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Effect of organic and nanoparticle trace minerals replacing inorganic trace minerals in diets on growth performance, immune response and economics of broilers

A V MANE[1]✉, K K KHOSE[1], M G NIKAM[1], M V DHUMAL[1], G R GANGANE[1] and V K MUNDE[1]

Maharashtra Animal and Fishery Sciences University Nagpur, Maharashtra 440 001 India

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ABSTRACT

The present study was designed to evaluate the effect of dietary supplementation of inorganic, organic and nanoparticle trace minerals on growth performance, immune response and economics of broilers. Experiment was conducted on 400 day-old Vencobb-430 straight run broiler chicks. The birds were supplemented with inorganic trace minerals (ITM) @ 1 kg/ton of feed in control group (T1). Organic trace minerals were added at 500 g/ton and 750 g/ton in treatment groups T2 and T3, respectively, replacing ITM through feed. Nanoparticle trace minerals were added at 500 g/ton and 750 g/ton in treatment groups T4 and T5, respectively, replacing ITM through feed for 6 weeks. The results showed significantly better cumulative weekly feed conversion ratio at 4th, 5th and 6th week of age in treatment groups T2, T3, T4 than control group. The antibody titers against New Castle Disease were significantly higher at 3rd and 6th week in treatment groups T4 and T5 than T1. Thus, it can be concluded that the supplementation of organic or nanoparticle trace minerals at 500 g/ton with replacing inorganic trace minerals at 1 kg/ton of feed improved growth performance, immune response and economics of broiler production.

Keywords: Broilers, Growth performance, Immune response, Economics, Inorganic, Organic and nanoparticle trace minerals

In commercial diets, inorganic trace minerals are typically used at higher levels than recommended by National Research Council (Inal *et al.* 2001) due to abundance and low cost. Supplementation with high levels of inorganic trace minerals may be harmful and wasteful to the environment as these are voided through faces. The elevated mineral concentrations in manure, when used as fertilizer, can lead high soil concentration that reduce crop yield (Nollet *et al.* 2007). Organic purely means that the mineral is bound to an organic material. These materials are usually amino acid complexes, proteinates, chelates, polysaccharide complexes and propionates. Although both organic and inorganic forms of copper and zinc supplements are in common use, important differences exist in the bioavailability and environmental concerns associated with the both forms. The bioavailability of various forms of the organic trace minerals is superior to that of inorganic element due to their better absorption rate (Lesson 2003).

Nano-particles have different physical and chemical properties than other forms of minerals. Nano-technology is a budding new science that utilizes matter at its dimensions from 1 to 100 nm with unique characteristics and novel applications. Nano-particles of various minerals have been utilized in poultry like zinc oxide (Fathi 2016), silver (Ahmadi and Kurdestany 2010), copper (Wang *et al*. 2011) and selenium (Ahmadi *et al*. 2018). Nano-particles of trace elements can lower mineral antagonism in the intestine leading to improved absorption, thereby reducing their excretion in the environment. These also encompass potential roles in improving bird's digestive efficiency and immune responses resulting in better feed efficiency (Gopi *et al.* 2017). Keeping this in view, the study was designed to evaluate the effect of dietary supplementation of inorganic, organic and nanoparticle trace minerals on growth performance, immune response and economics of broiler production.

MATERIALS AND METHODS

Experimental design and management: The experiment was carried out with 400 day-old Vencobb-430 straight run commercial broiler chicks for a period of 42 days (6 weeks). On arrival, the day old broiler chicks were weighed and randomly distributed into five treatment groups with 4 replicates of 20 chicks in each replicate. A treatment group T1 served as control with supplementation of inorganic trace minerals (ITM) @ 1 kg/ton of feed. Organic trace minerals (OTM) were added at 500 g/ton and 750 g/ton in treatment groups T2 and T3, respectively replacing inorganic trace minerals through feed. Nanoparticle trace minerals (NTM) were added at 500 and 750 g/ton in treatment groups T4

Present address: [1]College of Veterinary and Animal Sciences, Parbhani, Maharashtra (Maharashtra Animal and Fishery Sciences University, Nagpur, Maharashtra). ✉Corresponding author email: abhimane9906@gmail.com

and T5, respectively by replacing inorganic trace minerals. The biological experiment was conducted at the broiler unit, Department of Poultry Science, College of Veterinary and Animal Sciences, MAFSU, Parbhani.

