Zinc (Zn), copper (Cu) and manganese (Mn) are supplemented in broiler diets using inorganic salts such as oxides and sulphates. But the trace minerals tend to dissociate in the low pH environment of upper gastrointestinal tract, leaving the minerals susceptible to various nutrients and ingredient antagonisms that impair absorption (Underwood and Shuttle 1999). Chelated minerals can be utilized at a much lower concentration in the diet than inorganic minerals, without a negative impact on production performance. Higher bioavailability of proteinates and aminoacid chelates (Wedekind and Baker 1989, Wedekind et al. 1992, Cao et al. 2000) along with lowered mineral load in manure (Pierce et al. 2005) has resulted in increased use of these forms of trace minerals in feeding of livestock and poultry. Abdallah et al. (2009) observed that chicks fed diets containing 100% organic minerals (Zn, Cu, Mn and Fe) had significantly higher body weight and better feed conversion on comparison with those of inorganic minerals. In contrast to this, Peric et al. (2007) observed no significant performance differences in performance between birds fed inorganic and organic minerals. The present experiment was undertaken to evaluate the effect of chelated trace minerals (methionate complexes of Cu, Zn and Mn) replacing inorganic minerals (sulphates) on the performance of broilers.

**MATERIALS AND METHODS**

To study the effect of supplementation of organic minerals on the performance of commercial broilers (225) coloured synthetic straight run broiler chicks were randomly divided into 5 groups and each group was further divided into 3 replication having 15 chicks in each replication. The chicks were reared in cages and experiment feeding period was continued for 42 days. The experiment was carried out in 2 phases: a starter phase (0–28 days) and a finisher phase (28–42 days). Samples of experimental feeds were analyzed for proximate composition as per AOAC (1975). The ingredients composition and chemical compositions of the experimental feed are given in Tables 1 and 2, respectively. The inorganic minerals, viz. Zn, Cu and Mn were added @ 40, 8 and 60 ppm, respectively in control group (T1). The inorganic minerals of treatment group were replaced with organic minerals (Zn-methionine, Cu-methionine and Mn-methionine)
in treatment groups as T$_2$ (8 ppm organic Cu), T$_3$ (40 ppm organic Zn) and T$_4$ (60 ppm organic Mn) and T$_5$ (8, 40, and 60 ppm Cu, Zn and Mn, respectively). Weekly body weight and feed consumption were recorded. At 42 day, 3 birds of each treatment were bled to collect blood and subsequently serum was harvested for serum biochemical study. Serum biochemical indices determined were serum glucose, urea, alkaline phosphate (ALP), glutamic-oxaloacetic transaminase (SGOT or AST), glutamic-pyruvic transaminase (SGPT or ALP) and total protein by using crest biosystems kit.

At 42 day, 3 birds were randomly chosen from each treatment and slaughtered for carcass parameter study. The birds were kept off fed overnight before bleeding and only water was provided. The live weight of the birds was recorded as pre slaughter weight. The broiler birds were bled by modified Kosher’s method (Panda and Mohapatra 1989). The weight of the dried tibia was recorded with the help of electronic balance. The tibia bones were ashed in a muffle furnace at 600°C for 4 h. The total ash was determined on per cent weight basis. The tibia bone calcium was determined according to the method modified by Talapatra et al. (1940) and available phosphorus was determined as per IS: 1374–1968. For determination of tibia Zn, Cu and Mn contents, 0.2 g of ash samples were solubilised in 5 ml of 50% HCl and the mineral extract was filtered into a volumetric flask. The extract was diluted using triple distilled water to the required volume and Zn, Cu and Mn concentrations were determined.

Data obtained from the experiment were subjected to statistical analysis. Analysis of variance was obtained according to Snedecor and Cochran (1998).

RESULTS AND DISCUSSION

Body weight and feed conversion ratio: The weekly body weight of the experimental broilers and feed conversion ratio are presented in Tables 3 and 4, respectively. The body weights of broiler till third weeks of age of all the treated groups did not differ significantly (P<0.05). This corroborated with the findings of Baker and Halpin (1987) for Mn, Burrell et al. (2011) for Zn, Dozier et al. (2011) for Cu and Zhao et al. (2010) for Zn, Cu and Mn supplementation in form of organic minerals. The sixth week body weight of T$_3$ was significantly (P<0.05) higher than that of T$_1$. This corroborated with the findings of Abdallah et al. (2009) who reported that the body weight chicks at 35th day fed with 100% organic zinc were significantly higher than the group fed with 50% organic and 50% inorganic zinc and group fed with 100% inorganic zinc. Similar findings were also reported by Świtakiewicz et al. (2001). In contrast to this finding, Tronina et al. (2007) reported that at 21 day, the body weight of chicken receiving zinc oxide was lower by approximately 2% compared to chicken received zinc-glycine while on 42 day, the birds receiving ZnO had significantly higher body weight than zinc-glycine fed group.

