Indian Journal of Animal Sciences **84** (1): 60–67, January 2014/Article

Performance of Japanese quail on organically complexed minerals by replacing inorganic sources

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Received: 22 February 2013; Accepted: 29 September 2013

ABSTRACT

Day-old quails (459) were divided into 9 groups and each group was assigned with one dietary treatment, viz. T_0 (control), T_1 (100% organic Zn, Cu and Mn), T_2 (100% organic Mn), T_3 (50% organic Mn), T_4 (100% organic Cu), T_5 (50% organic Cu), T_6 (100% organic Zn), T_7 (50% organic Zn) and T_8 (50% organic Zn, Cu and Mn). Weekly body weight and feed consumption were recorded. At 42 day, the serum biochemical indices and carcass characteristics were determined. Also the tibia bone parameters and weight of the immune organs were studied at 42 day of age. At 0 day, 7th day, 14th day and 21st day, the body weight of experimental quail of all the groups did not differ significantly. At 6th weeks, the body weights of T_8 attained highest body weight with no significant difference with the body weight of T_1, T_3, T_4 and T_7. At 6th week, T_8 recoded better FCR with no significant difference from T_1, T_4, T_5 and T_7. The serum glucose, serum cholesterol, serum triglyceride, albumin, globulin, albumin and globulin ratio, calcium, phosphorus, SGOT, SGPT, ALP levels of all the treatments of the experimental quails did not differ significantly but the serum protein, urea and haemoglobin of the quails of treatment groups differed significantly. The carcass characteristics of the experimental quail did not differ significantly (P>0.05). The tibia wt (g), tibia length (mm), tibia Ca (%) and tibia P (%) of all the treatments of experimental quails did not differ significantly but the tibia ash content was significantly higher in organic mineral supplemented groups. The weight of lymphoid organs (spleen, bursa and thymus) of experimental quail at sixth week of age of all treatments did not differ significantly. It may be concluded that 50% replacement of inorganic Zn, Cu and Mn with their corresponding organic sources showed better performance in quail.

Key words: Organic minerals, Performance, Quail, Tibia bone

The Japanese quail (*Coturnix coturnix japonica*) is gaining popularity as alternate meat bird with better growth and egg production. Japanese quail besides being a premium meat producing bird, has also been recognized as a pilot research animal (Wilson *et al*.1961) as it offers easy handling, low maintenance cost, rapid generation turn over and good reproductive performances. To meet the mineral requirement, zinc (Zn), copper (Cu) and manganese (Mn) are supplemented in poultry 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 1990, Wedekind *et al*. 1992, Cao *et al*. 2000) along with lowered mineral load in manure 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. Research on chelated mineral on the production performance of quail under practical feeding system is very few. So this investigation was undertaken with the objectives of evaluating the effect of chelated trace minerals (methionate complexes of Cu, Zn and Mn) replacing inorganic minerals (sulphates) at 50% and 100% levels on growth, feed conversion, carcass traits, blood biochemical and tibia bone parameters of quails.

