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Effect of replacing inorganic with organic trace minerals on growth performance, carcass characteristics and chemical composition of broiler thigh meat

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Micro minerals (Trace minerals) are required for normal growth and development in broilers. The present study was undertaken to compare the effect of replacing inorganic with organic trace minerals on growth performance, carcass characteristics and chemical composition of broiler thigh meat. A corn soybean based diet supplemented with organic trace minerals (OTM) (x) and an inorganic trace mineral (ITM) (y) was prepared. Four hundred eighty birds were stratified by weight and randomly assigned to 6 dietary treatments with four replicates per treatment (20 birds/replicate pen). The treatments were A) Positive control group diet (x) supplemented for whole period (0-5 wk). B) Fed diet (x) during starter and grower phase (1-4 wk) and diet (y) was offered in finisher phase (5 wk). C) 1st 3 weeks were fed diet (x) and last two weeks were given diet (y). D) First 2 weeks were fed diet (x) while, diet (Y) offered in the last three weeks. In the treatment (E), diet (x) offered during initial phase and nourished with diet (y) during grower and finisher phase while in treatment (F), complete diet (y). The result showed that organic trace mineral supplementation did not affect growth performance in the first and last week of trail but during 2nd, 3rd and 4th weeks organic trace mineral supplementation showed better growth performance than that of inorganic trace mineral supplementation. Chicken fed with organic trace mineral supplemented diets had the better growth performance which differed from that of inorganic supplemented diet groups. Additionally, organic trace minerals supplementation did not affect dressing percentage and giblets weight but shank and keel lengths were improved. While, OTM supplementation did not alter dry matter, ash and moisture content in thigh meat; however, crude protein content was improved in thigh meat. Overall r**esults demonstrated that the quality of broiler chicken meat in high organic trace mineral supplement increased relative to the low supplemented groups. It is concluded that addition of organic trace mineral to feed can improve the growth performance of broiler particularly during growing phase.**

Key words: Carcass, dry matter, growth, performance, replacing.

INTRODUCTION

It is well recognized that demand of poultry meat and meat products has increased due to shortage of red meat supply (FAO, 2010) and price phenomena. Annual broiler global meat production was 84.6 million tons in 2013 (USDA, 2003) and covered 33% of global meat demand (FAO, 2010). The genetic advancement continuously elevated the broiler growth potential; broiler can attain mature body weight by consuming less feed (Mckay, 2009) and in shorter period of time. It is well established that trace minerals are important for broiler normal growth and development (Kratzer and Vohra (in press)). However, due to relative less economic importance, trace minerals sector failed to attracts poultry scientist attentions. The current interest in trace minerals nutrition has been vigorously undertaken due to better bioavailability of trace minerals (Wedekind et al. 1992, Oyagi and Baker, 1993) and concerns of environmental pollution (Lesson, 2003).

Poultry nutritionists balance the trace minerals requirements according to National Research Council (NRC, 1994) recommendations (NRC, 1994). However, these recommendations have not supported well due to many factors such as FAO, (2010) Broilers growth potential elevated trace minerals requirement, (USDA, 2003) negative interactions between the inorganic forms of trace elements (Du et al. 1996), Mondal et al. 2007). Therefore nutritionists increased trace minerals supplementation levels much more than that of NRC (1994) recommendations (Inal et al. 2001; Lesson, 2005). The studies conducted in last decades have shown that organic trace minerals supplementation significantly improved livestock production (Paik 2001). The bioavailability of various forms of the organic trace elements is superior to that of inorganic element due to their better absorption rate (Lesson, 2003; Nollet et al., 2005; Van Der Klis et al., 2002). Organic trace minerals make complexes with organic molecules and attaining structure which can easily pass through intestinal mucosa (AAFCO, 1997; Kincaid, 1989; Nelson, 1988).

