The Effect of Replacing Inorganic With Organic Trace Minerals in Broiler Diets on Productive Performance and Mineral Excretion

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Primary Audience: Poultry Feed Producers, Broiler Growers, Nutritionists, Researchers, Environmentalists

SUMMARY

In an experiment with 2,040 Ross 308 broiler chickens, the effect of substituting inorganic with organic minerals in broiler feed on performance was determined. The experiment comprised 2 dietary treatments, with 6 replicates of 170 mixed-sex broiler chickens per pen replicate. Experimental diets consisted of a control treatment, formulated with inorganic Mn, Zn, Fe, and Cu sulfates at levels of 70, 37, 45, and 12 ppm, respectively, and an organic mineral diet supplemented with lower levels of Mn, Zn, Fe (all 10 ppm), and Cu (2.5 ppm) supplied as peptide chelates (Bioplex). Production performance was measured during the 39-d trial period, and mineral excretion was evaluated at 26 d of age. In the starter period (0 to 14 d), FCR tended to improve ($P = 0.06$) in broilers fed the organic mineral diet. However, no significant differences were observed in any of the productive performance parameters measured during the trial. Significantly lower ($P < 0.05$) excretion rates were recorded for all minerals in fecal samples taken from broilers receiving the organic mineral diet. Fecal levels of Mn, Zn, Fe, and Cu were 46, 63, 73, and 55%, respectively, compared to the controls.

Key words: Bioplex, organic mineral, inorganic mineral, mineral excretion, broiler chicken

DESCRIPTION OF PROBLEM

Diets for livestock are supplemented with minerals to avoid deficiencies that can lead to a wide variety of clinical and pathological disorders. Trace minerals fulfill a central role in many metabolic processes throughout the body and are essential for correct growth and development of all animals. They predominantly act as catalysts in many enzyme and hormone systems [1] and, as a result, influence growth, bone development, feathering, enzyme structure and function, and appetite. Deficiency symptoms are typically manifested as disturbances in multiple metabolic processes, resulting in lower production performance, loss of appetite, reproductive disorders, and impaired immune response [2]. Deficiencies can be caused by inadequate mineral intake or by the presence of antagonists in the diet, which

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interfere with or unbalance mineral uptake. Traditionally, inorganic mineral salts (as oxides and sulfates) have been used within feed formulations, because they offer a cost-effective solution to meet the requirement of the animal for trace elements. The availability of minerals from these sources varies, but in general, sulfates are thought to have higher bioavailability than oxides [3].

Nowadays, livestock is generally fed highly concentrated diets that are formulated to provide an excess of nutrients to maximize performance [4]. Modern, large-scale commercial livestock production systems have given rise to many environmental concerns due to the amount of waste that must be removed and disposed from these facilities. High nutrient and mineral (e.g., N, P, and trace minerals) concentrations in manure, when used as fertilizer, can lead to soil concentrations that exceed crop requirements. These excess minerals can leach through soils, potentially contaminating ground water supplies.

Increased awareness of potential mineral pollution has stimulated discussions on how to reduce mineral supplementation levels in livestock nutrition without jeopardizing animal health and productive performance. The use of organically complexed or chelated minerals in premixes has been suggested as a solution to this problem, based on the hypothesis that mineral complexes have a higher bioavailability than inorganic salts. This implies that organic minerals may be added at a much lower concentration in the diet than inorganic minerals, without any negative affect on production performance and potentially reducing mineral excretion. The most reasonable solution to reduce the excretion of trace minerals is to use mineral sources with a higher availability, which enables a reduction in dietary application levels. Research suggests that this can be done by providing minerals in a chelated form to the animals [2, 4, 5, 6]. However, the potential antimicrobial effects of high levels of Cu added as inorganic Cu on crop and small intestine microflora to maintain a good gut health may be abolished by this strategy. Therefore, an additional nutritional strategy to maintain gut health may be required.

Proteinates are forms of protein/peptide/amino acids chelated to minerals, whose consistent bioavailability equates more closely to that of small peptides and amino acids, which appear to be a more suitable form to use in formulating diets containing minimal levels of trace minerals [4]. The use of organic mineral sources can improve intestinal absorption of trace elements as they reduce interference from agents that form insoluble complexes with the ionic trace elements [2]. The objective of the following experiment was to determine the effect that replacing inorganic minerals with organic forms of Mn, Zn, Fe, and Cu has on productive performance and mineral excretion in broiler chickens.