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The experiment was carried out at Central Poultry Development Organization, Bhubaneshwar, Odisha. The quail germplasm used in the investigation were obtained from CPDO, Bhubaneshwar in form of hatching eggs and hatched at the same experimental farm. The day-old quails were wing-banded, weighed individually and transferred to battery brooders immediately after hatch. Day-old quails (459) of the same hatch divided into 9 groups with 3 replications in each group and each replication having 17 quails to carry out the present experiment. Dietary treatments, viz. T_0 (control), T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 all having an isocaloric and isonitrogenous diet with suggested levels of microminerals (Cu, Mn, Zn) from different inorganic and organic sources were designed as mentioned in Table 1. The minerals, viz. Zn, Cu and Mn were supplemented at the levels of 25, 5 and 60 ppm, respectively, over the basal diet. Inorganic sources of minerals (Cu, Mn, Zn) were sulphates and the organic ones were methionate complexes of respective minerals. The composition of feed is given in Table 2. Samples of the experimental feed were analysed for dry matter, crude protein, ether extract, crude fibre, total ash and acid insoluble ash as per AOAC (1995). Calcium was measured according to Talapatra *et al*. (1940) and available phosphorus was determined as per IS: 1374–1968. The micro minerals content of the feed samples were estimated by using atomic absorption spectrophotometer. Weekly body weight of experimental quails and feed consumption were recorded. At 42 day, 3 ml of blood was drawn from the 12 quails per treatment (4/replicate) by cardiac puncture, into heparinised tubes. The serum was obtained by centrifugation of non coagulated blood at 700g for 5 min. The serum was stored at –20°C until analysis. The serum biochemical indices determined were glucose, urea, alkaline phosphate (ALP), glutamic-oxalloacetic transaminase (SGOT or AST), glutamic- pyruvic transaminase (SGPT or ALP) and total protein. using crest biosystems kit. At 42 day, 4 quails (2 males and 2 females) were randomly chosen from each treatment and slaughtered for carcass parameter study. For carcass study, the birds were kept off feed overnight before bleeding and only water was provided. The live weight of the birds was recorded as pre-slaughter weight. The quails 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. Length and width of tibia were determined using electronic slide calliper. The tibia bones were ashed in a muffle furnace at 600°C for 5 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. Data obtained from the experiment were subjected to statistical analysis wherever required. Analysis of variance were obtained according to the method of Snedecor and Cochran (1998).

RESULTS AND DISCUSSION

The weekly average body weight (g) and weekly average body weight gain of quails of different dietary treatment groups are presented in Tables 3 and 4, respectively. The body weight of experimental quail did not differ significantly during 0 day, 7th day, 14th day and 21st day of the experimental feeding period. During 7th day, 14th day and 21st day period, the weekly body weight gain of quails in all the experimental treatments did not differ significantly (P>0.05). Since most of the research work on chelated mineral feeding has been reported in broiler birds and not much reference is available for quail, so the discussion of this research paper is mainly based on broiler birds. The earlier workers reported no significant effect of Mn source on average daily weight gain (Henry *et al*. 1989). Similarly, Baker and Halpin (1987) conducted an experiment to compare the effect of protein chelated manganese and manganese sulphate in male chicks from a cross of New Hampsire males and Colubian females from 8 to 22 days post hatching and reported that Mn source (proteinate vs sulphate) had little effect on chick weight gain (263 vs 253 g). As regard to zinc alone feeding, no significant effect on body weight was observed up to 3 weeks age which corroborated with the finding of Namra *et al.* (2008). Similarly, Burrell *et al*. (2011) fed broilers with basal diet containing 30 mg/kg zinc in control and added inorganic zinc at the levels of 20, 40, 80 mg/kg. Similarly organic zinc was supplemented to other groups at the levels of 20, 40, 80 mg/kg. They reported that from 0–20 days of age, there was no

Table 1. Dietary treatments of experimental quails

Treatments		Minerals supplements			
T_0 (Control)	Basal Diet	100% inorganic Zn	100% inorganic Cu	100% inorganic Mn	
T_1	Basal Diet	100% organic Zn	100% organic Cu	100% organic Mn	
T_2	Basal Diet	100% inorganic Zn	100% inorganic Cu	100% organic Mn	
T_3	Basal Diet	100% inorganic Zn	100% inorganic Cu	50% inorganic Mn	50% organic Mn
T_4	Basal Diet	100% inorganic Zn	100% inorganic Mn	100% organic Cu	
T_5	Basal Diet	100% inorganic Zn	100% inorganic Mn	50% inorganic Cu	50% organic Cu
T_6	Basal Diet	100% inorganic Mn	100% inorganic Cu	100% organic Zn	
T_7	Basal Diet	100% inorganic Mn	100% inorganic Cu	50% inorganic Zn	50% organic Zn
T_8	Basal Diet	50% trace minerals from inorganic sources + 50% trace minerals from organic sources			