Pakistan has an agriculture based economy. About 70% of the total population is directly or indirectly involved in wide range of agriculture businesses. Livestock contributes about 55% of total the agriculture GDP and poultry sector has been expanding its wing as most integral and dynamic component of national economy (Anonymous, 2008). Commercial poultry sector is on the stage of rapid boom with annual growth rate of 20 to 25%. Kamal (2010), Pakistan Poultry industry has recommended the addition of organic trace minerals in poultry feed. However, industry is reluctant due to price phenomena and availability. Keeping in view the result of available literature, the present study was planned to determine the effect of replacing the inorganic with organic trace minerals on growth performance, carcass characteristic and composition of thigh meat of broilers.

MATERIALS AND METHODS

The present study methodology and protocols were approved by the Institutional Animal Care and Use Committee of University of Veterinary and Animal Science, Lahore (UVAS, Lahore). A total of 480 unsex broilers birds were randomly divided into six treatment groups (n=80 per group) and were grown over 35 days. Each treatment group is further divided into four replicate while each replicate was comprised of 20 chicks. Diet consisted of a corn Soy based ration supplemented with organic trace minerals (OTM) (x) and inorganic trace minerals (ITM) (y). Inorganic trace minerals were purchased from local market while Bioplx Cu, Bioplx Fe, Bioplex Zn, Bioplex Mn, and Sel-Plex were provided by Alltech Inc USA. The basal diet (Table 1) was formulated according to NRC (1994) recommendations. Analyzed by the AOAC (2000) and both feed were procured from commercial feed mill. The diets were fed *adlibitum* throughout experimental period. Dietary treatments were divided in different replicate pens A) x fed diet throughout trial period), B) fed diet (x) in week 1-4 and diet (y) was offered in last week. C) Diet (x) served weeks 1-3 followed by diet (y) week 4-5. D) First 2 weeks were fed diet (x) while, diet (y) offered in the last three weeks. In the treatment (E), only first week were fed diet (x) and remaining last 4 weeks were fed diet (y) while in treatment (F), complete diet (y) was fed to experimental birds. The initial temperature of house was maintained at 95°F at chick level and was reduced by 5°F every week to maintain the final temperature at 75°F.

Growth performance

The feed intake (F.I) and body weight (B.W) were recorded on day 7, 14, 21, 28 and 35 per pen. Feed conversion was calculated as feed to gain ratio. Livability was recorded daily and calculated as percent within the pen.

Carcass characteristics

At the end of trail feeding period, two birds close to mean body weight were selected from each replicate and slaughter. After skinning dressing percentage were recorded and giblets were collected and weight while shank and keel bone length were measured after removing meat.

Composition of thigh meat

Whole thigh meat were collect from every slaughter bird that were slaughtered at the end of feeding period and preserved in deep freeze at 4°C until further analysis. They were at room temperature and oven dried at 100 C^0 for 24h and ground it for proximate

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Table 1. Detail chemical composition of basal diet

Ingredients	Quantity (%)
Maize	33.87
Rice tips	30
Soybean meal	32.30
DCP	1.80
Salt	0.25
Lime stone	1.21
Supplement micro minerals (Bioplex, Alltech)	0.20
DL- Met. 99%	0.17
L- Lys-HCL. 78.4%	0.2
Total	100
Nutrients	**Composition**
Crude protein (%)	19
ME (Kcal)/kg	2900
Crude Fiber (%)	3.05
Ether Extract (%)	2.76
Total P%	0.73
Available P%	0.42
Calcium %	1.02
Lysine %	1.25
Methionine %	0.48
Methionine + Cystine %	0.82
Threonine%	0.80
Tryptophan%	0.25
Arginine%	1.39
Isoleucine%	0.93
Na%	0.18

Each 2 kg of Vit. and Min. Mixture contains: Vit. A 12000,000 IU, Vit. D3 2200,000 IU, Vit. E 10,000 mg, Vit. k3 2000 mg, Vit. B1 1000 mg, Vit. B2 5000 mg, Vit. B6 1500 mg, Vit. B12 10 mg, Pantothenic acid 10,000 mg, Niacin 30,000 mg, Folic acid 1000 mg, Biotin 50 mg, Manganese 100,000 mg, Zinc 80,000 mg, Copper 10,000 mg, Iron 50,000, Iodine 1000 mg, Selenium 300 mg, Cobalt 100 mg, Ca CO3 to 2,000 g.

analysis.

