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Research Article

Effect of Dietary Supplementation of Chromium Yeast Alone and in Combination with Antioxidants on Performance of Broilers

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Abstract | The present study was conducted to evaluate the impacts of dietary supplementation of chromium yeast alone and in combination with antioxidants on growth, feed conversion and nitrogen retention in broilers during winter season. A total of 180, Cob-400 straight run broiler chicks at one day-old, were randomly distributed into four equal groups replicated three times with 15 birds per replicate. The treatments consisted of 4 experimental groups as follows: T_0, T_1, T_2 and T_3. Chicks were fed corn-soya based broiler mash (basal diet) maintained as control (T_0), the basal diet supplemented with chromium (Cr)at 0.5 mg Cr/kg diet from chromium yeast (T_1), the basal diet + 0.5 mg Cr /kg diet from chromium yeast + 250 mg of ascorbic acid /kg of diet (T_2), and the basal diet + 0.5 mg Cr /kg diet from chromium yeast + 250 mg vitamin E /kg of diet (T_3). Body weight and feed consumption were recorded to evaluate the growth performance and feed conversion ratio (FCR). Nitrogen retention was observed by conducting metabolic trial during 6th week. The climatic data revealed that there were huge variations in house air temperatures within a day. In house relative humidity ranged from 29.01% to 44.21% during the experimental period. The average weight gains were numerically higher and FCR values were lower in supplemented groups particularly in T_2 group than T_0 group. The significantly higher ($p< 0.05$) nitrogen retention values were recorded in T_2 group followed by T_1than T_0 group. It was concluded that Cr in combination with ascorbic acid yielded better results in terms of performance in broilers, thus suggesting some synergetic action of both Cr and ascorbic acid that need to investigate further with specially designed projects.

Keywords | Ascorbic acid, Broiler, Chromium, Growth, Nitrogen retention, Vitamin E

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INTRODUCTION

Metabolism of glucose in birds is considerably different from mammals while blood glucose concentration is much higher in birds and insulin levels are low (Brooks et al., 2016). Birds as compared to mammals are considered to be less sensitive to insulin (Scanes, 2009) and effect of chromium to enhance insulin sensitivity in mammals is well documented (Vincent, 2001). Heat or cold stress increase circulating concentrations of corticosterone in broilers and it is well documented that corticosterone reduces insulin sensitivity in broilers (Zhao et al., 2009). Poultry is reared in open side houses in most of the tropical countries like India which results in huge temperature variation in shed (Rajkumar et al., 2011) causing stress which results in increased demand of antioxidant supplementation. Since cooling of poultry houses (environment control) is very expensive thus methods are focused on nutritional modifications (Attia et al., 2015) like search of new feed additives along with their different combinations to increase the performance of birds naturally. Stress increases mineral and vitamin mobilization from tissues and their excretion (Siegel, 1995), thus may exacerbate a marginal vitamin and mineral deficiency or an increased mineral and vitamin requirement. It has been reported that the negative effects of environmental stress could be prevented by the use of some minerals and vitamins supplements such as vitamin C and chromium (Sahin and Sahinm, 2001; Sahin and Kucuk, 2001). Chromium is postulated to function as an antioxidant (Farag et al., 2017, Kholy et al., 2017) and its deficiency can disrupt carbohydrate, protein metabolism along with impaired growth rate (Pagan et al., 1995). Though birds do not require any dietary vitamin source as it can synthesize vitamin (Pardue and Thaxton, 1986) reported that particular environmental stressors could alter ascorbic acid utilization or synthesis in poultry. It is well documented that under stress conditions such as low or high environmental temperatures, humidity and high productive rate ascorbic acid synthesis is inadequate (McDowell, 1989). Poultry cannot synthesize vitamin E thus vitamin E requirements must be met from dietary sources (Chan and Decker, 1994) in case of increased demand in stress. Vitamin E is a biological chain-breaking antioxidant that protects cells and tissue from lipoperoxidative damage induced by free radicals (McDowell, 1989). Sahin et al. (2002) reported that broilers supplemented with dietary chromium and vitamin E significantly alleviated the heat stress related decrease in performance suggesting that additional supplementation into diets may be necessary under stress conditions in growing birds.

As per available literature scanty work has been done on combination of chromium yeast alone and in combination with ascorbic acid and vitamin E. In this view, the present experiment was designed to study the effect of dietary supplementation of chromium yeast alone and in combination with antioxidants on feed conversion, growth and nitrogen retention in broiler chickens during the winter season.

