RESEARCH ARTICLE Asian Journal of Dairy and Food Research, Volume 42 Issue 3: 320-325 (September 2023)

Effect of Dietary Supplementation of Ferrous Sulphate on Growth, Immunocompetence Traits, Carcass Quality and Meat Composition of Turkey Poults

Ankit Sharma[1], Amitav Bhattacharyya[1], Pankaj Kumar Shukla[1], Vinod Kumar[2], Vaibhav Kumar Singh[1]

10.18805/ajdfr.DR-1599

ABSTRACT

Background: Inorganic iron compounds have a positive effect on the health and growth of the broiler chickens. However, limited work has been done in Turkeys. Thus a study was conducted to assess the effect of dietary supplementation of ferrous sulphate on the growth, immunocompetence traits, carcass quality and meat composition of Turkey poults.

Methods: Day old turkey poults (n=96) were distributed into four treatment groups (T1, T2, T3 and T4) having 3 replicates of 8 birds each. The poults in T1 were fed (control) basal diet, while for birds in T2, T3 and T4, $FeSO_4$ was supplemented @ 80, 120 and 160 mg/kg of feed, respectively.

Result: Weekly body weight gain was significantly higher in T4 than T1 and T2 birds at 6th ($P<0.01$) and 7th week ($P<0.05$). Phase wise body weight gain was also significantly higher ($P<0.05$) in T4 than T1 and T2 during 4 to 8 weeks and 0 to 8 weeks ($P<0.01$). Weekly feed conversion ratio of T4 group was significantly better ($P<0.01$) at 6th week and 7th week than T1 and T2 group birds. The birds fed with T4 had significantly ($P<0.05$) higher foot web index compared to T1 and T2 group birds. Iron supplemented groups had significantly ($P<0.01$) higher dressing per cent. T4 had significantly ($P<0.05$) higher deposition of iron in thigh muscle. Thus, dietary supplementation of $FeSO_4$ @ 160 mg/kg resulted in better growth performance, immunity, significantly higher dressing per cent and significantly higher deposition of iron in thigh meat cuts.

Key words: Body weight gain, Dressing percent, Ferrous sulphate.

INTRODUCTION

Iron (Fe) is an essential component of haemoglobin and myoglobin. It is mainly present as a part of haemoglobin (60 to 70%), myoglobin, cytochromes and other Fe containing enzymes (10%) as well as ferritin and hemosiderin (22 to 30%) in animals (Theil, 2004). Fe is an essential component of proteins in humans, taking part in oxygen transport. Fe is required for several metabolic processes like oxygen, electron transport and DNA synthesis. Fe is an essential trace element for broiler growth and it has many functions in neurotransmitter synthesis, energy metabolism, phagocyte antimicrobial activity and in the synthesis of DNA, collagen and bile acids (Brock, 1994). In cereals and oil seeds, Fe is mostly bound to phytate, which reduces its availability for poultry when diets are not supplemented with phytase. There was a positive effect of iron sulphate on live weight gain and feed conversion. Shinde *et al.* (2011) investigated that there was an improvement ($P<0.05$) in body weight gain and FCR during the finisher phase (21-35 days). Result of Kalwar *et al.* (2014) showed that with increasing Fe concentration in the range of 160 mg/kg, the feed intake was decreased, while live body weight was increased considerably and improved feed conversion ratio. Svetlana *et al.* (2008) found that in 21-day old chickens, there were significant ($P<0.001$) differences in cutaneous hypersensitivity to PHA (Phytohaemagglutinin) between the control group (40 mg/kg $FeSO_4$ supplementation) and all other experimental groups (Fe bound to yeast, ferrous ascorbate and iron chelates). Kwiecien *et al.* (2015) indicated that supplementation of 40 mg/kg Fe from 1 to 42 days had no significant effect on dry matter, crude ash and crude fat contents in broilers tissue. Inorganic iron compounds (ferrous sulphate, ferric oxide, *etc.*) have positive effect on

[1]Department of Poultry Science, College of Veterinary Science and Animal Husbandry, U.P. Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go-Anusandhan Sansthan, Mathura-281 001, Uttar Pradesh, India.

