



Effect of Supplementing Organic and Nano Trace Minerals at Reduced Dietary Levels on Broiler Chicken Performance

Omkar R. Ganamale, B. C. Umashankar*, T. M. Prabhu, B. N. Suresh, Vivek M. Patil, H. C. Indresh and H. M. Yathish

Department of Animal Nutrition, Veterinary College, Karnataka Veterinary, Animal and Fisheries Sciences University, Hebbal, Bengaluru - 560 024, Karnataka, India.

*Correspondence: umashankarbukkapattana@gmail.com

ABSTRACT

An experiment was conducted to evaluate the effect of supplementing organic and nano trace minerals (Mn, Cu and Zn) at reduced dietary levels on the growth performance of broiler birds. 240 day-old commercial broiler chicks (Cobb strain) were assigned in equal numbers to five groups consisting of four replicates each. The basal diet was supplemented with inorganic trace minerals (Sulphate of Mn, Cu and Zn) at 100% of the standard recommendation to serve as control (ITM-100). Four test diets were prepared by supplementing organic trace minerals (glycinate form) at 75 % (OTM-75) and 50 % (OTM-50) of the standard recommendation and nano trace minerals at 50 % (NTM-50) and 25 % (NTM-25) of the standard recommendation. Each diet prepared for pre-starter (1-7 days), starter (8-21 days) and finisher (22-42 days) phases was offered to four replicates. The results revealed that, there was a non-significant difference in cumulative body weight, feed intake, feed conversion ratio, nutrient metabolizability, blood biochemical parameters and tibial mineral deposition in broiler chickens under different test diets when compared to the control (ITM-100) at the end of trial. Survivability remained comparable among all the groups during all the phases. Mineral balance (Mn, Cu and Zn) was significantly ($P < 0.05$) influenced by different sources and higher retention percentage was observed in the organic and nano groups at reduced levels compared to control. It was concluded that similar performance in broilers can be achieved by using organic at 50 % or nano particle trace minerals at 25% of the standard recommendation in broiler chickens.

KEYWORDS: Broiler chicken, Nano and organic forms, Performance, Trace minerals

Article received: 03 January 2026; Article accepted: 11 March 2026.

INTRODUCTION

Poultry production has advanced considerably through genetic selection, improved management, and optimized nutrition meeting the requirements of birds for metabolizable energy, crude protein, fat, minerals and vitamins. Yet the realization of maximum growth potential remains contingent upon the adequate provision of micro-nutrients. Among these, trace minerals such as zinc (Zn), copper (Cu), manganese (Mn), iron (Fe), selenium (Se) and iodine (I) are indispensable due to their roles as enzyme cofactors, structural components, and regulators of metabolic and immune functions (McDowell, 1992; Favero et al., 2013). Conventionally, trace minerals are included in their inorganic forms (sulphates, oxides, carbonates, chlorides) in broiler diets. The inorganic trace minerals (ITM) are commonly used due to their easy

accessibility and low price but their low bioavailability necessitates using it at higher doses in order to meet the requirements (Patra and Lalhriatpui, 2020).

Over the last three decades, progress in poultry nutrition has led to the development of organic trace minerals (OTM), which enhances bioavailability, reduces antagonistic interactions in the gut resulting in improved poultry performance and overall health and minimizes environmental excretion compared to conventional sources. Organic minerals are the minerals which are chelated with organic compounds like amino acid complexes, proteinates, chelates, polysaccharide complexes and propionates (Byrne and Murphy, 2022). The ITM can be replaced with OTM at lower doses while achieving similar or improved growth performance in broilers (Britanico et al., 2012).