The birds were offered pre-starter, starter and finisher diets. All rations were made iso-caloric and iso-nitrogenous along with balancing lysine and methionine levels as per Bureau of Indian Standard (BIS) (2007). Organic trace minerals (Poultry Tmo Plus) were procured from Novus International Incorporated, Chennai, Tamil Nadu, India. Nanoparticle trace minerals (Nano Sym Tx Premix) were procured from Symbio Nutrients, Baner, Pune. The nutrient contents per kg in inorganic trace minerals (ITM), organic trace minerals (OTM) and nanoparticle trace minerals (NTM) is presented in Table 1.

Table 1. Nutrient content of various trace minerals supplemented in broiler diets

Micronutrient	Inorganic trace minerals (ITM)	Organic trace minerals (OTM)	Nanoparticle trace minerals (NTM)
Zinc (g/kg)	80	40	40
Manganese (g/kg)	100	40	40
Copper (g/kg)	15	8	8
Iron (g/kg)	90	5	10
Iodine (g/kg)	2.0	1.2	2.5
Selenium (mg/kg)	300	300	300
Chromium (mg/kg)	-	-	400
Methionine activity (%)	-	47	-

Growth performance parameters: The growth performance of broilers was evaluated in terms of weekly live body weight, cumulative body weight gain, cumulative feed consumption and cumulative feed conversion ratio.

Immune response: The birds from the experimental trial were assessed for the antibody titer against the New Castle Disease. Two birds from each replicate and total 8 birds from each treatment group were randomly selected for the blood collection at the end of 3rd and 6th week of age. Haemagglutination inhibition test was carried out to assess the antibody titer against New Castle Disease as per O.I.E. procedure (1992).

Mortality: The mortality was recorded as and when occurred and the weight of the dead birds was taken in order to minimize an error in feed conversion ratio. Mortality observed throughout the experiment was expressed as percentage for corresponding treatment group.

Economics of broiler production: The economics of broiler production was worked out by considering the prevailing prices of inputs and the amount received by sale of broilers in local market.

Statistical analysis: The data collected pertaining to all the parameters were subjected to statistical analysis as per Snedecor and Cochran (1994). The data generated was analyzed by using Complete Randomized Design for interpreting the result and conclusion.

RESULTS AND DISCUSSION

Weekly live body weight: The mean live body weights (g/b) at 6th week of age were 2462.33±45.21, 2574.47±23.36, 2590.59±42.47, 2568.55±23.86 and 2572.26±40.92 in treatment groups T1, T2, T3, T4 and T5, respectively. During the whole feeding trial, the treatment groups T2 (OTM @ 500 g/ton), T3 (OTM @ 750 g/ton), T4 (NTM @ 500 g/ton) and T5 (NTM @ 750 g/ton) recorded higher live body weights as compared to control group from 1st to 6th week of age but it was non-significant. Similar findings were recorded by Tavares *et al.* (2014) with inorganic and organic mineral premix in broiler diets and Khatun *et al.* (2019) with inorganic and three forms of organic trace minerals. Tahir *et al.* (2019) reported that the body weight was unaffected with effect of chromium loaded chitosan nanoparticles (Cr-CNPs) supplemented at 200, 400, 800 and 1200 µg/kg in broilers up to 35 days.