[2]Department of Animal Nutrition, College of Veterinary Science and Animal Husbandry, U.P. Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go-Anusandhan Sansthan, Mathura-281 001, Uttar Pradesh, India.

Corresponding Author: Amitav Bhattacharyya, Department of Poultry Science, College of Veterinary Science and Animal Husbandry, U.P. Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go-Anusandhan Sansthan, Mathura-281 001, Uttar Pradesh, India. Email: amitav6@gmail.com

How to cite this article: Sharma, A., Bhattacharyya, A., Shukla, P.K., Kumar, V. and Singh, V.K. (2023). Effect of Dietary Supplementation of Ferrous Sulphate on Growth, Immunocompetence Traits, Carcass Quality and Meat Composition of Turkey Poults. Asian Journal of Dairy and Food Research. 42(3): 320-325. doi: 10.18805/ajdfr.DR-1599.

Submitted: 06-11-2020 **Accepted:** 17-05-2022 **Online:** 28-06-2022

the health and growth of the broiler chickens. However, limited work has been done in turkeys. Hence, the present study was designed with the objective to study the effect of supplementation of ferrous sulphate on growth performance, immunocompetence traits, carcass quality traits and chemical composition of breast and thigh muscle of turkey poults.

MATERIALS AND METHODS

Nighty six straight run day old turkey poults were divided into four treatment groups comprising of three replicates and eight birds in each replicate. The poults were wing banded, weighed individually and distributed randomly on uniform body weight basis in the treatment groups. The poults were housed in deep litter system. Water was offered *ad lib*. The experiment was conducted at Poultry Farm of Department of Poultry Science, U.P. Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go-Anusandhan Sansthan (DUVASU), Mathura after due approval of the IAEC.

Preparation of experimental diet

The dietary treatments offered during the experimental period of 8 weeks were:

T1 - Control, Basal diet (Turkey starter ration; NRC, 1994).
T2 - Basal diet+supplementation of ferrous sulphate 80 mg/kg diet.
T3 - Basal diet+supplementation of ferrous sulphate 120 mg/kg diet.
T4 - Basal diet+supplementation of ferrous sulphate 160 mg/kg diet.

Growth performance parameters

Weekly body weight gain and FCR was recorded. Thereafter phase wise (0-4 weeks, 4-8 weeks and 0-8 weeks) body weight gain and FCR were calculated at the end of the experiment.

Immunocompetence traits

The general innate immune-competence status of turkey poults were assayed by measuring two important immunocompetence traits, *i.e*. antibody response to goat red blood cells (GRBC) and cell mediated immune response to PHA-P (Phytohaemagglutinin, lectin from *Phaseolus vulgaris*) after 8 weeks of age (Corrier and De Loach, 1990). The micro-titre plate haemagglutination procedure as described by Siegel and Gross (1980) with slight modifications was followed to measure total HA antibody titres in turkey poults on day zero and day 5th post injection.

Carcass quality traits

A total of 16 birds were taken after 8 weeks of age to slaughter and study various carcass traits *viz*. pre-slaughter fasting shrinkage in live weight (%), dressing (%) and total ready-to-cook yield (%).

Chemical composition of feed, breast (*pectoralis major*) and thigh (*iliotibialis*) muscle of turkey poults after 8 weeks of age

Samples of feed, breast (*pectoralis major*) and thigh (*iliotibialis*) muscles were processed and analyzed for dry matter (DM), crude protein (CP), ether extract (EE), total ash, calcium and phosphorous (AOAC, 1990). Iron content of meat sample was estimated as per Horowitz (1965) with slight modifications.

