IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 11, Issue 3 Ver. II (March 2018), PP 18-23
www.iosrjournals.org

Effect of boron and nano-boron on growth performance of broiler chicks

Thukra Mahdi Mousaand Balqees Hassan Ali*
** Department of pathology and poultry disease, College of Veterinary Medicine, university of Baghdad*
Corresponding Author: Thukra Mahdi Mousaand Balqees Hassan Ali

Abstract: *This study was to evaluate the effect of boron and nano-boron on growth performance of broiler chicks. A total of two hundred and fourty broiler chicks at one day old were used and randomly distributed to eight equal groups. Experimental groups were exposed to boron and nano-boron throughout of the experiment as follows: group B10 was received boron 10 mg/L of drinking water, group B20 was received boron 20 mg/L, group B40 was received boron 40 mg/L, group NB10 was receivednano-boron 10 mg/L, group NB20 was receivednano-boron 20 mg/L, group NB40 was receivednano-boron 40 mg/L, either control groups: group C+ was vaccinated only, group C- not treated. The maternal immunity was measured in the 2nd day for all groups by ELISA test, all groups were vaccinated (except group C-) with Newcastle disease vaccine at (15 and 25day old) and infectious bursal disease vaccine at (16 days old) via drenching route, growth performance of the chicks (body weight, body weight gain, feed intake and feed conversion ratio) were weekly determined. The results showed the effect of boron and nano-boron on growth performance, the group B20 which revealeda significant increase in live body weight and body weight gain in the 5th week, either feed consumption the group NB10 revealeda significant increase in the 2nd and 3rd weeks while group B20 revealed a significant decrease in feed conversion ratioin the 5th week compared to control groups. In conclusion the results of this study indicated that the addition of boron and nano-boron to drinking water caused improvement of the growth performance in the birds.*

Keywords*: boron,nano-boron,Elisa test, vaccines.*

Date of Submission: 05-02-2018 Date of acceptance: 19-03-2018

I. Introduction

A substantial number of metabolic processes in humans and animals are usefully influenced by physiologic amount of dietary boron **Hunt and Idso, 1999**which effect on the activity of many metabolic enzymes, as well as, the metabolism of steroid hormones and several micronutrients, including calcium, magnesium and vitamin D. Growing evidence has demonstrated that boron plays a central role in development of animals **Hunt, 2012**. Trace elements and their deficiencies or functions are of great interest in poultry diet. Boron has been known as an essential element for higher plants since 1920's, but some studies have been focus on the possible role of boron in animal and human nutrition **Nielsen, 1992**. Boron supplementation to broiler diets has become a concern of the broiler industry because of the importance of boron to body weight, feed conversion ratio, calcium metabolism and bone formation**Wilson and Ruszler, 1997**. Fruits, vegetables and legumes are good sources of boron, while whole grains include very little boron, nevertheless grains are widely used in poultry diets **WHO, 1998**and there is no recommended level of boron for daily intake in poultry **NRC, 1994**. In the faster pace of life and more consciousness of consumers about food safety and security, nanotechnology may be the important tool to augment the livestock products to fulfill the future demand **Akhilesh*et al*., 2012** and they stated that the development of the use of nanoparticles can produce meat, milk and poultry products in much faster pace with high safety. Examples of possible applications in animal agriculture and veterinary medicine consist of disease diagnosis and treatment delivery systems, new tools for molecular and cellular breeding, the security of animal food products, modification of animal waste, pathogen detection and many more **Chakravarthi and Balaji, 2010**.

II. Materials and methods

A total of two hundred and fourty, 1-d-old broiler chicks of the Ross breed, were weighted andrandomly divided into 8 groups, three boron groups (B) 10, 20 and 40 mg/L of drinking water, three nano-boron groups (NB) 10, 20 and 40 mg/L nano-boron and two control groups C+ and C-, group C+ was vaccinated only, group C- not treated.Blood samples were collected randomly from heart of chicks in the 2nd day to determine antibody titers against Newcastle disease virus and infectious bursal disease virus by using indirect method of ELISA test (Synbiotic-USA) thus determining the vaccine program, all groups were vaccinated (except group C-) against Newcastle disease and infectious bursal disease virus. The experimental period lasted for 35 days.In the trial, chicks received basal diets as in table 1, 2**Pesti*et al*., 2002**. Boric acid was used as the boron source, the boron nanoparticles was imported by mercialcorporation from China, some of them were sent to the laboratory for X-ray diffractometer(XRD 6000) to determine the crystalline structure of the nano-boron **Kasper,*et al*., 1950**.

