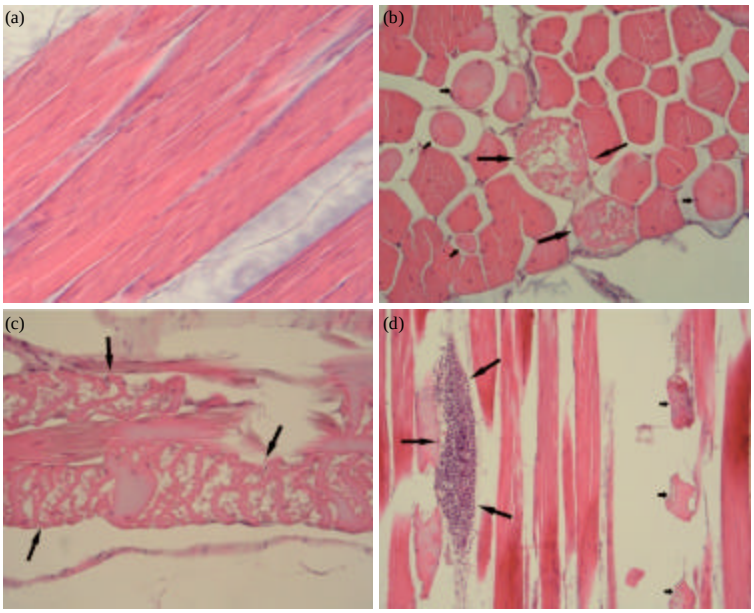

Fig. 3(a-d): Broiler muscle with (a) Normal appearance, control group, (b) Homogeneous pink-coloured necrotic areas (small arrows) and fragmented muscles (large arrows) in transverse cross section of muscle fibers, (c) Fragmented muscles as a result of necrosis in longitudinal cross section of muscle fibers (arrows) and (d) Necrotic muscles (small arrows) and mononuclear cell infiltrations (large arrows) in necrotic areas between in muscle fibers, H and E, x200

cartilage of bone and normal development and plasma mineral levels (Ca, P, Mg) (Hunt, 1989; Nielsen *et al*., 1988; Wilson and Ruszler, 1998; Kurtoglu *et al*., 2001). In this study, serum Mg levels decreased significantly ($p<0.001$) in 1000 mg kg^{-1} B treated chickens (Table 4). The decreases in the levels of Mg may result from either the reductions of utilisation in the gastrointestinal tract or the improvement of urinary losses (Hunt and Herbel, 1991b; Chapin *et al*., 1997; Gallardo-Williams *et al*., 2003) due to B supplementation as reported by the previous studies in broilers (Qin and Klandorf, 1991; Kurtoglu *et al*., 2001), in quails (Karabulut and Eren, 2006) and in rats (Nielsen *et al*., 1988; Hunt and Herbel, 1991b; Chapin *et al*., 1997).

CONCLUSION

The result of this study have shown that supplementation of 500, 750 and 1000 mg kg^{-1} boron in the form of boric acid did not cause mortality or result in histopathological lesions except for muscles but did cause a significant decrease in performance and changed some blood biochemical parameters in broilers. Especially, 1000 mg kg^{-1} B had harmful effect than 500 and 750 mg kg^{-1} B on growth performance and some blood chemistry. Generally, serum glucose, lipid profiles, AST and ALT enzyme activities as indicator of liver function were positively affected by dietary B supplementation. However, adverse effects in growth performance parameters, serum proteins, CK and LDH enzyme activities as sign of muscle damage and pathological lesion in the muscle were

observed. In conclusion, further more detailed investigations with B at various levels or different B compounds are needed to better understand the biochemical functions of boron in different animal species.

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