Statistical analysis

Data were subjected to one-way analysis of variance in a completely randomized design (Snedecor and Cochran, 1994) using Statistical Package for the Social Sciences (S.P.S.S., 2011). Homogenous subsets were separated using multiple range test described by Duncan (1955).

RESULTS AND DISCUSSION

Chemical composition of turkey starter feed

The chemical composition of turkey starter feed has been presented in Table 1. The feed was adequate in all nutrients as per nutritional requirements of turkey (NRC, 1994).

Body weight gain

The average weekly body weight gain of birds among various treatment groups has been tabulated in Table 2. Weekly

Table 1: Chemical composition of feed.

Category	DM%	Total Ash%	CP%	EE%	Ca%	P%	Fe (mg/kg)
Turkey starter feed	89.50	8.51	27.84	2.73	2.24	1.25	78.84

Table 2: Effect of dietary supplementation of ferrous sulphate on average weekly body weight gain (g) of Turkey poults during 0-8 weeks of age.

Treatment	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
T1	38.08	61.08	81.83	91.25	103.00	141.08^{a}	152.67^{a}	255.83
T2	38.50	61.00	81.50	91.83	103.25	141.17^{a}	152.67^{a}	256.00
T3	38.58	61.17	81.67	91.75	103.33	143.58^{b}	153.42^{ab}	256.08
T4	38.75	61.25	81.92	91.50	103.50	143.75^{b}	154.42^{b}	256.92
Pooled SEM	0.21	0.13	0.36	0.33	0.52	0.44	0.27	0.31
Sig level	NS	NS	NS	NS	NS	P<0.01	P<0.05	NS

Means bearing different superscripts within a column differ significantly (P<0.05).

NS: Not significant (P>0.05), SEM: Standard error of means.

body weight gain was significantly higher (P<0.01) in T4 than T1 and T2 at 6th week of age. At 7th week of age, weekly body weight gain was significantly higher (P<0.05) in T4 than T1 and T2. Phase wise body weight gain was significantly higher (P<0.05) in T4 than T1 and T2 during 4 to 8 weeks and significantly higher (P<0.01) in T4 than T1, T2 and T3 during 0 to 8 weeks (Table 3). There was no significant difference among the various treatment groups in body weight gain of birds during 0-4 weeks. There are several other studies that agree with our results. Pek *et al.* (2005) reported that supplementation of 100 mg/kg feed Fe significantly increased body weight gain. Talpur *et al.* (2016) noticed that supplementation of Fe @ 60 mg and 80 mg/kg feed resulted in significantly higher body weight gain. Vahl and Klooster (1987) found that supplementation of 20 and 60 mg Fe/kg feed to the basal diet containing 80 mg Fe/kg feed (total Fe 100 and 140 mg/kg diet) resulted in higher body weight gain in broilers compared to the control group fed on basal diet. In our study, higher body weight gain was observed in T4 where $FeSO_4$ was supplemented @ 160 mg/kg feed which was approximately 59 mg Fe/kg feed and this was addition to the basal diet containing approximately 79 mg Fe/kg (total Fe 138 mg/kg diet).

Feed conversion ratio

Results indicated that at 6th week, FCR of T4 group was significantly better (P<0.01) than T1 and T2 and comparatively better than T3 group birds (Table 4). Also at 7th week, FCR of T4 group was significantly better (P<0.01) than T1 and T2 and comparatively better than T3. However, there was no significant difference in FCR of birds during different phases of growth (Table 5). Further, our results showed that there was better weekly FCR with increasing ferrous sulphate supplementation. There are several studies that support our results. Kalwar *et al.* (2014) reported that the feed conversion ratio was significantly better (P<0.01) in group which was supplemented with 160 mg/kg Fe as compared with group which supplemented with 40 mg/kg Fe and control group. Further, FCR improved with increasing level of Fe supplementation. Talpur *et al.* (2016) reported that there was significantly better FCR in group which supplemented 160 mg/kg Fe than control group. Further, it was also observed that FCR improved with increased level of Fe supplementation in feed.