Statistical analysis

The data obtained on growth performance; carcass characteristics and meat composition were analyzed for Analysis of Variance (ANOVA) technique under Completely Randomized Design (Steel et al., 1997). Level of significance was kept at $P<0.05$. Means were compared for significance of difference with Duncan's Multiple Test (Duncan, 1955).

RESULTS

Growth performance

The supplementation of OTM is a possible solution to fulfill the modern broiler trace minerals requirement by using the NRC (1994) recommendations. Dietary supplementation of organic trace minerals did not affect feed intake, body weight gain and Feed conversion during first and last week of trail, suggesting that ITM replacement with OTM did not affect broiler performance during starter and finisher phase (1-7 days, 29-35 days). However, during growing phase (8-28 days), as OTM supplemented diet level increase weight gain by in taking less feed and FCR was improved. In the finisher phase (29-35 days) no significant differences were observed in feed intake and weight gain among all treatments groups (Tables 2, 3 and 4). In this study, overall growth performance values were slightly lower than those already reported studies, because the present study conducted in august and September month during these month temperature and relative humidity is much higher in Pakistan, these unfavorable conditions on the period of present study may be caused to lower BWG which may worse overall growth performance. Mortality rate among different experimental groups was also recorded and shown in Table 3. Non-significant difference was observed among 6 treatments groups. However, highest mortality rate was observed in group which was fed inorganic trace mineral supplemented diet throughout trail period. Overall mortality was within the acceptable ranges.

Carcass characteristics

Non-significant difference was observed between different treatments groups with little bit better dressing percentage were observed when feeding diet supplemented with ITM level. Table 4 present data on carcass characteristic. Organic trace minerals supplemented diet was found to have effect on shank and keel length, however it was not significant. as ITM diet level increased at 35 days trail, The shank length various treatment groups was 5.48, 5.45, 5.44, 5.43,5.39 and 5.40 cm respectively, and keel length measurement was 14.04, 14.01, 13.98, 13.95, 13.93 and 13.92 cm, respectively. Overall, organic trace mineral has effect on shank and keel bone length growth. While, organic trace mineral supplementation has no effect on weight of liver, spleen, heart but organic trace minerals supplementation has improved gizzard (gm) weight than that of ITM supplemented diet (Table 5). Table 6 shows the data on the variable presenting the chemical composition of thigh meat. Feeding OTM did not have any significant effect on DM, fat, ash, and water content in thigh meat. However, CP content was improved in the groups fed with OTM supplemented diets than those of ITM supplementation.

DISCUSSION

Growth performance and carcass characteristics are the main parameters which normally used to evaluate the broiler performance. Since last 70 years, the success of

Table 2. Average weekly feed intake.

T	7	14	21	28	35
A	158.6^{a}±3.2	434.3^{c}±0.2	624.2^{c}±2.6	915.2^{a}±11.5	1145.5^{a}±15.5
B	154.5^{ab}±0.3	438.0^{b}±1.9	632.1b^{c}±6.9	916.3^{a}± 1.9	1162.0^{a}±17.3
C	150.1^{b}±2.8	439.5^{b}± 1.2	649.1^{ab}±2.6	930.5^{a}± 11.9	1164.7^{a}±17.6
D	154.0^{ab}±1.1	440.8^{ab}±0.6	658.2^{a}±7.1	927.9^{a} ± 12.0	1166.1^{a}±17.8
E	151.5^{b}± 1.0	441.1^{ab}±0.7	648.1^{ab}± 6.2	929.8^{a} ± 11.8	1164.8^{a}±16.4
F	155.2^{ab}±0.2	442.9^{a} ±0.6	664.5^{a}±9.0	944.4^{a} ± 13.8	1166.7^{a}±16.5

Table 3. Average weekly weight gain.