Nonsignificant difference was observed between T$_2$ and T$_1$ throughout the experimental period. This result are in

| Weeks/ treatments | T$_1$ | T$_2$ | T$_3$ | T$_4$ | T$_5$
|-------------------|------|------|------|------|------
| 0 week            | 40.48±0.53 | 40.18±0.58 | 39.94±0.51 | 39.46±0.43 | 39.64±0.57
| First week        | 85.39±1.03 | 87.61±1.36 | 89.61±1.36 | 86.97±1.04 | 89.29±1.06
| Second week       | 277.68±3.41 | 274.11±2.22 | 280.01±2.37 | 271.65±3.43 | 282.56±4.80
| Third week        | 504.35±8.11 | 497.61±8.67 | 515.27±6.64 | 498.29±10.83 | 517.05±7.87
| Fourth week       | 684.73±12.63 | 679.45±10.70 | 776.43±9.00 | 696.61±15.43 | 730.88±9.00
| Fifth week        | 972.19±18.68 | 960.72±16.28 | 1073.11±7.38 | 972.55±16.18 | 1053.51±19.82
| Sixth week        | 1343.76±18.11 | 1327.53±16.51 | 1468.33±17.19 | 1340.73±19.23 | 1402.13±21.36

Means with same superscript in a row did not differ significantly (P<0.05).
according to Banks et al. (2004) and Zhao et al. (2010) who reported no significant difference with respect to body weight in poultry by replacing inorganic Cu at 50% and 100% level with organic. Except T2, broilers fed diets containing inorganic minerals were significantly recorded the lowest live body weight than that of organic minerals fed group. This is in agreement with the findings of Abdallah et al. (2009). They reported significantly lower body weight in 100% inorganic mineral fed groups than feeding organic minerals to broiler birds. The lower body weight in T1 might be due to the reason that use of organic mineral sources can improve intestinal absorption of trace elements as they reduce interference from agents that form insoluble complexes with the ionic trace elements (Van and Kemme 2002). The significantly higher body weight in T3 than that of other treated groups might be due to higher feed intake as the first sign of Zn deficiency in broiler chickens is decreased feed intake followed by poor growth. Under conditions of Zn deficiency, broiler chickens did not benefit from supplemental Cu and Mn, suggesting that Zn mainly affected bird feed intake and the deficiency of primary nutrients strongly depressed broiler growth rate (Bao et al. 2007).

The feed conversion ratio (FCR) of all the treated groups did not differ significantly (P>0.05). This is in agreement with the findings of Rossi et al. (2007) who reported that the feed consumption and feed conversion were not influenced by addition of increasing levels of dietary organic Zn in experimental quails and Swiatkiewicz and Koreleski (2008) by feeding Zn and Mn both from organic and inorganic sources. Contradictory findings were reported by Abdullah et al. (2009).

**Serum biochemical parameters:** Biochemical constituents, viz. blood glucose (mg/dl), cholesterol (mg/dl), total protein (g/dl), blood urea (mg %), blood urinary nitrogen (mg %), albumen (g/dl), globulin (g/dl), A:G ratio, calcium (mg/dl), phosphorus (mg/dl), SGPT (IU/l), SGOT (IU/l), ALP (IU/l) of broilers at sixth week of age, under different treatments of zinc are presented in Table 5. The studied biochemical parameters, viz. serum glucose, albumin, globulin, albumin and globulin ratio, protein, urea, calcium, phosphorus, and SGOT levels of all the treatments of the experimental broilers did not differ significantly (P>0.05). Similar observations were also recorded earlier (Chowdhury et al. 2004, Idowu et al. 2011 and Parak and Strakova 2011). However, some contradictory results were reported by Al-Daraji and Amen (2011).

