EFFECTS OF SUPPLEMENTING DIETS WITH AMINO ACID CHELATES OF COPPER, ZINC, MANGANESE AND IRON ON THE PERFORMANCE OF BROILERS

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ABSTRACT

Three hundred twenty (320) straight-run broilers were fed diets supplemented with inorganic and organic trace minerals. Treatments included trace mineral level according to the recommendations of U.S. NRC (1994) as satisfied by minerals from inorganic source as control and three levels from organic source in the form of amino acid chelates. Diets with trace minerals at much lower levels using amino acid chelates did not significantly affect the body weight gain, feed consumption, feed efficiency, livability and dressing percentage of broilers compared to those fed diets with inorganic trace minerals. Broilers fed diets with inorganic minerals had a significant increase in liver manganese and iron compared to those fed diets with chelated minerals. Concentrations of copper and zinc in tibia bone and liver as well as iron in tibia bone did not differ significantly between those fed diets with inorganic and with chelated trace minerals. Due to the high cost of chelated minerals, supplementation of the diets with inorganic minerals was economically beneficial in terms of income over feed and chick cost.

Keywords: amino acids, broiler, chelated minerals, copper, iron, manganese, zinc

INTRODUCTION

Traditionally, inorganic minerals were used to meet the mineral requirements of the animal. In practice, feed formulators tend to include inorganic trace mineral more than what is recommended. As a consequence, a large amount is excreted which resulted to increasing concerns over the contribution of minerals as pollutant in the environment.

The chemical form of mineral source significantly influences the absorption and bioavailability of the minerals (Shapes *et al*., 2004). Bioavailability of inorganic minerals may vary from as low as 5-20% to as high as 80-90% depending on physical forms and reactions with other dietary nutrients (Motyka, 2001). On the

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other hand, there are claims that amino acids are ideal ligand for minerals to create a more stable and bioavailable form of trace minerals. It is postulated that a functional amino acid chelate is electrically neutral, has constant stability and contains easily metabolized ligand and, thus, assumed to be more bioavailable (Motyka, 2001).

Utilization of organic trace mineral is hampered by its high cost compared to inorganic minerals. The goal of amino acid chelates in the diet is to provide the animal with bioavailable minerals in much reduced amount compared to diets that are supplemented with inorganic minerals. Such reduction in level should not compromise the productive performance of the animal (Nollet, 2007), or even better if it can surpass the performance of the animals given with inorganic microminerals. The variability of the results observed by the researchers posted questions on the validity of chelated mineral application in animal production. Though some reports confirmed effectiveness in productivity and lesser excretion, the cost of traditional mineral sources with the organic sources under the Philippines condition is under question, hence this study.

The study was conducted to: 1) determine the effect of inorganic minerals and different levels of amino acid chelated trace minerals on the performance of broilers; 2) determine the difference in mineral tissue concentration between birds fed diets supplemented with inorganic minerals and three levels of amino acid chelated trace minerals; and 3) evaluate the economics of using inorganic and amino acid chelated trace minerals (copper, zinc, manganese, iron) in broiler production.

MATERIALS AND METHODS

Test materials

The inorganic and chelated trace mineral sources used in the experiment were obtained from a premix company and local distributor, respectively. The inorganic trace mineral premix was prepared based on the nutrient recommendation of the U.S. National Research Council (1994) for broiler diets, while the chelated mineral premix was based on the recommendation of the manufacturer.

Diet formulation

The basal chick pre-starter (CPSM), starter (CSM) and finisher (CFM) diets were formulated to contain 22, 20 and 18.5% crude protein, respectively. All basal diets contained 3000 metabolizable energy (kcal/kg) and supplemented with required amino acids, vitamins, and minerals, excluding the trace minerals (copper, zinc, manganese, iron). Table 1 shows the ingredients and nutrient content of basal pre-starter, starter, and finisher diets.

Experimental design and statistical analysis

A total of 320 day-old straight-run broiler chicks were used in the feeding trial. The dietary treatments were randomly assigned to 32 cages following a completely randomized design. Comparisons of the treatment means were done

Table 1. Ingredients and nutrient content of basal pre-starter, starter, and finisher diets.