Similarly, nanotrace minerals (NTM) exhibit enhanced bioavailability due to their smaller particle size, larger specific surface area, higher catalytic efficiency, and stronger absorption capacity (Gopi et al., 2017). Studies suggested that supplementation with nano forms of essential trace minerals not only supports optimal growth, skeletal integrity, and immune competence in poultry but also reduces dietary inclusion levels and minimizes mineral excretion, thereby contributing to both productivity and environmental sustainability (Gowtham et al., 2022; Mane et al., 2022) and similar egg production performance in layers (Sachin et al., 2024). Studies have indicated that the dose of NTM can be reduced up to 25 % of the requirement without negatively affecting the production performance of birds (Gowtham et al., 2022; Mane et al., 2022; Aminullah et al., 2023; Aminullah et al., 2024; Sachin et al., 2024). Currently, there are limited comparative studies available on the effects of organic and nanoparticle trace minerals at reduced dietary levels in broiler chickens, particularly on nutrient metabolizability, blood biochemical profile, mineral retention and tibial mineral deposition. Hence, the present study was undertaken to assess the impact of replacing inorganic trace minerals (Mn, Cu, Zn) with organic and nanoforms at reduced dietary levels on the performance of broiler chickens.

MATERIALS AND METHODS

Experimental birds, diets, and management

The experiment was carried out with 240 day-old (Cobb strain) straight-run commercial broiler chicks for a period of 42 days (6 weeks). At the initiation, the day-old broiler chicks were weighed, wing banded and randomly distributed into five treatment groups with 4 replicates of 12 chicks in each replicate. A basal diet excluding Mn, Cu, and Zn salts was prepared as per BIS (2007) specifications. The control diet was prepared with supplementation of inorganic trace minerals (ITM 100) at 100% of recommendation to the basal diet. Test diets were prepared by supplementing organic trace minerals at 75 % (OTM 75) or 50 % (OTM 50) of recommendation or nanoparticles trace minerals at 50 % (NTM 50) or 25 % (NTM 25) of recommendation. Such diets were prepared for pre-starter (1-7 days), starter (8-21 days) and finisher phases (22-42 days) and offered *ad libitum* to the respective groups. The ingredient composition of basal diets prepared for different phases is presented in Table 1. The inorganic, organic, and nano trace minerals used were procured from M/s Quadrigen Vet Health Pvt. Ltd., Bengaluru, Karnataka, India. The trace minerals in ITM, OTM, and NTM premixes is presented in Table 2.

Table 1. Feed ingredient and nutrient composition of basal diets prepared for different

Ingredients, Kg	Pre-starter diet (1-7 days)	Starter diet (8-21 days)	Finisher diet (22-42 days)
Yellow maize	54.2	55.1	59.81
Soybean meal	40.3	37.75	32.24
Vegetable oil	2.1	3.75	4.65
Di-calcium phosphate	1.6	1.7	1.5
Limestone	1.0	1.05	1.05
Common salt	0.2	0.15	0.2
DL- Methionine	0.1	0.1	0.15
L-Lysine	0.2	0.1	0.1
Mineral premix ¹	0.1	0.1	0.1
Vitamin premix	0.05	0.05	0.05
Toxin binder	0.1	0.1	0.1
Coccidiostat	0.05	0.05	0.05
Total	100	100	100
Nutrient composition (%)			
ME (kcal/kg)	3012	3120	3206
Crude protein	22.96	21.89	20.06
Calcium	1.06	1.05	0.9
Available phosphorous	0.46	0.48	0.44
Digestible lysine	1.36	1.15	1.03
Digestible methionine	0.44	0.41	0.44

¹Each kg contain: Calcium 300g, Phosphorus 60g, Magnesium 10g, Cobalt chloride 500mg, Choline chloride 10g, Chromium 0.2g, Iron 40g, Iodine 1g, Selenium 0.35g, excluding Manganese, Copper and Zinc.

Table 2. Composition of trace mineral premixes

Trace mineral (g/kg)	Inorganic trace minerals (ITM)	Organic trace minerals (OTM)	Nano trace minerals (NTM)
Yellow maize	54.2	55.1	59.81
Manganese	100	66.66	100
Copper	15	10	15
Zinc	100	66.66	100

Growth performance

The growth performance of broilers was evaluated in terms of weekly body weight, feed consumption, and feed conversion ratio. Mortality was recorded as it occurred, and the weight of each deceased bird was measured to reduce errors in calculating the feed conversion ratio. The overall mortality observed during the experiment was expressed as a percentage for each corresponding treatment group.

Nutrient metabolizability

A three-day metabolic trial was conducted using 2 birds from each replicate in which excreta from the 39th to 41st day were collected, pooled within the pen, weighed, and dried at 60°C for 72 h. The feed and dried excreta samples were ground to pass through a 1 mm mesh screen and mixed thoroughly before analysis. The dry matter (DM), crude protein (CP), crude fiber (CF), ether extract (EE) and nitrogen free extract (NFE) contents were determined according to AOAC (2023).

