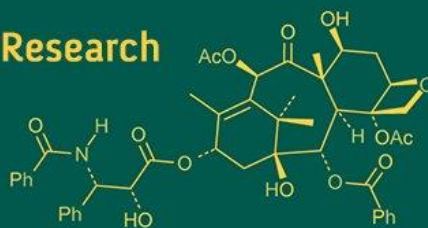
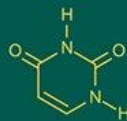
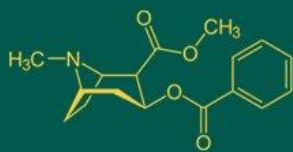


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Effect of various levels of trace mineral sources on growth performance of commercial broiler chicken

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Abstract

The effects of varying trace mineral source inclusion levels on the growth performance of commercial broiler chickens were assessed using a controlled experimental investigation. A total of 120 day-old Cobb-400 chicks with identical ages and genetic backgrounds were split into five nutritional treatment groups at random, with four duplicates of 24 birds in each group. 100% inorganic trace minerals (ITM) were added to the basal diet of the control group (T₁), while OTM gradually replaced ITM in different ratios in the experimental diets: T₂ = 75% ITM + 25% OTM, T₃ = 50% ITM + 50% OTM, T₄ = 25% ITM + 75% OTM, and T₅ = 100% OTM. Key growth performance metrics, such as live body weight, body weight gain, and feed conversion ratio (FCR), were carefully documented every week for all duplicates over the six-week trial period. Data analysis showed that birds fed the T₅ diet, which completely substituted organic sources for inorganic trace minerals, had significantly ($p < 0.05$) higher final body weights, greater cumulative weight gain, and better feed utilization efficiency than birds fed the control diet. These findings suggest that organic trace elements can effectively improve nutrient utilization, encourage healthy growth, and increase feed conversion efficiency in broiler chickens due to their increased bioavailability and enhanced absorption. In order to optimize growth performance and overall production efficiency under commercial raising circumstances, it may be possible to replace some or all of the inorganic trace minerals in broiler diets with organic versions.

Keywords: Broiler, inorganic trace minerals, organic trace minerals, growth performance

Introduction

The poultry sector is one of the fastest-growing components of India's agricultural industry, contributing significantly to rural livelihoods and food security. Among the various inputs involved in broiler production, feed constitutes a major cost factor—accounting for approximately 70-80% of the total production expenses (Osei and Amo, 1987) ^[12]. To prevent nutritional deficiencies that could lead to clinical or pathological disorders, mineral supplementation has become a standard practice in poultry nutrition (Nollet *et al.*, 2007) ^[11]. For appropriate physiological and metabolic processes, chickens need at least fourteen key inorganic elements. Based on their quantitative needs, these minerals can be roughly divided into two classes. Macro-minerals are necessary in comparatively large quantities and are essential for metabolic control and structural integrity. On the other hand, trace minerals, also known as micro-minerals, are essential cofactors for enzymes and other physiological processes but are required in very small amounts (Bao and Choct, 2009) ^[3]. Zinc (Zn), copper (Cu), iron (Fe), iodine (I), manganese (Mn), cobalt (Co), selenium (Se), chromium (Cr), and molybdenum (Mo) are important trace minerals that are frequently found in broiler diets. These components are essential for many metabolic, digestive, and biochemical processes that support immunity, development, and general health (Bao and Choct, 2009) ^[3].

Because of their greater bioavailability and durability, organic trace minerals (OTMs) have been more popular in recent years than conventional inorganic sources such as sulfates, oxides, carbonates, and phosphates (Ghasemi *et al.*, 2020) ^[18]. OTMs show improved absorption and utilization efficiency while lowering mineral excretion and environmental contamination. They are commonly given as amino acid chelates, proteinates, or organic acid complexes. Supplementation of broiler diets with organic trace minerals has been associated with multiple production and health benefits, including reduced mortality, improved skin and feather quality, fewer lesions, and enhanced carcass characteristics (Tavares *et al.*, 2013) ^[18].

