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(RESEARCH ARTICLE)



## Examining the effects of adding boric acid at different doses into mixed feed on fattening performance, carcass characteristics, and bone quality of Japanese quails

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### Abstract

The aim of this study is to investigate the effects of adding different doses of boric acid (H<sub>3</sub>BO<sub>3</sub>) to the mixed feed of Japanese quail (*Coturnix coturnix Japonica*) on fattening performance, carcass and bone properties. For this purpose, a total of 96 quails aged 15 days were balanced according to their live weight and sex, and 4 trials were randomly divided into groups. Each group is composed of 4 repetitions. Trial groups; the control group (C) given mixed feed, the group with 100 mg / kg boric acid (BA) added to the feed BA100; 300 mg / kg boric acid was added to the feed group BA300 and 500 mg / kg boric acid added to the feed group BA500. Data for the fattening period were followed for 15-43 days. At the end of the experiment, carcass and bone characteristics of 8 quails (two quails from each repeat) from each group were examined. The live weight and live weight gain of the quail was similar among the experimental groups (P>0.05). Adding boric acid to feed did not affect feed consumption and feed utilization rate (P>0.05). While the breast rate decreased significantly due to the increasing levels of boric acid addition (P<0.01), an increase in the back and neck ratio was detected (P <0.05). The highest thigh ratio was found in BA300 and BA500 groups (P<0.05). Carcass yield, wing and liver rates were similar between the groups (P>0.05). Tibia and femur weights and dimensions were not affected by the addition of boric acid (P>0.05). The highest femoral ash level was determined in the BA300 group (P=0.05). The tibia ash level increased from the Control group towards BA300 and was the lowest in the BA500 group (P<0.05). As a result, while the addition of boric acid to the feed cannot be affected to the fattening performance of quail, its effect on carcass and bone properties has been found significant.

**Keywords:** Boric acid; Performance; Carcass; Bone Quality; Quail

### 1. Introduction

The use of poultry meat, which is important for human health, in human nutrition has gradually increased the importance of poultries such as quail, chicken and turkey, which reach to slaughter weight in a short time, in recent years. This rapid increase in live weight in poultries, brings along the problems related to skeletal system [1].

Boron is the fifth metal in the periodic table and it has been included in Group IIIA based on its chemical and physiological characteristics [2]. Its atomic number is 5 and its melting point is 2300 oC. Boron is not found in nature alone, it is found in combination with the other elements generally named as "borates" in oxygen and salts. More than 250 minerals containing boron have been identified. The most common ones are sodium, calcium or magnesium salts. Boron is an element found rarely in nature [3]. Boric acid is a brilliant and water-soluble acid crystallized in white flakes.

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Many of the minerals contain boric acid but the most important ones are borax, colemanite, ulexite, and kernite in boron industry [3, 4]. Boron, which is used in many areas in industry and has many biological effects, is a mineral which should be taken into the body through nutrients.

The biochemical action mechanism of boron element in human and animal tissues is not known exactly but it has been included intensely in various biochemical studies on human and animal metabolism as a nutritive micro element after the 80s. It has been reported that boron has important functions in mineral, lipid and energy metabolism, endocrine system, immune system and brain, increases performance and may be used for preventing osteoporosis, osteoarthritis, and arthritis [5, 6]. In addition, it has been revealed that boron strengthens antioxidant defense system by increasing catalase, superoxide dismutase, and glutathione production in tissues, has an immunostimulant effect, has an anti-inflammatory and epithelizing effect by decreasing mRNA expression levels of Bax proteins and suppressing TNF- $\alpha$  production induced by lipopolysaccharide [4, 7], causes increase in steroid hormones (plasma estradiol and testosterone) [4, 7, 8], and has an antimicrobial character [9]. Boron interacts with calcium, phosphor, vitamin D and magnesium, which are important in bone metabolism, and accumulates in bone in the concentrations based on the consumed amount of boron [10]. It enhances the balance of bone strength by playing an important role in the metabolism of macro minerals, mainly calcium, and decreases the losses caused by bone fractures [8, 11]. Boric acid compounds is found in different types in carbohydrates (glucose and polysaccharides), nucleotides (adenosine monophosphate and niacinamide adenine dinucleotide) and vitamins (ascorbic acid, pyridoxine, riboflavin). Also, boron element has important functions in brain functions, immune system, cell structure and functions [12]. Due to these important biological effects of boron, its usage opportunities in farming has gained importance day by day.

