International Journal of Livestock Research, Vol. 10 (9) Sep' 2020
http://www.ijlr.org
eISSN: 2277-1964
NAAS Rating 2020 – 5.36

Original Research

Effect of Dietary Supplementation of Organic Chromium on Carcass Characteristics and Haemato-Biochemical Profile in Broiler Chickens

S. P. Trivedi[1], S. S. Patil[2]*, D. D. Garg[1], H. H. Savsani[1], M. M. Pawar[2], V. K. Singh[1], J. A. Chavda[1] and P. C. Boradiya[1]

[1]Department of Animal Nutrition, College of Veterinary Science and Animal Husbandry, Junagadh Agricultural University, Junagadh, Gujarat, INDIA
[2]Department of Animal Nutrition, College of Veterinary Science and Animal Husbandry, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, INDIA

*Corresponding Author: drsrpatt@gmail.com

How to cite this paper: Trivedi, S. P., Patil, S. S., Garg, D. D., Savsani, H. H., Pawar, M. M., Singh, V. K., Chavda, J. A. & Boradiya, P. C. Effect of Dietary Supplementation of Organic Chromium on Carcass Characteristics and Haemato-Biochemical Profile in Broiler Chickens. *International Journal of Livestock Research*, 10(9), 105-112. doi: http://dx.doi.org/10.5455/ijlr.20200508055030

Received : May 08, 2020
Accepted : Jul 05, 2020
Published : Sep 30, 2020

Abstract

A study was conducted to evaluate the effect of dietary supplementation of organic chromium on carcass characteristics and haemato-biochemical profile in broiler chickens. Day old, 200 broiler chicks were divided into four treatment groups with replicates of 10 chicks in each and were assigned into four iso-nutritive diets, viz., T1: Control diet (feed without organic chromium (CrPro) supplementation), T2: Control diet supplemented with CrPro @ 400 µg/kg feed, T3: Control diet supplemented with CrPro @ 800 µg/kg feed and T4: Control diet supplemented with CrPro @ 1200 µg/kg feed. The feeding experiment was carried out for 42 days. Dietary supplementation of organic chromium in broiler chicken diet had non-significant (P>0.05) effect on carcass traits, dressing percentage and weights of liver, heart, gizzard, kidney and spleen in broiler chickens. No significant (P>0.05) effect was found in levels of haemoglobin, packed cell volume, total leukocyte count and total erythrocyte count by the organic chromium supplementation. Significant (P<0.05) reduction in concentrations of serum glucose, triglycerides and total cholesterol were observed in organic chromium supplemented groups. Based on results, it was concluded that organic chromium supplementation in broiler chickens reduced serum levels of glucose, triglycerides and total cholesterol, but did not affect carcass traits and haemato-biochemical parameters.

Keywords: Broiler Chickens, Carcass Traits, Haemato-Biochemical Organic Chromium, Profile

Introduction

Chromium is one of the essential minerals, which is required for enhancing production performance in poultry because of its important functions in digestion, growth and reduction in serum lipids and protein peroxidation (Farag *et al.*, 2017). The most common chromium forms used as supplements to poultry and animal diets are chromium picolinate, chromium nicotinate, chromium tri-picolinate, chromium yeast, chromium propionate and chromium tri-chloride (Abd El-Mageed *et al.*, 2016). Chromium is employed in food, feed and pharmaceutical purposes owing to its role in nutrient metabolism such as proteins, carbohydrates, fats, amino acids and nucleic acids (Anandhi *et al.*, 2006). Chromium was proposed to be a proactive piece of a bio-molecule called chromodulin, which is a piece of the insulin flagging pathway and seems to influence sugar and lipid digestion (Vincent, 2000). The essential part of chromium in digestion is to potentiate the activity of insulin through an organo-metallic particle called glucose resistance factor (Kegley and Spears, 1995). Immunological capacity upgrades by trivalent chromium and its belongings appear to be more articulated amid the seasons of stress (Borgs and Mallard, 1998). Supplemental dietary chromium as chromium picolinate alters glucose metabolism (Haq *et al.*, 2018). In addition, supplementation of chromium increased serum total protein, albumin and insulin, but corticosterone and cholesterol concentrations were decreased in blood. Reduction in corticosterone has positive effect in broilers by increasing the carcass quality since corticosterone can affect protein synthesis in the muscles (Sahin *et al.*, 2005).

