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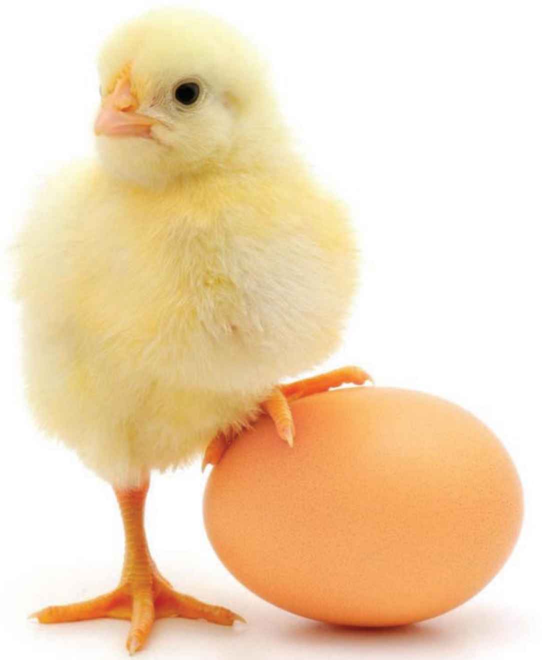

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Research Article

Total Replacement of Inorganic Minerals with Organic Ones Improves the Productive Performance of Broilers

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Abstract

Background and Objective: The effectiveness of mineral use is an essential topic in modern poultry feeding. The trend of using organic minerals over inorganic sources in poultry is increasing rapidly as they are supposed to be more bioavailable and efficient. The objective of this study was to evaluate the effect of the total replacement of zinc, copper, manganese, iron and selenium mineral supplementation in inorganic form by organic minerals, in the form of chelates - amino acids, on productive performance and pododermatitis score in broiler chickens. **Materials and Methods:** A total of 480 Cobb broiler chicks were distributed in a completely randomized design with two treatments and eight replications, as follows: T1 (control, with the inclusion of inorganic minerals) and T2 (total replacement of inorganic mineral sources by the blend of organic minerals, in the inclusion of 1.0 kg t^{-1}, meeting the nutritional requirements of the strain). During 42 experimental days, weight gain, feed intake, feed conversion, viability, productive efficiency index and pododermatitis score were measured. **Results:** The birds fed with 1 kg t^{-1} of the organic blend showed lower feed intake ($p = 0.0091$), better feed conversion rates ($p = 0.043$), productive efficiency ($p = 0.0065$) and viability ($p = 0.0465$) in relation to the control group. The other variables did not differ statistically, although the group fed with organic minerals had a smaller number of animals with pododermatitis in the most severe scores of the disease. **Conclusion:** It is concluded that the blend of organic minerals met the nutritional requirements of the strain, by providing better rates of productive performance and can be an efficient substitute for inorganic sources of minerals.

Key words: Amino acids, chelates, feed conversion, organic micro mineral, pododermatitis, poultry feed, poultry health

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The performance and health of birds are the main factors affecting the profits of poultry producers. The recent state-of-the-art opinion points to a positive impact of mineral supplements on the general health status in poultry. The effectiveness of the use of microelements is an essential topic in modern poultry feeding[1].

Trace minerals such as selenium, copper, iron, manganese and zinc are essential to chicken development because they are active in several metabolic pathways. These minerals are involved in many biochemical, physiologic and endocrine functioning as catalysts for enzymatic processes, secretion of hormones and immune responses and are essential for the growth and health of the poultry, including reproduction, growth and sanity[2-4].

When supplementing trace minerals in poultry feed, differences in availability and contamination are of great concern[5]. It is a well-known fact that in commercial poultry feed, the inorganic form of trace minerals is added (sulfate or oxide salts) at up to ten-fold higher dose than the nutritional recommendations because of its low retention rates[6] but there are two main disadvantages of using inorganic minerals in the diet of birds.

First, the contamination factor: Copper sulfate and zinc oxide, for example, are common inorganic sources of copper and zinc used in the diet of birds but these two sources are derived from the steel industry and have a large number of contaminants, such as fluorine and cadmium, which are transferred to the diet of birds[7]. Second, the antagonistic effects between inorganic minerals can decrease their metabolism and absorption rate[8]. These factors are important and have a strong impact on increasing production costs.