MATERIALS AND METHODS

Experimental Design

One hundred eighty day old Cobb-400 broiler chicks of comparable body weight were equally distributed into four treatment groups viz. T_0, T_1, T_2 and T_3. Each treatment group contained forty five chicks with three replicates of fifteen birds in each. The diet (Table 1) was maize-soybean-based broiler mash was formulated as per BIS (Bureau of Indian Standards, 1992) specifications to meet the nutrient requirements of broilers. The standard starter mash (0 - 3 weeks) and finisher mash (4 - 6) were fed. Chicks were fed corn-soya based broiler mash (basal diet) maintained as control (T_0), the basal diet supplemented with chromium at 0.5 mg Cr/kg diet from chromium yeast (T_1), the basal diet + 0.5 mg Cr /kg diet from chromium yeast + 250 mg of ascorbic acid /kg of diet (T_2) and the basal diet + 0.5 mg Cr /kg diet from chromium yeast + 250 mg vitamin E /kg of diet (T_3).

Table 1: Composition of broiler mash (%)

Ingredients	Starter Mash	Finisher Mash
Maize	56.2	62.5
Soybean meal	37.6	31.3
Vegetable oil	2.0	2.0
Dicalcium Phosphate	2.6	2.6
Calcite	1.0	1.0
Trace mineral mixture *	0.2	0.2
Salt	0.4	0.4
Other supplement (g/100 kg)		
Vitamin premix**	25	25
Methionine	155	34
Lysine	63	17
Choline Chloride	60	60
Maduramicin	50	50
Toxin binder	100	100
Nutrient analysis of broiler starter and finisher mash (% DM)		
Nutrients	**Starter mash**	**Finisher mash**
Dry matter	93.78	93.02
Crude protein	22.84	20.61
Ether extract	4.14	4.56
Crude fiber	3.73	3.44
Nitrogen free extract	63.12	64.98
Total ash	6.17	6.41
Calculated ME (kcal/kg)	2888	2942

*1 Kg contains Mn 90 g; Zn 80 g; Fe 90 g; Cu 15 g; I 2.0 g and Se 300 mg.
**500 gm contains Vit.A 12; 50 MIU; Vit.D_3 2.80 MIU; Vit.E 30.00 g; Vit.K 2.00 g; Vit.B_1 2.00 g and Vit.B_2 2.00 g.

Data Collection

The maximum and minimum in house air temperature and relative humidity were recorded daily during the 42 day experimental period (5th February to 17th March) by thermo-hygrometer and temperature humidity index (THI) was calculated. Record of weekly feed offered and weekly feed leftover from different treatment groups was maintained. The data obtained was used for the calculation of weekly feed consumption of broilers in each treatment groups during particular week. Body weight of individual chick was recorded using digital weighing balance at day one and thereafter at weekly interval till six weeks of age and weekly body weight gain was calculated. Feed conversion ratio (FCR) was calculated from weekly feed consumption and body weight gain. At the end of fifth week, three birds (one from each replicate) from each treatment group were randomly selected for metabolic trial which

Table 2: Mean weekly in house air temperature, relative humidity and temperature humidity index

Weeks	Mean in house air temperature (°C)			In house relative humidity(%)	Temperature humidity index
	Minimum	Maximum	Avg. house air temperature		
1	12.9^{a}±0.49	32.12^{ab}±0.81	22.58^{ab} ±0.48	35.50^{ab} ±1.44	20.98^{ab} ±0.36
2	13.92^{ab}±0.7	28.32^{a}±0.51	21.24^{a} ±0.32	39.21^{b} ±2.73	19.94^{a} ±0.25
3	15.67^{b}±1.08	28.71^{a}±0.28	22.17^{a} ±0.61	44.21^{b} ±2.33	20.84^{ab} ±0.56
4	11.88^{a}±0.75	34.00^{b}±1.77	22.25^{a} ±1.0	41.07^{b}±2.81	21.05^{ab} ±0.95
5	11.52^{a}±0.69	36.82^{c}±0.64	24.1^{b} 7±0.63	35.35^{ab} ±3.42	22.26^{b} ±0.59
6	11.87^{a}±0.51	37.77^{c}±0.78	24.84^{b} ±0.61	29.01^{a} ±1.54	22.48^{b} ±0.51

Means bearing different superscripts (a,b,c) in column differ significantly (P<0.01).