Organic chromium sources have shown better beneficial impacts on heat-stressed birds in comparison with inorganic sources due to their increased absorption and bioavailability (Moeini *et al.*, 2011). Recent studies (Farag *et al.*, 2017; Haq *et al.*, 2017; Kulkarni *et al.*, 2018; Ezzat *et al.*, 2018; Kashyap *et al.*, 2018; Trivedi *et al.*, 2019) have reported that dietary supplementation of organic chromium in the diet of chicken improved growth performance, carcass characteristics, blood metabolic profile and immune response. Therefore, the present study was conducted to assess the effect of dietary supplementation of organic chromium on carcass characteristics and haemato-biochemical profile in broiler chickens.

Materials and Methods

Location of Study

The present experiment was carried out at Poultry unit of Instructional Livestock Farm Complex, College of Veterinary Science and Animal Husbandry, Junagadh Agricultural University, Junagadh. It is located on the West Coast of India in Gujarat State and lies between 20' 30' to 23° N latitude and 69° to 72° E longitude.

Birds and Experimental Design

Total 200 day-old broiler chicks of Vencobb 400 strain were wing banded and distributed randomly into four groups having five replicates of 10 birds in each by completely randomized design and were assigned to four iso-nutritive diets, *viz.*, T_1: Control diet (feed without organic chromium (CrPro) supplementation), T_2: Control diet supplemented with CrPro @ 400 µg/kg feed, T_3: Control diet supplemented with CrPro @ 800 µg/kg feed and T_4: Control diet supplemented with CrPro @ 1200 µg/kg feed. The feeding experiment was carried out for 42 days. Organic chromium (KEMTRACE Chromium dry powder) was procured from Kemin Industries South Asia Pvt. Ltd., Chennai, India. Diets were formulated as BIS (2002) specifications. Ingredients composition of starter and finisher broiler ration are presented in Table 1. Representative samples of feeds were analyzed for proximate composition using standard methods of AOAC (1999). The experimental birds were reared under standard management conditions.

Carcass Traits

On the 42^{nd} day of age, ten birds per treatment were randomly selected as per body weight closer to mean and slaughtered to study the carcass characteristics. The birds were kept off feed for eight hours prior to slaughter but drinking water was offered to them. The carcass parameters like dressing percentage, heart, liver, kidney, spleen and empty gizzard weight was recorded and expressed as % of live weight.

Table 1: Ingredients composition of feed

Ingredients	Broiler Starter (kg)	Broiler Finisher (kg)
Maize	61	64
Soybean meal	33.27	28.4
Calcite powder	1.25	1.25
DCP	1	1
Vitamins	0.05	0.05
Vitamin B_{12}	0.01	0.01
Trace minerals	0.1	0.1
Choline Chloride 60%	0.1	0.1
Lysine	0.25	0.16
Methionine	0.18	0.15
Phytase	0.01	0.01
Enzyme	0.05	0.05
Salt	0.1	0.1
Sodium Bicarbonate	0.36	0.35
Liver Tonic	0.1	0.1
Immuno-modulator	0.05	0.05
Toxin Binder	0.1	0.1
Growth promoter	0.02	0.02
Anti-coccidial	0.05	0.05
Emulsifier	0.05	0.05
Oil	1.9	3.9
Total (Kg)	100	100

Haemato-Biochemical Parameters

Blood was collected randomly from ten birds from each treatment (two birds from each replicate) at the end of 6th week. Blood was collected from the wing vein into labeled vial containing sodium ethylene diamine tetra acetic acid (Na-EDTA) as anticoagulant for estimation of hematological parameters. Haemoglobin (Hb) was estimated by Sahli's acid hematin method, packed cell volume (PCV) by micro hematocrit method, while total leukocyte count (TLC)and total erythrocyte count (TEC) were recorded using hemocytometer (Samour, 2006). For estimation of biochemical parameters blood samples were also collected in another set of labeled vials without anticoagulant for the separation of serum. Serum was separated by centrifugation of coagulated blood at 3000 rpm for 10 minutes for the determination of aspartate amino transferase, alanine amino transferase, glucose, triglycerides and total cholesterol in serum biochemical analyzer (Dia-CHEM 240 Plus) using diagnostic kits.