In present study, there was an overall beneficial effect of dietary supplementation of ferrous sulphate on growth performance. This may be due to the fact that iron produces connective tissue within the body, maintains immune system, carries oxygen within the body and iron metal complex binds molecular oxygen in the lungs and carries it to all of other cells within the body including muscles that needs oxygen to perform their activities.

Table 3: Effect of dietary supplementation of ferrous sulphate on average body weight gain (g) of Turkey poults at different phases of growth during 0-8 weeks of age.

Treatment	0-4 weeks	4-8 weeks	0-8 weeks
T1	272.25	652.58^{a}	924.83^{a}
T2	272.92	653.67^{a}	926.58^{a}
T3	273.42	656.00^{ab}	929.42^{b}
T4	273.33	658.58^{b}	931.92^{c}
Pooled SEM	0.52	0.86	0.87
Sig level	NS	P<0.05	P<0.01

Means bearing different superscripts within a column differ significantly (P<0.05).

NS: Not significant (P>0.05) SEM: Standard error of means.

Humoral immune response

The statistical analysis revealed that there was no significant difference in total immunoglobulins, IgG and IgM values among treatment groups (Table 6). However, apparently higher values of total immunoglobulins, IgG, IgM were observed in T4 as compared to the other treatment groups. There are few studies that fall in line with present study. Ekiz *et al.* (2005) demonstrated that iron deficient status causes humoral immunodeficiency.

Cell mediated immune response

Cell mediated immune response to PHA-P at 8 weeks of age indicated that T4 birds had significantly higher (P<0.05) foot web index compared to T1 and T2 groups and comparatively higher than T3 group (Table 6). Further, all the iron supplemented groups had apparently higher CMI response than the control group poults. The effect of iron on immune system is probably due to its role in secretion of TNF-α and interleukins (Safuanova *et al.*, 2004). There are few studies that fall under the scope of present study. The effect of iron preparations were observed in pigs, in which

Table 4: Effect of dietary supplementation of ferrous sulphate on weekly feed conversion ratio of Turkey poults during 0-8 weeks of age.

Treatment	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
T1	2.07	2.63	2.79	2.44	2.57	2.40^{b}	2.67^{c}	2.25
T2	2.06	2.63	2.78	2.44	2.55	2.39^{b}	2.65^{bc}	2.25
T3	2.06	2.62	2.77	2.43	2.55	2.35^{a}	2.63^{ab}	2.25
T4	2.05	2.61	2.77	2.44	2.55	2.34^{a}	2.61^{a}	2.24
Pooled SEM	0.011	0.006	0.013	0.008	0.012	0.008	0.008	0.004
Sig. level	NS	NS	NS	NS	NS	P<0.01	P<0.01	NS

Means bearing different superscripts within a column differ significantly (P<0.05).

NS: Not significant (P>0.05) SEM: Standard error of means.

Table 5: Effect of dietary supplementation of ferrous sulphate on feed conversion ratio at different phases of growth of Turkey poults during 0-8 weeks of age.

Treatment	0-4 weeks	4-8 weeks	0-8 weeks
T1	2.53	2.55	2.54
T2	2.53	2.60	2.56
T3	2.52	2.59	2.56
T4	2.52	2.59	2.56
Pooled SEM	0.005	0.013	0.009
Sig. level	NS	NS	NS

NS: Not significant (P>0.05) SEM: Standard error of means.

Table 6: Effect of dietary supplementation of ferrous sulphate on humoral response [antibody titre (log2) values] to 1% GRBC and cell mediated immune response to (PHA-P) in Turkey poults at 8 weeks of age.