T	7	14	21	28	35
A	161.7^{a} ±1.49	356.7^{a}± 0.85	607.5^{a}± 1.25	1108.0^{a}±20.6	1603.5^{a}±14.5
B	150.2^{bc}±4.13	353.2^{ab}±1.79	586.5^{b} ± 1.55	1133.5^{a}± 11.8	1614.7^{a}±31.0
C	145.4^{c}±3.015	352.0^{b}± 1.95	563.0^{c} ± 1.22	1087.7^{ab}±18.0	1547.2^{a}±17.7
D	153.5^{b}±1.90	352.0^{b}± 0.91	550.0^{dc}± 2.85	1084.5^{ab}±13.7	1566.2^{a}±17.5
E	148.0± 0.81	349.0^{b}±0.91	548.0^{dc}±10.59	1014.0^{c}±19.3	1586.5^{a}±29.1
F	147.7±0.85	337.5^{c}±1.32	539.7^{d}± 11.30	1049.5^{b}±14.3	1577.2^{a}±3.6

Table 4. Average weekly feed conversion ratio.

T	7	14	21	28	35
A	1.0^{a}±0.0	1.7^{b}±0.0	2.2^{a}±0.1	1.9^{c}±0.0	2.0^{c}±0.0
B	1.0^{a}±0.1	1.7^{ab}±0.0	2.2^{a}±0.1	1.9^{c}±0.0	2.1^{bc}±0.0
C	1.0^{a}±0.0	1.7^{ab}±0.0	2.2^{a}±0.0	2.0b^{c}±0.0	2.1^{a}±0.0
D	1.0^{a}±0.0	1.7^{ab}±0.0	2.2^{a}±0.1	2.0^{c}±0.0	2.1^{ab}±0.0
E	1.0^{a}±0.0	1.7^{ab}±0.0	2.2^{a} ±0.1	2.2^{b}±0.1	2.1^{abc}±0.0
F	1.0^{a}±0.0	1.7^{a}±0.0	2.3^{a}±0.1	2.1^{ab}±0.0	2.1^{ab}±0.0

Table 5. Carcass characteristics of meat.

T	Shank length	Keel length	Dressing %	Spleen weight	Liver weight	Heart weight	Bursa weight	Gizzard weight
A	5.5^{a}+0.0	14.0^{a}+0.0	61.4^{a}+1.0	1.8^{a}+0.2	46.2^{a}+2.7	11.9^{a}+1.6	2.3^{c}+0.0	70.2^{a}+3.4
B	5.4^{b}+0.0	14.0^{b}+0.0	60.2^{a}+2.0	2.3^{a}+0.3	55.2^{a}+5.2	10.1^{a}+0.4	2.3^{b}+0.0	62.9^{ab}+3.0
C	5.4^{b}+0.0	14.0^{c}+0.0	62.7^{a}+2.3	2.2^{a}+0.2	48.2^{a}+5.2	9.1^{a}+ 0.6	2.3^{b}+0.0	52.9^{b}+4.4
D	5.4^{b}+0.0	13.9^{d}+0.0	63.9^{a}+2.0	2.0^{a}+0.4	48.4^{a}+2.1	10.4^{a}+ 0.4	2.3^{ab}+0.0	63.1^{ab}+5.6
E	5.4^{c}+0.0	13.9^{e}+0.0	47.6^{a}+15.6	1.8^{a}+ 0.4	51.0^{a}+1.6	8.9^{a}+ 0.5	2.4^{ab}+0.0	60.5^{ab}+ 5.1
F	5.4^{c}+0.0	13.9^{e}+0.0	66.2^{a}+ 0.7	1.5^{a}+0.2	53.4^{a}+4.6	10.4^{a}+1.2	2.4^{a}+0.0	63.6^{ab}+4.3

higher broiler performance has been successfully achieved through genetic improvement which demands better management and appropriate nutrition, especially in trace element nutrition. It is well established that dietary requirement of trace minerals are negligible; however, it is important to note that these negligible element are important for broiler enzymes system, metabolism, growth and reproduction (Berger and Cunha, 2006).