Organic micro-mineral sources are an alternative to inorganic sources and have been increasingly used in broiler diets due to their greater bioavailability compared with traditional sources (inorganics). The application of organic mineral sources in poultry nutrition may prevent minerals from creating indigestible complexes with some dietary components and reciprocal mineral antagonisms in the intestine that could decrease their absorption rate[9].

The objective of this study was to evaluate the effect of the total replacement of the inorganic sources of copper, iron, manganese, zinc and selenium minerals, by a blend composed of the respective minerals in organic form, on the performance and pododermatitis score of broilers.

MATERIALS AND METHODS

All the procedures of the present study were carried out in accordance with the precepts of Law No. 11,794, of October 8, 2008, of Decree n°6,899, of July 15, 2009 and with the norms of the National Council for the Control of Animal Experimentation (CONCEA) and by the Commission on Ethics in the Use of Animals (CEUA) of the Company Samitec-CEUA/SAMITEC (Registration No. 0017.01.22).

A total of 480 one day old male broilers (Cobb 500 strain) with an average initial weight of 45.84 g were used in this study. Birds received feed and water *ad libitum* during the experimental period (1-42 days). The experimental trial was conducted on a commercial farm, with a semi-controlled environment, temperatures and ventilation suitable for each stage of development (according to the Cobb Management Guide reference). The animals were distributed in a completely randomized design and subdivided into two treatments, with eight replications and 30 birds/repeat, as follows: T1 = basal diet, without supplementation of the inorganic mineral blend. In this treatment, all the nutritional requirements of the birds were supplied by inorganic sources of minerals and, T2 = basal diet with the total replacement of inorganic sources of minerals by organic sources, offered in the form of a blend of organic minerals B-360 Poultry (Yessinergy do Brasil Agroindustrial LTDA), in the inclusion of 1.0 kg t^{-1}. The basal diet was isonutritive, formulated in accordance with the requirements of National Research Councill[10], according to the respective stages of chicken development, after evaluation by the NIRS technology. Composition of experimental diet is presented in Table 1.

Raw materials and experimental diets were analyzed for the presence of mycotoxins (aflatoxins, deoxynivalenol, diacetoxyscirpenol, fumonisins, ochratoxin A, T-2 toxin and zearalenone). No mycotoxins were detected in the raw materials used.

Parameters measured

Feed consumption: Feed consumption was recorded weekly from consumption in each repetition with mortality adjustment.

Live weight of birds: Live weight was obtained by weighing the birds/repetition.

Daily weight gain: To find the daily weight gain the difference between "live weight of the birds" and "initial weight of the birds" was divided by the number of days of the week.

Table 1: Experimental diets

	1-10 days		11-35 days		36-42 days	
Ingredients	Control	Organic minerals	Control	Organic minerals	Control	Organic minerals
Corn	58.50	58.50	62.20	62.20	68.10	68.10
Soybean meal	35.35	35.35	30.00	30.00	24.70	24.70
Soybean oil	1.60	1.60	3.80	3.80	3.75	3.75
Dicalcium phosphate	2.00	2.00	1.80	1.80	1.52	1.52
Limestone	1.00	1.00	0.82	0.82	0.82	0.82
Salt	0.46	0.46	0.45	0.45	0.40	0.40
Methionine Lysine	0.24	0.24	0.22	0.22	0.19	0.19
Lysine	0.20	0.20	0.16	0.16	0.17	0.17
Pre-Mix[1]	0.60	0.00	0.50	0.00	0.30	0.00
Pre-Mix[2]	0.00	0.50	0.00	0.40	0.00	0.20
Blend of organic minerals[3]	0.00	0.10	0.00	0.10	0.00	0.10
Kaolin	0.05	0.05	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition						
Crude protein (%)	22.00	22.00	20.00	20.00	18.00	18.00
Metabolizable energy (kcal kg^{-1})	2920.00	2920.00	3100.00	3100.00	3150.00	3150.00
Methionine and cystine (%)	1.02	1.02	0.87	0.87	0.79	0.79
Lysine (%)	1.44	1.44	1.23	1.23	1.09	1.09
Calcium (%)	0.93	0.93	0.88	0.88	0.76	0.76
Useful phosphorus (%)	0.47	0.47	0.44	0.44	0.38	0.38
Sodium (%)	0.22	0.22	0.21	0.21	0.19	0.19