Cumulative body weight gain: The differences between mean cumulative weekly body weight gains of broilers from all treatment groups were statistically non-significant as revealed by analysis of variance (Table 2). At the end of experiments, the broilers fed with organic and nanoparticle trace minerals with different dose levels recorded higher cumulative body weight gain than control group. The present findings are in accordance with Abdallah *et al.* (2009) who reported non-significant differences with weight gain between groups fed 50% and 100% of organic Mn or Cu or Fe in broilers. Zakaria *et al.* (2017) also reported non-significant differences in body weight gain of birds when diet was supplemented with inorganic and organic form of Zn. Boostani *et al.* (2015) found non-significant difference in body weight gain of birds with supplementation of inorganic, organic and nano forms selenium in diet. Wang *et al.* (2011) reported that there was non-significant difference in average daily gain in treatment groups supplemented with 50, 100, 150 mg/kg of copper-loaded chitosan nanoparticle in broilers.

Cumulative feed consumption: The cumulative feed consumption was higher in treatment groups T2, T3, T4 and T5 as compared to control group at the end of 6th week. However, the differences were statistically non-significant (Table 3). Similar results were obtained by M'Sadeq *et al.* (2018) who reported non-significant differences for feed intake by the supplementation of inorganic trace minerals at 750 g/ton and 375 g/ton and 500 g/ton organic yeast proteinate trace mineral premix. Ibrahim *et al.* (2017) found that dietary supplementation with inorganic ZnO, organic Zn, nano ZnO and Zn-mix (organic Zn and nano-ZnO) @ 50 mg/kg of diet had not affected the feed intake of broilers significantly. Asheer *et al.* (2018) found that supplementation of nano zinc @ 25% revealed non-significant differences with cumulative feed consumption.

*Cumulative feed conversion ratio:*The results obtained at 1st, 2nd and 3rd week of age reported that, there were non-significant differences for cumulative weekly feed conversion ratio (FCR) in all treatment groups.

Table 2. Cumulative weekly body weight gain (g/bird) of broilers fed different levels of various trace minerals in diets

Treatment	Age (weeks)					
	1st	2nd	3rd	4th	5th	6th
T1	113.73 ±0.98	402.05 ±4.14	843.15 ±9.57	1415.41 ±20.31	1980.61 ±32.09	2416.45 ±45.27
T2	119.53 ±3.23	411.83 ±6.83	878.50 ±12.74	1463.63 ±12.47	2059.30 ±19.41	2528.72 ±23.32
T3	120.26 ±2.06	413.58 ±4.16	886.93 ±12.96	1474.50 ±21.60	2071.59 ±29.26	2544.86 ±42.54
T4	118.00 ±2.43	411.35 ±3.52	870.04 ±6.23	1457.81 ±9.56	2052.23 ±12.73	2522.70 ±23.73
T5	122.75 ±3.04	416.03 ±6.67	876.16 ±15.79	1470.46 ±19.87	2059.21 ±30.22	2526.36 ±40.92
Significant	NS	NS	NS	NS	NS	NS
CV %	4.176	2.557	2.736	2.395	2.527	2.906

NS, Non-significant; CV, Coefficient of variance.

Table 3. Cumulative weekly feed consumption (g/bird) of broilers fed different levels of various trace minerals in diets

Treatment	Age (weeks)					
	1st	2nd	3rd	4th	5th	6th
T1	145.06 ±2.58	529.31 ±7.63	1181.19 ±15.41	2080.01 ±34.85	3166.70 ±53.61	4180.58 ±90.27
T2	147.50 ±1.88	533.00 ±3.75	1186.38 ±12.88	2080.75 ±20.88	3194.28 ±32.71	4218.36 ±23.90
T3	149.80 ±0.80	534.90 ±4.07	1211.50 ±13.23	2102.40 ±14.74	3214.72 ±35.86	4281.68 ±76.26
T4	147.40 ±1.29	534.28 ±3.30	1196.21 ±22.92	2073.49 ±26.60	3204.39 ±18.49	4245.80 ±61.29
T5	152.03 ±2.69	538.38 ±6.13	1205.63 ±17.18	2122.84 ±28.22	3234.68 ±35.94	4291.25 ±59.76
Significant	NS	NS	NS	NS	NS	NS
CV %	2.675	1.963	2.797	2.483	2.314	3.117

NS, Non-significant; CV, Coefficient of variance.