MATERIALS AND METHODS

A total of 2,040 Ross 308 [7] one-day-old broiler chickens (mean weight 42 g) were used in the feeding trial that lasted until the birds reached 39 d of age. In total, 12 floor pens (surface area 10 m^2) were used, each containing 85 male and 85 female broilers, to give 6 pen replicates and a total of 1,020 birds per treatment. The birds were given ad libitum access to feed and water. A lighting schedule of 23L:1D was imposed throughout the experimental period. Ambient temperature was gradually decreased from 32°C on d 1 to 22°C at the end of the experiment. On d 1, birds were vaccinated against infectious bronchitis. Newcastle disease vaccination was performed on d 8, whereas the Gumboro vaccination took place on d 20.

Feed intake and bird weight were determined at 15, 29, and 39 d of age and were used to calculate FCR. The litter score on d 21 was visually determined by 4 experienced technicians, using a scale of 1 (very wet litter) to 10 (very dry litter).

On d 26, fecal samples were taken for mineral analysis. Ten birds per pen were randomly selected and placed in cages, where lighting was reduced for approximately 15 min, until sufficient droppings were produced (minimum of 50 g per 10 birds). After fecal collection, birds were returned to their original pen. Fecal samples from each pen were homogenously mixed and analyzed for Mn, Zn, Fe, and Cu contents, to determine the level of mineral excretion.

The nutrient composition of the experimental diets (Table 1) was calculated from Centraal Veevoederbureau standards and formulated to meet the nutrient requirements of broilers [8]. The control diet was formulated using 12 ppm

Table 1. Nutritional composition of feeds

Raw materials (%)	Starter (0 to 14 d of age)	Grower (15 to 28 d of age)	Finisher (29 to 39 d of age)
Wheat	47.75	50.00	55.00
Maize	10.55	9.52	4.34
Soybean meal	28.82	27.92	26.10
Rapeseed meal	2.00	2.59	3.93
Soybean oil	2.72	3.00	3.20
Animal fat	2.47	2.58	3.62
Limestone	1.12	0.84	0.78
Monocalcium phosphate	0.63	0.18	0.08
Salt	0.12	0.10	0.11
Premix Lys (25%)	0.60	0.45	0.47
Premix Met (99%)	0.02	0.00	0.00
Premix Thr (15%)	0.50	0.32	0.32
Premix (vitamins)[1]	1.00	0.50	0.50
Premix (trace minerals)[2]	0.50	0.50	0.50
Premix Cycostat[3]	0.25	0.00	0.00
Premix Stenorol	0.00	0.50	0.00
Premix xylanase[4]	0.45	0.50	0.55
Premix phytase[5]	0.50	0.50	0.50
Calculated nutrient content (g/kg)			
AME (kcal/kg)	2,903	2,952	3,026
Moisture	130	134	135
CP	208	207	203
Digestible Lys	10.6	10.2	10.0
Digestible Met calculated	4.9	4.7	4.7
Digestible Met + Cys	7.9	7.7	7.6
Ca	8.4	6.6	6.3
Total P	5.4	4.4	4.2
Na	1.5	1.4	1.4
K	9.3	9.2	8.9
Cl^-	2.7	2.3	2.4
Crude fat	69	73	84
CF	29	29	30
Starch	371	375	371