[1]Mineral and vitamin premix Initial: Folic acid (min) 140 mg kg^{-1}, pantothenic acid (min) 1,700 mg kg^{-1}, Biotin: 15 mg kg^{-1}, Calcium (min/max) 30/130 g kg^{-1}, copper (min) 1410 mg kg^{-1}, choline (min) 40 g kg^{-1}, dl-methionine (min) 260 g kg^{-1}, enramycin: 1,333 mg kg^{-1}, iron (min) 8,500 mg kg^{-1}, Iodine (min) 150 mg kg^{-1}, Lysine (min) 50 g kg^{-1}, manganese (min) 12 g kg^{-1}, niacin (min) 5,930 mg kg^{-1}, selenium (min) 45 mg kg^{-1}, Vitamin A (min) 1,800.00 IU kg^{-1}, Vitamin B1 (min) 580 mg kg^{-1}, Vitamin B12 (min) 3,000 mcg kg^{-1}, Vitamin B2 (min) 960 mg kg^{-1}, Vitamin B6 (min) 730 mg kg^{-1}, Vitamin D3 (min) 300,000 IU kg^{-1}, Vitamin E (min) 3,750 IU kg^{-1}, Vitamin K3 (min) 300 mg kg^{-1}, Zinc (min) 9,170 mg kg^{-1}. Mineral and vitamin premix Growth: Folic acid (min) 170 mg kg^{-1}, pantothenic acid (min) 1,700 mg kg^{-1}, biotin: 8 mg kg^{-1}, BHA: 0.10 mg kg^{-1}, Ethoxyquin (min) 0.12 mg kg^{-1}, calcium (min/max) 30/130 g kg^{-1}, copper (min) 1700 mg kg^{-1}, choline (min) 40 g kg^{-1}, Dl-methionine (min) 280 g kg^{-1}, iron (min) 10 g kg^{-1}, Iodine (min) 175 mg kg^{-1}, Lysine (min) 40 g kg^{-1}, manganese (min) 9,140 g kg^{-1} , niacin (min) 7,120 mg kg^{-1}, selenium (min) 50 mg kg^{-1}, Vitamin A (min) 1,430.00 IU kg^{-1}, Vitamin B1 (min) 260 mg kg^{-1}, Vitamin B12 (min) 3,950 mcg kg^{-1}, Vitamin B2 (min) 1000 mg kg^{-1}, Vitamin B6 (min) 520 mg kg^{-1}, Vitamin D3 (min) 350,000 IU kg^{-1}, Vitamin E (min) 3,590 IU kg^{-1}, Vitamin K3 (min) 350 mg kg^{-1}, Zinc (min) 11 g kg^{-1}, Beta Glucans (min) 5,400 mg kg^{-1}, Glucomannans (min) 7,560 mg kg^{-1}, Mannan-oligosaccharides (min) 2,160 mg kg^{-1}, Finishing mineral and vitamin premix: Folic acid (min) 80 mg kg^{-1}, pantothenic acid (min) 1,300 mg kg^{-1}, BHA (min) 0.11 mg kg^{-1}, Biotin: Ethoxyquin (min) 0.14 mg kg^{-1}, 15 mg kg^{-1}, calcium (min/max) 100/230g/kg, copper (min) 2,260 mg kg^{-1}, choline (min) 15 g kg^{-1}, Dl-methionine (min) 210 g kg^{-1}, iron (min) 14 g kg^{-1}, Iodine (min) 145 mg kg^{-1}, manganese (min) 16 g kg^{-1}, niacin (min) 4,450 mg kg^{-1} , selenium (min) 60 mg kg^{-1}, Vitamin A (min) 1,480.00 IU kg^{-1}, Vitamin B1 (min) 140 mg kg^{-1}, Vitamin B12 (min) 2,480 mcg kg^{-1}, Vitamin B2 (min) 950 mg kg^{-1}, Vitamin B6 (min) 140 mg kg^{-1}, Vitamin D3 (min) 280,000 IU kg^{-1}, Vitamin E (min) 2,480 IU kg^{-1}, Vitamin K3 (min) 140 mg kg^{-1}, Zinc (min) 14 g kg^{-1}, [2]Initial vitamin premix: Vitamin A (min) 1,800.00 IU kg^{-1}, Vitamin B1 (min) 580 mg kg^{-1}, Vitamin B12 (min) 3,000 mcg kg^{-1}, Vitamin B2 (min) 960 mg kg^{-1}, Vitamin B6 (min) 730 mg kg^{-1}, Vitamin D3 (min) 300,000 IU kg^{-1}, Vitamin E (min) 3,750 IU kg^{-1}, Vitamin K3 (min) 300 mg kg^{-1}. Vitamin Premix Growth: Vitamin A (min) 1,430.00 IU kg^{-1}, Vitamin B1 (min) 260 mg kg^{-1}, Vitamin B12 (min) 3,590 mcg kg^{-1}, Vitamin B2 (min) 1000 mg kg^{-1}, Vitamin B6 (min) 520 mg kg^{-1}, Vitamin D3 (min) 350,000 IU kg^{-1}, Vitamin E (min) 3,590 IU kg^{-1}, Vitamin K3 (min) 350 mg kg^{-1}. Vitamin premix Termination: Vitamin A (min) 1,480.00 IU kg^{-1}, Vitamin B1 (min) 140 mg kg^{-1}, Vitamin B12 (min) 2,480 mcg kg^{-1}, Vitamin B2 (min) 950 mg kg^{-1}, Vitamin B6 (min) 140 mg kg^{-1}, Vitamin D3 (min) 280,000 IU kg^{-1}, Vitamin E (min) 2,480 IU kg^{-1}, Vitamin K3 (min) 140 mg kg^{-1}, [3]B-360 Poultry: Copper amino acid chelate (min) 8 g kg^{-1}, Iron amino acid chelate (min) 35 g kg^{-1}, manganese amino acid chelate (min) 55 g kg^{-1}, zinc amino acid chelate (min) 55 g kg^{-1}, selenium complex amino acid (min) 200 mg kg^{-1}, iodine (min) 1200 mg kg^{-1}