Table 2. Ingredient and proximate composition of the experimental diet

Ingredients	Parts per quintal	Parameters	Percentage on DM basis
Crushed yellow maize	55	Dry matter	91.2
Soyabean meal	41	Crude protein	24.3
Oyster shell meal	1.5	Ether extract	4.6
DCP	1.5	Crude fibre	3.9
Mineral mixture$	0.5	Total ash	8.1
Salt	0.4	Acid insoluble ash	3.9
Premix$	0.1	Nitrogen free extract*	46.4
		Calcium	0.83
		Available phosphorus	0.42
		Metabolizable energy*	2918 (k.cal/kg)
		Lysine *	1.31
		Methionine*	0.51
		Copper#	6.83 ppm
		Zinc#	32.63 ppm
		Manganese#	15.68 ppm

$ Without zinc, copper and manganese, #Analysed values, * calculated value.

significant difference in body weight, feed conversion or incidence of mortality. Also Rossi *et al.* (2007) reported that by adding 0, 15, 30, 45, 60 ppm organic zinc to a basal diet ration containing 60 ppm zinc from inorganic sources did not have significant effect on feed consumption, body weight, feed conversion ratio, mortality and carcass yield parameters of the broilers. As regard to supplementation of copper, Dozier *et al.* (2011) reported nonsignificant effect of copper (both 100% and 50%) in comparison to copper sulphate at 4, 8 and 12 ppm on the body weight of broiler birds 17th days of age. The body weight of quail in T_1 and T_8, where organic Zn, Cu and Mn were included in the diet @ 100% and 50%, respectively did not differ significantly. Similar findings were also reported by Zhao *et al*. (2010). They reported that dietary treatment by replacing 50% of the inorganic Zn, Cu, Mn in the control ration with chelated minerals, the body weight increased nonsignificantly in broilers (both in Ross and Cobb breed).

At fourth, fifth and sixth weeks of age, the body weights of quail of group T_8 attained highest body weight with no significant difference with the body weight of T_1, T_2, T_5 and T_7. Quail fed diets containing inorganic minerals were significantly recorded the lowest live body weight. This is in agreement with the findings of Abdallah *et al*. (2009). On comparison of the body weight of T_8 (50% Zn, Cu, and Mn organic mineral) with T_1 (100% Zn, Cu, and Mn organic minerals), though the body weight of both the groups did not differ significantly at fourth, fifth and sixth week, but numerical higher body weight was recorded in T_8. This is in agreement with the findings of Bao *et al.* (2007) who reported that medium level of organic minerals supplementation had higher body weight gain than that of high or low level of organic mineral supplementation. The body weight of quail of T_6 (100% organic zinc) and T_7 (50% inorganic zinc) did not differ significantly throughout the experimental period. In contradiction to our finding, Abdallah *et al*. (2009) reported that chicks fed diets containing 100% organic Zn were significantly higher in body weight than that fed on 50% organic Zn. The nonsignificant difference in body weight of quail between T_6 (100% organic zinc) and T_7 (50% inorganic zinc) might be due to higher zinc availability from organic source, as inclusion of zinc either in chelated form or inorganic sources in excess of the requirement had no beneficial effect on body weight gain of broilers (Owens *et al*. 2009).

Nonsignificant difference was observed between T_4 (100% organic copper supplemented group) and T_5 (50% organic copper supplemented group) throughout the experimental period. The results are in accordance with Banks *et al.* (2004) who reported no significant difference with respect to body weight in poultry by replacing inorganic Cu at 50% and 100% level. Similarly, the body weight of T_6 (100% organic Zn supplemented group) and T_7 (50% organic

Table 3. Average weekly body weight (g) of quails in different dietary treatments (from 0 day to 6th week of age)