[1]On total feed basis: 12 ppm of Cu as $CuSO_4$ (25%), 37 ppm Zn as $ZnSO_4$ (35%), 70 ppm Mn as MnO (52%), and 45 ppm Fe as $FeSO_4$ (30%) in the inorganic premix and 2.5 ppm Cu, 10 ppm Zn, Mn, and Fe as Bioplex. Both diets contained 0.15 ppm Se added as sodium selenite.
[2]On total feed basis: 12,000 IU of vitamin A, 5,000 IU of vitamin D_3, 50 IU of vitamin E, 3 mg of vitamin K, 2 mg of vitamin B_1, 7 mg of vitamin B_2, 5 mg of vitamin B_6, 15 mg of vitamin B_{12}, 50 mg of nicotinic acid, 15 mg of pantothenic acid, 1 mg of folic acid, 200 mg of biotin, 0.5 mg of Co (as cobalt carbonate), and 1 mg of I (as calcium iodate).
[3]Cycostat (66 mg of robinidin-HCl per kg of feed), Alpharma Inc. (Bridgewater, NJ)
[4]Ronozyme WX (80 Farvet xylanase units of endo 1,4 β xylanase per kg of feed), Novozyme A/S (Bagsvaerd, Denmark).
[5]Ronozyme P (500 FYT of 6-phytase per kg of feed), Novozyme A/S.

Cu as $CuSO_4$ (25%), 37 ppm Zn as $ZnSO_4$ (35%), 70 ppm Mn as MnO (52%), and 45 ppm Fe as $FeSO_4$ (30%) to meet normal trace element requirements in feed. These standard levels reflect the normal supplementary levels and sources of minerals for commercial broiler feed in the Netherlands. In the experimental diet, the supplemental inorganic minerals were entirely replaced by lower levels of organic minerals (10 ppm of Zn, Mn, and Fe and 2.5 ppm Cu) as the commercial proteinates, Bioplex [9]. Feeds were formulated to provide 3 phases during the experiment: a starter (0 to 14 d), grower (15 to 28 d), and finisher (29 to 37 d). The diets were pelleted through a 2.5-mm die. All feeds were analyzed for mineral content. Mineral analyses in feed and feces were performed by acid-heat destruction (2-g sample in 20 mL of HNO_3 and 10 mL of $HClO_4$ for 30 min) followed by an induced coupled plasma-atomic emission spectrometry measurement using a standard produced in similar acid mixture.

Table 2. Technical performance of broilers fed diets formulated with inorganic or low-concentration organic mineral (Bioplex) inclusion[1]

Parameter	Inorganic mineral diet	Organic mineral diet	LSD	P-value
d 1 to 14				
BW (g)	463	466	10	0.419
Feed intake (g)	534	529	13	0.355
FCR	1.269	1.246	0.024	0.060
Mortality (%)	2.1	1.5	1.6	0.383
d 15 to 29				
BW gain (g)	1,059	1,065	34	0.651
Feed intake(g)	1,763	1,771	32	0.551
FCR	1.665	1.663	0.039	0.869
Mortality (%)	0.8	1.7	1.4	0.167
d 30 to 39				
BW gain (g)	899	914	73	0.616
Feed intake (g)	1,853	1,866	61	0.598
FCR	2.070	2.050	0.169	0.763
Mortality (%)	1.1	0.8	1.3	0.578
d 1 to 39				
BW (g)	2,421	2,445	87	0.495
Feed intake (g)	4,154	4,163	44	0.607
FCR	1.747	1.733	0.068	0.616
Mortality (%)	3.9	3.9	1.7	0.985
Litter quality (21 d)[2]	5.6	5.4	0.7	0.693

[1]n = 6 per treatment.
[2]Visually determined by 4 experienced technicians, using a scale of 1 (very wet litter) to 10 (very dry litter).

Each pen of broilers was considered to be 1 experimental unit, for the purpose of statistical analysis. Feed intake, BW gain, FCR, mortality rate, and litter scores were analyzed by ANOVA using Genstat [10]. Treatment means were compared by LSD. Differences between treatments were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Broiler Production Performance

In the starter period (1 to 14 d), no significant differences were observed between any of the performance parameters measured ($P > 0.05$; Table 2). There was a tendency toward improved FCR for the broilers fed organic minerals ($P = 0.06$). In the grower period (d 15 to 28) and in the finisher period (d 29 to 39), no significant differences were observed in production performance. Likewise, when growth performance over the entire experimental period was analyzed (1 to 39 d), no significant treatment effects were observed.

Litter quality as measured by litter score at d 21 showed no significant differences between the control and the experimental diet (Table 2).

Mineral Excretion

The analyzed values (Table 3) represent the total minerals derived from the raw materials plus the mineral supplements from either the inorganic premix (control) or the organic source. The variation in mineral contents reflects the difference in added concentration of minerals between the 2 treatments.