Table 3: Effects of treatments on feed consumption (g) of broilers

Weeks	Groups			
	T_0	T_1	T_2	T_3
1*	122.88^{a}±0.41	123.64^{a}±0.32	126.13^{b}±1.02	123.62^{a}±0.70
2#	298.33±1.35	302.91±4.65	305.31±4.08	300.12±1.16
3#	673.85±3.53	672.70±7.89	672.77±6.11	682.13±2.07
4#	908.77±11.21	831.39±15.15	863.30±23.23	842.79±8.26
5#	1035.33±0.99	1033.95±25.89	1058.95±4.95	1046.79±15.32
6**	1114.81^{b}±2.89	1125.75^{b}±4.61	1138.48^{b}±8.37	1086.39^{a}±6.04

Mean bearing different superscripts (a,b) in row different significantly (P<0.05)*,(P<0.01)** and # Non significant.
T_0= Control; **T_1** = basal diet supplemented with 0.5 mg Cr/kg diet; **T_2**= basal diet supplemented with 0.5 mg Cr /kg diet + 250 mg of ascorbic acid /kg of diet; **T_3** = basal diet supplemented with 0.5 mg Cr /kg diet + 250 mg vitamin E /kg of diet

Table 4: Effects of treatments on feed conversion ratio of broilers

Weeks	Groups			
	T_o	T_1	T_2	T_3
1	1.89±0.03	1.79±0.02	1.84±0.01	1.86±0.03
2	1.68±0.02	1.66±0.029	1.66±0.01	1.66±0.03
3	2.17±0.05	2.18±0.01	2.11±0.05	2.22±0.04
4	2.30±0.21	1.92±0.01	2.04±0.10	2.02±0.01
5	2.13±0.04	1.85±0.14	1.81±0.02	1.89±0.11
6	2.16±0.02	2.13±0.02	2.06±0.08	2.15±0.17
Average	2.05±0.25	1.92±0.26	1.92±0.25	1.97±0.24

#Non significant difference was recorded for weeks 1 to 6.
T_0= Control; **T_1** = basal diet supplemented with 0.5 mg Cr/kg diet; **T_2**= basal diet supplemented with 0.5 mg Cr /kg diet + 250 mg of ascorbic acid /kg of diet; **T_3** = basal diet supplemented with 0.5 mg Cr /kg diet + 250 mg vitamin E /kg of diet

was conducted for 5 consecutive days for determining the nitrogen retention collected at 24 hourly basis. During metabolic trial, daily record of feed offered, feed left over and faeces voided was maintained and used for nitrogen analysis as per AOAC (1990).

Statistical Analysis

The data generated throughout the experimental period was analyzed statistically by applying the Completely Randomized Design to study the effect of treatment on various parameters (Snedecor and Cochran, 1994). The climatic data regarding in-house air temperature and humidity was analyzed using RBD to study the weekly variations (Snedecor and Cochran,1994).

RESULTS AND DISCUSSION

The climatic data revealed that there were huge variations in temperature within a day (Table 2). The difference between minimum and maximum temperature in a day from morning to evening was more than double during the experiment. The maximum average in house air temperature of 37.77°C was recorded during 6th week and minimum of 11.52°C in 5th week. The data of in house relative humidity

Table 5: Effects of treatments on body weight gain (g) of broilers.

Weeks	Groups			
	T_0	T_1	T_2	T_3
1	64.89±1.34	68.48±0.93	68.15±0.55	66.46±1.50
2	176.89±3.53	181.54±2.40	183.73±3.18	180.17±4.25
3	310.71±6.79	308.11±2.11	318.31±11.22	307.35±7.32
4	394.22±3.23	432.11±6.14	424.44±15.57	416.97±3.82
5	484.78±9.42	566.44±17.67	584.80±5.21	556.24±31.95
6	509.17±11.18	502.82±7.95	552.54±25.58	475.89±27.25

#Non significantdifference was recorded for weeks 1 to 6.