Japanese quail (*Coturnix coturnix Japonica*) is a breed commonly raised for its meat and egg. It reaches a live weight of 200-250 g when it is 40-42 day-old and a quail consumes 25-30 g of feed daily. The average feed conversion rate in quails varies between 3 and 4. Extensive quail farming has increased rapidly in recent years due to the biological characteristics of its meat and egg, easy and economic production and its suitability to the taste of the public. It is also good animal model in poultry researches due to the features given above. The attraction of the quail products has caused many studies to be conducted on quail farming in different environmental conditions and that the studies affecting both the amount and the quality of the products have still arouse interest and have led to preservation of its up-to-dateness [13, 14]. There are various research studies on the use of different forms and doses of boron in the feed of quails and the other poultry species. However, different results have been obtained on the effect of boron on poultry performance and metabolism in these researches [10, 14, 15]. Accordingly, it is thought that there is a need for different studies on the use of different doses and forms of boron compounds as feed supplements.

In this sense, the aim of this planned study was to examine the effects of boric acid added to feed in different doses on the fattening performance, carcass characteristics, and bone quality in Japanese quails.

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## 2. Material and methods

### 2.1. Ethical approval

This study was conducted in Elazığ Veterinary Control Institute Poultry Unit. Approval was received from Elazığ Veterinary Control Institute Local Ethics Committee (EVKEM: 2020/01).

### 2.2. Experimental design

A total of 96 Japanese quails (*Coturnix coturnix Japonica*) were used in the study. The quails were raised in deep litter system for 15 days. Within this period, the quails were fed with feed and water *ad libitum* in the rooms with the suitable temperature and humidity for their physiology. They were weighed after fifteen days and divided in experimental groups. At the start of the experiment, the experimental groups were balanced in terms of live weight and gender. Sex determination was performed by considering the type of hair growth on breast. In the study, different doses of boric acid (H3BO3, Lot No: 081118108001) were added into the mixed feed (Table 1).

**Table 1** Characteristics of used boric acid (H3BO3)

Content	%
Purity	>99.5
Borontrioksit (B2O3)	>56.0
Sulfate (SO4)	<0.02
Chloride (Cl)	<0.001
Iron (Fe)	<0.0007

Experimental groups were formed as follows; the control group (C) for which any addition was applied, the group in which 100 mg/kg boric acid (BA) was added in feed (BA100), the group in which 300 mg/kg boric acid was added in feed (BA300) and the group in which 500 mg/kg boric acid was added in feed (BA500). The quails were raised for 15-43 days in the special cages used of quails. The experimental groups were arranged with 6 quails in each repetition and with 4 repetitions and including totally 24 quails in each group. During the experiment, feed and water were given ad libitum. The basal feed used in the study was prepared in accordance with the National Research Council (NRC) standards [16] and presented in Table 2. The nutrient composition of the basal ration was determined based on Association of Official Analytical Chemists (AOAC) [17]. The metabolizable energy content of the ration was predicted using Carpenter and Clegg [18] equation.  $ME, \text{ kcal/kg} = 53 + 38 [(crude \text{ protein, \%}) + (2.25 \times ether \text{ extract, \%}) + (1.1 \times starch, \%) + (sugar, \%)]$  (1 kcal = 4.19 kJ). During the experiment, live weights (LW) were determined by weekly weighing measurements. Feed was given by weighing daily and the remaining feed was weighed weekly and daily feed intake (FI) was calculated. The daily consumed feed was proportioned to the daily live weight increase (LWG) and the feed conversion rate (FCR) was calculated. As no quail died during the study, the survival ability was assessed as 100%. To perform the carcass analyses at the end of the fattening period (43rd day), 2 quails (1 female, 1 male) from each repetition reflecting the repetition average, 8 quails from each group and totally 32 quails were slaughtered in the experimental groups.