Ingredients	Chick pre-starter mash	Broiler starter mash	Broiler finisher mash
Yellow Corn	56.05	56.84	61.46
US Soya HP	37.30	31.54	27.62
Rice Bran D1	-	-	5.00
Coco Oil	2.50	2.74	1.93
Limestone	1.64	1.79	1.81
Monodicalcium phosphate	1.56	1.29	1.31
Iodized salt	0.25	0.25	0.25
DL-methionine	0.27	0.12	0.13
Vitamin premix	0.12	0.12	0.12
Mineral premix	0.10	0.10	0.10
Choline 50%	0.10	0.10	0.10
Mold inhibitor	0.05	0.05	0.05
Anti-oxidant	0.01	0.01	0.01
Anti-coccidia	0.05	0.05	-
	100.00	100.00	100.00
Calculated Analysis:			
Crude protein, %	22.00	20.00	18.50
Crude fat, %	5.08	5.79	5.07
Crude fiber, %	2.93	3.19	3.14
Calcium, %	1.00	1.00	1.00
Phosphorus (total), %	0.71	0.70	0.72
Phosphorus (available), %	0.50	0.45	0.45
Metabolizable energy (kcal/kg)	3,000	3,000	3,000
Lysine,%	1.12	1.04	0.94
Methionine, %	0.81	0.65	0.54
Meth+cysteine	1.20	0.96	0.84

using Duncan's Multiple Range Test (DMRT). Each treatment was replicated eight times with a cage of ten chicks per replicate. The dietary treatments are shown in Table 2.

Data gathered

The body weight gained at 7, 28 and 42 days was determined by subtracting initial body weights from body weights at 7th, 28th and 42nd days of age, respectively. The average feed consumption was calculated by subtracting the weights of feed left from the total amount of feeds offered per period. Feed efficiency was calculated by dividing the total feed consumed by the total weight gain of the bird per period. The total number of live birds at the end of the study was divided by the total number of birds used, multiplied by 100, to obtain the livability. Dressing percentage

Table 2. Level of trace minerals added in elemental form in the diets, g/ton of feed.

Treatment[1]	Mineral			
	Cu	Zn	Mn	Fe
I	8.00	40.00	60.00	80.00
II	1.00	4.50	6.00	7.50
III	2.00	9.00	12.00	15.00
IV	2.50	11.25	15.00	18.75

[i]Treatment I: Inorganic ($CuSO_4$, ZnO, $MnSO_4$, $FeSO_4$); Treatment II, III, IV: Amino acid chelates of Cu, Zn, Mn and Fe.

(with giblets) was calculated by obtaining the dressed weight divided by liveweight, multiplied by 100.

At 42 days of age, the whole liver and right tibia bone sample from one bird of each replicate were collected and stored at 0℃. These were prepared and analyzed for trace minerals (copper, zinc, manganese, iron) content using atomic absorption spectrophotometer (Perkin Elmer AAnalyst® and Shimadzu Model AA-6650 Atomic Absorption Spectrophotometer).

Cost of feeds, chicks and trace mineral supplements used, livability and the return from sales of the liveweight of broilers were recorded to determine the income over feed and chick cost using the formula below:

IOFCC = [average live weight x % livability x PhP/kg] –
[(feed consumed x cost of feeds) + cost of chick +
cost of chelated trace mineral]

RESULTS AND DISCUSSION

Trace mineral content of feed samples

In general, the levels of trace minerals increased; feed mineral contents were consistently increased in all diets (Table 3). This is expected since the inclusion levels of chelated trace minerals of diets in Treatment II, III and IV were much lower than the inclusion level in Treatment I.

Performance parameters

The results indicated that the minimum and twice the minimum inclusion level of chelated trace minerals were sufficient to meet the requirements of pre-starter and starter stages of broiler chickens. Based on the overall weight gain of the broilers (Table 4), the results showed that 2.5 times the minimum recommended level of chelated trace minerals were required to equal the body weight gain of

Table 3. Average copper, manganese, zinc, and iron contents of chick pre-starter, broiler starter and finisher diets supplemented with inorganic or amino acid chelated trace mineral premixes (moisture free), µg/g.

Treatment	Mineral(µg/g)			
	Cu	Zn	Mn	Fe
Chick booster				
I	12.63[a]	65.05[a]	63.20[a]	183.67[a]
II	4.94[b]	14.71[d]	12.64[c]	79.61[d]
III	6.86[b]	24.23[c]	20.92[bc]	102.43[c]
IV	7.87[b]	34.41[b]	29.24[b]	120.67[b]
CV (%)	11.35	12.22	14.21	4.49
Broiler starter				
I	13.61[a]	63.59[a]	64.33[a]	189.97[a]
II	5.02[b]	12.56[d]	12.42[c]	80.24[d]
III	6.62[bc]	24.28[c]	21.57[bc]	105.31[c]
IV	8.13[c]	32.95[b]	29.56[b]	121.34[b]
CV (%)	15.67	5.42	13.37	5.87
Broiler finisher				
I	11.73 [a]	59.05[a]	68.42[a]	180.64[a]
II	3.60[b]	10.04[d]	18.83[c]	65.24[d]
III	5.84[bc]	21.90[c]	25.12[bc]	93.31[c]
IV	7.73[c]	29.75[b]	35.00[b]	105.34[b]
CV (%)	19.36	6.57	16.07	10.47

Means with the same superscript within column are not significantly different (P>0.05).

broilers fed diets with inorganic trace mineral premix. This is supported by the study of Wang *et al*. (2008) and Nollet *et al*. (2007) that using lower levels of chelated minerals gave no significant difference in body weight gain compared to those fed diets with higher level of inorganic minerals.