Treatment	HA	IgG	IgM	FWI
T1	7.63	2.50	5.13	0.66^{a}
T2	7.88	2.63	5.25	0.68^{a}
T3	8.13	2.75	5.38	0.69^{ab}
T4	8.38	2.88	5.50	0.74^{b}
Pooled SEM	0.16	0.09	0.13	0.01
Sig. level	NS	NS	NS	P<0.05

Means bearing different superscripts within a column differ significantly (P<0.05).

NS: Not significant (P>0.05) SEM: Standard error of means.

Table 7: Effect of dietary supplementation of ferrous sulphate on carcass quality traits of Turkey poults at 8 weeks of age (% live weight).

Treatment	Shrinkage %	Dressing %	Ready to cook yield %
T1	4.43	73.33^{a}	57.10
T2	4.49	74.29^{b}	56.78
T3	4.64	75.07^{c}	56.95
T4	4.65	75.46^{d}	56.69
Pooled SEM	0.05	0.22	0.15
Sig. level	NS	P<0.01	NS

Means bearing different superscripts within a column differ significantly (P<0.05).

NS: Not significant (P>0.05), SEM: Standard error of means.

Fe-Gly @90 mg/kg of feed stimulated T lymphocyte proliferation (Creech *et al.*, 2004). Jarosz *et al.* (2016) reported that there was a beneficial effect on lymphocyte proliferation in broiler chickens fed on feed containing an iron chelate with glycine and resulted in an increase in the percentage of CD4 and CD8 cells.

Carcass quality traits

No significant differences were recorded in carcass quality traits among the treatment groups except dressing percentage (Table 7). T4 had significantly higher (P<0.01) dressing % as compared to T1, T2 and T3. Further, all the iron supplemented groups had significantly higher (P<0.01) dressing percent compared to control. It may be due to the fact that iron carries oxygen within the body as iron metal complex binds molecular oxygen in the lungs and carries it to all the cells within the body (*e.g.* muscles) that needs oxygen to perform their activities. Kalwar *et al.* (2014) also reported that percent dressing weight was remarkably higher in broilers supplemented with Fe at different levels and the highest dressing percent was obtained with 160 mg/kg dietary Fe supplementation.

Chemical composition of breast (*pectoralis major*) muscle and thigh (*iliotibialis*) muscle

No significant difference was observed in the chemical composition of breast (*Pectoralis major*) of turkey poults at 8 weeks of age (Table 8). However, the birds fed with T4 diethad apparently higher deposition of Fe in breast muscle than T1, T2 and T3 treatment group. The results obtained in present study fall in the line of few other studies. Behroozlak *et al.* (2020) observed that there were no changes of moisture and ether extract but significantly increased Fe content of broiler breast meat after dietary supplementation of Fe @ 80 mg/kg diet. In our study too, Fe content in breast muscle was apparently higher in T4 where $FeSO_4$ was supplemented @ 160 mg/kg feed which was approximately 59 mg Fe/kg feed in addition to the basal diet containing approximately 79 mg Fe/kg (total Fe 138 mg/kg diet).

There was no significant difference in the chemical composition of thigh (*iliotibialis*) muscle of turkey poults at 8 weeks of age (Table 9). However, there was significantly higher (P<0.05) deposition of Fe in thigh muscle of T4 birds as compared to T1, T2 and T3 treatment group. Seo *et al.* (2008) also reported that iron content in leg muscle was

Table 8: Effect of dietary supplementation of ferrous sulphate on chemical composition of Breast muscle (*pectoralis major*) of Turkey poults at 8 weeks of age.

Treatment	Moisture%	DM%	CP%	EE%	Total Ash%	Ca (mg/100 g)	P (mg/100 g)	Fe (mg/kg DM)
T1	74.02	25.98	25.16	0.58	1.07	3.19	230.27	10.84
T2	74.91	25.09	25.38	0.57	1.03	3.20	229.95	10.85
T3	75.12	24.88	25.14	0.58	0.97	3.17	229.90	10.88
T4	74.90	25.09	25.98	0.62	1.05	3.19	230.32	11.05
Pooled SEM	0.20	0.21	0.22	0.02	0.02	0.01	0.08	0.08
Sig. level	NS	NS	NS	NS	NS	NS	NS	NS

NS: Not Significant (P>0.05), SEM: Standard error of means.