Statistical Analysis

The data were subjected to statistical analysis using one-way ANOVA as described by Snedecor and Cochran (1994). The significance of mean difference was tested by Tukey (1949) post hoc test.

Results and Discussion

Proximate Composition of Feed

The proximate composition of feed offered to the bird during starter and finisher phase is given Table 2. The crude protein (CP) content (%) of starter and finisher feed was 22.30 to 22.44 and 20.21 to 20.47 as per the recommendations of BIS (2002). All other nutrients were also within in the prescribed limit of BIS (2002) specification.

Table 2: Proximate composition of experimental feeds (on % DM Basis)

Nutrient	Treatments							
	Starter Feed				Finisher Feed			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
DM	89.9	90.26	89.46	90	90.86	89.73	89.93	90.03
OM	93	92.6	92.6	92.5	92.8	93.1	92.7	92.4
CP	22.44	22.31	22.44	22.3	20.21	20.42	20.21	20.47
EE	4.33	5.33	4.49	4.49	4.5	4.99	4.16	4.99
CF	4.25	3.75	3.75	4.25	3	3	3.25	2.75
NFE	61.98	61.21	61.92	61.46	65.09	64.69	65.08	64.19
TA	7	7.4	7.4	7.5	7.2	6.9	7.3	7.6
Ca	0.92	0.95	0.94	0.93	0.98	0.93	0.97	0.95
P	0.46	0.51	0.53	0.52	0.53	0.51	0.52	0.54

EE: Ether extract, DM: Dry matter, OM: Organic matter, CP: Crude protein, CF: Crude fiber, NFE: Nitrogen free extract, TA: Total ash, Ca: Calcium, P: Phosphorus

Carcass Characteristics

Evaluation of carcass characteristics in broiler production is of prime importance along with the economic traits like gain in weight, feed consumption, feed conversion ratio, etc. Average values of live weight, dressed weight, dressing per cent and liver, heart, gizzard, kidney and spleen weights are shown in Table 3. Results revealed non-significant (P>0.05) effect of organic chromium supplementation on dressing percentage and weight of different organs (liver, heart, gizzard, kidney and spleen) as compared to the control.

Table 3: Effect of dietary supplementation organic chromium on carcass characteristics of broiler chickens

Parameters	Treatments				SEM	P value
	T_1	T_2	T_3	T_4		
Live weight (g)	2148.80±52.11	2240.00±63.17	2208.40±103.58	2219.80±61.72	768.63	0.83
Dressed weight (g)	1499.80±43.04	1577.80±44.96	1595.00±71.24	1657.20±56.72	209.96	0.28
Dressing per cent (%)	69.90±2.19	70.44±0.50	72.26±0.45	74.61±0.63	22.55	0.06
Liver weight (g)	32.40±0.80	34.70±0.78	33.50±1.38	37.00±1.92	19.43	0.11
Heart weight (g)	8.70±0.64	9.90±0.48	10.70±1.10	11.10±0.51	5.6	0.13
Gizzard weight (g)	51.00±2.28	52.20±3.14	48.70±3.21	53.40±1.84	20.11	0.64
Kidney weight (g)	9.76±0.26	10.50±0.55	10.70±0.30	11.10±0.22	1.58	0.09
Spleen weight (g)	3.20±0.38	2.80±0.25	2.80±0.20	3.30±0.37	0.35	0.54

NS = Non-significant

The results observed in present study are corroborated with the findings of Mohammed *et al.* (2014), Huang *et al.* (2016), Zheng *et al.* (2016), Xiao *et al.* (2017),Haq *et al.* (2017) and Kulkarni *et al.* (2018) who reported non-significant (P>0.05) effect of organic chromium supplementation in broiler chickens on carcass characteristics. However, Samanta *et al.* (2008) and Ebrahimzadeh *et al.* (2013) found contrary results as compared to present findings. Moreover, Sahin *et al.* (2003) reported that dietary addition of Cr was beneficial to augment the relative yields of liver, heart, spleen and gizzard. Further, Guo *et al.* (1999) revealed that supplemental Cr as Cr-yeast and Cr-chloride (2.0 and 10.0 mg/kg diet respectively) had positive effect on meat yield. Similarly, Chen *et al.* (2001) accounted that Cr supplementation significantly increases the breast and thigh muscle yield.