Parameters included:
Live body weight (BW): was recorded weekly for each group by weighting chicks individually at days 7, 14, 21, 28 and 35 of age according to the following equation **Morgan and Lewis, 1962**:

$$\text{Average live body weight of birds (gm)} = \frac{\text{Total birds weight (gm)}}{\text{Total number of birds (gm)}}$$

Body weight gain (BWG): wasrecorded depending on the difference in body weight between the beginning of the week and the end of it according to the following equation **Al-Zubayedi, 1986**:

BWG(gm) = final weight(gm) – Primary weight(gm).

Feed intake (FI): wasrecorded weekly by following the equation:
Feed intake (gm) = Total quantity of offered feed during the week for the whole group (gm) –The quantity of the remained feed at the end of the week (gm)
Feed conversion ratio (FCR): was measured by applying the following equation **Al-Zubayedi, 1986**:

$$\text{FCR} = \frac{\text{Finally average feed intake (gm)}}{\text{Finally average body weight gain (gm)}}$$

Data were analyzed by the Statistical Analysis System- SAS **SAS., 2012**program due to effect of difference factors in study parameters. Also Duncan **Duncan, 1955**multiple range test (ANOVA) was used to significant compare between means.

Table 1 the materials used in the 1st stage (starter) from one day to 21 days

Components	Amount/1000kg	Percentage
Corn	465 kg	46.5%
Wheat	200 kg	20%
Soy bean meal	300 kg	30%
Calcium	17 kg	1.7%
Premix 1%	15 kg	1.5%
Salt	2 kg	0.2%
Mycofix select	1 kg	0.1%
Energy	2940	
Protien	21.9	

Table 2the materials used in the 2nd stage (final) from 21until the end of the experiment

Components	Amount/1000kg	Percentage
Corn	500kg	50%
Wheat	207kg	20.7%
Soya bean meal	265kg	26.5%
Calcium	10kg	1.0%
Premix	15kg	1.5%
Salt	2kg	0.2%
Mycofix select	1kg	0.1%
Energy%	3170	
Protien%	19.6	

III. Results and dissection

Live body weight (BW):

The current study showed there were no significant differences in BW in the 1st, 2nd and 3rd week (Table 3) but there were a significant differences ($P \leq 0.05$) in the 4th and 5th week. The group B20 was higher BW in the5th week followed by NB40, NB10, B10, NB20, B40 compared to the control groups. The results revealed that three level of boron and nano-boron induced improvement of the growth by significantly increase of BW at 21-35days of age, regarding to boron these results are in agreement with **Al-Hamdani,2016**who indicated that the use of boron in the diets of broiler with 15 mg/ kg of diet led to improvement in BW at the age 14, 28 and 35 days. **Jin *et al*.,2014**alsoreported that 100 mg boron/L of drinking water could improve the growth and the BW obviously increased at 4-6 weeks,while**Sizmaz and Yildiz, 2014**reportedthat supplementationof boric acid with 175mg/kgof diet significantly increased in BW at the first of 21 days of the experimental period.

Body weight gain (BWG):

The current study revealed there were no significant differences in BWGin the 1st, 2nd and 3rd week (Table 4) but there were a significant differences ($P \leq 0.05$) in the 4th and 5th week, inthe 5th week showed that B20 was higher BWG followed by NB40, B10, NB10, NB20, B40 compared tothe control groups. The results showed that all the birds'supplemented boron and nano-boron were higher BWG at 21-35days of age. Regarding to boron these results are in agreement with **Jin *et al*.2014**who found that 100 mg boron/L of drinking water could improve the growth and the BWG obviously increased at 4-6 weeks, also**Lin and Ying, 2003**pointed that supplementation of boron as boron acid at levels 20,40,60,80,100,120 mg/kg diet led to increaseBWG.Additionally, **Al-Hamdani, 2016**indicated in study that the use of boron in the diets of broiler with 15 mg/ kg diet resulted in a positive effecton WG during the experiment period 1-35 days.