**Table 2** The content of basal feed and nutrient compound (%)

Feed Materials	%
Corn, Yellow	51.50
Soybean meal, 48%	28.00
Corn Gluten, 43% Hp	12.00
Wheat Bran, Coarse	5.00
Vegetable Oil	0.51
Dicalcium Phosphate	0.70
DL-Methionine	0.01
Limestone	1.35
L-Lysine Hydrochloride	0.27
L- Threonine	0.16
Salt	0.25
Vitamin-Mineral Mix*	0.25
<b>Total</b>	<b>100.00</b>
<b>Chemical Composition</b>	
KM, %	89.9
HP, %	24.0

ME, kcal/kg	2900
Ca, %	0.80
Ash P, %	0.30
Na, %	0.13
Cl, %	0.20
Met+Sis, %	0.82
Lysine	1.30
Threonine, %	1.03
Tryptophane, %	0.28
Linoleic acid, %	1.41
HY, %	2.48
HK, %	5.52
HS, %	3.32
Starch, %	37.65
Sugar, %	3.65
Electrolyte Balance, mEq/kg KM	223

\*Vitamin-mineral premix (For each 1 kg): Vitamin A, 12.000 IU; Vitamin D3, 3.300 IU; vitamin E, 20 mg; Vitamin K3, 4 mg; Vitamin B1, 3.0 mg; Vitamin B2, 7.0 mg; Vitamin B6, 5.0 mg; Vitamin B12, 0.015 mg; Niacin, 25.0 mg; D-calcium pantothenate, 10.0 mg; folic acid, 1.0 mg; D-biotin, 0.05 mg; choline chloride, 175 mg; manganese, 100 mg; iron, 60 mg; zinc 60 mg; copper, 5 mg; cobalt, 0.5 mg; iodine, 2 mg; selenium, 0.15 mg; phytase, 300.

Slaughtering was performed by using decapitation. The slaughtered quails were plucked and after their carcass weights were determined, they were divided into their parts in accordance with Turkish Standards Institution (TSI) standards [19]. Carcass parts and liver were weighed. Hot carcass and liver weights were proportioned to the slaughter weight and the weights of the carcass parts were proportioned to carcass weight and expressed as percentage. After the humerus and tibio-tarsal bones of the left legs of the quails were separated from meat, they were kept at +4 oC for analyses. The tibio-tarsal and humerus bones were weighed by using precision balance. The width of the bones from their exact midpoint and their length from the distance between the longest two points were measured using a digital caliper (Tresna, USA). The bones were burned in muffle furnace (Protherm, Turkey) at 600 oC for 7-8 hours and then ash measurements were performed [20].

### 2.3. Data analysis

Normality analysis was performed for all the data and it was determined that the data had a normal distribution. The difference between mean values of the groups was assessed by using analysis of variance and advance analyses were also evaluated using Tukey HSD test. Windows-compatible SPSS software was used in performing statistical analyses. If it was  $P \leq 0.05$ , the effects were assessed to be significant. The data were given as mean  $\pm$  standard error [21].

## 3. Results

Table 3 shows the effects of boric acid added at different doses in mixed feed on the fattening performance of the quails. Boric acid added in feed was not effective on the LW of quails in the examined periods, except for the 29th day. The highest LW of the 29th day was obtained in BA500 group ( $P < 0.05$ ). The experimental groups had similar values in terms of the LWG ( $P > 0.05$ ). The effects of boric acid on the FI and FCR were not determined to be significant ( $P > 0.05$ ).

When the effects of boric acid at different doses on carcass characteristics were examined (Table 4), it was determined that breast rate decreased significantly depending on dose increase ( $P < 0.01$ ); whereas, the back and neck rate increased ( $P < 0.05$ ). The highest thigh rate was determined in BA300 and 500 groups ( $P < 0.05$ ). The other characteristics (wing rate, liver rate) were found to be similar between the groups ( $P < 0.05$ ).

Table 5 shows the effect of boric acid added in mixed feed on the bone characteristics of quails. Tibia and femur weights, width and length values were not affected by addition of boric acid ( $P>0.05$ ). Tibia ash level increased from the control group to BA300 and was observed at the lowest level in the BA500 group ( $P<0.05$ ). Ash level of femur was also determined at the highest level in BA300 group ( $P=0.05$ ).