Haemato-Biochemical Profile

Haemato-biochemical parameters are given in Table 4. Statistical analysis of Hb and PCV values of experimental birds showed non-significant (P>0.05) difference among the different treatment groups. The parameters Hb and PCV are indicators of erythrocytes' normalcy and general well beings of birds. Levels of Hb and PCV value of experimental birds observed in the present study were within the normal physiological range for poultry (Onyishi *et al.*, 2017). The feeding of organic chromium in broiler diet did not have any adverse effect on the hematological parameters. The TEC and TLC values of experimental birds showed non-significant (P>0.05) difference among different treatment groups. Non-significant effect of organic chromium in present study haematological parameters such as Hb, PCV, TEC and TLC is supported by Toghyani *et al.* (2012) who reported non-significant ($P>0.05$) effect of chromium supplementation on haematological parameters of broilers. Whereas, Toghyani *et al.* (2006) reported that value of Hb was significantly ($P<0.05$) higher in treatment groups as compared to control by supplementation of chromium picolinate as contrary to present findings.

Table 4: Effect of dietary supplementation organic chromium on haemato-biochemical profile of broiler chickens

Parameters	Treatments				SEM	P value
	T_1	T_2	T_3	T_4		
Hb (g/dL)	10.84±0.22	11.83±0.49	12.15±0.45	12.35±0.38	2.25	0.07
PCV (%)	30.10±0.93	29.70±1.19	30.90±1.70	30.10±1.58	1.27	0.93
TEC (x 10^6 /µL)	2.73±0.20	2.77±0.18	3.13±0.17	2.92±0.15	0.16	0.39
TLC (x 10^3 /µL)	28.00±0.89	28.27±1.06	28.11±1.03	29.15±1.24	1.37	0.86
AST (IU/L)	350.17±9.65	353.82±7.80	356.74±9.13	363.24±9.55	152.74	0.77
ALT (IU/L)	6.34±0.44	6.32±0.72	6.24±0.62	6.36±0.66	0.0134	0.99
Glucose (mg/dL)	257.90^c±9.91	253.20^b±1.97	246.32^b±2.25	235.60^a±2.69	468.95	0.04
Triglycerides (mg/dL)	83.90^a±1.30	79.10^b±1.90	75.00^{ab}±1.41	71.40^c±2.40	144.81	0.001
Total cholesterol (mg/dL)	170.80^a±2.47	168.00^b±2.74	160.80^{ab}±4.42	154.80^b±2.27	260.8	0.009

Means within a row bearing different superscripts differ significantly.

The AST and ALT values of experimental birds showed non-significant ($P>0.05$) difference among different treatment groups. Serum AST activity is present in both in cytoplasm and mitochondria and thus enzyme is released even by mild degenerative changes that occur in acute and occasionally in chronic liver diseases but remarkably higher values are recorded in muscle damage (Cruz *et al.*, 2018). The activity of AST and ALT is an indicator of damage to liver and muscles (Cruz *et al.*, 2018). However, activities of both AST and ALT in the present study did not show any adverse effect of supplementation organic chromium as a feed additive in the diets of broilers. Results revealed significant ($P<0.05$) reduction in serum glucose level of birds due to organic chromium supplementation. Serum glucose level in T4 group significantly ($P<0.05$) lowered as compared to the control group. In the present study, decreased glucose concentration serves as evidence that chromium is essential for normal glucose metabolism, work with insulin to move glucose into cells for glucose utilization (Colgan, 1993). Cupo and Donaldson (1987) reported that chromium supplementation (20 ppm of $CrCI_3.6H_2O$) increased the rate of glucose utilization by 16%. Steele and Rosebrough (1981) reported that turkeys fed a diet supplemented with chromium had greater liver glycogen levels as a result of increasing activity of the enzyme glycogen synthase and that chromium supplementation increased glucose transport by increasing insulin activity. In the agreement with present findings, Patil *et al.* (2008), Al-Bandr *et al.* (2010), Mohammed *et al.* (2014), Sathyabama *et al.* (2017) and Haq *et al.* (2018) also reported significant ($P<0.05$) reduction in glucose values on supplementation of chromium in broiler diets. Whereas, Sahin *et al.* (2002) and Moeini *et al.* (2011) reported contrast results as compared to present findings.