Table 4. Cumulative weekly feed conversion ratio of broilers fed different levels of various trace minerals in diets

Treatment	Age (weeks)					
	1st	2nd	3rd	4th	5th	6th
T1	1.28±0.01	1.32±0.01	1.40±0.01	1.47±0.01^a	1.60±0.00^a	1.73±0.01^a
T2	1.24±0.02	1.29±0.01	1.35±0.01	1.42±0.01^b	1.55±0.00^b	1.67±0.01^b
T3	1.25±0.02	1.29±0.01	1.37±0.01	1.43±0.01^b	1.55±0.01^b	1.68±0.00^b
T4	1.25±0.02	1.30±0.01	1.37±0.03	1.42±0.02^b	1.56±0.01^b	1.68±0.02^b
T5	1.24±0.01	1.29±0.01	1.38±0.01	1.44±0.01^{ab}	1.57±0.01^{ab}	1.70±0.02^{ab}
Significant	NS	NS	NS	*	*	*
CV %	3.043	1.470	2.163	1.633	1.183	1.400

Means bearing different superscripts within a column differ significantly; *, Significant (P<0.05); NS, Non-significant; CV, Coefficient of variance.

The cumulative FCR at 4th, 5th and 6th week of age was significantly (P<0.05) better in treatment groups T2 (OTM @ 500 g/ton of feed), T3 (OTM @ 750 g/ton of feed) and T4 (NTM @ 500 g/ton of feed) than control group T1 (Table 4). Similarly, El-Katcha *et al.* (2017) reported that supplementation of organic or nano Zn at 60, 45 or 30 ppm had improved FCR significantly (P<0.05) than inorganic Zn supplementation at 60 ppm in broilers. Ibrahim *et al.* (2017) recorded significantly better FCR in treatment groups supplemented with organic Zn, nano Zn and mixture of both as compared inorganic Zn. Jamima *et al.* (2020) reported that dietary supplementation of nano-selenium had significantly (P<0.05) improved FCR during 5th week of age in commercial broilers.

Mortality: The mortality for treatment groups T1, T2, T3, T4 and T5 fed with different levels of various trace mineral in diet was 3.75, 2.50, 1.25, 2.50 and 2.50%, respectively. The overall mortality observed during the experimental trial was 2.50% which was well within normal range. The results are in agreement with Baloch *et al.* (2017) who observed non-significant differences in mortality rates between the treatment groups supplemented with different inorganic and organic minerals. Ahmadi *et al.* (2013) also reported lower mortality among treatments throughout the experiment when supplemented with different levels of silver nanoparticles in diet.

Immune response: The antibody titers against New Castle Disease at the end of 3rd and 6th week of age were numerically higher in treatment groups T2 and T3 than control group, whereas, the statistical differences were non-significant. However, the antibody titers against New Castle Disease was significantly higher at 3rd week (P<0.01) and (P<0.05) at 6th week in treatment groups T4 and T5 supplemented with nanoparticle trace minerals as compared to control group T1 (Table 5). The findings are in accordance with Abdallah *et al.* (2009) who reported that chicks fed 100% organic Zn recorded highest antibody titer and groups supplemented with single element of organic Zn, Cu, Mn or Fe (peptide chelates at 50% and 100%) were found non-significant differences. Rao *et al.* (2016) reported that dietary concentrations of Zn, Se and

Table 5. Antibody titers of broilers against New Castle Disease at the end of 3rd and 6th week of age fed with different levels of various trace minerals in diets

Treatment	New Castle Disease titers @ 8 HAU (log_2)	
	3rd week	6th week
T1	$1.88^{c}\pm0.52$	$2.50^{c}\pm0.46$
T2	$2.88^{bc}\pm0.35$	$3.25^{abc}\pm0.25$
T3	$2.88^{bc}\pm0.48$	$3.13^{bc}\pm0.30$
T4	$3.88^{ab}\pm0.30$	$3.75^{ab}\pm0.25$
T5	$4.38^{a}\pm0.32$	$4.13^{a}\pm0.40$
Significant	**	*
CV %	35.862	28.875

Means bearing different superscripts within a column differ significantly. *, significant (P<0.05); **, significant (P<0.01); CV, Coefficient of variance.