**Table 3** The effect of boric acid added to mixed feed on the fattening performance of Japanese quails.

	Control	BA100	BA300	BA500	P value
Live Weight (LW), g					
15 (baseline)	45.91±1.42	45.75±1.36	45.75±1.70	45.79±1.23	1.000
22	68.12±2.05	70.41±2.21	72.83±2.52	73.41±1.95	0.308
29	121.75±4.21 <sup>ab</sup>	112.83±3.20 <sup>b</sup>	123.70±3.52 <sup>ab</sup>	126.87±3.09 <sup>a</sup>	0.039
36	165.37±3.26	158.70±3.84	167.54±3.82	169.37±3.53	0.183
43	194.37±4.61	197.75±4.66	203.87±5.00	202.16±5.53	0.525
Live Weight Gain (LWG), g					
15-22	3.17±0.25	3.55±0.35	3.86±0.30	3.94±0.34	0.339
23-29	7.66±0.43	6.09±0.22	7.26±0.36	7.63±0.44	0.059
30-36	6.23±0.68	6.27±0.40	6.26±0.29	6.07±0.30	0.987
37-43	4.14±0.57	5.63±0.54	5.19±0.16	4.68±0.78	0.318
15-43	4.94±0.23	5.03±0.29	5.27±0.11	5.21±0.22	0.720
Feed intake (FI), g/day/quail					
15-22	16.83±1.90	17.20±1.40	16.49±2.27	15.91±1.94	0.968
23-29	21.37±1.03	20.78±1.19	18.87±2.07	17.91±1.90	0.427
30-36	18.12±2.33	20.16±3.28	22.99±2.49	23.62±2.22	0.445
37-43	17.83±2.90	21.12±2.14	20.20±2.41	15.66±0.72	0.331
15-43	18.53±1.86	19.81±1.82	19.64±2.18	18.27±1.17	0.905
Feed conversion ratio (FCR), g FC/g LWG					
15-22	5.27±0.23	4.84±0.74	4.27±0.71	4.03±0.69	0.559
23-29	2.80±0.15	3.42±0.22	2.62±0.34	2.34±0.35	0.115
30-36	2.89±0.12	3.21±0.73	3.69±0.40	3.89±0.55	0.496
37-43	4.30±0.69	3.75±0.69	3.89±0.56	3.34±0.63	0.833
15-43	3.75±0.24	3.94±0.52	3.73±0.43	3.51±0.23	0.828

The data were given as mean and standard error. When it was  $P\leq 0.05$ , the differences between the mean values were considered as significant. a.b: The differences between the mean values expressed by different letters were significant.

**Table 4** The effect of boric acid added into mixed feed on the carcass characteristics of Japanese quails

Characteristics (%)	Control	BA100	BA300	BA500	P value
Carcass yield	67.61±1.02	68.33±0.72	66.66±2.05	70.44±1.53	0.302
Breast rate	39.25±0.47 <sup>a</sup>	38.67±0.76 <sup>ab</sup>	35.49±0.93 <sup>b</sup>	35.49±1.05 <sup>b</sup>	0.003
Thigh rate	36.99±0.47 <sup>ab</sup>	36.31±0.55 <sup>b</sup>	38.61±0.45 <sup>a</sup>	38.55±0.75 <sup>a</sup>	0.017
Wing rate	9.60±0.22	9.85±0.44	9.45±0.19	8.70±0.32	0.079
Back+neck rate	14.14±0.32 <sup>b</sup>	15.16±0.89 <sup>ab</sup>	16.43±0.80 <sup>ab</sup>	17.24±0.81 <sup>a</sup>	0.033
Liver rate	2.69±0.19	3.27±0.27	2.91±0.32	2.92±0.18	0.445

The data were given as mean and standard error. When it was  $P\leq 0.05$ , the differences between the mean values were considered to be significant. a.b: The differences between the mean values expressed by different letters were significant.