The chelation process, wherein minerals are bound to organic ligands, improves their stability within the gastrointestinal tract and minimizes antagonistic interactions with other dietary components. This mechanism facilitates efficient mineral absorption in the small intestine, ultimately promoting better physiological utilization and improved overall performance in broiler chickens (Richards *et al.*, 2010) [15].

Materials and Methods

The experiment was carried out at the Poultry Research Station, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Anand, Gujarat. A total of 120 straight-run, day-old commercial broiler chicks with a uniform genetic background were obtained from a single private hatchery to ensure consistency in genetic makeup and health status.

Table 1: Proportion of feed ingredients (%) used for preparation of broiler diets (control diet)

S. No	Ingredients/Component	Broiler Pre-Starter (0-1 wk)	Broiler Starter (2-3 wk)	Broiler Finisher (4-6 wk)
1	Maize (Yellow)	56.4	58.5	60.6
2	Soybean De-oiled Meal	37.1	35.0	29.4
3	De-oiled Rice Bran (DORB)	2.0	0.8	2.7
4	Limestone Powder (CaCO ₃)	1.3	1.2	1.1
5	Dicalcium Phosphate (DCP)	1.4	1.3	1.5
6	Vitamin Premix	0.05	0.05	0.05
7	Vitamin B ₁₂	0.01	0.01	0.01
8	Choline Chloride (60%)	0.10	0.10	0.10
9	L-Lysine	0.06	0.01	0.05
10	DL-Methionine	0.15	0.12	0.13
11	Phytase Enzyme	0.01	0.01	0.01
12	Enzyme Complex	0.02	0.02	0.02
13	Common Salt (NaCl)	0.25	0.25	0.25
14	Sodium Bicarbonate (NaHCO ₃)	0.10	0.10	0.10
15	Hepatic Tonic	0.10	0.10	0.10
16	Immunomodulators	0.05	0.05	0.05
17	Mycotoxin Binder	0.10	0.10	0.10
18	Coccidiostat	0.05	0.05	0.05
19	Emulsifying Agent	0.05	0.05	0.05
20	Veg. Oil/Fat	1.6	2.9	4.6
21	Inorganic Trace Minerals (ITM)	0.10	0.10	0.10
22	Organic Trace Minerals (OTM)	-	-	-
	Total	100.0	100.0	100.0
	Crude Protein (%)	23.0	22.0	20.0
	Metabolizable Energy (ME, kcal/kg)	3000.5	3100.6	3200.8

Materials and Methods

Experimental Design and Birds

The Poultry Research Facility conducted a six-week feeding trial from February 26, 2021, to April 8, 2021. Each of the 120 day-old Cobb-400 broiler chicks was weighed and given a wing band to help with identification upon arrival. After that, the chicks were divided into five dietary treatment groups at random, each with 24 birds, four replicates per treatment, and six chicks per replicate.

Vaccination and Health Management

To guarantee optimum health, vaccination protocols were adhered to: infectious bursal disease (IBD) using the Lasota strain on day 14, Newcastle disease on days 7 and 21, and Marek's disease at the hatchery. For the duration of the experiment, standard management procedures were followed.

Diets and Treatments

Pre-starter (0-7 days), starter (8-21 days), and finisher (22-42 days) were the three growth phases for which experimental diets were designed. Commercial vendors provided the glycinated organic and inorganic trace minerals. The following were the dietary interventions:

- T₁: 100% inorganic trace minerals (ITM) added to a basal diet

- T₂: 75% ITM plus 25% organic trace minerals (OTM) added to a basal diet
- T₃: 50% ITM + 50% OTM added to a basal diet
- T₄: 25% ITM + 75% OTM added to a basal diet
- T₅: 100% OTM added to a basal diet

All diets were formulated to be isocaloric and isonitrogenic, ensuring uniform nutrient intake across all treatment groups.