Table 6. Economics of broiler production fed with different levels of various trace minerals in diets

Parameter	Treatment Groups				
	T1 (ITM @ 1 kg/ton)	T2 (OTM @ 500 g/ton)	T3 (OTM @ 750 g/ton)	T4 (NTM @ 500 g/ton)	T5 (NTM @ 750 g/ton)
Chick cost (₹/chick)	7	7	7	7	7
Feed intake (g/b)					
• Pre-starter	145.06	147.50	149.80	147.40	152.03
• Starter	1036.13	1038.88	1061.70	1048.81	1053.60
• Finisher	2999.39	3031.98	3070.19	3049.59	3085.63
Total Feed consumption (g/b)	4180.58	4218.36	4281.68	4245.80	4291.25
Feed price (₹/kg)					
• Pre-starter	31.45	31.47	31.53	31.48	31.56
• Starter	31.81	31.83	31.89	31.84	31.92
• Finisher	31.34	31.36	31.42	31.37	31.45
Feed cost (₹/b)					
• Pre-starter	4.56	4.64	4.72	4.64	4.80
• Starter	32.96	33.07	33.86	33.39	33.63
• Finisher	94.00	95.08	96.47	95.67	97.04
Total feed cost (₹/b)	131.52	132.79	135.05	133.70	135.47
Miscellaneous cost (₹/b)	10	10	10	10	10
Net cost of production (₹/b)	148.52	149.79	152.05	150.70	152.47
Cost of production (₹/kg) live weight	60.32	58.18	58.69	58.67	59.27
Body weights at the end of 6th week (g/b)	2462.33	2574.47	2590.59	2568.55	2572.26
Return on sale @ ₹79/kg live weight	194.52	203.38	204.66	202.92	203.21
Net profit (₹/b)	46.00	53.59	52.61	52.22	50.74
Net profit (₹/kg)	18.68	20.82	20.31	20.33	19.72
More Profit than control (₹/kg)		2.14	1.63	1.65	1.04
Per cent improved in net profitability		11.46	8.73	8.83	5.57

Cr in organic form did not influence New Castle Disease titer as compared to inorganic trace minerals. However, Ahmadi *et al.* (2018) observed birds fed with nano-selenium at 0.3 mg/kg and 0.5 mg/kg recorded significantly increased ($P<0.05$) New Castle Disease hemagglutination-inhibition titer compared to the control. El-Katcha *et al.* (2017) reported that supplementation of nano Zn at 30 and 45 ppm in broiler diets significantly increased New Castle Disease titers as compared to inorganic Zn at 60 ppm but it was non-significant between organic and inorganic Zn supplementation on 28th day.

Economics of broiler production: The cost of production (₹/kg) live weight for treatment groups T1, T2, T3, T4 and T5 was 60.32, 58.18, 58.69, 58.67 and 59.27, respectively (Table 6). The highest per cent net profit on ₹/kg was recorded in treatment group T2 (11.46) followed by T4 (8.83), T3 (8.73) and T5 (5.57) than control group T1. The supplementation of organic and nanoparticle trace minerals improved the profitability per kg body weights of the birds. The results are in agreement with Abdallah *et al.* (2009) who reported that chicks fed 100% organic minerals recorded best economical efficiency 94% compared to inorganic supplemented diet. Sagar *et al.* (2018) also reported that nano zinc (NZ) proved to be better source than inorganic or organic sources of zinc for improved performance and immunity of broilers chicken considering cost of broiler production.

Therefore, it can be concluded that the supplementation of organic or nanoparticle trace minerals at 500 g/ton with replacing inorganic trace minerals at 1 kg/ton of feed, improved growth performance, immune response and economics of broiler production. Moreover, the supplementation of organic trace minerals @ 500 g/ton replacing inorganic trace minerals @ 1 kg/ton of feed improved overall growth performance and economics of broiler production.

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