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Effects of zinc glycine chelate on growth performance, carcass characteristics, bone quality, and mineral content in bone of broiler chicken

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ABSTRACT

A total of 250 one-day-old male broilers (Ross 308) were used to investigate the effects of dietary Zn-Gly (zinc glycine chelate) supplementation on growth performance, carcass characteristics, bone quality, and mineral content in bones. All broilers were randomly assigned to five treatment groups, each of which was replicated five times (10 birds in each cage). 5 groups were formed: control negative – CN (corn-wheat and soybean meal control diet with no supplementation of Zn), control positive – CP (CN+100 mg of Zn as oxide/kg of diet), and 3 groups with Zn-Gly supplementation at three doses: 25, 50, or 100 mg kg^{-1} (CN +25, 50, or 100 mg of Zn as glycine chelate/kg of diet). The experimental diets were fed to chicks for over 6 weeks. In the study, a positive trend to gain body weight and the weight of breast, thigh, and drumstick muscles was observed when organic Zn was introduced, in particular at a dose of 50 and 25 mg. The addition of Zn, regardless of its source, had an effect on the increase ($P < 0.05$) in the intake of feed. A considerable increase in values such as cross-sectional area (A), second moment of inertia (Ix), and mean relative wall thickness (MRWT) was found both in the femur and in the tibia in the group supplemented with 50 mg Zn-Gly. The use of Zn-Gly improved the quality of the tibia and femur and their strength parameters, perhaps due to the increased deposition of Ca and P in bones. The addition of Zn-Gly increased ($P < 0.05$) the accumulation of Zn in bones. In conclusion, these results suggest that the supplementation of Zn-Gly in amounts lower than recommended has no negative effect on the production performance of Ross broiler chickens, which in turn suggests that such an amount of Zn is sufficient to ensure the optimum body weight and positive production performance and is the condition of correct ossification and mineralisation of the bone tissue.

1. Introduction

The strength of poultry bones is affected by many factors having both a direct and indirect effect, nutrition being one of the most significant ones. Few studies dealing with biochemical changes in bones resulting from Zn deficiency suggest that this element is necessary to ensure the correct course of ossification and mineralisation of the bone tissue (Salim et al., 2008). Incorrect bone development is one of the basic symptoms of Zn deficiency in the birds' diet (El-Husseiny et al., 2012). Zn ions occur in the active centres of many enzymes such as alkaline phosphatase (a significant role in formation of "nuclei" of crystallization in the form of Zn phosphate) or carbonic anhydrase (necessary to ensure the resorptive activity of osteoclasts); thus, Zn is highly important to ensure correct ossification and mineralisation of the bone tissue (Scrimgeour et al., 2007). Depending on the dose, Zn affects bone metabolism and simulates bone-forming processes: it stimulates the synthesis of DNA in osteoblasts and increases bone weight and the concentration of Ca ions (Ma and Yamaguchi, 2000). Both the excess and deficiency of Zn can cause a gradual decrease in the body weight, bone weight, and bone thickness, and can give rise to bone deformation, low mineralisation, and reduced content of calcium ions in bones and blood plasma (Rath et al., 2000). According to Wang et al. (2002), Zn deficiency (10 mg kg^{-1}) in young birds has a negative effect on the formation of the skeleton. On the other hand, introducing 100 mg kg^{-1} into chicken feed significantly increased bone strength and decreased the likelihood of locomotor disorders (Štofanikova et al., 2011).

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Fast growing broiler chickens have different requirements regarding mineral components and the composition of the feed mixture, depending on the species, age, and productivity of poultry (Sesztáková et al., 2010). Available literature provides various data concerning the optimum content of Zn in poultry feed. According to NRC (1994), the requirement of Zn corresponds to 40 mg kg^{-1} of the diet. Underwood and Suttle (1999) consider 40–70 mg Zn/kg feed as the optimum Zn dose for broilers, whereas Ross 308 producers give 100 mg kg^{-1} Zn (Aviagen, 2013).