Period	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	P value
0 day	7.10±0.06	7.07±0.06	7.03±0.04	6.97±0.05	7.07±0.05	6.96±0.06	7.01±0.04	7.03±0.04	7.10±0.05	0.44
1st week	24.27±0.30	25.03±0.35	24.89±0.24	24.88±0.27	24.65±0.28	24.39±0.22	24.66±0.24	25.01±0.32	25.31±0.27	0.16
2nd week	56.39±1.53	56.51±2.25	56.26±1.02	56.18±1.85	56.28±1.28	56.36±1.12	55.42±0.92	56.36±1.32	56.88±1.59	0.99
3rd week	86.84±1.31	90.02±2.25	90.05±2.36	87.33±2.60	87.42±1.31	90.50±1.28	89.24±1.01	90.30±2.01	90.80±1.34	0.10
4th week	117.73^{bc} ±1.29	121.96^{ab} ±1.78	122.02^{ab} ±2.99	116.88^{c} ±1.88	118.18^{bc} ±2.04	121.46^{abc} ±1.86	117.74^{bc} ±1.07	122.38^{ab} ±1.21	123.81^{a} ±2.94	0.03
5th week	146.99^{d} ±2.08	157.99^{ab} ±5.15	156.63^{ab} ±3.21	151.98^{bc} ±2.37	151.78^{bcd} ±5.75	147.01^{d} ±2.26	156.52^{ab} ±1.90	159.13^{a} ±2.77	160.16^{a} ±6.35	0.01
6th week	182.83^{c} ±3.27	193.26^{abc} ±3.82	187.93^{bc} ±6.08	193.30^{abc} ±4.01	193.78^{abc} ±4.31	190.38^{bc} ±3.83	183.62^{bc} ±6.74	194.26 ^{ab} ±3.99	203.57^{a} ±3.68	0.01

Means with different superscript in a row differed significantly ($P<0.05$).

Table 5. Cumulative feed consumption of quails in different dietary treatments (from 0 day to 6th week of age)

Period	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	P value
0 to 1st week	24.66 ±0.88	24.33 ±1.20	22.66 ±0.88	22.33 ±0.88	22.00 ±1.00	24.33 ±0.33	23.66 ±0.66	15.00 ±6.50	22.66 ±0.33	0.19
0 to 2nd week	111.96 ±5.67	106.78 ±9.30	113.67 ±5.96	107.52 ±8.29	108.09 ±5.71	107.40 ±5.71	108.26 ±5.70	111.19 ±5.67	111.25 ±6.25	0.99
0 to 3rd week	243.38 ±4.35	242.70 ±5.33	246.24 ±16.31	241.53 ±4.22	244.71 ±9.38	250.94 ±11.94	247.26 ±10.54	249.69 ±12.53	251.71 ±2.84	0.99
0 to 4th week	351.40 ±5.21	316.08 ±4.07	360.46 ±6.01	344.13 ±8.67	327.15 ±13.31	356.85 ±13.72	349.72 ±12.27	365.66 ±10.98	338.74 ±9.10	0.08
0 to 5th week	503.66 ±23.65	463.65 ±15.13	497.45 ±15.47	485.59 ±7.17	515.34 ±15.91	462.86 ±17.02	500.32 ±17.44	545.93 ±18.69	501.00 ±15.64	0.08
0 to 6th week	683.96 ±13.90	657.94 ±28.89	716.30 ±11.48	683.90 ±5.10	672.54 ±12.58	650.74 ±23.28	697.91 ±25.05	690.60 ±10.89	652.95 ±9.26	0.17

Means with different superscript in a row differed significantly (P<0.05).

Table 6. Feed conversion ratio (FCR) of quails in different dietary treatments (from 0 day to 6th week of age)