Growth Performance Measurements

Over the course of the 42-day experiment, each bird's individual body weight (BW) and weekly body weight increase (BWG) were noted. Feed intake (FI) was determined by measuring feed provided and feed residues per replicate on a weekly basis. The ratio of feed intake to live body weight was used to calculate the feed conversion ratio (FCR). At the end of the trial, average final body weights were recorded.

Statistical Analysis

In compliance with Snedecor and Cochran (1994) [17], all gathered data were statistically analyzed using a Completely Randomized Design (CRD). For comparison, the means of duplicates within each treatment were utilized. Duncan's Multiple Range Test was used to determine whether treatment mean differences were statistically significant (Duncan, 1955) [7].

Results and Discussion

Body Weight

Table 2 displays the average body weight (BW) of broilers at day-old age and on a weekly basis. From the second to the sixth week, birds fed diets enriched with organic trace minerals showed significantly ($p < 0.05$) higher body weights than the control group (T_1), which was provided 100% inorganic trace elements. Over the course of the experiment, birds in the T_5 group (100% OTM) consistently attained the highest total body weight among all treatments, demonstrating the beneficial impact of fully substituting organic sources for inorganic minerals.

These findings are consistent with those of Abdallah *et al.* (2009) [1], who found that broilers fed diets containing 100% organic trace minerals had considerably greater body

weights at 42 days than birds fed just inorganic trace minerals. In a similar vein, Ciurescu *et al.* (2007) [15] found that broilers supplemented with organic trace minerals had significantly higher body weight at 42 days (2071.93 g) than broilers fed an inorganic mineral diet (2006.10 g). Aksu *et al.* (2011) [2] observed similar results, noting that broilers fed organic trace mineral-supplemented diets reached considerably greater body weights (705.60 g) during the early growth phase compared to those receiving inorganic mineral supplementation (664.40 g).

The increased bioavailability and absorption efficiency of organic trace elements, which improve nutrient utilization and foster optimal growth performance in broiler hens, are responsible for the observed increase in body weight.

Table 2: Effect of graded substitution of inorganic trace minerals (ITM) with organic trace minerals (OTM) on body weight (g) of broiler chickens (Mean $\pm$ SE)

Traits	T ₁ (100% ITM)	T ₂ (75% ITM + 25% OTM)	T ₃ (50% ITM + 50% OTM)	T ₄ (25% ITM + 75% OTM)	T ₅ (100% OTM)	SEM	CD (5%)	CV%
BW ₀ (day-old)	46.88 $\pm$ 0.58	46.50 $\pm$ 0.65	46.88 $\pm$ 0.58	45.92 $\pm$ 0.63	46.33 $\pm$ 0.66	0.62	NS	6.56
BW ₁ (1 week)	149.79 $\pm$ 1.89	154.08 $\pm$ 2.77	153.79 $\pm$ 3.00	154.38 $\pm$ 3.88	156.96 $\pm$ 2.69	2.85	NS	9.04
BW ₂ (2 weeks)	373.92 ^a $\pm$ 5.46	390.13 ^{abc} $\pm$ 4.79	384.17 ^{ab} $\pm$ 5.64	394.17 ^{bc} $\pm$ 6.60	403.33 ^c $\pm$ 6.80	5.86	16.36	7.36
BW ₃ (3 weeks)	745.26 ^a $\pm$ 18.96	782.29 ^a $\pm$ 12.63	770.21 ^a $\pm$ 14.40	794.58 ^{ab} $\pm$ 14.50	838.92 ^b $\pm$ 20.41	16.18	45.76	10.03
BW ₄ (4 weeks)	1161.52 ^a $\pm$ 29.19	1282.13 ^b $\pm$ 23.72	1282.25 ^b $\pm$ 27.32	1304.63 ^b $\pm$ 30.64	1353.92 ^b $\pm$ 21.12	26.39	74.14	10.14
BW ₅ (5 weeks)	1555.65 ^a $\pm$ 46.14	1664.61 ^{ab} $\pm$ 40.16	1778.17 ^{bc} $\pm$ 38.12	1702.21 ^b $\pm$ 49.91	1862.75 ^c $\pm$ 40.19	42.89	119.78	12.24
BW ₆ (6 weeks)	1715.32 ^a $\pm$ 63.81	1920.22 ^b $\pm$ 56.90	2066.92 ^{bc} $\pm$ 52.96	1963.04 ^b $\pm$ 79.61	2180.04 ^c $\pm$ 42.27	59.09	166.92	14.72

Means within a row with different superscripts (a, b, c) differ significantly ($p < 0.05$); NS = Non-significant.