<u>Feed consumption</u>

The data in Table 4 suggest that the inclusion of 2.5 times the minimum inclusion level was adequate to support normal feed intake as evidenced by the similarity in feed consumption of birds fed diets with inorganic trace minerals. Feed consumption of broilers from 8 to 28 days of age across treatments was higher than usual due to very low environmental temperature during the starting period. Nollet *et al*. (2007) observed no significant differences (P>0.05) in the feed intake of birds fed diets with lower inclusion level of trace minerals compared to those fed diets with higher levels of inorganic trace minerals. Wang *et al*. (2009) and MacDonald as cited by Bao *et al*. (2007) suggested that trace minerals may have an effect in stimulating feed intake of birds. Furthermore, the animal’s response is to maintain relatively normal although reduced metabolic levels of these minerals.

Table 4. Average performance of broilers fed diets supplemented with inorganic and with chelated trace minerals (copper, zinc, manganese and iron) from 0 to 42 days of age.

Parameter	Treatment I	Treatment II	Treatment III	Treatment IV	CV%
Average initial body weight (g)	43.17	43.61	44.39	42.90	4.06
Average body weight gain (g)					
0-7 days	101.70	98.66	97.75	101.87	8.05
8-28 days	774.51[ab]	722.35[b]	721.12[b]	803.73[a]	6.79
29-42 days	1087.63	1032.63	1036.75	1061.75	7.08
0-42 days	1963.83[a]	1853.61[b]	1855.61[b]	1967.35[a]	4.37
Average feed consumption (g)					
0-7 days	126.34	130.25	125.63	129.98	6.60
8-28 days	1595.59[ab]	1576.50[b]	1495.88[b]	1618.75[a]	6.99
29-42 days	2286.32	2211.07	2240.86	2293.60	5.31
0-42 days	4008.25	3917.82	3862.37	4042.33	4.92
Feed efficiency					
0-7 days	1.24	1.32	1.29	1.28	8.77
8-28 days	2.06	2.18	2.07	2.01	8.78
29-42 days	2.10	2.15	2.16	2/16	8.49
0-42 days	2.04	2.11	2.08	2.05	5.22
Livability	99.00	100.00	98.88	96.63	3.20
Dressing percentage	79.51[ab]	77.49[b]	79.39[ab]	82.52[a]	3.90

*Averages within row with different superscripts are significantly different at 5% level of probability.

Feed efficiency

Generally, broilers fed diets with inorganic trace minerals gave better feed efficiency among treatments except during the starter period (Table 4). The insignificant differences in feed efficiency indicate that the levels used for chelated minerals were already sufficient to meet the requirement for normal feed efficiency. Nollet *et al*. (2007) and Wang *et al*. (2008) stated that chelated trace minerals can be added at a lower level without negative effect on the feed efficiency of broilers.

Livability

No significant differences in mortality were observed between birds fed diets with chelated and inorganic minerals, in agreement with the study of Sogunle *et al*. (2007), who stated that the insignificant result in mortality cannot be attributed to treatment effect. Considering the weather condition and extreme environmental temperature at the time of the experiment, treatment effects of mortality yielded unclear result.

Dressing percentage

Dressing percentage was observed to be significantly higher in Treatment IV compared to Treatment II. This may suggest that the minimum recommended level of chelated trace minerals might have not been enough to satisfy the requirement. The observation in the present study is partially similar to the trials conducted by Waldroup *et al*. (2003) who reported no significant differences on the dressing percentage while Tactacan (2001) observed higher dressing percentage with 100% replacement of proteinated minerals. In contrast, Coronel (2000) reported lower dressing percentage in birds fed diets with chelated minerals.

Income over feed and chick cost

Income over feed and chick cost was higher in birds fed diets with inorganic trace minerals compared to those fed diets with chelated minerals. The higher price of chelated trace minerals as well as lower livability of birds fed diets supplemented with twice and 2.5 times the minimum recommended level of chelated trace minerals contributed to its relatively lower IOFCC compared to those fed diets with inorganic minerals (Table 5).