The triglycerides and total cholesterol values showed significant ($P<0.05$) difference among the experimental groups. Significantly ($P<0.05$) lowest values of triglycerides and total cholesterol were found in T_4 group, followed by T_3, T_2 and T_1 groups. Chromium favors the interactions between insulin and its specific receptors located in target organs such as muscles and fat tissue (Moorandian and Morley, 1987) which might have led to lower triglycerides and cholesterol levels in chromium supplementation groups. Lower cholesterol values were found due to the fact that Cr improves lipoprotein lipase and lecithin cholesterol acyltransferase activity which in turn accelerated cholesterol esterification and excretion (Brindley and Salter, 1991). In line with the present findings, Bakhiet and Elbadwi (2007), Sathyabama *et al.* (2017) and Haq *et al.* (2018) also reported significant ($P<0.05$) decline in serum triglycerides level on supplementation of chromium in broiler diets. Whereas, Al-Bandr *et al.* (2010) and Xiao *et al.* (2017) reported contrast results in comparison with present findings. Regarding total cholesterol, Bakhiet and Elbadwi (2007), Patil *et al.* (2008), Al-Bandr *et al.* (2010), Mohammed *et al.* (2014) and Haq *et al.* (2018) reported similar significant ($P<0.05$) reduction in total cholesterol on supplementation of chromium in broiler diets. Whereas, Suksombat and Kanchanatawee (2005), Sathyabama *et al.* (2017) and Xiao *et al.* (2017) reported contrary results as compared to present findings.

Conclusion

Based on the findings, it was concluded that organic chromium supplementation in broiler chickens reduced serum levels of glucose, triglycerides and total cholesterol, indicating the positive health-effects. However, supplementation of organic chromium did not have any impact on carcass traits and haematological parameters in broilers.

Acknowledgements

The authors acknowledge the facilities and financial support provided for the present study from Director of Research, Junagadh Agricultural University, Junagadh, Gujarat, India.

Conflict of Interests

There is no conflict of interest.

Publisher Disclaimer

IJLR remains neutral concerning jurisdictional claims in published institutional affiliation.

References

1. Abd El-Mageed, M. A., Khalifa, M. A., Abd El-Azeem, A. M. and Bahnas, M. S. (2016). Effect of dietary organic chromium supplementation on growth performance of broiler during summer season in Egypt. *Egyptian Poultry Science Journal*, 36(4), 1075-1085.
2. Al-Bandr, L. K., Ibrahim, D. K. and Al-Mashhadani, E. H. (2010). Effect of supplementing different sources of Chromium to diet on some physiological traits of broiler chickens. *Egyptian Poultry Science*, 30(2), 397-413.
3. Anandhi, M., Mathivanan, R., Viswanathan, K. and Mohan, B. (2006). Dietary inclusion of organic chromium on production and carcass characteristics of broilers. *International Journal of Poultry Science*, 5(9), 880-884.
4. AOAC. (1999). Official methods of analysis. 5th edition. Association of Official Analytical Chemists (AOAC), Washington D. C., USA.
5. Bakhiet, A. O. and Elbadwi, S. M. A. (2007). Effects of dietary chromium supplementation on the performance and some serum parameters in bovans-type chicks. *Journal of Pharmacology and Toxicology*, 2(4), 402-406.
6. BIS. (2002). Nutrient requirements for poultry. In: 9863-1992 (Reaffirmed 2002), Bureau of Indian Standards, First revision. Manak Bhawan, 9, Bahadur Shah Zafar Marg, New Delhi, India.
7. Borgs, P. and Mallard, B. A. (1998). Immune-endocrine interactions in agricultural species: chromium and its effect on health and performance. *Domestic Animal Endocrinology*, 15(5), 431-438.
8. Brindley, D. N. and Salter, A. M. (1991). Hormonal regulation of the hepatic low density lipoprotein: relationship with the secretion of very low density lipoprotein. *Journal of Lipid Research*, 30, 349-360.
9. Chen, K. L., Lu, J. J., Lien, T. F. and Chiou, P. W. S. (2001). Effects of chromium nicotinate on performance, carcass characteristics and blood chemistry of growing turkeys. *British Poultry Science*, 42, 399-404.
10. Colgan, M. (1993). Chromium boosts insulin efficiency. In: Optimum Sports Nutrition. Advanced Research Press. New York. pp: 313-320.
11. Cruz, C. E. B., Freitas, E. R., Braz, N. D. M., Salles, R. P. R. and Silva, I. N. G. D. (2018). Blood parameters and enzymatic and oxidative activity in the liver of chickens fed with calcium anacardate. *Revista Ciência Agronômica*, 49(2), 343-352.
12. Cupo, M. A. and Donaldson, W. E. (1987). Chromium and vanadium effects on glucose metabolism and lipid synthesis in the chick. *Poultry Science*, 66(1), 120-126.
13. Ebrahimzadeh, S., Farhoomand, P. and Noori, K. (2013). Effects of chromium methionine supplementation on performance, carcass traits, and the Ca and P metabolism of broiler chickens under heat-stress conditions. *Journal of Applied Poultry Research*, 22(3), 382-387.
14. Ezzat, W., Abdallah, E. A., Rizk, A. M., Ouda, M. M. M. and El-krim, R. E. A. (2018). The effect of chromium picolinate supplementation on immune response and heat shock proteins of laying hens under heat stress conditions. *Egyptian Poultry Science Journal*, 38(1), 65-89.