* The means bearing different superscript within same row differ significantly ($p < 0.05$), NS: Non-Significant

Body Weight Gain

Pre-starter phase (0-1 week)

The average body weight increase (BWG) of broilers during various growth stages is shown in Table 3. The treatment groups showed uniform early adaptation to the experimental diets throughout the pre-starter phase, with no significant differences ($p > 0.05$) found. This implies that within the first week, all birds, irrespective of the nutritional therapy, adapted to the basal feed in a comparable manner.

Starter phase (1-3 weeks)

During the starter phase, broilers fed diets that replaced some or all of the inorganic trace minerals (ITM) with organic trace minerals (OTM) showed significantly higher BWG ($p < 0.05$) than the control group (T_1). These diets were T_2 (75% ITM + 25% OTM), T_4 (25% ITM + 75% OTM),

and T_5 (100% OTM). This suggests that growth performance during the crucial early growth stage is positively impacted by even a partial substitution of inorganic minerals with organic forms.

Finisher and overall phases (4-6 weeks and 0-6 weeks):

Broilers fed diets that substituted organic trace minerals (OTM) for some or all of the inorganic trace minerals (ITM) during the starting phase had significantly greater BWG ($p < 0.05$) than the control group (T_1). T_2 (75% ITM + 25% OTM), T_4 (25% ITM + 75% OTM), and T_5 (100% OTM) were these diets. This implies that even a partial replacement of inorganic minerals with organic forms has a positive effect on growth performance during the critical early growth stage.

Table 3: Mean $\pm$ SE (n = number of birds) of weekly body weight gain (g) of broilers fed with different treatment diets

Traits	T ₁ (100% ITM)	T ₂ (75% ITM + 25% OTM)	T ₃ (50% ITM + 50% OTM)	T ₄ (25% ITM + 75% OTM)	T ₅ (100% OTM)	SEm	CD at 5%	CV (%)
BWG ₀₋₁	102.92 $\pm$ 1.65	107.58 $\pm$ 2.88	106.92 $\pm$ 2.86	108.46 $\pm$ 3.85	110.63 $\pm$ 2.65	2.78	NS	12.63
BWG ₁₋₂	224.13 ^a $\pm$ 4.37	236.04 ^{ab} $\pm$ 4.28	230.38 ^{ab} $\pm$ 4.91	239.79 ^{ab} $\pm$ 7.13	246.38 ^b $\pm$ 5.77	5.29	15.11	10.93
BWG ₂₋₃	372.04 ^a $\pm$ 16.23	392.17 ^a $\pm$ 9.62	386.04 ^a $\pm$ 10.95	400.42 ^{ab} $\pm$ 10.48	435.58 ^b $\pm$ 14.63	12.38	35.07	15.22
BWG ₃₋₄	416.26 ^a $\pm$ 19.28	499.83 ^b $\pm$ 14.94	512.04 ^b $\pm$ 15.76	510.04 ^b $\pm$ 23.08	515.00 ^b $\pm$ 9.71	16.55	47.72	16.67
BWG ₄₋₅	394.13 ^a $\pm$ 37.95	388.04 ^a $\pm$ 24.77	495.92 ^b $\pm$ 23.49	397.58 ^a $\pm$ 37.86	508.83 ^b $\pm$ 24.17	29.63	84.29	33.98
BWG ₅₋₆	170.32 $\pm$ 40.76	255.61 $\pm$ 38.41	288.75 $\pm$ 45.41	260.83 $\pm$ 54.97	317.29 $\pm$ 28.07	41.52	NS	81.59
BWG ₁₋₃	571.29 ^a $\pm$ 30.54	628.21 ^b $\pm$ 11.03	616.42 ^{ab} $\pm$ 12.67	640.21 ^{bc} $\pm$ 14.40	681.92 ^c $\pm$ 19.39	17.61	52.67	14.83
BWG ₄₋₆	886.29 ^a $\pm$ 76.96	1094.58 ^b $\pm$ 70.30	1296.71 ^c $\pm$ 52.10	1168.46 ^{bc} $\pm$ 78.19	1341.13 ^c $\pm$ 34.36	62.38	179.14	27.81
BWG ₀₋₆	1668.68 ^a $\pm$ 63.86	1873.70 ^b $\pm$ 56.97	2020.04 ^{bc} $\pm$ 52.99	1917.13 ^b $\pm$ 79.65	2133.71 ^c $\pm$ 42.24	59.13	167.02	