Table 9: Effect of dietary supplementation of ferrous sulphate on chemical composition of thigh muscle (*iliotibialis*) of Turkey poults at 8 weeks of age.

Treatment	Moisture%	DM%	CP%	EE%	Total ash%	Ca (mg/100 g)	P (mg/100 g)	Fe (mg/kg DM)
T1	74.49	25.51	23.63	1.45	1.43	4.86	278.37	16.86[a]
T2	74.41	25.59	23.85	1.35	1.45	4.83	278.48	16.81[a]
T3	75.05	24.95	23.95	1.38	1.50	4.86	280.39	16.96[ab]
T4	74.81	25.19	24.02	1.37	1.40	4.84	279.17	17.38[b]
Pooled SEM	0.15	0.15	0.17	0.04	0.03	0.007	0.58	0.09
Sig. level	NS	NS	NS	NS	NS	NS	NS	P<0.05

Means bearing different superscripts within a column differ significantly (P<0.05).

NS: Not significant (P>0.05), SEM: Standard error of means.

significantly higher in ferrous sulphate (200 ppm) supplemented group than control group but no significance difference between ferrous sulphate (100 ppm) and control group. The higher Fe deposition in thigh muscle may be due to increased expression of transferrin receptors (TfR1 and TfR2) located in the target cell membrane. Transferrin is responsible for transporting iron to most cells and normally about 25-30% of transferrin is saturated by iron.

CONCLUSION

Dietary supplementation of ferrous sulphate @ 160 mg/kg showed better growth performance, immunity and significantly higher dressing percent in turkey poults. Dietary supplementation of ferrous sulphate @ 160 mg/kg resulted in significantly higher deposition of iron in thigh meat cuts. Dietary supplementation of ferrous sulphate did not result in any adverse effect on carcass quality traits and chemical composition of breast (*Pectoralis major*) and thigh (*iliotibialis*) muscle of turkey poults at 8 weeks of age. Thus, ferrous sulphate @ 160 mg/kg of diet may be supplemented to turkey poults for better growth, immunity and deposition of iron in thigh meat cuts.

ACKNOWLEDGEMENT

The authors are thankful to Vice Chancellor, DUVASU, Mathura for providing the necessary facilities for carrying out this study.

Conflict of interest: None.

REFERENCES

AOAC. (1990). Officialy Method of Analysis.15th edition. Association of Official Analytical Chemists Washington. D.C. 2004.

Behroozlak, M.A., Daneshyar, M., Farhoomand, P. and Nikoo, A. (2020). Broiler responses to ferrous sulfate at different time periods: A comprehensive research on qualitative parameters of breast meat. Journal of Food Science and Technology. https://doi.org/10.1007/s13197-020-04642-9.

Brock, J.H., Halliday, J.W., Pippard, M.J. and Powell, L.W. (1994). Iron in Infection, Immunity, Inflammation and Neoplasia. In: (eds): Iron Metabolism in Health and Disease. W.B. Saunders, London, UK.

Corrier, D.E. and Deloach, J.R. (1990). Evaluation of cell mediated, cutaneous basophil hypersensitivity in young chickens by inter digital skin test. Poultry Science. 69: 403-408.

Creech, B.L., Spears, J.W., Flowers, W.L., Hill, G.M., Loyd, K.E., Armstrong, T.A. and Engle, T.E. (2004). Effect of dietary trace mineral concentration and source (inorganic vs chelated) on performance, mineral status and fecal mineral excretion in pigs from weaning through finishing. Journal Animal Science. 82: 2140-2147.