15. Farag, M. R., Alagawany, M., Abd El-Hack, M. E., Arif, M., Ayasan, T., Dhama, K. and Karthik, K. (2017). Role of chromium in poultry nutrition and health: beneficial applications and toxic effects. *International Journal of Pharmacology*, 13(7), 907-915.
16. Guo, Y. L., Lou, X. G., Hao, Z. L., Liu, B., Chen, J. L., Gao, F. S. and Yu, S. X. (1999). Effect of chromium on growth performance, serum biochemical traits immune functions and carcass quality of broiler chickens. *Scientia Agricultura Sinica*, 32, 79-86.
17. Haq, Z., Jain, R., Farooq, J., Ganai, I. A., Gull, G. and Khan, N. (2017). Effect of dietary supplementation of chromium yeast alone and in combination with antioxidants on performance of broilers. *Journal of Animal Health and Production*, 5(4), 159-164.
18. Haq, Z., Jain, R., Mahajan, A., Ganai, I. A., Khan, N. and Mudasir, S. (2018). Dietary supplementation of chromium yeast alone and in combination with antioxidants for designing broiler meat. *Journal of Entomology and Zoological Studies*, 6(1), 766-770.
19. Huang, Y., Yang, J., Xiao, F., Lloyd, K. and Lin, X. (2016). Effects of supplemental chromium source and concentration on growth performance, carcass traits, and meat quality of broilers under heat stress conditions. *Biological Trace Element Research*, 170(1), 216-223.
20. Kashyap, S., Shukla, P., Bhattacharyya, A. and Sirohi, R. (2018). Effect of dietary supplementation of graded levels of chromium picolinate on the production performance, immune competence traits, development of digestive organs and carcass quality traits of coloured chicken. *International Journal of Livestock Research*, 8(4), 65-70.
21. Kegley, E. B. and Spears, J. W. (1995). Immune response, glucose metabolism, and performance of stressed feeder calves fed inorganic or organic chromium. *Journal of Animal Science*, 73(9), 2721-2726.
22. Kulkarni, R., Mandal, A., Bhanja, S., Goel, A. and Mehara, M. (2018). Dietary Supplementation of chromium picolinate on productive performance and cost economics of coloured broiler chicken during hot-humid summer. *International Journal of Livestock Research*, 8(10), 132-139.
23. Moeini, M. M., Bahrami, A., Ghazi, S. and Targhibi, M. R. (2011). The effect of different levels of organic and inorganic chromium supplementation on production performance, carcass traits and some blood parameters of broiler chicken under heat stress condition. *Biological Trace Element Research*, 144(1-3), 715-724.
24. Mohammed, H. H., El-Sayed, B. M., Abd El-Razik, W. M., Ali, M. A. and Abd El-Aziz, R. M. (2014). The influence of chromium sources on growth performance, economic efficiency, some maintenance behaviour, blood metabolites and carcass traits in broiler chickens. *Global Veterinaria*, 12(5), 599-605.
25. Mooradian, A. D. and Morley, J. E. (1987). Micronutrient status in diabetes mellitus. *The American Journal of Clinical Nutrition*, 45(5), 877-895.
26. Onyishi, G. C., Oguine, C. C., Nwani, S. I., Aguzie, I. O. and Nwani, C. D. (2017). Haematological parameters dynamics of developing *Gallus gallus domesticus*. *Animal Research International*, 14(2), 2769-2776.
27. Patil, A., Palod, J., Singh, V. S. and Kumar, A. (2008). Effect of graded levels of chromium supplementation on certain serum biochemical parameters in broilers. *The Indian Journal of Animal Sciences*, 78(10), 1149-1152.
28. Sahin, K., Sahin, N. and Kucuk, O. (2003). Effects of chromium and ascorbic acid supplementation on growth, carcass traits, serum metabolites, and antioxidant status of broiler chickens reared at a high ambient temperature. *Nutrition Research*, 23, 225-238.
29. Sahin, K., Sahin, N., Onderci, M., Gursu, F. and Cikim, G. (2002). Optimal dietary concentration of chromium for alleviating the effect of heat stress on growth, carcass qualities, and some serum metabolites of broiler chickens. *Biological Trace Element Research*, 89(1), 53-64.
30. Samanta, S., Haldar, S., Bahadur, V. and Ghosh, T. K. (2008). Chromium picolinate can ameliorate the negative effects of heat stress and enhance performance, carcass and meat traits in broiler chickens by reducing the circulatory cortisol level. *Journal of the Science of Food and Agriculture*, 88(5), 787-796.
31. Samour, J. (2006). Diagnostic value of hematology. În: Clinical Avian Medicine. GJ Harrison and TL Lightfoot. Spix Publishing: Palm Beach, FL. pp. 587-607.
32. Sathyabama, T., Nanjappan, K., Ravi, R., Jagadeeswaran, A. and Visha, P. (2017). Effect of Various Forms of Chromium Supplementation on Growth Performance, Blood Biochemical Constituents of Broiler Chickens. *Indian Veterinary Journal*,94(3), 22-24.
33. Snedecor, G. W. and Cochran, W. G. (1994). Statistical Methods. 8th (ed.) Oxford and IBH Publishing Co. Calcutta, India.
34. Steele, N. C. and Rosebrough, R. W. (1979). Trivalent chromium and nicotinic acid supplementation for the turkey poult. *Poultry Science*, 58(4), 983-984.