* The means bearing different superscript within same row differ significantly ($p < 0.05$), NS: Non-Significant

Growth Performance

In line with earlier research, broilers given organic trace mineral supplements showed better body weight gain over the course of the entire period (0-6 weeks). Birds fed diets

containing organic trace elements gained much more weight than those fed diets containing inorganic sources, according to Paik (2001) [13] and Nollet *et al.* (2008) [10]. Ghasemi *et al.* (2020) [8], Carvalho *et al.* (2018) [4], and M'sadeq *et al.*

(2018) [9] all reported similar improvements in growth performance, demonstrating the advantageous function of organic mineral supplementation in broiler diets.

Feed Consumption

By the conclusion of the third week, birds fed the T₅ diet had the highest feed intake ($p < 0.05$), as Table 4 illustrates. During the remaining stages, however, there were no statistically significant differences between the treatments. These findings are consistent with those of Bao *et al.* (2009) [3], Patel *et al.* (2021) [14], and Paik (2001) [13], who found that broilers fed organic trace minerals had comparable or

numerically higher feed consumption than those fed inorganic ones.

Feed Conversion Ratio (FCR)

According to Table 5, birds fed diets that either fully or partially replaced inorganic minerals with organic trace elements (T₂-T₅) demonstrated considerably ($p < 0.05$) higher FCR than the control group (T₁). Deniz *et al.* (2005) [6], Saenmahayak *et al.* (2010) [6], Vieira *et al.* (2020) [19], and Yin *et al.* (2021) [20] observed comparable increases in FCR as a result of organic mineral supplementation, showing improved feed efficiency with organic mineral inclusion.

Table 4: Mean $\pm$ SE of feed consumption (g/bird) of broilers fed with different treatment diets (n = 4)

Traits	T ₁	T ₂	T ₃	T ₄	T ₅	SEm	CD (5%)	CV (%)
FC ₁	160.23 $\pm$ 1.47	158.56 $\pm$ 4.28	161.62 $\pm$ 3.10	161.78 $\pm$ 2.87	165.42 $\pm$ 1.84	2.66	NS	3.32
FC ₂	327.39 $\pm$ 2.84	335.42 $\pm$ 4.91	328.05 $\pm$ 3.23	327.54 $\pm$ 3.25	325.68 $\pm$ 2.06	3.14	NS	1.92
FC ₃	546.83 ^a $\pm$ 8.03	559.24 ^a $\pm$ 4.46	558.66 ^a $\pm$ 6.58	560.12 ^a $\pm$ 8.45	598.12 ^b $\pm$ 16.76	8.81	29.49	3.10
FC ₄	676.08 $\pm$ 25.47	760.36 $\pm$ 14.91	755.26 $\pm$ 28.21	762.43 $\pm$ 55.74	755.48 $\pm$ 10.17	26.85	NS	7.21
FC ₅	749.17 $\pm$ 66.88	753.52 $\pm$ 43.25	848.94 $\pm$ 28.36	769.14 $\pm$ 57.70	879.21 $\pm$ 25.46	44.26	NS	11.34
FC ₆	582.74 $\pm$ 99.72	605.38 $\pm$ 92.77	718.25 $\pm$ 52.70	580.19 $\pm$ 135.53	758.12 $\pm$ 40.63	84.25	NS	27.35
TFC ₀₋₁	160.23 $\pm$ 1.47	158.56 $\pm$ 4.28	161.62 $\pm$ 3.10	161.78 $\pm$ 2.87	165.42 $\pm$ 1.84	2.66	NS	3.32
TFC ₂₋₃	874.26 $\pm$ 9.48	894.88 $\pm$ 3.21	886.64 $\pm$ 6.98	888.19 $\pm$ 10.68	924.23 $\pm$ 18.36	9.71	NS	2.15
TFC ₄₋₆	2008.31 $\pm$ 143.81	2119.18 $\pm$ 142.20	2323.22 $\pm$ 69.25	2112.16 $\pm$ 194.53	2393.68 $\pm$ 63.11	122.56	NS	8.16
TFC ₀₋₆	3042.71 $\pm$ 137.24	3173.45 $\pm$ 145.27	3372.19 $\pm$ 68.54	3163.62 $\pm$ 200.58	3484.14 $\pm$ 78.79	126.05	NS	