Period	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	P value
0 to 1st week	1.44±0.04	1.35±0.05	1.27±0.05	1.25±0.04	1.25±0.05	1.40±0.03	1.34±0.04	0.84±0.36	1.24±0.01	0.13
0 to 2nd week	2.27±.20	2.19±0.21	2.31±0.12	2.23±0.21	2.20±0.17	2.22±0.15	2.21±0.08	2.29±0.09	2.31±0.31	0.99
0 to 3rd week	3.00±0.06	2.97±0.10	3.01±0.05	2.96±0.10	3.02±0.05	3.01±0.05	2.98±0.08	3.00±0.05	2.98±0.03	0.99
0 to 4th week	3.18^{a}±0.09	2.78^{c}±0.05	3.13^{ab}±0.02	3.16^{ab}±0.09	2.94^{abc}±0.11	3.13^{ab}±0.19	3.16^{ab}±0.04	3.18^{a}±0.03	2.92^{bc}±0.03	0.04
0 to 5th week	3.60^{a}±0.15	3.07^{c}±0.08	3.33^{abc}±0.13	3.35^{abc}±0.05	3.56^{ab}±0.10	3.31^{abc}±0.16	3.54^{ab}±0.14	3.59^{ab}±0.06	3.27^{bc}±0.10	0.05
0 to 6th week	3.89^{abc}±0.06	3.53^{cd}±0.14	4.03^{a}±0.20	3.67^{abcd}±0.08	3.61^{bcd}±0.12	3.55^{cd}±0.14	3.95^{ab}±0.11	3.70^{abcd}±0.13	3.33^{d}±0.12	0.02

Means with different superscript in a row differed significantly (P<0.05).

Zn supplemented group) did not differed significantly at fourth, fifth and sixth week stage. This implied that inclusion of 50% level of Cu and Zn in the diet in the form of organic zinc resulted in same growth as that recorded in 100% level of organic Cu and Zn. Abdallah *et al*. (2009) reported that chicks fed diets containing 100% organic-Cu were found non-significantly different than that fed on 50% organic- Cu.

Feed conversion ratio: The average cumulative feed consumption and average cumulative FCR of quails in different treatments (from 0 day to sixth week of age) are presented in Tables 5, 6, respectively. Cumulative feed consumption throughout the study period did not show any significant difference among the treatment groups. No significant difference was observed among the dietary treatments until the period of 3 week of age with respect to FCR. As regards to FCR of experimental quail in fourth weeks of age, significantly (P<0.05) better FCR was observed in T_1 which differed nonsignificantly from T_4 and T_8. In fifth week, similar FCR level was recorded. But in sixth week, performance of T_8 recoded better FCR which did not differ significantly (P>0.05) from T_1, T_4, T_5 and T_7. On summarization, it was observed that, supplementation of organic minerals in quail diet either at 50% or 100% level resulted in better FCR. Feed efficiency of quails fed on diets containing only inorganic minerals was significantly inferior to that of other groups. This is in agreement with the findings of Abdullah *et al*. (2009). Cao *et al*. (2000) also observed similar findings. Contradictory findings were recorded by Rossi *et al*. (2007) as they reported the body weight gain, feed consumption and feed conversion were not influenced by addition of increasing levels of dietary organic Zn in experimental quails. Fifty percent level of inclusion of organic trace minerals (Zn, Cu, and Mn) recorded better FCR than their respective mineral inclusion at 100% level in the diet of experimental quail, though statistically nonsignificant, might be due to less intake in comparison to weight gain. This is in agreement with the findings of Bao *et al*. (2007) and Abdallah *et al*. (2009). The insignificant differences in

Table 7. Serum biochemical levels of experimental quails on different dietary treatments of organic minerals