Table 5. Average feed cost, sales of finished broilers and income over feed and chick cost (IOFCC) of broiler fed diets supplemented with inorganic or amino acid chelated trace mineral premix from 1 to 42 days of age.

Treatment	Chick cost (PhP)[1]	Average feed cost (PhP)[2]	Sales of finished broiler (PhP)[3]	IOFCC
I	25.00	77.58	149.02	46.44
II	25.00	75.95	142.29	41.34
III	25.00	84.98	140.50	40.92
IV	25.00	78.60	145.69	42.09

[1]Chick cost/head - PhP25.00

[2]Based on the following feed costs: CPSM = PhP24.48/kg; BSM = PhP19.64/kg; BFM PhP18.82/kg; inorganic trace mineral premix at PhP29.97/kg; chelated trace minerals at PhP46.74, PhP91.93, PhP114.52/kg, for Treatments II, III, and IV, respectively. CPSM = chick pre-starter mash; BSM = broiler starter mash; BFM = broiler finisher mash.

[3]Broiler cost/kg - PhP75.00/kg.

Trace mineral content

Liver samples

The results presented in Table 6 indicate that there is an efficient concentration of the trace minerals in the liver even at lower level of inclusion. Cu and Zn content of birds in all treatments were not significantly different while

Table 6. Average copper, manganese, zinc, and iron contents of liver of 42 days old broiler fed diets supplemented with inorganic or amino acid chelated trace mineral premix (moisture free), µg/g.

Treatment	Mineral (µg/g)			
	Cu	Zn	Mn	Fe
I	36.97	77.37	11.86^{a}	303.96^{a}
II	30.37	63.46	2.88^{b}	248.01^{b}
III	29.06	61.91	3.89^{b}	257.41^{b}
IV	29.12	66.19	5.18^{b}	253.62^{b}
CV(%)	28.46	24.28	26.11	21.03

Means with the same superscript within column are not significantly different (P>0.05). Treatment I:Inorganic mineral ($CuSO_4$, ZnO, $MnSO_4$, $FeSO_4$); Treatment II, III, IV: Amino Acid Chelates Cu, Zn, Mn, Fe.

concentrations of Mn and Fe in Treatment I registered the highest among all the treatments. This was supported by the study of Sunder *et al*. (2009) who found similar liver mineral profile except that growth depression was recorded in low level chelated mineral inclusion. Moreover, Bao *et al*. (2007) also reported that even at lower level of chelated trace minerals, trace mineral content was almost equal to those fed diets supplemented with inorganic form of trace minerals.

<u>Tibia bone samples</u>

Statistical analysis of the data reported in Table 7 showed that copper, zinc and iron of tibia bone were not significantly influenced (P>0.05) by the inclusion of inorganic or different levels of chelated trace minerals in the diets. The mineral analysis profile of tibia bone was comparable to the liver mineral analysis as well as the dynamics of their concentration. Birds fed diet with minimum and twice the inclusion level of chelated trace mineral had slower growth but mineral tissue level was maintained. This was consistent with the reports of Bao *et al*. (2007), Lauzon (2006) and Yan and Waldroup (2006).

CONCLUSION

Within the conditions under which the study was conducted, it could be concluded that the there is the possibility of decreasing the inclusion level of trace mineral in broiler diet depending on mineral source, its chemical form and bio-availability. Hence, the minimum recommendation level of chelated minerals by the manufacturer used in this experiment was sufficient to meet the requirement of

Table 7. Average copper, manganese, zinc, and iron contents of tibia bone of 42 days old broilers fed diets supplemented with inorganic or amino acid chelated trace mineral premix (moisture and fat free), µg/g.

Treatment	Mineral (µg/g)			
	Cu	Zn	Mn	Fe
I	9.40	157.46	7.60[b]	72.68
II	10.70	172.29	7.37[b]	75.58
III	10.25	197.24	9.36[a]	92.78
IV	11.31	203.24	9.25[a]	100.77
CV(%)	28.46	24.28	26.11	21.03

Means with the same superscript within column are not significantly different ($P>0.05$). Treatment I:Inorganic mineral ($CuSO_4$, ZnO, $MnSO_4$, $FeSO_4$); Treatment II, III, IV: Amino Acid chelates Cu, Zn, Mn, Fe.

broilers. At higher levels of chelated mineral in the diets, there was a trend for greater bone concentration and dressing percentage compared to the inorganic mineral source.

ACKNOWLEDGEMENT

The authors wish to express their most sincere gratitude to Sci-Pro, Inc. and Department of Science and Technology – Philippine Council for Agriculture, Forestry and Natural Resources Research and Development for the financial support.

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