Feed intake (FI):

Table 5showed no significant differences in FIin the 1st, 4th and 5th week while observed significant differences ($P \leq 0.05$) in the 2nd and 3rd week, thegroup NB10 was higher FI followed by NB40, (B20, B40) equal, (B10, NB20) and C- and C+ in the2nd week. In the 3rd week NB10 also was higher FI followed by NB40, B40, (B10, B20) and (NB20, C-) and C+. The results showed that the addition of boron and nano-boron led to an increase in feed consumption comparedtothe control groups, regarding to boron these results are in agreement with **Eren*et al*.2012**who used boric acid and borax additions 10, 50, 100, 250 mg/kg of diet and recorded that feed consumption tended to increase with boron supplementation, particularly with boric acid at 10 and 50 mg/kg during the 1st 3 weeks. Also supplementation of boric acid 175 ppm resulted in a significant increase in FI during the 1st 21 days of the experimental period in study by **Sizmaz and Yildiz, 2014**. In agreement with **Fassani*et al*.2004**also who assessed the effects of boron supplementation on broiler performance levels and revealed that FI increased from 1-21 days when the dose 30 mg/kg of diet.

The positive effect on body weight, body weight gain and feed intake may be attributed to the role of boron on metabolic processes of enzymes and minerals in animals**WHO, 1998**. In study by **Devirian and Volpe, 2003** pointed that boron may have role in metabolism because it activates some important enzymes, it increase activity of Lactate Dehydrogenase enzyme (LDH) and Creatine Kinase enzyme (CK) as pointed by **Eren*et al*., 2012a**. The important role ascribed to the CK and its ability to stimulate the conversion of ADP to ATP, an important energy for muscle **Kongas and VanBeek, 2015**, while LDH enzyme produce nicotinamide adenine dinucleotide NAD^+**Lemire*et al*., 2008**, an important coenzyme in metabolism **Lin and Guarente, 2003**. The improvement in BW may be due to antioxidant role of boron**Gregory and Kelly, 1997**who pointed that the increase concentration of boron led to an increase in activity of the superoxide dismutase (Sod), an antioxidant enzyme that remove the free radicals **Shahidi, 2008** and it converts the free radical (O_2^-) to hydrogen peroxide (H_2O_2) which is less dangerous **Ahl, 2010**,or maybe the improvement due to several studies indicated that boron increase concentration of testosterone and estrogen by increasing their process of manufacture **Devirian and Volpe, 2003**, testosterone helps to stimulate the production of proteins in the muscle and stimulate the secretion of growth factor similar to insulin-like growth factor IGF-1then increase muscle mass**Bhasin*et al*., 2001**. In study conducted by **Cinar*et al*. 2015**on the effect of boron on the thyroid activity, who stated that boronincreases the hormones thyroxineand triiodothyronine, these hormones are important in increasing the metabolism of energy and protein **Mullur,*et al*., 2014**.

Regarding tonano-boron which is the first time that using in chicken in doses (10, 20 and 40) mg/L of drinking water, the results showed improvement in growth and a significant increasein BW, BWG and FI, the group NB40 was higher BW and BWG in the 5th week than groups NB10 and NB20, while group NB10 was higher FI in the 2nd and 3th week.

Feed conversion ratio (FCR):