Constituents	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	P value
Glucose	336.93	298.59	316.70	349.07	321.205	366.754	356.962	316.297	353.592	0.08
(mg/dl)	±14.68	±7.23	±8.52	±21.47	±13.453	±16.781	±14.028	±16.930	±9.335	
Cholesterol	156.01	131.38	150.26	132.85	143.035	141.213	139.972	160.163	159.899	0.86
(mg/dl)	±11.08	±10.26	±19.16	±8.72	±8.561	±9.295	±22.891	±10.631	±13.328	
Triglyceride	124.94	117.41	138.70	147.08	128.191	148.120	119.990	112.051	150.885	0.32
	±14.84	±12.39	±9.19	±7.47	±12.113	±8.847	±10.392	±10.671	±12.499	
Protein	3.88^{bc}	4.76^{a}	3.88^{bc}	3.86^{bc}	3.809^{bc}	3.694^{c}	4.207^{bc}	4.143^{bc}	4.265^{ab}	0.02
(g/dl)	±0.09	±0.08	±0.14	±0.08	±0.142	±0.153	±0.179	±0.193	±0.380	
Albumen	2.416	2.54	2.23	2.346	2.060	2.611	2.538	1.982	2.464	0.07
(g/dl)	±0.05	±0.13	±0.11	±0.040	±0.034	±0.083	±0.062	±0.022	±0.043	
Globulin	2.68	2.17	2.09	2.234	2.365	2.351	2.551	2.563	2.566	0.99
(g/dl)	±0.09	±0.15	±0.15	±0.106	±0.078	±0.077	±0.116	±0.083	±0.100	
A:G ratio	0.52	0.39	0.71	0.695	0.465	0.682	0.695	0.556	0.629	0.75
	±0.04	±0.01	±0.30	±0.104	±0.075	±0.093	±0.126	±0.079	±0.133	
Urea	2.27^{a}	1.155^{b}	2.27^{a}	1.355^{b}	2.474^{a}	1.225^{b}	1.368^{b}	1.425^{b}	1.185^{b}	0.01
(mg%)	±0.22	±0.274	0.22	±0.076	±0.278	±0.146	±0.273	±0.321	±0.088	
BUN (mg%)	0.80	0.905	1.065	0.732	1.664	0.715	0.639	1.065	0.666	0.27
	±0.31	±0.291	±0.074	±0.390	±0.365	±0.289	±0.050	±0.053	±0.085	
Calcium	8.53	11.242	13.894	9.968	14.212	12.166	10.677	10.542	15.757	0.30
(mg/dl)	±1.65	±2.422	±2.484	±1.988	±1.357	±2.433	±1.386	±1.394	±0.921	
Phosphorus	5.92	4.081	6.175	6.469	3.759	3.340	2.698	5.986	8.605	0.12
(mg/dl)	±1.89	±1.372	±1.424	±1.343	±0.922	±0.594	±0.932	±1.082	±1.233	
SGOT(U/L)	56.52	61.405	56.739	64.609	68.248	70.057	56.447	58.728	59.703	0.48
	±4.88	±5.301	±4.298	±6.271	±5.142	±4.298	±2.586	±3.810	±4.928	
SGPT (U/L)	50.405	49.853	56.739	48.923	46.648	48.457	47.847	50.128	59.609	0.58
	±4.471	±8.990	±3.375	±2.464	±3.374	±2.137	±3.499	±2.830	±3.120	
ALP (U/L)	765.30	833.680	701.035	833.189	762.555	826.872	796.501	787.747	813.317	0.13
	±17.55	±19.974	±10.029	±25.575	±32.087	±33.759	±43.547	±42.022	±15.506	
Hb (g%)	10.50^{cd}	11.80^{abc}	10.60^{cd}	10.800^{bcd}	10.200^{d}	11.200^{abcd}	12.100^{ab}	12.000^{ab}	12.467^{a}	0.04
	±0.153	±0.643	±0.503	±0.929	±0.416	±0.252	±0.416	±0.379	±0.318	

Means with different superscript in a row differed significantly (P<0.05).

feed efficiency indicated 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 could be added at a lower level without negative effect on the feed efficiency of broilers.

Effect on biochemical parameters: The serum biochemical levels of experimental quails on different dietary treatments of organic minerals are presented in Table 7. The studied biochemical parameters, viz. serum glucose, serum cholesterol, serum triglyceride, albumin, globulin, albumin and globulin ratio, calcium, phosphorus, SGOT, SGPT, ALP levels of all the treatments of the experimental quails did not differ significantly (P<0.05). Similar observations were also recorded earlier (Chowdhury *et al*. 2004, Idowu *et al*. 2011). However, some contradictory results were reported by Al-Daraji and Amen (2011). The serum protein, urea and haemoglobin of the quails of treatment groups differed significantly in some groups but did not show any definite trend. The serum protein level was highest in T_1 which differed nonsignificantly from T_8. In all other groups, the serum protein levels remained more or less same. Idowu *et al*. (2011) observed significant difference in serum protein and uric acid concentrations between control and zinc-proteinate groups with higher levels in zinc-proteinate group which corroborated with our findings.