In this study, we evaluated the effect of replacing ITM with OTM on growth performance, carcass characteristics and meat composition of thigh meat. We observed non significance difference in growth performance parameters between different treatment groups during 1st week of trial

Table 6. Proximate analysis of thigh meat.

T	D. M.%	C. P.%	M%.	Ash%
A	26.0^{a}±1.043	77.8^{a}±0.3	74.0^{a}±1.0	3.6^{a}±0.2
B	24.9^{a}±0.35	77.2^{ab}±0.4	75.0^{a}±0.3	2.9^{a}±0.2
C	24.8^{a}±0.32	77.4^{bc}±0.3	75.1^{a}±0.3	2.9^{a}±0.3
D	24.2a±0.19	76.9^{abc}±0.2	75.8^{a}±0.2	3.0^{a}±0.3
E	23.9^{a}±1.32	76.3^{bc}±0.3	76.1^{a}±1.3	3.0^{a}±0.2
F	26.4^{a}±1.14	76.3^{c}±0.3	73.6^{a}±1.1	3.2^{a}±0.2

which are completely in line with previous reports (Bao et al., 2007). However, we found differences in production performance of various treatment groups, these result are consistent with a pervious observations (Xia et al. 2004; Abdallah et al. 2009; El-Hussein et al., 2012). Current study findings were supported in their subsequent investigation in which they reported that OTM supplementation according to NRC (1994) recommendations is reasonable for highly growing broilers due to their inherent better bioavailability (Fly et al., 1989). However, inorganic trace element does not fulfill modern broiler trace element requirements due to their less bioavailability and negative interaction (Du et al. 1996; Mondal et al., 2007). However during 5th week non-significant difference was identified, these finding are in agreement with Bao and Choct (2009) and Smith et al. (1995) who reported that OTM efficacy decrease as birds age increased (Bao et al. 2009; Smith et al. 1995).

Current study observations about carcass characteristics parameters are in line with the finding of Lu et al. (2006) who reported that broiler intake diet supplemented with organic Mn had shown lower percentage of abdominal fat, further OTM supplemented diet had no significant effect on the weight of liver (g), heart (g), and spleen (g). Our result are completely in agreement with the studies of Bao and Choct (2007) (2009) and Zhao et al. (2010) who reported that organic trace mineral had no effect on dressing percentage and giblets weight. In the present study, organic trace minerals supplementation improved the growth of shake and keel bone length. Osama et al. (2012) reported that organic Zn, Cu, Mn has improved the Tibia weight and length. In 2009, a study was conducted on turkeys and researcher observed that organic trace minerals supplementation improved biochemical properties of bone (Ferket et al. 2009). Similar observation has been reported on equine in which improvement of bone growth has been observed in yearling feeding organic trace mineral supplemented diet than those fed inorganic trace mineral supplemented diet (Ott and Johnson. 2001).

Poultry nutritionist are conscious about organic trace minerals supplementation due to price phenomena, however, we found that organic trace mineral supplementation become inexpensive due increased weight gain with better feed efficiency. The observation of present study are completely in line with the studies conducted by Osman and Raga (2007) and Abdallah et al. (2009), Osama et al. (2012) and El-Hussein et al. (2012) who reported that broilers fed diet supplemented with organic trace minerals has improved profit by decreasing cost of production.

Proximate analysis of thigh meat after skinning indicate that OTM supplementation did not affect significantly on DM, ash and Moisture content, however, crude protein content was improved among OTM fed groups than that of ITM supplemented group. This higher content was may be due to OTM forming complexes with organic compounds which are more soluble and mobile to the cell membranes and easily absorbed (Kincaid, 1989; Nelson, 1988).