Feed conversion ratio: It is the ratio between "feed consumption" and "bird live weight" including mortality by repetition.

Productive efficiency index: It can be obtained from "daily weight gain", viability (%) and "feed conversion" per repetition.

The pododermatitis data were obtained from the evaluation of 70 birds/treatment according to the classification[11].

Data were analyzed using One-way analysis of variance (ANOVA) followed by Duncan's Multiple-Range (DMR) using the software Statgraphics Centurion XV® version 15.1.

RESULTS

Productive performance data are shown in Table 2.

Feed consumption for T2 was lower than that of the control treatment ($p = 0.0091$). However, no difference was observed between average live weight ($p = 0.6619$) and

Table 2: Average of the productive performance of broilers receiving, or not, blend of organic minerals in the diet, during the period of 42 experimental days

Treatments	FCons[1] (g bird^{-1})	LW[2] (g)	DWG[3] (g)	FConv[4] (g g^{-1})	Viab[5] (%)	PEI[6]
Control	5.152[a]	3.031	71.09	1.72[a]	95.41[b]	393.85[b]
BMO[7]	4.971[b]	3.106	70.71	1.65[b]	98.33[a]	419.33[a]
p-value	0.0091	0.6619	0.6561	0.0043	0.0466	0.0065

[a-b]Means in columns with different letters differ by Duncan's test ($p \leq 0.05$), [1]Feed consumption, [2]Live weight, [3]Daily weight gain, [4]Feed conversion, [5]Viability, [6]Production efficiency index, [7]Blend of organic minerals

Table 3: Pododermatitis score of broiler chickens fed with ration containing a blend of organic minerals for 42 days

Treatments	Score 0	Score 1	Score 2	Score 3	Score 4	Chi-square
Control	4/70	5/70	19/70	22/70	20/70	0.5952
Blend of organic minerals	0/70	7/70	27/70	21/70	15/70	

70 birds/treatment

average daily weight gain of birds (p = 0.6561) which reflected better feed conversion (p = 0.0043) compared to the control group. These findings showed that in the test group, the lowest feed intake can meet the nutritional requirements and increase the viability of the birds (p = 0,0466).