The current study showed there were no significant differences in FCRin the 1st and 3rd week (Table 6) but observed significant differences ($P \leq 0.05$) in the 2nd, 4th and 5th week, the group B20 was lower FCR in the 5th week followed by NB40, B10, NB10, NB20, B40 compared to the control groups. The results showed that the addition of boron and nano-boron led to improvement in FCR, regarding to boron these results are in agreement with **Bozkurt*et al*. 2012**who found that low doses of boron 30 and 60 mg/kg of diet improved FCR and concluded that the results obtained herein concerning feed conversion could be definitive of boron requirements in broiler diets based on maize and soybean meal. Similarly, **Küçükyilmaz*et al*.2017**reported that the basal diet supplemented with boron 20 mg/kg led to beneficial effect ($P<0.05$) in FCR between 1-42 days of age. **Sizmaz and Yildiz, 2014**also reported that inclusion boric acid 120 mg/kg of diet improved FCR during 1-42 days. The regulatory role of boron in metabolism of Ca, P and Mg **Chapin,*et al*., 1998**, energy-substrate metabolism, steroid hormones, immune system function and antioxidant defense systems may be partly responsible for this improvement **Hunt, 1998**. It is not clear that the improvement in FCR may be due to the increased nutrient which promoted by boron**Küçükyilmaz*et al*., 2017**. The improvement in feed conversion factor may be due to the role of boron in increase concentration of copper in the serum **Kurtoğlu*et al*., 2005**, boron prevents the loss of copper from the body and the latter contributes to increase the absorption of sugars and amino acids from the intestine and stimulate some digestive enzymes and thus increase metabolic process**Luo,*et al*., 2005**.

Regarding tonano-boron,the resultsreported that supplementation of nano-boronresulted in apositive effect on growth and a significant decreased inFCR, the group NB40 waslower FCR than groups NB10 and NB20 in the5th week.

IV. Conclusion

The present results indicated that supplementation of boron and nano-boron in drinking water of chickens cause improvement of growth performance.

Table 3 Body weight (gram) of different groups in different periods (mean±SE) of the experiment

The group	Mean ± SE				
	Week 1	Week 2	Week 3	Week 4	Week 5
B_{10}	113.05 ± 6.42 a	386.85 ± 12.68 a	661.28 ± 15.74 a	872.26 ± 19.04 ab	1324.00 ± 26.32 a
B_{20}	104.59 ± 6.96 a	367.51 ± 10.44 a	626.38 ± 13.97 a	858.53 ± 22.63 ab	1372.13 ± 19.05 a
B_{40}	104.61 ± 6.22 a	362.07 ± 10.32 a	621.35 ± 13.82 a	851.74 ± 18.26 ab	1242.79 ± 21.32 b
NB_{10}	110.59 ± 7.03 a	403.86 ± 15.49 a	656.37 ± 22.75 a	904.75 ± 25.67 a	1342.41 ± 16.26 a
NB_{20}	105.27 ± 5.33 a	377.05 ± 9.50 a	622.57 ± 14.09 a	859.55 ± 14.38 ab	1256.98 ± 22.74 b
NB_{40}	110.73 ± 7.57 a	377.55 ± 9.42 a	648.42 ± 12.85 a	894.84 ± 14.61 aa	1350.29 ± 25.08 a
C+	95.44 ± 4.26 a	385.10 ± 9.51 a	624.89 ± 20.17 a	847.68 ± 16.54 ab	1228.79 ± 20.61 b
C-	101.25 ± 6.32 a	353.65 ± 8.95 a	605.00 ± 17.92 a	805.65 ± 15.73 b	1037.20 ± 22.78 c
Level of sig.	NS	NS	NS	*	*
* (P≤0.05), NS: Non-significant. Means having with the different letters in same column differed significantly.					

Table 4 Weight gain (gm) of different groups in different periods (Mean± SE) of the experiment

The group	Mean ± SE				
	Week 1	Week 2	Week 3	Week 4	Week 5
B_{10}	75.52 ± 4.15 a	273.80 ± 11.43 a	264.51 ± 10.55 a	193.57 ± 7.65 b	451.73 ± 16.59 a
B_{20}	65.82 ± 2.93 a	262.92 ± 8.92 a	258.87 ± 10.64 a	232.15 ± 10.09 ab	513.59 ± 13.16 a
B_{40}	65.51 ± 2.88 a	257.46 ± 8.52 a	259.28 ± 13.61 a	230.38 ± 10.42 ab	391.05 ± 15.04 b
NB_{10}	69.51 ± 3.07 a	293.27 ± 10.44 a	252.51 ± 9.50 a	248.37 ± 11.07 a	437.64 ± 22.53 ab
NB_{20}	66.52 ± 2.76 a	271.77 ± 7.49 a	245.52 ± 12.82 a	236.97 ± 10.36 ab	397.42 ± 14.67 b
NB_{40}	68.95 ± 3.16 a	266.81 ± 10.56 a	270.86 ± 16.02 a	246.42 ± 9.54 a	455.44 ± 21.92 a
C+	57.44 ± 2.64 a	289.66 ± 11.08 a	239.78 ± 12.45 a	222.78 ± 11.30 ab	381.10 ± 15.37 b
C-	63.03 a 3.77	252.40 ± 10.06 a	251.35 ± 12.87 a	200.65 ± 9.54 b	231.55 ± 18.02 c
Level of sig.	NS	NS	NS	*	*
* (P≤0.05), NS: Non-significant. Means having with the different letters in same column differed significantly.					