Traditionally, feed mixtures are supplemented with inorganic Zn (ZnO, $ZnSO_4$) to ensure correct growth, health, and reproduction. However, intensive genetic selection leading to increasingly higher muscle weight of chickens gives rise to a question whether the current doses and sources of Zn will be adequate in the future to cover the needs of the birds (Nollet et al., 2008). The assimilability of respective microelements varies depending on the combination with organic or inorganic carriers used. The increased assimilability of microelements from organic forms is an effect of the process of absorption, i.e. they penetrate through the intestinal barrier more easily and are more effectively used by the body (Huang et al., 2009). Some authors (El-Husseiny et al., 2012; Sahraei et al., 2012; Salim et al., 2012) claim that Zn administered in an organic form is more effective than inorganic Zn. However, the results of different studies are not uniform (Osman et al., 2010).

The present studies address a current issue, both on a national and international scale, i.e. improvement of the availability of minerals in the diet for chicks, which is also connected with the reduced secretion of minerals. The results of previous studies carried out by our team (Kwiecień et al., 2014, 2015a, 2015b; Winiarska-Mieczan and Kwiecień, 2015) indicate that the use of glycine-based forms of Cu and Fe does not deteriorate the production results or physiochemical, strength, and morphometric properties of thigh bones in chickens, which can suggest that microelements administered as glycine chelates assimilate better compared to their inorganic forms, even at amounts smaller than the recommended dose. Therefore, it was necessary to check whether Zn used as a glycine chelate (Zn-Gly) at the recommended or lower than the recommended level will have no negative effect on general development of broiler chickens, including the skeleton. The primary objective of this study, therefore, was to evaluate the broiler growth, carcass characteristics, bone quality, and mineral content in bone upon supplementation of diets with various doses of Zn-Gly.

Table 1
Ingredient and nutrient composition (*as*-fed basis) of the basal diet.

Ingredients (%)	1–21 days (starter)	22–35 days (grower)	36–42 days (finisher)
Maize	24.44	40.00	40.00
Wheat	42.99	27.84	28.84
Soybean meal (46% protein)	25.00	24.97	22.87
Soybean oil	2.50	36.9	3.98
Monocalcium phosphate	0.90	0.90	0.81
Limestone	1.40	1.13	1.09
Sodium bicarbonate	0.08	0.08	0.08
NaCl	0.29	0.25	0.26
Vitamin–mineral premix[a]	0.50[b]	0.50[c]	0.50[d]
Fat-protein concentrate	1.00	–	1.00
DL-methionine 99%	0.30	0.23	0.23
L-lysine HCl	0.42	0.28	0.27
L-threonine 99%	0.18	0.13	0.07
Values calculated			
Metabolizable energy (MJ kg^{-1})[e]	12.7	13.1	13.2
Available P, %	0.42	0.41	0.39
Total Ca/available P	2.12	1.90	1.92
Values analysed			
Crude protein, %	20.2	18.2	18.1
Crude fibre, %	3.06	2.99	2.99
Ether-extract, %	4.66	6.08	6.43
Lysine, %	1.29	1.13	1.09
Methionine+cysteine, %	0.93	0.83	0.81
Total Ca, %	0.88	0.78	0.75
Total P, %	0.66	0.65	0.63
Fe, mg	40.12	39.82	39.78
Cu, mg	14.51	14.73	13.60

[a] The premix (without Zn – CN) was added Zn as ZnO (100 mg ZnO) in an amount of 100 mg kg^{-1}, and Zn-Gly in an amount of 25, 50 or 100 mg kg^{-1}.