Balance of trace minerals

Balance of trace minerals in the body of broiler chicken was calculated based on their intake and outgo. The feed and excreta samples were processed to prepare soluble ash as per AOAC (2023) method. The trace mineral composition of soluble ash samples were analysed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). The mineral retention was estimated using the formula,

$$\text{Retention (mg/d)} = \text{Mineral intake (mg/d)} - \text{Mineral outgo (mg/d)}$$

Tibial mineral deposition

At the end of the experiment (42nd day), left tibia

samples were collected from 2 birds in each replicate for tibia mineralization study. The procedure involved preparation of mineral extract for estimation of trace minerals (Mn, Cu, Zn) deposition on tibial bone. Mineral extract samples were subsequently analysed for Mn, Cu and Zn using an Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES).

Statistical analysis

The experimental design employed in this study was a complete randomized design (CRD) with one-way analysis (ANOVA). The data collected for all parameters were statistically analyzed following the methods outlined by Snedecor and Cochran (1994) and significant differences in means if any were tested using Tukey's test at $P < 0.05$.

RESULTS AND DISCUSSION

Body weight

The body weight of birds at different weeks of experimental period is presented in Table 3. Although a significant difference ($P < 0.05$) observed during first three weeks, the body weights of broilers during last three weeks of age did not differ among groups supplemented with inorganic, organic, or nano trace minerals. These findings are consistent with the reports of Britanico et al. (2012) and Gheisari et al. (2010), who observed similar body weights in broilers receiving reduced levels of organic trace minerals. Likewise, Mane et al. (2022) reported no significant effect at 75–50% organic or 50–25% nano trace minerals inclusion levels. In contrast, Gowtham et al. (2022) documented improved body weight gains in birds supplemented with nano minerals at 50% of the requirement compared with those receiving 100% inorganic or organic supplementation.

Table 3. Weekly body weight of experimental birds under different treatments

Experimental group	Trace mineral form and level	Body weight (g/bird)					
		Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
ITM 100	Inorganic 100%	154.5 ± 1.37 ^{ab}	434.4 ± 3.16 ^a	876.1 ± 6.27 ^a	1409 ± 17.64	2094 ± 25.00	2707 ± 21.95
OTM 75	Organic 75%	154.6 ± 1.73 ^{ab}	439.0 ± 3.08 ^{ab}	902.7 ± 4.75 ^b	1454 ± 19.36	2153 ± 29.15	2761 ± 28.60
OTM 50	Organic 50%	156.2 ± 1.57 ^b	445.0 ± 1.65 ^b	920.2 ± 3.03 ^c	1466 ± 17.49	2133 ± 25.58	2769 ± 20.82
NTM 50	Nano 50%	152.9 ± 1.42 ^{ab}	441.4 ± 2.34 ^{ab}	878.9 ± 3.72 ^a	1434 ± 24.33	2102 ± 29.76	2741 ± 24.76
NTM 25	Nano 25%	149.7 ± 1.25 ^a	436.7 ± 1.81 ^{ab}	884.7 ± 3.58 ^a	1436 ± 15.78	2130 ± 23.96	2756 ± 20.30
	P value	0.029	0.031	<0.001	0.213	0.291	0.273

^{ab}Mean values bearing different superscripts within the column differ significantly ($P \leq 0.05$)

Feed consumption

The weekly cumulative feed intake was non-significant across treatments (Table 4). The results are consistent with Britanico et al. (2012) who reported non-significant differences in feed intake by the supplementation of OTM at 50% of recommendation. Aminullah et al. (2022) found that dietary supplementation of organic and nano forms of Cu with the dose reduced up to 50 and 25% of recommendation, respectively had not affected the feed intake of Giriraja birds compared to group fed

inorganic Cu at 100 % of recommendation. Feed intake in the 50% nano Zn, Mn, and Cu group was higher than in the 100% inorganic group, resulting in improved body weight gain (Gowtham et al., 2022). In contrast, Mane et al. (2022) reported comparable feed intake among broilers supplemented with 100% inorganic, 75% organic or nano, and 50% organic or nano trace minerals, suggesting that responses may vary depending on mineral source and inclusion level.