**Table 5** The effect of boric acid added into mixed feed on the bone characteristics of Japanese quails.

	Control	BA100	BA300	BA500	P value
Tibia weight, mg	68.04±3.33	71.55±3.20	70.54±2.71	76.31±2.40	0.267
Femur weight, mg	50.73±1.76	54.01±3.37	57.49±2.11	57.86±2.14	0.152
Tibia length, mm	51.94±0.89	53.47±0.37	51.86±0.43	52.28±0.62	0.250
Tibia width, mm	2.80±0.07	3.17±0.12	3.05±0.08	3.15±0.11	0.051
Femur length, mm	41.77±0.62	42.95±0.49	42.35±0.45	41.84±0.49	0.365
Femur width, mm	3.10±0.05	3.14±0.11	2.94±0.07	3.14±0.10	0.354
Tibia ash level, %	39.37±1.31 <sup>ab</sup>	40.28±0.94 <sup>ab</sup>	41.78±0.77 <sup>a</sup>	36.69±1.07 <sup>b</sup>	0.015
Femur ash level, %	35.00±1.13 <sup>b</sup>	39.07±1.93 <sup>ab</sup>	41.65±1.50 <sup>a</sup>	37.46±1.90 <sup>ab</sup>	0.050

The data were given as mean and standard error. When it was  $P \leq 0.05$ , the differences between the mean values were considered to be significant. a,b: The differences between the mean values expressed by different letters were significant.

#### 4. Discussion

The skeleton and bone integrity problems in poultry as well as problems related to eggshell quality in laying poultry are important economic, welfare and health problems for the poultry industry. For this reason, the role of boron in poultry farming is important in terms of increasing productivity and improving animal welfare. Boron is an important and known feed factor in calcium metabolism reflecting its importance in normal bone development. As it interacts with pyridine, riboflavin, dehydro-ascorbic acid and pyridine nucleotides, its existence and supplement are highly important [22].

As a result of the present study, it was determined that in the quails fed with boric acid addition (100, 300 and 500 mg/kg boric acid), the effects of boric acid on their fattening performance such as FI, FCR and LWG were not important. Among other studies, Olgun et al. [23] reported that the addition of calcium (Ca) and boron (Borax Pentahydrate) at different rates in feed of laying chicken did not affect LW, LWG, FCR and egg quality parameters, significantly. Ayasan et al. [24] reported that addition of boric acid in mixed feed in quails did not have any significant effect in FI, egg production, egg shell weight, and egg shape index but addition of 400 ppm boric acid increased cumulative FI. It increased egg weight but it decreased egg thickness compared to the Control group. In another study [25], it was determined that LW decreased in 150 and 300 mg/kg boron addition compared to those fed by the feed with 0 and 75 mg/kg boron in 20-weeks old pullets. Similar findings were also found in the study by Waleed and Hayani [15]. They determined that there was a decrease in LW in the Japanese quail fed with the feed containing 50, 75 and 100 mg/kg boric acid [boric acid 16% boron (B)] addition and, the use of 100 mg/kg boric acid caused a significant decrease in FI. Eren et al. [26] found the addition of 10, 60, 120 and 240 mg/kg boron into feed decreased LW, FI and FCR of the quails and the hot and cold carcass yield and carcass dry matter level were not affected but the carcass fat and ash levels of male quails increased. Sızmaz et al. [27] reported that boric acid containing 17.5% boron and ascorbic acid, when used only and together, did not affect LW, FCR, egg weight, shell breaking resistance, egg thickness, egg albumen and yolk rates, haugh unit and yolk weight. However, bone ash and phosphorus (P) level significantly increased in tibia. Eren et al. [28] reported that 0, 5, 10, 50, 100, 200 and 400 mg/kg boric acid ( $H_3BO_3$ ) was added in feed of laying chicken for 8 weeks after 10-day adaptation. In the group with 400 mg/kg boron addition, LW, FI and egg production decreased and eggs quality parameters changed. Serum Ca, inorganic P and magnesium (Mg) levels also increased. Hakan et al. [29] found that 90 ppm boric acid and 1 g/kg humate were added in feed of laying chicken did not have a significant effect on FI, egg weights and production, egg quality parameters (egg thickness, shell breaking resistance and shape index) compared the control group. However, it was determined that boric acid and humate mixture enhanced FCR significantly. Sızmaz et al. [30] stated that boric acid (60 mg/kg feed) and plant extract mixture (Fitococci, F) (0.75 g/kg feed), when used only or together, did not have a significant effect in terms of FCR, egg weight and yield, egg quality parameters (egg thickness, shell breaking resistance, and shape index) and blood cholesterol levels compared to the control group. FI increased significantly in the group fed by mixture of plant extract and boric acid. Yıldız et al. [31] determined that the addition of 2.5 g/kg of *Saccharomyces cerevisiae* (yeast) and 60 mg/kg of boric acid only or together into broiler ration did not have a significant effect on performance, carcass characteristics, blood parameters and tibia ash and boron levels. Kara [32] reported that adding different levels of zinc (0, 50 and 100 mg/kg) and boron (0, 30, 60, 120 and 240 mg/kg) into feed of breeder quails significantly affected average egg weight, egg surface area, shell rate, shell strength, egg specific weight, tibia and femur ash amount (g and %), femur Ca, P, Mg, potassium (K), sulfur (S), Zinc (Zn), boron