T_0= Control; **T_1** = basal diet supplemented with 0.5 mg Cr/kg diet; **T_2**= basal diet supplemented with 0.5 mg Cr /kg diet + 250 mg of ascorbic acid /kg of diet; **T_3** = basal diet supplemented with 0.5 mg Cr /kg diet + 250 mg vitamin E / kg of diet

Table 6: Effects of treatments on total nitrogen intake, excretion and retention of broilers

Group	Nitrogen intake** (g)	Nitrogen excretion (g)	Nitrogen retention* (g)	%Nitrogen retention*
T_0	4.16^a±0.09	1.52±0.11	2.64^a±0.24	63.46^a±1.76
T_1	4.91^b±0.12	1.50±0.23	3.4^b±0.23	69.24^b±1.40
T_2	5.01^b±0.08	1.41±0.09	3.6^c±0.04	71.85^b±1.38
T_3	4.23^a±0.24	1.35±0.20	2.87^a±0.14	67.84^{ab}±1.51

Mean bearing different superscripts (a,b,c) in column different significantly ($P<0.05$)*, ($P<0.01$)** &# Non significant

T_0= Control; **T_1** = basal diet supplemented with 0.5 mg Cr/kg diet; **T_2**= basal diet supplemented with 0.5 mg Cr /kg diet + 250 mg of ascorbic acid /kg of diet; **T_3** = basal diet supplemented with 0.5 mg Cr /kg diet + 250 mg vitamin E /kg of diet

depicts gradual increase from 35.50% at first week to 44.21% at 3rd week thereafter gradual reduction in relative humidity was recorded and it was 29.01% at 6th week and THI ranged from 19.94 (2nd week) to 22.48 (6th week). As THI exceeds 20.4°C, broilers show reduced performance and increased variability in performance metrics (Purswell et al., 2012). These variations in the environment are indicator of imposing environmental stress on birds. Environmental temperature varies in many regions of the world during winter months and such conditions cause adverse effects on intake, nutrient digestibility and feed efficiency in poultry (Sahin, 2001). Environmental stress causes deficiency of chromium and vitamin C due to increased chromium mobilization from tissues and its excretion, also depresses ascorbic acid synthesis for poultry (NRC, 1997), thus justifying the use of chromium and antioxidants.

Feed consumption in general did not exhibited much significant difference among all treatment groups with exception of 1st and 6th week wherein T_2 group supplemented with chromium and ascorbic acid reflected significantly ($P<0.05$) higher feed consumption in 1st week (Table 3). In 6th week T_3 (chromium + vitamin E) supplemented groups recorded the lowest ($P<0.01$) feed intake due which the values became statistically significant but rest groups had no significant difference between them. The results are in agreement with Anandhi et al. (2006); Suksombat and Kanchanatawee (2005); Noori et al. (2012) except in the 1st week that exhibit a significant increase in T_2 group, and in 6th week that exhibit a significant decreased in T_3 group for feed consumption.

FCR among the treatments were recorded as 2.05, 1.92, 1.92 and 1.97 for T_o, T_1, T_2 and T_3 groups respectively with non-significant difference (Table 4). However supplemented groups had lower FCR than the control group and T_1 and T_2 recorded same FCR. Toghyani et al. (2006); Chaudhari et al. (2006); Anandhi et al. (2006) and Suksombat and Kanchanatawee (2005) however, observed the non-significant effect on weekly feed conversion ratio in the chromium supplemented broilers and their observations are in tune with present findings. The findings of present experiment were found contrary to Samanta et al. (2008) who observed the significantly improved feed conversion ratio in broilers at 2nd, 3rd and 5th week, however, Kaoud (2010) observed increased feed conversion ratio only at 3rd week in broilers.

The mean weekly live body weights at 6th week were 1981.85, 2100.50, 2160.53 and 2044.97g in T_0, T_1, T_2 and T_3, respectively (Table 5). An extra weight of 178.68 g/bird was recorded in group T_2 followed by 118.65 g/bird in T_1 and 63.12g/bird in T_3 as compared to control group in 6th week. However, all the supplemented groups recorded numerically higher weights than control but difference between groups was statistically not significant. There were no significant differences in mean weekly gain in body weight. However numerically the average weight gain of all the supplemented groups was higher than control and chromium and ascorbic acid combination recorded maximum gain than other groups. Similar findings of non-significant gain in body weight in broilers have been reported by supplementation of organic chromium (Liarn, 1993; Anandhi et al., 2006).

The results of metabolic trial indicated average nitrogen retention values of 63.46, 69.24, 71.85 and 67.84% in T_0, T_1, T_2 and T_3 group, respectively (Table 6). The observation revealed significantly higher nitrogen retention in all supplemented groups than control group. The higher nitrogen retention was recorded in T_2 group followed by T_1, T_3 and T_0 (control) group. The results are suggestive of the fact that the dietary chromium yeast supplemented groups exhibited superior nitrogen retention than control group and it was maximum (71.85%) in chromium yeast plus ascorbic acid supplemented (T_2) group. Amatya et al. (2004) also reported significantly ($P<0.05$) increased crude protein metabolizability in chromium supplementation in broilers from chromium yeast in comparison to control. These findings are in agreement with observations in the present study.