Table 4. Cumulative feed consumption of experimental birds under different treatments

Experimental group	Description of the treatment	Cumulative feed consumption (g/bird)					
		Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
ITM 100	Inorganic 100%	121.6 ± 4.07	471.3 ± 14.28	1112 ± 16.21	2008 ± 12.33	3126 ± 10.86	4377 ± 11.45
OTM 75	Organic 75%	127.3 ± 4.80	488.3 ± 14.37	1159 ± 21.40	2055 ± 15.66	3163 ± 19.59	4385 ± 19.77
OTM 50	Organic 50%	125.2 ± 6.58	484.0 ± 15.56	1145 ± 21.35	2048 ± 27.39	3157 ± 20.70	4424 ± 18.67
NTM50	Nano 50%	119.0 ± 3.58	472.1 ± 7.58	1114 ± 8.40	2018 ± 14.09	3129 ± 8.81	4360 ± 12.33
NTM 25	Nano 25%	124.7 ± 2.75	477.9 ± 8.66	1126 ± 13.24	2052 ± 16.84	3164 ± 12.24	4429 ± 15.50
	P value	0.733	0.839	0.263	0.239	0.145	0.095

Feed conversion ratio

The weekly cumulative feed conversion ratio (FCR) of broiler birds did not differ significantly ($P > 0.05$) among the treatment groups (Table 5). These findings are consistent with Britanico et al. (2012) who reported that supplementation with OTM at 50% of recommended levels had no significant effect on FCR in broilers. Similarly, Aminullah et al. (2022) observed that Cu supplementation in organic and nano forms at 50% and 25% of recommended levels, respectively did

not influence cumulative FCR. In contrast, Ahmadi et al. (2013) and Zhao et al. (2014) documented improved FCR in broilers fed diets supplemented with OTM, while Mane et al. (2022) reported comparable values across treatments. This study suggests that lowering dietary mineral supplementation, while using alternative organic or nano sources, can maintain feed efficiency comparable to conventional inorganic supplementation in broilers.

Table 5. Cumulative feed conversion ratio of experimental birds under different treatments

Experimental group	Description of the treatment	Cumulative feed conversion ratio					
		Day 7	Day 14	Day 21	Day 28	Day 35	Day 42
ITM 100	Inorganic 100%	1.074 ± 0.01	1.201 ± 0.01	1.333 ± 0.01	1.469 ± 0.01	1.522 ± 0.01	1.641 ± 0.01
OTM 75	Organic 75%	1.120 ± 0.03	1.231 ± 0.02	1.347 ± 0.02	1.456 ± 0.03	1.498 ± 0.02	1.612 ± 0.01
OTM 50	Organic 50%	1.093 ± 0.03	1.200 ± 0.02	1.304 ± 0.02	1.437 ± 0.01	1.508 ± 0.01	1.621 ± 0.02
NTM 50	Nano 50%	1.056 ± 0.01	1.184 ± 0.03	1.332 ± 0.01	1.450 ± 0.01	1.518 ± 0.01	1.615 ± 0.02
NTM 25	Nano 25%	1.139 ± 0.02	1.210 ± 0.01	1.336 ± 0.02	1.471 ± 0.01	1.515 ± 0.01	1.635 ± 0.01
	P value	0.287	0.758	0.102	0.338	0.904	0.264

Survivability

No mortality occurred during the 42-day trial, indicating that reduced levels of trace minerals in organic and nano forms did not compromise survivability. These findings are consistent with Baloch et al. (2017), who reported no significant differences in mortality among broilers supplemented with varying levels of OTM (60, 50 and 25%) compared with those receiving inorganic sources. Similarly, Gowtham et al. (2022) concluded that supplementation with organic and nano forms of trace minerals at lower inclusion levels did not affect the survivability of birds. These results confirm that reduced inclusion of organic and nano mineral sources can maintain flock health

and survivability comparable to conventional inorganic supplementation.