Table 5 Feed Intake (gm) of different groups in different periods (Mean ± SE) of the experiment

The group	Mean ± SE				
	Week 1	Week 2	Week 3	Week 4	Week 5
B_{10}	106.10 ± 4.52 a	262.50 ± 8.47 a	369.23 ± 8.51 ab	394.73 ± 11.74 a	568.42 ± 15.21 a
B_{20}	113.89 ± 6.73 a	269.23 ± 6.55 a	369.23 ± 7.44 ab	384.61 ± 11.31 a	553.84 ± 11.94 a
B_{40}	111.92 ± 4.67 a	269.23 ± 6.94 a	369.24 ± 7.56 ab	384.61 ± 9.22 a	553.84 ± 11.57 a
NB_{10}	118.24 ± 8.05 a	283.78 ± 11.03 a	389.19 ± 9.42 a	405.40 ± 16.56 a	583.78 ± 20.43 a
NB_{20}	110.85 ± 6.46 a	262.50 ± 7.51 a	360.00 ± 9.03 ab	375.00 ± 9.50 a	540.00 ± 15.73 a
NB_{40}	108.97 ± 5.24 a	276.31 ± 7.93 a	378.95 ± 13.68 a	394.73 ± 12.19 a	568.42 ± 18.62 a
C+	96.94 ± 3.96 a	223.40 ± 5.35 b	336.17 ± 9.55 b	372.34 ± 9.42 a	564.89 ± 15.39 a
C-	103.02 ± 3.41 a	260.70 ± 7.26 a	360.00 ± 14.03 ab	375.00 ± 11.67 a	535.00 ± 18.62 a
Level of sig.	NS	*	*	NS	NS
* (P≤0.05), NS: Non-significant. Means having with the different letters in same column differed significantly.					

Table 6 Feed conversion ratio (kg) of different groups in different periods (Mean ± SE) of the experiment

The group	Mean ± SE				
	Week 1	Week 2	Week 3	Week 4	Week 5
B_{10}	1.404 ± 0.06 a	0.958 ± 0.02 ab	1.395 ± 0.06 a	2.039 ± 0.09 a	1.258 ± 0.05 bc
B_{20}	1.730 ± 0.08a	1.023 ± 0.02 a	1.426 ± 0.06 a	1.656 ± 0.06 b	1.078 ± 0.03 c
B_{40}	1.708 ± 0.05 a	1.045 ± 0.04 a	1.424 ± 0.04 a	1.669 ± 0.11 b	1.416 ± 0.09 b
NB_{10}	1.701 ± 0.03 a	0.967 ± 0.06 ab	1.541 ± 0.10 a	1.632 ± 0.06 b	1.333 ± 0.01 bc
NB_{20}	1.666 ± 0.01 a	0.965 ± 0.03 ab	1.466 ± 0.03 a	1.582 ± 0.08 b	1.358 ± 0.05 bc
NB_{40}	1.580 ± 0.04 a	1.035 ± 0.02 a	1.399 ± 0.02 a	1.601 ± 0.04 b	1.248 ± 0.02 bc
C+	1.687 ± 0.06 a	0.771 ± 0.02 b	1.401 ± 0.02 a	1.671 ± 0.05 b	1.482 ± 0.06 b
C-	1.637 ± 0.04 a	1.032 ± 0.02 a	1.432 ± 0.02 a	1.868 ± 0.04 ab	2.310 ± 0.06 a
Level of sig.	NS	*	NS	*	*

* ($P \leq 0.05$), NS: Non-significant.
Means having with the different letters in same column differed significantly.