The feed efficiency index was measured using the daily weight gain, viability and feed conversion ratio. Results revealed that the feed efficiency index was better for T2 (p = 0.0065) than that of the control group.

At the end of the experimental period, no difference was observed between the frequencies for pododermatitis in birds (p = 0.5952) however, there was a decrease in the number of animals affected with the most severe scores of the disease (Table 3).

DISCUSSION

Productive performance: In recent years, extensive research work has been done to investigate the bioavailability of different trace mineral sources[12] and it has been established by several researchers[13-16] that organic chelated minerals are more bioavailable than inorganic salts for several reasons, including increased absorption. However, despite the potential for synergistic effects, few studies have evaluated these additives in combination[17].

The animals that consumed the blend of organic minerals had significantly lower feed intake (p = 0.0091) and better feed conversion ratio (p = 0.0043) when compared to the control treatment, however, live weight of the animals was not negatively affected by the blend. Trace minerals such as selenium, copper, iron, manganese and zinc are essential to chicken development because they are active in several metabolic pathways[18].

Furthermore, in poultry, FE (feed efficiency) is generally expressed as feed conversion ratio (FCR), which represents the ratio between feed intake and body weight gain for a specific period of growth. From another perspective, FE could also be considered as a homoeostatic process representing the net result between 'energy intake', which is determined by the voluntary feed intake and the efficacy of digestive processes (i.e. nutrient digestion and absorption) and 'energy expenditure', which depends on the maintenance requirements, specific nutrients repartitioning mechanisms and the rate of metabolic processes and intermediary metabolism in tissues and organs[19,20].

This is an extremely important result, because, over the last few years, the broiler’s body weight gain has increased by 30.2 g per year at the same time the FCR has reduced annually by 0.036%, contributing to an increase of 167% in poultry meat production, responsible for 35% of the total meat production in the last 30 years[20].

The highest viability was observed for birds that received the organic source of minerals. It is observed that supplementation of organic trace minerals improved the general health of the birds. Greater bioavailability can translate into numerous benefits to birds, including improvements in tissue development and integrity, enhanced immune function and growth performance[21].

The birds that consumed the organic minerals had efficient metabolism as the minerals are essential co-factors in different metabolic routes. Moreover, blend of organic minerals have greater bioavailability, leading to good health and viability of birds[22].

The higher bioavailability of blend is due to the fact that different production process is involved in manufacturing of organic minerals.

Soybean meal as amino acid matrix was used to produce the blend of minerals, which is considered one of the most commonly used nutritional raw materials in the animal feed industry, due to its balanced amino acid profile[23].

It is known that amino acid side chains show an affinity for certain oxidation states of metals, resulting in a typical selectivity pattern[24]. In the formation of metal complexes in an aqueous medium, the equilibrium constant or stability constant (Ks) is used to determine the strength of interaction between reagents that make the final product after the formation of bonds[25].

In general, stability means that a complex may be stored for a long time under suitable conditions[25] and is very significant to understand the role and behavior of ligand(s) in stabilizing the connections[26]. Thus, probably, due to the unique aminogram of soy, the minerals have been able to establish their preferential bonds with these amino acids, arriving with greater bioavailability at the intestinal absorption sites of chickens.

It is the matter of fact that the organic mineral blend was formulated to contemplate the daily requirements of these minerals for the birds.

Pododermatitis score: Although no difference was observed between the frequencies of pododermatitis, a decrease in the number of birds with the most severe scores of the disease was observed for the group that consumed the blend of organic minerals.

Microminerals play a key role in the structural integrity of the skin and wound healing[27]. Footpad injuries result in discomfort and pain, when severe ulcers develop birds feel difficulty in movement and access to water and feed, this situation affect not only the quality of life and well-being of these birds[28,29] but also causing a high economic impact[30,31]. In addition, the lesions constitute a gateway for a wide range of bacteria that proliferate in the internal tissues of the paws, with the possibility of systemic dissemination. *Staphylococcus aureus* is the most prevalent pathogen associated with pododermatitis and accounting for more than two-thirds of cases[32].

CONCLUSION

The observed results indicate that the replacement of inorganic minerals with a blend of organic minerals can improve the productive performance of broilers. This fact can probably be attributed to the greater bioavailability of the organic source, being a viable alternative for animal production.

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