Nutrient metabolizability

The metabolizability of DM, CP, CF, EE and NFE was unaffected by dietary treatments (Table 6). These results are consistent with the findings of Sarvestani et al. (2016), who reported that supplementation of broiler diets with 100 ppm nano-Cu did not exert a notable effect on nutrient metabolizability. In contrast, Sa'aci et al. (2021) observed a significant improvement ($P < 0.05$) in metabolizability when diets were supplemented with nano-Se (0.10 ppm) and nano-Zn (50 ppm), likely due to their role as essential enzyme cofactors in nutrient metabolism.

Table 6. Metabolizability (%) of nutrients in experimental diets under different treatments

Experimental group	Description of treatment	Dry matter	Organic matter	Crude protein	Ether extract	Crude fibre	Nitrogen free extract
ITM 100	Inorganic 100%	72.59 ± 2.09	74.86 ± 4.16	70.34 ± 2.04	77.13 ± 1.38	46.13 ± 2.58	79.83 ± 1.09
OTM 75	Organic 75%	74.79 ± 0.90	77.05 ± 1.45	73.76 ± 0.41	80.12 ± 0.65	48.29 ± 1.95	80.87 ± 0.82
OTM 50	Organic 50%	73.42 ± 1.74	75.65 ± 2.93	75.01 ± 1.68	79.24 ± 0.40	50.55 ± 2.48	78.87 ± 0.74
NTM 50	Nano 50%	72.85 ± 1.13	74.81 ± 4.05	74.00 ± 1.20	78.85 ± 1.34	48.32 ± 1.98	82.16 ± 0.84
NTM 25	Nano 25%	72.54 ± 1.26	75.29 ± 2.72	72.83 ± 1.61	76.95 ± 2.56	49.67 ± 1.90	80.67 ± 0.28
	P value	0.492	0.987	0.311	0.281	0.893	0.496

Mineral balance

Trace mineral intake decreased linearly with reduced supplementation in experimental birds, while excretion was lowest and retention highest in the 25% nano-supplemented group (Table 7). These findings corroborate the reports of Chen et al. (2022) and Cufadar et al. (2020), who demonstrated that inclusion of organic and nano forms of trace

minerals in layer diets, even at reduced levels, enhances the retention of key minerals such as Mn, Cu, and Zn. The present results reinforce the superior bioavailability of nano and organic mineral sources compared with conventional inorganic forms, highlighting their potential to improve mineral utilization efficiency in poultry nutrition.

Table 7. Balance of trace minerals in experimental birds under different treatments

Particulars,mg/d	ITM 100	OTM 75	OTM 50	NTM 50	NTM 25	P value
Manganese Intake	18.65 ± 0.40 ^a	13.46 ± 0.54 ^b	9.48 ± 0.09 ^c	9.66 ± 0.18 ^c	4.96 ± 0.26 ^d	<0.001
Outgo	15.39 ± 0.63 ^a	9.89 ± 0.57 ^b	6.95 ± 0.27 ^c	7.49 ± 0.44 ^c	3.47 ± 0.30 ^d	<0.001
Retention	3.26 ± 0.34 ^a	3.57 ± 0.13 ^a	2.53 ± 0.20 ^b	2.16 ± 0.26 ^{bc}	1.49 ± 0.12 ^c	<0.001
Retention(%intake)	17.47 ± 2.02 ^a	26.52 ± 1.50 ^{ab}	26.68 ± 2.36 ^{ab}	22.55 ± 3.06 ^{ab}	30.26 ± 3.06 ^b	0.038
Copper						
Intake	2.79 ± 0.06 ^a	2.01 ± 0.08 ^b	1.42 ± 0.01 ^c	1.45 ± 0.02 ^c	0.74 ± 0.03 ^d	<0.001
Outgo	1.66 ± 0.11 ^a	1.11 ± 0.04 ^b	0.79 ± 0.03 ^c	0.77 ± 0.07 ^c	0.30 ± 0.03 ^d	<0.001
Retention	1.18 ± 0.05 ^a	0.90 ± 0.04 ^b	0.62 ± 0.03 ^{cd}	0.67 ± 0.05 ^c	0.43 ± 0.04 ^d	<0.001
Retention(%intake)	40.61 ± 2.84 ^a	44.70 ± 0.82 ^{ab}	44.20 ± 2.44 ^{ab}	46.76 ± 4.15 ^{ab}	58.59 ± 4.67 ^b	0.027
Zinc Intake	18.97 ± 0.40 ^a	13.46 ± 0.54 ^b	9.48 ± 0.90 ^c	9.66 ± 0.18 ^c	4.96 ± 0.26 ^d	<0.001
Outgo	14.58 ± 0.91 ^a	9.72 ± 0.15 ^b	6.02 ± 0.23 ^c	7.19 ± 0.32 ^c	3.36 ± 0.13 ^d	<0.001
Retention	4.39 ± 0.64 ^a	3.74 ± 0.38 ^{ab}	3.46 ± 0.17 ^{ab}	2.47 ± 0.25 ^{bc}	1.60 ± 0.18 ^c	<0.001
Retention(%intake)	23.14 ± 3.65 ^a	27.78 ± 1.80 ^{ab}	36.49 ± 2.05 ^b	25.56 ± 2.74 ^{ab}	32.25 ± 2.31 ^b	0.020