The results from the mineral analysis in manure samples on d 26 are shown in Table 4. Although it would have been better to include a marker in the diet to correct for fecal DM and DM digestibility between the 2 treatments, some findings can be drawn from this table. Broilers fed the organic mineral diet excreted much lower concentrations of all the minerals under examination (46, 63, 73, and 55%, respectively, for Mn, Zn, Fe, and Cu) compared with fecal samples from broilers fed the control diets [100 − (level in control feces − level in treatment feces)/ level in control feces]. The significantly lower excretion rates observed in the organic mineral diet are a consequence of the overall higher concentrations of minerals supplied in the control diet supplemented with inorganic minerals rela-

Table 3. Calculated and analyzed Mn, Zn, Fe, and Cu content (mg/kg of DM) of feed

Mineral and diet phase	Inorganic mineral diet (mg/kg)	Organic mineral diet (mg/kg)
Calculated supplemental mineral (Mn)	70	10
Analyzed mineral levels		
Starter phase	116	60
Grower phase	118	55
Finisher phase	107	50
Calculated supplemental mineral (Zn)	37	10
Analyzed mineral levels		
Starter phase	96	70
Grower phase	93	62
Finisher phase	84	59
Calculated supplemental mineral (Fe)	45	10
Analyzed mineral levels		
Starter phase	262	199
Grower phase	212	168
Finisher phase	199	146
Calculated supplemental mineral (Cu)	12	2.5
Analyzed mineral levels		
Starter phase	20.5	9.7
Grower phase	23.3	11.3
Finisher phase	20.5	9.7

tive to the organic experimental diet. However, these results also prove that much lower concentrations of minerals can be supplied to broilers in an organic form without losses in animal growth performance and with lower concentrations being excreted in manure.

Feeding studies conducted in Canada demonstrated that chelated trace minerals are at least 30% more bioavailable than inorganic trace mineral salts when fed to broilers [4]. Similar studies have been conducted in pigs, in which improvements in growth have been observed in herds receiving organic forms of Cu [11]. It is thought that organic minerals that are chelated to small peptides have much greater bioavailability through increased selective transport of peptides at gut level [12]. However, it has yet to be conclusively proven that mineral chelates are better absorbed in the monogastric enterocyte. The higher availability of chelates may be linked to the shielding of the minerals positive charge during chelation. This allows the mineral to withstand the binding activity of the negatively charged mucin layer and results in lower competition between minerals of similar charge in their resorption from the gut and transfer to the enterocyte [13]. These 2 parameters, combined with lower complex formation in the intestinal lumen with compounds such as phytate, may contribute to the higher absorption of minerals from the gut.

Feeding trials in mammalian species have shown that organic minerals have higher relative bioavailabilities than inorganic oxides and sulfates. Chelated Fe has a bioavailability of 1.3 to 1.85 times the bioavailability of their inorganic forms in pigs, whereas the organic Mn bioavailability is 1.2 times the bioavailability of its sulfate in broilers, and chelated Zn increased broiler tibia mineral levels by 35% more than inorganic sulfate [14].

Table 4. Analyzed Mn, Zn, Fe, and Cu of fecal samples taken on d 26 (DM basis; n = 6 per treatment)

Diet	Mn (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)
Inorganic mineral diet	380[b]	277[b]	707[b]	48[b]
Organic mineral diet	177[a]	176[a]	520[a]	27[a]
SE	10.8	19.4	33.6	1.4

[a,b]Values with no common superscript in a column differ significantly ($P < 0.05$).

CONCLUSIONS AND APPLICATIONS

1. Organic minerals can be included at much lower levels in the diet than the current recommendations for inorganic minerals, without any negative affect on broiler performance.
2. Feeding organic minerals replacing inorganic sources may have benefits in FCR in young broilers.
3. Using lower levels of organic minerals in broiler chicken diets results in significantly lower concentrations of minerals in manure, compared with birds fed conventional feeds formulated with inorganic minerals.
4. Broiler producers and nutritionists in countries and regions with ground water pollution due to excess mineral levels can utilize organic minerals in poultry diets to reduce the risk of contamination from manure without compromising animal performance.

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