35. Suksombat, W. and Kanchanatawee, S. (2005). Effects of various sources and levels of chromium on performance of broilers. *Asian-Australasian Journal of Animal Sciences*, 18(11), 1628-1633.
36. Toghyani, M., Shivazad, M., Gheisari, A. A. and Zarkesh, S. H. (2006). Performance, carcass traits and hematological parameters of heat-stressed broiler chicks in response to dietary levels of chromium picolinate. *International Journal of Poultry Science,* 5(1), 65-69.
37. Toghyani, M., Toghyani, M., Shivazad, M., Gheisari, A. and Bahadoran, R. (2012). Chromium supplementation can alleviate the negative effects of heat stress on growth performance, carcass traits, and meat lipid oxidation of broiler chicks without any adverse impacts on blood constituents. *Biological Trace Element Research*, 146(2), 171-180.
38. Trivedi, S. P., Patil, S. S., Garg, D. D., Savsani, H. H., Pawar, M. M. and Gohel, B. C. (2019). Effect of dietary supplementation of organic chromium on feed intake, growth performance and economics in commercial broiler chickens. *Journal of Entomology and Zoology Studies*, 7(2), 374-378.
39. Tukey, J. W. (1949). Comparing individual means in the analysis of variance. *Biometrics*, 5(2), 99-114.
40. Vincent, J. B. (2000). The biochemistry of chromium. *The Journal of Nutrition*, 130(4), 715-718.
41. Xiao, F., Ao, D., Zhou, B., Spears, J. W., Lin, X. and Huang, Y. (2017). Effects of supplemental chromium propionate on serum lipids, carcass traits, and meat quality of heat-stressed broilers. *Biological Trace Element Research*, 176(2), 401-406.
42. Zheng, C., Huang, Y., Xiao, F., Lin, X. and Lloyd, K. (2016). Effects of supplemental chromium source and concentration on growth, carcass characteristics, and serum lipid parameters of broilers reared under normal conditions. *Biological Trace Element Research*, 169(2), 352-358.

****