Blood biochemical profile

The mean blood biochemical profile values viz., serum calcium, phosphorus, total protein, albumin, cholesterol, aspartate aminotransferase (AST), alanine aminotransferase (ALT), uric acid and triglycerides were statistically similar ($P > 0.05$) among groups (Table 8). The current study demonstrated that reducing recommended dietary levels of organic and nano trace minerals had no significant ($P > 0.05$) impact on the blood

biochemical parameters. Ghasemi et al. (2020) studied the effects of replacing inorganic trace minerals with organic trace minerals at lower levels (25 and 50%) observed no significant difference in serum glucose, triglycerides, cholesterol, total protein, or albumin levels among the treatment groups ($P > 0.05$) supplemented with Mn, Cu and Zn (40-7-40 mg/kg) in organic and nano forms compared to control.

Table 8. Blood biochemical profile of experimental birds on 42nd day under different treatments

Experimental group	Calcium (mg/dl)	Phosphorus (mg/dl)	Total Protein (gm/dl)	Albumin (gm/dl)	Cholesterol (mg/dl)	ALT (U/L)	AST (U/L)	Uric acid (mg/dl)	Triglycerides (mg/dl)
ITM 100	10.92 ± 0.11	8.80 ± 0.45	3.27 ± 0.10	1.75 ± 0.06	110.00 ± 9.82	3.970 ± 1	448.60 ± 38.50	4.45 ± 1.04	45.77 ± 5.26
OTM 75	11.03 ± 0.30	9.27 ± 0.42	3.67 ± 0.16	1.92 ± 0.08	117.85 ± 1.06	3.050 ± 0.96	393.60 ± 19.54	3.42 ± 0.60	41.57 ± 4.11
OTM 50	10.86 ± 0.12	8.72 ± 0.25	3.44 ± 0.16	1.82 ± 0.08	108.80 ± 7.16	1.375 ± 0.33	385.67 ± 22.82	3.95 ± 1.46	38.85 ± 2.03
NTM 50	10.92 ± 0.18	8.75 ± 0.23	3.30 ± 0.17	1.75 ± 0.09	117.42 ± 7.55	2.800 ± 0.64	401.90 ± 23.57	4.47 ± 1.01	33.85 ± 3.22
NTM 25	10.84 ± 0.16	8.67 ± 0.61	3.07 ± 0.06	1.70 ± 0.09	103.15 ± 8.51	2.200 ± 0.47	370.12 ± 36.19	3.87 ± 0.53	41.75 ± 4.84
P value	0.057	0.068	0.062	0.395	0.608	0.164	0.424	0.937	0.363

Tibial mineral deposition

At 42 days of age, tibial mineral deposition in broilers did not differ ($P > 0.05$) in manganese (Mn), copper (Cu), or zinc (Zn) concentrations among the treatment groups (Table 9). These findings are consistent with previous studies (Zhao et al., 2014; Britanico et al., 2012), which reported that partial substitution of inorganic Zn, Cu, and Mn with

organic chelates (up to 50%) did not significantly influence tibial mineral content. Similarly, Underwood and Suttle (1999) observed that reduced supplementation with organic minerals had no measurable effect on tibia weight, length, or mineral composition. Collectively, these results suggest that moderate replacement of inorganic trace minerals with organic sources does not compromise skeletal mineralization in broilers.