Effect on carcass characteristics: The carcass characteristics of the quails of different dietary treatments at sixth week of age are presented in Table 8. The dressed weight, eviscerated weight, drum stick yield, thigh yield, back yield, neck yield, breast yield and wing yield of all the treatments of the experimental quail 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).

Tibia bone parameters: The tibia bone characteristics of experimental quails on different dietary treatments of organic minerals at sixth week age are presented in Table 9. The tibia wt (g), tibia length (mm), tibia Ca (%) and tibia P (%) of all the treatments of experimental quails did not differ

Table 8. Carcass quality traits of experimental quails on different dietary treatments at sixth week age

Constituents	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	P value
Live weight	192.318 ±11.548	194.424 ±13.347	196.996 ±9.116	195.223 ±14.783	200.162 ±9.629	190.268 ±12.295	189.763 ±10.260	184.917 ±11.436	193.822 ±8.705	0.99
Dressed yield	72.680 ±2.056	70.389 ±1.565	69.566 ±2.529	71.008 ±2.176	69.370 ±1.527	70.663 ±1.878	72.070 ±1.527	71.149 ±1.581	72.504 ±1.820	0.93
Eviscerated yield	71.620 ±1.828	68.824 ±1.679	65.164 ±1.860	67.662 ±2.349	66.629 ±1.975	64.313 ±1.899	68.824 ±1.679	68.349 ±1.404	69.771 ±1.166	0.15
Drumstick yield	9.434 ±0.409	9.137 ±0.352	8.571 ±0.543	9.238 ±0.589	8.898 ±0.741	9.809 ±0.513	10.014 ±0.381	9.890 ±0.549	9.116 ±0.457	0.48
Thigh yield	12.452 ±0.585	12.300 ±0.667	11.280 ±1.159	10.251 ±0.581	11.856 ±0.458	10.937 ±0.516	10.133 ±0.573	11.573 ±0.500	11.303 ±0.581	0.21
Back yield	20.431 ±1.007	18.903 ±0.573	19.017 ±0.993	18.898 ±1.204	19.222 ±1.151	19.320 ±0.464	19.600 ±0.870	20.694 ±0.581	21.163 ±0.581	0.84
Neck yield	7.902 ±0.581	9.453 ±0.833	8.906 ±1.000	9.301 ±1.159	8.587 ±0.754	9.680 ±1.159	8.525 ±1.269	10.417 ±0.928	11.110 ±0.884	0.44
Breast yield	35.256 ±2.883	38.342 ±2.314	36.118 ±3.460	34.275 ±2.305	34.086 ±2.651	35.065 ±3.607	36.515 ±3.210	34.009 ±3.511	36.909 ±3.057	0.93
Wings yield	7.538 ±0.585	8.311 ±1.147	9.208 ±0.333	8.367 ±0.763	8.246 ±1.163	7.642 ±1.000	7.812 ±0.616	8.161 ±0.530	7.535 ±0.887	0.89
Giblet yield	5.450 ±0.103	5.778 ±0.222	5.243 ±0.155	5.222 ±0.253	5.566 ±0.090	5.574 ±0.127	5.650 ±0.204	5.423 ±0.106	5.298 ±0.094	0.23
Heart	0.134 ±0.025	0.140 ±0.098	0.127 ±0.027	0.120 ±0.036	0.109 ±0.013	0.118 ±0.014	0.116 ±0.012	0.101 ±0.015	0.127 ±0.010	0.09
Liver	2.272 ±0.032	2.395 ±0.133	2.441 ±0.224	2.337 ±0.209	2.503 ±0.200	2.372 ±0.151	2.556 ±0.156	2.256 ±0.035	2.525 ±0.176	0.92

Means with different superscript in a row differed significantly ($P<0.05$).