Reference

[1] Hunt, C.D. and Idso, J.P. (1999). Dietary Boron as a physiological regulator of the normal inflammatory response: a review and current research progress. Journal Trace Elements Experimental Medicine, 12:221-233.

[2] Hunt, C.D. (2012). Dietary boron: progress in establishing essential roles in human physiology. Journal Trace Elem Med Bio, 26: 157-160.

[3] Nielsen, F.H. (1992): Fact and fallacies about boron. Nutrition Today, May/June, pp. 6±12.

[4] Wilson, J.H. and Ruszler, L. (1997). Effects of boron on growing pullets. Biological Trace Element Research, 56: 287-294.

[5] WHO (1998). International program on chemical safety, Environmental health criteria 204, Boron, Ohio, USA. pp. 1-20.

[6] NRC, B. (1994). National Research Council. Nutrients requirements of poultry. 9th edition, National Academic of Sciences Press, Washington, D.C. pp. 15.

[7] Akhilesh, K.; Verma, V.P.; Singh H. and Pathak V. (2012). Application of Nanotechnology as a Tool in Animal Products Processing and Marketing: An Overview. American Journal of Food Technology, 7: 445-451.

[8] Chakravarthi, V.P. and Balaji, N.S. (2010). Applications of nanotechnology in veterinary medicine. Vet. World, 3: 477-480.

[9] Pesti, G.M.; Miller, B.R. and Hargrave, J. (2002). User-Friendly Feed Formulation, Done Again (UFFDA). University of Georgia. Physiological effects. Crit. Rev. Food Sci. Nutr., 47:735-748.

[10] Kasper, J.S.; Lucht, C.M.; and Harker, D. (1950). "The Crystal Structure of Decaborane, $B_{10}H_{11}$." ActaCryst. 3, 436-455.

[11] Morgan, J.T. and Lewis, D. (1962). Nutrition of pigs and poultry. Butterworths, (8): 465-470.

[12] Al-Zubayedi, S.S.A. (1986). Poultry management. First ed., the College of Agriculture. Basra University .associated with the aflatoxin bio synthetic pathway, Bioorganic Chemistry,33: 426-438.

[13] SAS. (2012). Statistical Analysis System, User's Guide. Statistical. Version 9.1th ed. SAS. Inst. Inc. Cary. N.C. USA.

[14] Duncan, D.B. (1955). Multiple Rang and Multiple F-test. Biometrics. 11: 4-42.

[15] Al-Hamdani, S. A. J. (2016). Effect of adding different levels of boric acid as a source of boron to the diet on productive and some physiological traits of broiler chickens. University of Baghdad-College of Agriculture. M. Sc. in animal production.

[16] Jin, E.; Gu, Y.; Wang, J.; Jin, G. and Li, S. (2014). Effect of supplementation of drinking water with different levels of boron on performance and immune organ parameters of broilers. Italian Journal of Animal Science, 13: 205-213.

[17] Sizmaz, O. and Yildiz, G. (2014). Effects of single or combined dietary supplementation of boric acid and ascorbic acid on growth performance, bone mineralization and cholesterolemia in broilers. Inter Journal Agriculture Bioscience, 3(5): 214-218.

[18] Lin, L.U. and Ying, Y.U. (2003). Effects of boron on the performance and deposition of boron in tissue and organs of broilers [J] China, ActaZoonutrimentaSinica: 01.

[19] Eren, M. Uyanik, F.; Kocaogluguclu, B. and cinarM. (2012). Effects of dietary boric acid and borax supplementation on growth performance and some biochemical parameters in broilers. Revue de médecinevétérinaire.163(11): 546-55.

[20] Fassani, E. J.; Bertechini, A. G.; Brito, J. A. G.; Kator, K.; Fialhoe, T. and Geraldo, A., (2004). Boron supplementation in broiler diets. Brazilian Journal Poultry Science, 4: 213-217.

[21] Devirian, T. A. and Volpe, S. L. (2003). The physiological effects of dietary boron. Crit. Rev. Food Science, 43: 219-231.