Table 9. Tibial mineral content in experimental birds on 42nd day under different treatments

Treatments	Mn (ppm)	Cu (ppm)	Zn (ppm)
ITM 100	10.81 ± 0.43	2.52 ± 0.26	220.55 ± 7.01
OTM 75	11.62 ± 0.52	2.64 ± 0.19	238.76 ± 4.50
OTM 50	11.44 ± 1.16	2.80 ± 0.35	236.96 ± 5.66
NTM 50	12.59 ± 0.70	2.90 ± 0.28	223.77 ± 8.59
NTM 25	11.23 ± 0.51	2.75 ± 0.25	228.73 ± 10.79
P value	0.529	0.878	0.419

CONCLUSION

The results revealed that the dietary supplementation with organic trace minerals at 75% and 50%, as well as nano trace minerals at 50% and 25% of the recommended levels, produced comparable outcomes in growth performance, nutrient metabolizability, and tibial mineral deposition. Importantly, trace minerals retention was significantly ($P < 0.05$) enhanced at 50% and 25% inclusion levels. These findings demonstrate that organic and nano trace minerals can effectively substitute inorganic sources at reduced dietary inclusion rates (50% and 25%, respectively) without compromising broiler growth performance. The improved bioavailability of these mineral forms highlights their potential contribution to sustainable poultry nutrition by reducing dependence on conventional inorganic supplementation and minimizing environmental mineral excretion.

REFERENCES

- Ahmadi, F., Khah, M. M., Javid, S., Zarneshan, A., Akradi, L. and Salehifar, P. 2013. The effect of dietary silver nanoparticles on performance, immune organs, and lipid serum of broiler chickens during starter period. *International Journal of Bioscience*. 3(5): 95-100.
- Aminullah, N., Prabhu, T. M., Naik, J., Suresh, B. N. and Suma, N. 2022. Effect of reduced dietary copper levels sourced from organic and nanoparticles forms on performance and nutrient utilization in Giriraja birds. *Indian Journal of Animal Research*. 56(1): 58-64.
- Aminullah, N., Prabhu, T. M., Suresh, B. N., Ahmadullah, Z., Sudharshan, S. and Azizi, M.N. 2024. Carcass, Bone and meat quality characteristics of Giriraja chicken fed reduced levels of organic and nano copper supplemented diets. *Indian Journal of Animal Nutrition*. 40(3): 337-346.
- Aminullah, N., Prabhu, T. M., Suresh, B. N. and Mostamand, A. 2023. Nano copper in poultry nutrition: potential effect and future prospect - a review. *Indian Journal of Animal Nutrition*. 39(4): 332-347.
- AOAC. 2023. Official Methods of Analysis. 22nd Edn. Association of Official Analytical Chemists. Washington D.C., USA.
- Baloch, Z., Yasmeen, N., Pasha, T. N., Ahmad, A., Taj, M. K., Khosa, A. N., Marghazani, I. B., Bangulzai, N., Ahmad, I. and Hua, Y. S. 2017. Effect of replacing inorganic with organic trace minerals on growth performance, carcass characteristics, and chemical composition of broiler thigh meat. *African Journal of Agricultural Research*. 12(18): 1570-1575.
- BIS. 2007. Chicken Feeds Specification. IS:1374 (5th revision). Bureau of Indian Standards, Manak Bhavan, New Delhi, India.
- Britanico, E. B., Merca, F. E., Angeles, A. A., Acda, S. P. and Luis, E. S. 2012. Effects of supplementing diets with amino acid chelates of copper, zinc, manganese, and iron on the performance of broilers. *Philippine Journal of Veterinary and Animal Sciences*. 38(1):1-10.
- Byrne, L. and Murphy, R. A. 2022. Relative bioavailability of trace minerals in production animal nutrition: A review. *Animals*. 12(15): 1981-1990.
- Chen, X., Ma, X. M., Yang, C. W., Jiang, S. Z., Huang, L. B., Li, Y. and Yang, W. R. 2022. Low level of dietary organic trace elements improve the eggshell strength, trace element utilization, and intestinal function in late-phase laying hens. *Frontiers in Veterinary Science*. 9: 615-903.
- Cufadar, Y., Gocmen, R., Kanbur, G. and Yildirim, B. 2020. Effects of dietary different levels of nano, organic and inorganic zinc sources on performance, eggshell quality, bone mechanical parameters and mineral contents