CONCLUSION

Results indicated that supplementation of chromium alone or in combination with ascorbic acid/vitamin E have little influences on feed consumption, body weight gain and feed conversion ratio, however increased the nitrogen retention in broilers. According to numerical values the best performer group was chromium yeast plus ascorbic acid suggesting some synergistic action between them and must be evaluated further.

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CONFLICT OF INTEREST

The authors have no conflict of interest with each other or any organization.

AUTHORS CONTRIBUTION

This manuscript is the part of MVSc thesis work of the first author.

REFRENCES

- AOAC (1990). Official Methods of Analysis 15th Edn. Association of Official Analytical Chemists. Washington, D.C.
- Amatya JL, Haldar S, Ghosh TK (2004). Effect of chromium supplementation from inorganic and organic sources on nutrient utilization mineral metabolism and meat quality in broiler chicken exposed to natural heat stress. Brit. J. Anim. Sci. 79: 241-253. https://doi.org/10.1017/S135772980009010X
- Anandhi MR, Mathivanan K, Viswanathan A, Mohan B (2006). Dietary inclusion of organic chromium on production and carcass characteristics of broilers. Int. J. Poult. Sci. 5(9): 880-884. https://doi.org/10.3923/ijps.2006.880.884
- Attia KM, Tawfeek FA, Mady MS, Assar AH (2015). Effect of chromium, selenium and vitamin C on productive performance and blood parameters of local strain dokkiin Egypt summer conditions. Egypt. Poult. Sci. 35: 311-329.
- Bureau of Indian Standards (1992). Poultry Feed Specifications (4th version) IS: 1374, Manak Bhavan, New Delhi, India.
- Brooks MA, Grimes JL, Spears KE, Krafka K, Lamptey A, Lloyd JW (2016). Chromium propionate in broilers: effect on insulin sensitivity. Poult. Sci. 1: 1–9. https://doi.org/10.3382/ps/pew018
- Chaudhari PP, Ranade AS, Patil MB, Desai DN, Avari PE, Deshmukh AD, Vaghmare DL, Bhapkar PT, Vaidya PN (2006). Effect of chromium picolinate on performance of broilers. J. Bombay Vet. Coll. 14(1): 38-40.
- Chan KM, Decker EA (1994). Endogenous skeletal muscle antioxidants. Crit. Rev. Food Sci. Nutr. 34: 403–426. https://doi.org/10.1080/10408399409527669
- El-Kholy MS, El-Hindawy MM, Alagawany M, Abd El-Hack ME, El-Sayed SE (2017). Dietary supplementation of chromium can alleviate negative impacts of heat stress on performance, carcass yield, and some blood hematology and chemistry indices of growing Japanese quail. Biol. Trace Elem. Res. 179 (1): 148–157. https://doi.org/10.1007/s12011-017-0936-z
- Farag MR , Alagawany M, Mohamed Ezzat Abd El-Hack, Muhammad Arif, Tugay Ayasan, Kuldeep Dhama, Amlan Patra, Kumaragurubaran Karthik (2017). Role of Chromium in Poultry Nutrition and Health: Beneficial Applications and Toxic Effects. Int. J. Pharmacol. 3 (7): 907-915. https://doi.org/10.3923/ijp.2017.907.915
- Kaoud HA (2010). Functional feed supplementation and Health of broilers. Natur. Sci. 8(5): 181-189.
- Liarn TF, Chen S, Horng Y, Hu CY (1993). The effects of adding chromium picolinate on the growth performance, serum traits, liver ATP-citrate lyase, fructose-1, 6-diphosphataseactivities and carcass characteristics of broilers. Taiwan Vet. Med. Anim. Husb. 62:1-5.
- McDowell LR (1989). Comparative aspects to human nutrition. Vitamin A and E. In: McDowell L.R. (ed.): Vitamins in Animal Nutrition. Academic Press, London. 93–131. https://doi.org/10.1016/B978-0-12-483372-2.50010-2
- National Research Council (1997). The role of chromium in Animal Nutrition. National Academy Press, Washington, D.C.
- Noori K, Farhoomand P, Ebrahimzadeh SK (2012). Effects of the chromium methionine supplementation on performance, serummetabolites and carcass traits in broiler chickens. J. Anim. Sci. Adv. 2(2): 230-235.
- Purswell, JL, William A, Hammed AO, Jeremiah D, Hongwei X, Richard SG (2012). Effect of Temperature-Humidity Index on Live Performance in Broiler Chickens. In: Ninth

International Livestock Environment Symposium by ASABE Valencia Conference Centre Valencia, Spain July 8 - 12, 2012.