Conclusion

1) It is proved that OTM supplementation according to NRC (1994) recommendation could be fully satisfy high genetic broilers requirement.
2) Feeding broiler diet with organic trace mineral during growing phase is improved broiler growth performance.
3) Feeding the diet supplemented with organic trace mineral has improved broiler thigh meat quality and overall economic efficiency of flock.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

Abbreviations

OTM, Organic trace mineral; **ITM,** inorganic trace mineral; **CP,** crude protein; **DM,** dry matter; **NRC,** National Research Council; **BWG,** body weight gain; **g,** gram.

REFERENCES

AAFCO (1997). Association of American feed Control officials. Official Publication Atlanta, G.A.
Abdallah AG, El-Husseiny OM, Abdel-Latif KO (2009). Influence of

some dietary organic minerals supplementations on broilers performance. Int. J. Poult. Sci. 8:291-298.
Anonymous (2008). Economic Survey of Pakistan 2008-2009. Economic Adviser Wing, Finance, Division, Government of Pakistan, Islamabad pp. 32-35.
Bao YM, Choct M, Iji PA, Bruerton K (2007). Effect of organically complexed copper, iron, manganese, and zinc on broiler performance, mineral excretion, and accumulation on in tissues. J. Appl. Poult. Res. 16:448-455.
Bao YM, Choct M, Lji PA, Bruerton K (2009). Optimal dietary inclusion of organically complexed Zinc for Broiler chickens. Brit. Poult. Sci. 50:95-102.
Bao YM, Choct M (2009). Trace minerals nutrition for broiler chickens and prospects of application of organically complexed trace minerals: A review Anim. Prod. Sci. 49:269-282.
Berger LL, Cunha TJ (2006). Trace minerals. In: Cunha TJ 2006 (ed), Salt and trace minerals for livestock, poultry and other animals. Salt Institute, Alexandria.
FAO (2010). Director investment center Division. Poultry, Meat and Eggs viale delle term e di caracalla, 00153 Rome, Italy.
Du Z, Hemken RW, Jackson JA, Trammell DS (1996). Utilization of copper in copper proteinate, copper lysine, and cupric sulfate using the rat as an experimental model. J. Anim. Sci. 74:1657–1663.
Duncan DB (1955). Multiple ranges and multiple F test. Biometrics 11:1-42.
El-Hussein OM, Samia MH, Ali AR, Sohair AA, Abd El-samee DL, Ahmad A (2012). Olemy. Effect of feeding organic zinc manganese and copper on Broiler growth, carcass characteristics, bone quality and Mineral content in bone, live and excreta. Int. J. Poult. Sci. 1:368-377.
Ferket PR, Oviedo-Rondon EO, Mente PL, Bohorquez DV, Santos AA, Grimes JL, Richards JD, Dibner JJ, Felts V (2009). Organic trace minerals and 25-hydroxycholecalciferol affect performance characteristics, leg abnormalities, and biomechanical properties of leg bones of turkeys. Poult. Sci. 88:118-131.
Fly AD, Izquierdo OA, Lowry KR, Baker DH (1989). Manganese bioavailability in a Mn-methionine chelate, Nutr. Res. 9:901-910.
Inal F, Coskun B, Gulsen N, Kurtoglu V (2001). The effects of withdrawal of vitamin and trace mineral supplements from layer diets on egg yield and trace mineral composition. Br. Poult. Sci. 42:77-80.
Kamal MM (2010). Pakistan poultry- A success story and challenges of next decade National Poultry and Food Expo. Lahore.
Kincaid R (1989). Availability, biology of chelated, sequestered minerals explored. Feedstuff pp. 61-22.
Kratzer FH, Vohra P (In press). Chelates in nutrition. CRC Press, Inc., Boca Raton, Florida.