- of the tibia, liver, serum and excreta in laying hens. *Biological Trace Elements Research*.193:241-251.
- Favero, A., Vieira, S. L., Angel, C. R., Bess, F., Cemin, H. S. and Ward, T. L. 2013. Reproductive performance of Cobb 500 breeder hens fed diets supplemented with zinc, manganese, and copper from inorganic and amino acid-complexed sources. *Journal of Applied Poultry Research*. 22(1): 80-91.
- Ghasemi, H. A., Hajkhodadadi, I., Hafizi, M., Taherpour, K. and Nazaran, M. H. 2020. Effect of advanced chelate technology-based trace minerals on growth performance, mineral digestibility, tibia characteristics, and antioxidant status in broiler chickens. *Nutrition Metabolism*.17: 1-12.
- Gheisari, A. A., Rahimi-Fathkoohi, A., Toghyani, M. and Gheisari, M. M. 2010. Effects of organic chelates of zinc, manganese, and copper in comparison to their inorganic sources on performance of broiler chickens. *Journal of Animal and Plant Sciences*. 6(2): 630-636.
- Gowtham, B., Ramesh, J., Karunakaran, R., Karthikeyan, N. and Raja, P. 2022. Effects of dietary supplementation of different levels of zinc, manganese and copper nanoparticles on growth performance and bioavailability in commercial broilers chicks. *Indian Journal of Animal Research*. DOI: 10.18805/IJAR.B-4950.
- Gopi, M., Beulah, P., Kumar, R. D., Muthuvel, S. and Govindasamy, P. 2017. Role of nanoparticles in animal and poultry nutrition: modes of action and applications in formulating feed additives and food processing. *International Journal of Pharmacology*. 13(7): 724-731.
- Mane, A. V., Khose, K. K., Nikam, M. G., Dhumal, K. V., Gangane, G. R. and Munde, V. K. 2022. Effect of organic and nanoparticle trace minerals replacing inorganic trace minerals in diets on growth performance, immune response and economics of broilers. *Indian Journal of Animal Sciences*. 92 (4): 465–470
- McDowell, L. R. 1992. *Minerals in Animal and Human Nutrition*. Elsevier Science BV, Amsterdam.
- Patra, A. and Lalhriatpuii, M. 2020. Progress and prospect of essential mineral nanoparticles in poultry nutrition and feeding: a review. *Biological Trace Element Research*.197(1): 233-253.
- Sa'aci, Z. A., Jiya, E. Z. and Ijaiya, A. T. 2021. Influence of dietary nano zinc and selenium supplementation on growth performance, nutrients digestibility and carcass characteristics of broiler chickens. *Nigerian Journal of Animal Science*.23(3): 185-198.
- Sachin, B. K., Suresh, B. N., Prabhu, T. M., Indresh, H. M C., Suma, N. and Gouri, M. D. 2024. Effect of organic and nano trace minerals at reduced levels in layer diets on egg quality characteristics and its trace mineral content. *Indian Journal of Animal Sciences*. 94(8): 700-706.
- Sarvestani, S. S., Resvani, M., Zamiri, M. J., Shekarforoush, S., Atashi, H. and Mosleh, N. 2016. The effect of nano copper and mannan oligosaccharide supplementation on nutrient digestibility and performance in broiler chickens. *Journal of Veterinary Research*.71(2): 153- 161.
- Snedecor, G. W. and Cochran, W. G. 1994. *Statistical Methods*. 8th Edn. Iowa State University Press, Ames, Iowa.
- Underwood, E. J. and Suttle, N. F. 1999. *The Mineral Nutrition of Livestock*. 3rd Edn. Wallingford, Oxon: CABI Publishing.
- Zhao, C. Y., Tan, S. X., Xiao, X. Y., Qiu, X.S., Pan, J. Q. and Tang, Z. X. 2014. Effects of dietary zinc oxide nanoparticles on growth performance and antioxidative status in broilers. *Biological Trace Element Research*. 160: 361-367.