Table 9. Tibia bone characteristics of experimental quails on different dietary treatments at sixth week age

Parameters	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	P value
Tibia wt (g)	0.906 ±0.131	1.050 ±0.180	1.061 ±0.180	1.020 ±0.105	1.002 ±0.180	1.090 ±0.251	0.934 ±0.208	0.960 ±0.035	1.065 ±0.186	0.99
Tibia length (mm)	48.603 ±4.631	49.753 ±4.702	47.850 ±3.464	48.733 ±5.608	48.937 ±2.963	51.490 ±5.686	48.260 ±2.887	45.880 ±1.732	49.630 ±4.041	0.99
Tibia ash (%)	40.864^{b} ±1.008	51.049^{a} ±2.193	49.054^{a} ±1.116	48.589^{a} ±2.331	48.065^{a} ±1.208	47.586^{a} ±1.735	48.233^{a} ±1.732	49.261^{a} ±3.052	49.598^{a} ±1.732	0.03
Tibia Ca (%)	11.210 ±0.441	12.693 ±0.333	11.837 ±0.416	12.034 ±0.333	10.631 ±0.441	12.345 ±0.467	10.847 ±0.577	11.105 ±0.882	12.613 ±0.825	0.11
Tibia P (%)	8.218 ±0.664	9.316 ±0.240	8.682 ±0.217	8.831 ±0.236	7.793 ±0.527	9.053 ±0.222	7.948 ±0.275	8.149 ±0.655	9.241 ±0.468	0.15

Means with different superscript in a row differed significantly ($P<0.05$).

significantly. The tibia ash content was observed to be significantly higher in organic mineral supplemented groups than inorganic mineral group. 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. Increased tibia ash content in organic mineral fed groups may be attributed to better bone mineralization due to higher bioavailability of organic mineral sources. The higher bioavailability of chelated minerals might be linked to shielding of the minerals with positive charge during chelation. This allowed the mineral to withstand the binding activity of the negative charged mucin layer and resulted in lower competition from gut and transfer to the enterocyte (Power *et al*. 2006). However, contradictory observations were reported by Idowu *et al*. (2011).

Weight of lymphoid organs: Weight of lymphoid organs of experimental quails on different dietary treatments of organic minerals at sixth week of age is presented in Table

Table 10. Weight of lymphoid organs of experimental quails on different dietary treatments at sixth week age

Organ	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	P Value
Thymus	0.135 ±0.015	0.146 ±0.003	0.133 ±0.003	0.129 ±0.003	0.142 ±0.004	0.135 ±0.003	0.147 ±0.004	0.135 ±0.008	0.154 ±0.003	0.20
Spleen	0.034 ±0.001	0.038 ±0.004	0.032 ±0.003	0.031 ±0.002	0.031 ±0.005	0.029 ±0.002	0.036 ±0.005	0.033 ±0.001	0.035 ±0.002	0.72
Bursa	0.134 ±0.025	0.140 ±0.018	0.127 ±0.027	0.120 ±0.036	0.109 ±0.013	0.118 ±0.014	0.116 ±0.012	0.101 ±0.015	0.127 ±0.010	0.87

Means with different superscript in a row differed significantly (P<0.05).

10. The weight of lymphoid organs (spleen, bursa and thymus) of experimental quail at sixth week of age of all treatments did not differ significantly. This result was in accordance to the findings of Namra *et al.* (2008). Supplementation of zinc did not improve the weight of the lymphoid organs as more nutrients being repatriated to develop body weight and production whereas immune system needed a small amount of nutrient in relation to that needed for growth and production (Bartlett and Smith 2003). As a contradiction to our results, Idowu *et al*. (2011) observed significant higher percentage of spleen in zinc- proteanate group than the inorganic group. Moghaddam and Jahanian (2009) also reported significant difference in thymus percentage. From this experiment, it may be concluded that 50% replacement of inorganic Zn, Cu and Mn with their corresponding organic sources showed better performance in quail.

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