[22] Eren, M.; Uyanik, F. Guclu B. K. and Atasever, A. (2012a). The Influence of Dietary boron supplementation on performance, some biochemical parameters and organs in broilers. Asian Journal of Animal and Veter. Adv. 7: 1079 – 1089.

[23] Kongas, O. and Van Beek, J.H. (2015).Creatine kinase in energy metabolic signaling in muscle. http://www.icsb-2001.org/Papers/08-Kongas-Paper.pdf. data of access: 14/10/2015.

[24] Lemire, J.; Mailloux R.J. and Appanna, V.D. (2008). Mitochondrial lactate dehydrogenase is involved in oxidative-energy metabolism in human astrocytoma cells (CCF-STTG1). PLoS ONE 3(2): e1550.

[25] Lin, S. and Guarente, L. (2003). Nicotinamide adenine dinucleotide, a metabolic regulator of transcription, longevity and disease. Current Opinion in Cell Biology. 15: 241–246.

[26] Gregory, S. and Kelly N. D. (1997). Boron: A Review of its Nutritional Interactions and Therapeutic Uses. Alternative. Medicine. Review. 2: 48 – 56.

[27] Shahidi, F. (2008). Antioxidants: Extrication, Application and Efficacy Measurement Ejeaf. Che. 7: 3325 – 3330.

[28] Ahl, I. M. (2010). Protein Engineering of Extracellular Superoxide Dismutase.Division of Cell Biology, Department of Clinical and Experimental Medicine, Faculty of Health Sciences, Linkoping University. No. 1159.

[29] Bhasin, S., Woodhouse L. and Storer, T.W. (2001). Proof of the effect of testosterone on skeletal muscle. Journal of Endocrinology. 170: 27 – 38.

[30] Cinar, M.; Kucukyilmaz, K.; Bozkurt, M.; Catli, A. U.; Bintas, E.; Aksit, H.; Konak, R.; Yamaner, C. and Seyrek, K. (2015). Effects of dietary boron and phytase supplementation on growth performance and mineral profile of broiler chickens fed on diets adequate or deficient in calcium and phosphorus. Br. Poultry Science, 56 (5): 576 – 589.

[31] Mullur, R.; Liu Y.Y. and Brent, G.A. (2014). Thyroid Hormone Regulation of Metabolism. Physiol. Rev. 94: 355–382.

[32] Bozkurt, M.; Kucukyilmaz, K.; Cath, U. A.; Cinar, M.; Cabuk, M. and Bintas, E. (2012). Effects of boron supplementation to diets deficient in calcium and phosphorus on performance with some serum, bone and fecal characteristics of broiler chickens. Asian – Aust. Journal Animal Science, 25: 248 – 255.

[33] Küçükyilmaz, K.; Bozkurt, M.; Çınar, M. and Tüzün, A. E. (2017). Evaluation of the Boron and Phytase, Alone or in Combination, in Broiler Diets. The Journal of Poultry Science, 54(1): 26-33.

[34] Chapin, R.E.; Ku, W.W.; Kenney, M.A. and McCoy, H. (1998). The effects of dietary boric acid on bone strength in rats. Biological Trace Element Research, 66: 395-399.

[35] Hunt, C.D. (1998). One possible role of dietary boron in higher animals and humans, Biological Trace Element Research, 66: 205-225.

[36] Kurtoğlu, F.; Kurtoğlu, V., Çelik, İ., Keçeci, T. and Nizamlıoğlu, M. (2005). Effects of dietary boron supplementation on some biochemical parameters, peripheral blood lymphocytes, splenic plasma cells and bone characteristics of broiler chicks given diets with adequate or inadequate cholecalciferol (vitamin D3) content. Br. Poultry Science, 46: 87-96.

[37] Luo, X.G.; Ji, F.; Lin, Y.X.; Steward, F.A.; Lu, L.; Liu B. and Yu, S.X. (2005). Effect of dietary supplementation with copper sulfate or tribasic chloride performance, relative copper bioavailability, and oxidation stability of vitamin E in feed. Poultry Sci. 84: 888 – 893.

Thukra Mahdi Mousaand Balqees Hassan Ali "Effect of boron and nano-boron on growth performance of broiler chicks" IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 11.3 (2018): 18-23.