The significantly (P<0.05) lower serum cholesterol and higher SGPT and ALP levels were observed in organic Zn fed groups. Herzig et al. (2009) proved that there was a significant decrease of plasma cholesterol when broilers were fed with high amounts of zinc in diet. Though the T1, T3 and T5 groups received same level of zinc, the lower cholesterol level in T3 and T5 might be due to higher bioavailability of zinc from organic source. The serum SGPT level of organic zinc fed birds were found to be significantly higher than the inorganic zinc fed and control groups. A significant difference in SGPT level was found in birds of T3 and T5 fed with same

<table>
<thead>
<tr>
<th>Weeks/ treatments</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
</tr>
</thead>
<tbody>
<tr>
<td>First week</td>
<td>1.64±0.03</td>
<td>1.65±0.02</td>
<td>1.60±0.00</td>
<td>1.67±0.04</td>
<td>1.60±0.00</td>
</tr>
<tr>
<td>Second week</td>
<td>1.80±0.05</td>
<td>1.79±0.02</td>
<td>1.83±0.04</td>
<td>1.78±0.08</td>
<td>1.77±0.04</td>
</tr>
<tr>
<td>Third week</td>
<td>1.84±0.03</td>
<td>1.85±0.09</td>
<td>1.82±0.02</td>
<td>1.87±0.04</td>
<td>1.82±0.03</td>
</tr>
<tr>
<td>Fourth week</td>
<td>1.87±0.04</td>
<td>1.88±0.04</td>
<td>1.88±0.03</td>
<td>1.93±0.04</td>
<td>1.87±0.01</td>
</tr>
<tr>
<td>Fifth week</td>
<td>1.92±0.04</td>
<td>1.94±0.01</td>
<td>1.93±0.06</td>
<td>1.97±0.05</td>
<td>1.91±0.07</td>
</tr>
<tr>
<td>Sixth week</td>
<td>2.04±0.16</td>
<td>2.05±0.23</td>
<td>1.99±0.27</td>
<td>2.07±0.13</td>
<td>1.97±0.18</td>
</tr>
</tbody>
</table>

Means with same superscript in a row did not differ significantly (P>0.05).
levels of Zn-Met. The ALP level in the serum of zinc supplemented birds was found to be significantly different (P<0.05) from the control. Idowu et al. (2011) also observed significant difference in the levels of ALP between control and zinc proteinate groups with higher levels in zinc proteinate and opined that due to zinc binding capacity of serum, alkaline phosphate acts as a good indicator of zinc status. The increase in ALP level on zinc supplementation might be due to increase in corticosteroid hormone secretion, epinephrine and nor-epinephrine (Al-Daraji and Amen 2011).

In contrast to this, nonsignificant level of serum ALP in organic zinc fed groups was reported by Parak and Strakova (2011).

### Carcass characteristics:

Carcass characteristics of the broilers of different dietary treatments at sixth week of age are presented in the Table 6. The live weight, dressed weight, eviscerated weight, drum stick yield, thigh yield, back yield, neck yield, breast yield and wing yield of all the treatments of experimental broilers did not differ significantly (P>0.05). This finding corroborated with the findings of Waldroup et al. (2003), Rossi et al. (2007) and Zhao et al. (2010). In contrast to this, Britanico et al. (2012) reported that dressing percentage was observed to be significantly superior in higher level of chelated mineral inclusion in the diet of broiler.

### Effect on tibia bone:

Tibia bone parameters of broilers at 42nd day of age in different dietary treatments are presented in Table 7. The tibia wt (g), tibia ash (%), tibia Ca (%), tibia P (%), tibia Cu (ppm) and tibia Mn (ppm) of all the treatments of experimental broilers did not differ significantly. Similar results were also reported by Abdallah et al. (2009) who reported that supplementation of organic Zn, Cu and Mn at 50% and 100% levels in the diet of broilers did not have any significant effect on the tibia wt (g), tibia length (mm), tibia Ca (%) and tibia P (%) levels. Underwood and Shuttle (1999), Zhao et al. (2010) and Britisho et al. (2012) also had the similar findings. However, contradictory observations were reported by Wedekind and Baker (1989), Bao et al. (2007), Wang et al. (2008) and Idowu et al. (2011). With replacement of inorganic minerals with chelated minerals in the experimental diets, no significant difference was observed in the tibia mineral levels. This is in agreement with the findings of Zhao et al. (2010). They reported that by replacing 50% of the inorganic Zn, Cu and Mn in the control ration with chelated minerals in dietary treatments, no significant difference was observed between the control and treatment groups for tibia mineral content.

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