(B), manganese (Mn) and molybdenum Mo amounts (mg/kg) during the experimental period and the some bio-mechanical characteristics of bone. Olgun et al. [33] determined that the addition of 60, 120 and 240 mg/kg boron into feed improved bone characteristics significantly although it decreased eggshell thickness together with the increasing dose. Mızrak et al., [34] stated that 50, 100 and 200 mg/kg boron into feed at the age of 64 weeks resulted in a lower LW compared to the control group. It was also reported that boron addition did not affect FI, egg production, egg weight, egg mass, and broken and cracked egg incidence. In the study conducted by Wilson and Ruzler [35] to investigate the effects of the boron (0, 50, 100, 200 and 400 mg/kg) addition in white leghorn rations revealed that LW, FI, egg weight and egg production decreased in 400 mg/kg boron addition in feed and the boron concentrations in breast, liver, thigh and bone tissues increased in parallel with the boron addition at increasing levels. Yıldız et al. [36] reported that boric acid (60 mg/kg) added in feed in different farming periods of broiler chickens did not cause a significant effect on growth performance, carcass characteristics and cholesterolemia. In Japanese quails, 40, 80 or 120 mg/kg boron were added in corn-soybean based feed from 4 different sources (boric acid, anhydrous borax; borax pentahydrate; borax decahydrate) did not significantly affect 0-3 weeks performance characteristics and carcass weight of quails, except for FI, the boron sources used in the ration affected bone thickness-outer diameter significantly and it was found to be significantly higher than all the other sources in the quails fed by boric acid [37]. In the present study, it was determined that the carcass yield was similar between the experimental groups, breast rate decreased significantly depending on dose increase and back and neck rate increased. The highest thigh rate was determined in BA300 and BA500 groups. Similar to present study, Özdemir et al. [14] reported that breast rate decreased in quails by addition of boron. Rossi et al. [8] fed 144 one-day old broiler chicks in the experimental group 1 for 21 days with 0, 5, 40, 80 and 120 ppm boron added feed in two experimental groups and stated that tibias resisted more load compared to the control group. In the experimental group 2, 288 one-day-old chicks were fed with 0, 60, 120, 240 and 300 ppm boron added feed for 22 days. Tibia ash percentage was determined at the highest level in the group fed with the 300 ppm boron added ration. Similarly, Cufadar et al. [38] reported that adding 300 mg/kg boric acid, anhydrous borax, borax pentahydrate and borax decahydrate from different sources into feed had a positive effect on bone tension and bone strength. In the present study, tibia and femur weights and width and length characteristics were not affected by addition of boric acid but the tibia ash level increased from the control to BA300 group and the femur ash level was determined to be at the highest level in the BA300 group. The findings of this study and the aforementioned studies' findings were generally in compliance. Unlike the previous studies, the bone ash level in the BA500 group of this study decreased significantly. This result was considered to be caused by overdose and lead to a toxic effect.

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## 5. Conclusion

Both the results of this study and the results of the similar studies revealed that boron affected mineral metabolism but the mentioned effect may change based on the poultry species, genetic structure, the boron level added into feed and its source and the period of feeding by boron. Consequently, it was determined that addition of boric acid into feed did not have a negative effect on the fattening performance and carcass characteristics of quails but it may be useful on their bone quality. The highest ash level was determined in 300 mg/kg group and the bone ash level decreased in 500 mg/kg group. It was concluded that adding boric acid at an appropriate level had a positive effect on bone quality as it caused an increase in bone ash level and it may be useful in preventing the skeleton problems observed especially in poultry farming based on rapid live weight increase.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The authors declare that there is no conflict of interest in the present study.

### *Statement of ethical approval*

The approval of Elazığ Veterinary Control Institute Local Ethics Committee (EVKEM: 2020/01) was obtained for the study.

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