* The means bearing different superscript within same row differ significantly ($p < 0.05$), NS: Non-Significant

Table 5: Mean $\pm$ SE of feed conversion ratio of broilers fed with different treatment diets (n = 4)

Traits	T ₁	T ₂	T ₃	T ₄	T ₅	SEm	CD at 5%	CV %
FCR ₀₋₁	1.07 $\pm$ 0.02	1.03 $\pm$ 0.03	1.04 $\pm$ 0.03	1.05 $\pm$ 0.02	1.06 $\pm$ 0.02	0.02	NS	4.25
FCR ₀₋₂	1.31 ^a $\pm$ 0.01	1.27 ^{ab} $\pm$ 0.01	1.28 ^{ab} $\pm$ 0.01	1.25 ^{bc} $\pm$ 0.02	1.23 ^c $\pm$ 0.02	0.01	0.05	2.15
FCR ₀₋₃	1.39 $\pm$ 0.02	1.35 $\pm$ 0.02	1.36 $\pm$ 0.02	1.33 $\pm$ 0.03	1.31 $\pm$ 0.01	0.02	NS	3.09
FCR ₀₋₄	1.47 ^a $\pm$ 0.01	1.42 ^b $\pm$ 0.02	1.41 ^{bc} $\pm$ 0.02	1.39 ^{bc} $\pm$ 0.01	1.37 ^c $\pm$ 0.01	0.01	0.05	2.00
FCR ₀₋₅	1.59 ^a $\pm$ 0.02	1.55 ^{ab} $\pm$ 0.04	1.49 ^b $\pm$ 0.02	1.52 ^{ab} $\pm$ 0.03	1.47 ^b $\pm$ 0.01	0.02	0.08	3.08
FCR ₀₋₆	1.79 ^a $\pm$ 0.02	1.65 ^b $\pm$ 0.02	1.63 ^b $\pm$ 0.03	1.61 ^b $\pm$ 0.01	1.59 ^b $\pm$ 0.01	0.02	0.07	2.94

* The means bearing different superscript within same row differ significantly ($p < 0.05$), NS: Non-Significant

Conclusion

The study demonstrated that replacing inorganic trace minerals with organic trace minerals in broiler diets positively influenced growth performance. Broilers fed diets with partial to complete inclusion of organic trace minerals (T₂-T₅) exhibited significantly higher body weight and body weight gain compared to the control group (T₁), with the T₅ group (100% organic trace minerals) achieving the maximum growth.

While the total feed consumption (TFC₀₋₆) was numerically highest in the T₅ group, differences across treatments were not statistically significant. Notably, the feed conversion ratio (FCR₀₋₆) improved significantly in birds receiving diets containing organic trace minerals, whether partially or fully replacing inorganic sources.

Overall, these findings suggest that inorganic trace minerals can be entirely substituted with organic trace minerals in broiler diets to enhance growth performance and optimize feed utilization efficiency.

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