[b] Composition of the premix per kg of starter diet: Mn 100 mg, J 1 mg, Fe 40 mg, Cu 16 mg, Se 0.15 mg, vit. A 15,000 UI, vit. D_3 5000 UI, vit. E 75 mg, vit. K_3 4 mg, vit. B_1 3 mg, vit. B_2 8 mg, vit. B_6 5 mg, vit. B_{12} 0.016 mg, biotin 0.2 mg, folic acid 2 mg, nicotic acid 60 mg, pantothenic acid 18 mg, choline 1800 mg.

[c] Composition of the premix per kg of grower diet: Mn 100 mg, J 1 mg, Fe 40 mg, Cu 16 mg, Se 0.15 mg, vit. A 12,000 UI, vit. D3 5000 UI, vit. E 50 mg, vit. K3 3 mg, vit. B1 2 mg, vit. B2 6 mg, vit. B6 4 mg, vit. B12 0.016 μg, biotin 0.2 mg, folic acid 1.75 mg, nicotic acid 60 mg, pantothenic acid 18 mg, choline 1600 mg.

[d] Composition of the premix per kg of finisher diet: Mn 100 mg, J 1 mg, Fe 40 mg, Cu 16 mg, Se 0.15 mg, vit. A 12,000 UI, vit. D3 5000 UI, vit. E 50 mg, vit. K3 2 mg, vit. B1 2 mg, vit. B2 5 mg, vit. B6 3 mg, vit. B12 0.011 μg, biotin 0.05 mg, folic acid 1.5 mg, nicotic acid 35 mg, pantothenic acid 18 mg, choline 1 600 mg.

[e] Calculated according to European Table (Janssen, 1989) as a sum of the metabolizable energy content of components.

2. Materials and methods

2.1. Experimental design, birds, and diets

All procedures used throughout the study were approved by the Local Animal Welfare Committee at the University of Life Sciences in Lublin, Poland (Resolution No. 37/2011 of 17 May 2011). A total of 250 1-day-old Ross 308 male broiler chicks with an average initial weight of 47.8 g $\pm$ 0.62 (SD) were used. The experiment was conducted over 42 days. The broilers were weighed and randomly placed in 25 battery cages (1 m $\times$ 1 m) with 10 broilers per cage, giving 5 replicate cages per dietary treatment. All the cages were kept in the same room and electric lighting was used throughout the rearing period (24 h/day). During the first week of the experiment, the chickens were kept at 33 °C. The temperature was reduced by 2–3 °C every week until the final temperature of 22–24 °C was reached.

A 3-stage feeding program was used: starter from 1 to 21 days, grower from 22 to 35 days, and finisher from 36 to 42 days. The starter, grower, and finisher diets were prepared based on cereal meals (corn and wheat) and soybean meal. The nutrient content of the basal diet was calculated on the basis of the chemical composition of raw feedstuffs, and the metabolizable energy value was in line with equations from the European Tables (Janssen, 1989). The composition and nutritional value of the basal diets are presented in Table 1. Next, the basal diet was differentiated as an experimental diet with addition of Zn in the form of oxide (ZnO) and glycine chelate Zn (Zn-Gly). 5 groups were formed: control negative - CN (corn-wheat and soybean meal control diet with no supplementation of Zn), control positive – CP (CN+100 mg of Zn as oxide/kg of diet), and three CN groups supplemented with Zn in the form of Zn-Gly at three doses: 25, 50, or 100 mg $\cdot$ kg^{-1} (CN +25, 50, or 100 mg of Zn as glycine chelate/kg of diet). The concentration of Zn in water provided to chicks during the experiment was 0.299 mg l^{-1}. The analysed content of Zn in the experimental diets is presented in Table 2. In the experiment, *GLYSTAR FORTE* chelate, supplied by ARKOP Sp. z. o.o., containing 16% Zn and 36% glycine and ZnO with 78% Zn was used. The chickens' requirement for minerals in the diets was based on the nutrition recommendations for Ross 308 broiler chickens, i.e. 100 mg kg^{-1} Zn (Aviagen, 2013). From 1 to 42 days of age, all the chickens were