- Preuss HG, Grojec PL, Lieberman S, Anderson RA (1997). Effects of different chromium compounds on blood pressure and lipid peroxidation in spontaneously hypertensive rats. Clin. Nephrol. 47(5): 325–30.
- Pagan JD, Jackson SG, Duren SE (1995) The effect of chromium supplementation on metabolic response to exercise in thoroughbred horses. In: Biotechnology in the Feed Industry: Proceedings of Alltech's Eleventh Annual Symposium. Lyons TP, Jacques KA, editors. Nottingham, UK: Nottingham University Press, Pp 249–256.
- Pardue SL, Thaxton JP (1984). Evidence of amelioration of steroid mediated immunosuppression by ascorbic acid. Poult. Sci. 63:1262–8. https://doi.org/10.3382/ps.0631262
- Rajkumar U, Reddy MR, Rama Rao SV, Radhika K, Shanmugam M (2011). Evaluation of growth, carcass, immune response and stress parameters in naked neck chicken and their normal siblings under tropical winter and summer temperatures. Asian Aust. J. Anim. Sci. 24(4): 509-516. https://doi.org/10.5713/ajas.2011.10312
- Sahin K (2001). Effects of supplemental dietary chromium on yield and nutrient digestibility of laying hens under low temperature. T. J. Vet. Anim. Sci. 25: 823–831.
- Sahin N, Sahin K (2001). Optimal dietary concentrations of vitamin C and chromium picolinate for alleviating the effect of low ambient temperature (6.2 °C) on egg production, some egg characteristics, and nutrient digestibility in laying hens. Vet. Med. – Czech. 46: 229-236.
- Sahin K, Sahin M, Ondercin M (2002). Vitamin E supplementation can alleviate negative effects of heat stress on egg production, egg quality, digestibility of nutrients and egg yolk mineral concentrations of Japanese quails. Res. Vet. Sci. 73, 307–312 https://doi.org/10.1016/S0034-5288(02)00126-1
- Sahin K, Kucuk O (2001). Effects of vitamin C and vitamin E on performance, digestion of nutrients, and carcass characteristics of Japanese quails reared under chronic heat stress. J. Anim. Physiol. Anim. Nutr. 85: 335–342. https://doi.org/10.1046/j.1439-0396.2001.00340.x
- Samanta S, Haldar S, Ghosh TK (2008). Production and carcass traits in broiler chicken given diets supplemented with inorganic trivalent chromium and an organic acid blend. Brit. J. Poult. Sci. 49:155-163.
- Scanes CG (2009). Perspectives on the endocrinology of poultry growth and metabolism. Gen. Comp. Endocrin. 163:24–32 https://doi.org/10.1016/j.ygcen.2009.04.013.
- Siegel HS (1995). Stress, Strains and Resistance. Br. Poult. 3–22.
- Sndecor GW, Cochran WG (1994). Statistical Methods. 8th ed. Oxford and IBH Publishing Co. PVt.Ltd. New Delhi.
- Suksombat W, Kanchanatwee S (2005). Effect of various sources and levels of chromium on performance of broilers. Asian Aust. J. Anim. Sci. 18(11): 1628-1633. https://doi.org/10.5713/ajas.2005.1628
- Toghyani M, Shivazad M, Gheisari AA, Zarkesh SH (2006). Performance, carcass traits and haematological parameters of het-stressed broiler chcikes in response to dietary levels of chromium picolinate. Int. J. Poult. Sci. 5(1): 65-89. https://doi.org/10.3923/ijps.2006.65.69
- Vincent JB (2001). The bioinorganic chemistry of chromium (III). Polyhedron. 20:1–26. https://doi.org/10.1016/S0277-5387(00)00624-0
- Zhao JP, Lin H, Jiao HC, Song ZG (2009). Corticosterone suppresses insulin- and NO-stimulated muscle glucose uptake in broiler chickens (Gallus gallus domesticus). Comp. Biochem. Physiol. 149: 448–454. https://doi.org/10.1016/j.cbpc.2008.10.106