Lesson S (2003). A new look at trace mineral nutrition of poultry: can we reduce the environmental burden of poultry manure? In nutritional biotechnology in feed and food industries. T. Lyson, K.A. Jaques: Nottingham University Press.
Lesson S (2005). Trace mineral requirement of poultry- validity of the NRC (1994) recommendation. In redefining mineral nutrition. Nottingham Univ. Press. Nottingham. UK.
Lu L, Ji C, Luo XG, Liu B, Yu SX (2006). The effect of supplemental manganese in broilers diets on abdominal fat deposition and meat quality. Anim. Feed Sci. Technol. 129:49-59.
Mckay JC (2009). The genetics of modern commercial poultry, in HOCKING, P.M. (Ed) Biology of Breeding Poultry. Poult. Sci. Symp. pp. 3-9.
Mondal MK, Das TK, Biswas P, Samanta CC, Bairagy B (2007). Influence of dietary inorganic and organic copper salt and level of soybean oil on plasma lipids, metabolites and mineral balance of broiler chickens. Anim. Feed Sci. Technol. 139:212–233.
National Research Council (1994). Nutrient requirement for poultry. Ninth Revised Edition, National academy Press, National Research Council, Washington, D.C.
Nelson J (1988). Review of trace minerals chelates and complexes available to the feed industry Proc. Western Nutr. Conf. 2-36.
Nollet L, Wakeman W, Belyavin C (2005). Replacement of inorganic Cu, Mn, Fe and Zn with Bioplex on growth performance and faecal mineral excretion in broilers. 15th Balatonfu¨red, Hungary Eur. Symp. Poult. Nutr. 173–175.
Osman AMR, Raga MS (2007). Performance and carcass characteristics of broiler chicks fed diets supplemented with commercial Zinc-Methionine. 4th World Poultry Congress Sharm El-Sheikh pp. 347-364.
Ott EA, Johnson EL (2001). Effect of trace mineral proteinates on growth and skeletal and hoof development in yearling horses. J. Equine Vet. Sci. 21:287–291.
Oyagi S, Baker DH (1993). Protective effect of copper-amino acid complexes against inhibitory effects of L-cysteine and ascorbic acid. Poult. Sci. 72:82.
Paik IK (2001). Application of chelated minerals in animal production. Asian Austr. J. Anim. Sci. 14:191-198.
Smith MO, Sherman LL, Miller LC, Robbins KR, Halley JT (1995). Relative biological availability of manganese sulfate, and manganese monoxide in broilers reared at elevated temperatures. Poult. Sci. 74:702–707.
Steel RGD, Torrie JH, Ddickey D (1997). Principle and Procedure of statistics. A Biometrical Approach 3rd Ed. McGraw Hill Book Co. Inc., New York pp. 352–358.
USDA (2003). U.S. Department of agriculture. AMS livestock, Poultry and grain Market News 16(18):1-3.
Van Der Klis JD, Kemme AD (2002). An appraisal of trace elements: inorganic and organic, in poultry feedstuffs: supply, composition and nutritive value. J. M. McNab and K. N. Boomrman, ed. Cab Int., Wallingford, UK. pp. 99-108.
Wedekind KJ, Hortin AE, Baker DH (1992). Methodology for assessing zinc bioavailability: efficacy estimates for zinc-methionine, zinc sulfate, and zinc oxide. J. Anim. Sci. 70:178-187.
Xia MS, Hu CH, Xu ZR (2004). Effects of copper bearing montmorillonite on growth performance digestive enzymes activities and intestinal microflora and morphology of mail broilers. Poult. Sci. 83:1868–1875.
Zhao J, Shirley RB, Vazquez-Anon M, Dibner JJ, Richards JD, Fisher P, Hampton T, Christensen KD, Allard JP, Giesen AF (2010). Effect of chelated trace minerals on growth performance, breast meat yield, and footpad health in commercial meat broilers Poultry Science Association, Inc. J. Appl. Poult. Res. 19:365-372.