Duncan, D.B. (1955). Multiple Range and Multiple F-Test. Biometrics. 11: 1-5.

Ekiz, C., Agaoglu, L., Karakas, Z., Gurel, N. and Yalcin, I. (2005). The effect of iron deficiency anemia on the function of the immune system. The Hematology Journal. 5(7): 579-583.

Horowitz, W. (1965).Official Methods of Analysis of the Association of Official Agricultural Chemists. Washington: Association of Official Agricultural Chemists.

Jarosz, L., Kwiecienb, M., Marek, A., Gradzkia, Z., Winiarska-Mieczan, A., Kalinowski, M. and Laskowskaa, E. (2016). Effects of feed supplementation with glycine chelate and iron sulfate on selected parameters of cell-mediated immune response in broiler chickens. Research in Veterinary Science. 107: 68-74.

Kalwar, B.A., Sahito, H.A., Kalwar, M.A., Memon, Z.N. and Lal, M. (2014).Calculation of FCR and RBC with varied effect of iron in broiler agriculture, forestry and fisheries. Special Issue: Agriculture Ecosystems and Environment. 3(6-1): 46-51.

Kwiecien, M., Samolinska, W. and Bujanowicz-Haras, B. (2015). Effects of iron-glycine chelate on growth, carcass characteristic, liver mineral concentrations and haematological and biochemical blood parameters in broilers. Journal of Animal Physiology and Animal Nutrition. 99(6): 1184-1196.

NRC, (1994). Nutrient Requirement of Poultry. 9th Revised edition. The National Academies Press, Washington. DC.

Pek, H., Avci, M., Yertk, M. and Aydlek, N. (2005). Effects of copper and iron addition to diets on growth performance and some blood parameters in quail. Ataturk University Journal of Veterinary Sciences. 21(1/2): 45-50.

Safuanova, G.S.H., Nikulicheva, V.I. and Bakirov, AB. (2004). Comprehensive evaluation of the immune system and various cytokines in patients with iron-deficient anemia. Russian Clinical Laboratory Diagnostics. 24: 33-35.

Seo, S.H., Lee, H.K., Ahn, H.J. and Paik, I.K. (2008).The effect of dietary supplementation of Fe-methionine chelate and $FeSO_4$ on the iron content of broiler meat. Asian-Australasian Journal of Animal Sciences. 21(1): 103-106.

Shinde, P.L., Ingale, S.L., Choi, J.Y., Kim, J.S., Pak, S.I. and Chae, B.J. (2011). Efficiency of inorganic and organic iron sources under iron depleted conditions in broilers. British Poultry Science. 52(5): 578-583.

Siegel, P.B. and Gross, W.B. (1980).Production and persistency of antibodies in chickens to sheep erythrocytes. 1. Directional selection. Poultry Science. 59: 1-5.

Snedecor, G.W. and Cochran, W.G. (1994). Statistical Methods.8th Edition Oxford and IBH Publishing Co, Calcutta.

SPSS (2011). Statistics Version 20.0. IBM SPSS Inc., USA.

Svetlana, M., Lazarevi, M., Jokic, Z., Jovanovic, I., Olivera, P., Danijela, K. and Marinkovic, D. (2008). The influence of organic and inorganic Fe supplementation on red blood picture, immune response and quantity of iron in organs of broiler chickens. Acta Veterinaria (Beograd). 58(2-3): 179-189.

Talpur, H.S., Shafi, I., Dad, R., Bhattarai, D., Rehman, Z., Ullah, F. and Ullah, A.A. (2016). Effects of supplementation of ferrous sulphate (iron) on the growth of Hubbard broiler chicks. Science International. 28(5): 4687-4692.

Theil, E.C. (2004). Iron, ferritin and nutrition. Annual Review of Nutrition. 24(1): 327-343.

Vahl, H. and Klooster, A.T.V. (1987). Dietary iron and broiler performance. British Poultry Science. 28: 567-576.