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EFFECT OF VARIOUS FORMS OF ZINC APPLIED IN CONCENTRATE MIXTURES FOR BROILER CHICKENS ON ITS BIOAVAILABILITY AS WELL AS MEAT COMPOSITION AND QUALITY

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This study focused on evaluation of bioavailability of zinc for broiler chickens from the inorganic (ZnO) and organic (Zn-glycine) forms of chemical bounds of this element. The Zn-glycine applied in mixtures contributed to the decrease of body weight and mortality of chickens, whereas feed conversion rate was similar in either group. On the other hand, in the chickens receiving Zn-glycine from feed, a higher proportion of breast and leg muscles as well as thick flanks in the carcass with their increased dressing percentage were observed. A higher fat content in the breast and leg muscles as well as a higher content of zinc in the breast and leg muscles, liver, kidneys, and the thigh bone were also found.

INTRODUCTION

The variable content of zinc in feeds, particularly in the components of concentrate mixtures for poultry and the fact that zinc bonds with phytic acid inside the intestine environment to form sparingly soluble complexes justify the necessity to maintain proper balance of this element in mixtures [Underwood & Suttle, 1999].

The most commonly used forms of zinc in mineral and vitamin mixtures are inorganic salts, such as oxides, *i.e.* ZnO, sulphates – $ZnSO_4 \times H_2O$, $ZnSO_4 \times 7H_2O$, chlorates– $ZnCl_2 \times H_2O$ and carbonates– $ZnCO_3$. Organic forms of zinc are also permitted to be used and these include amino-acid chelates, bioplexes, proteins as well as lactates and acetates. Scientific Committee for Animal Nutrition, a scientific organ of reference of the European Union dealing with animal feeding, permits the maximum supplementation of zinc in animal feeds up to the level of 250 ppm, however, no more than 80 ppm is allowed to come from the organic bonds [Opinion of the Scientific Committee for Animal Nutrition on the use of Zinc in Feedingstuffs, 2003].

The results of the study on application of organic bonds of zinc in poultry feeding are not clear-cut and some of them are even controversial. The results of the research carried out by Świątkiewicz & Koreleski [2001] and Johnson [1998] indicate a positive influence of these forms of bonds of zinc upon the bioavailability of zinc, productivity and the overall health condition of the animals. A better availability of zinc form the inorganic bonds, on the other hand, was the result of the research carried out by Fairweather-Tait [1992].

The variety of organic bonds of zinc available on the polish feed market justifies the need to determine the bioavailability of zinc from these forms for chickens.

MATERIALS AND METHODS

The research material consisted of 180 unsexed Isa Vedetta breed chickens that were randomly allocated to 2 groups (90 heads per each) with 3 repetitions per group (30 heads per each).

The chickens were kept in boxes on dry sawdust bedding. The poultry house was fitted with a mechanical ventilation system and the air exchange rate was adjusted to the requirements for Isa Vedetta breed chickens. The relative humidity during the experimental rearing ranged from 67 to 77%.

The chickens were fed with the following loose mash: Starter – from day 1 to 21, Grower – from day 21 to 35, Finisher – from day 35 to 42 of their life (Table 1). The factor differentiating all-mash concentrate mixtures for the chickens in each of the groups were the two zinc compounds applied in the mineral and vitamin mixtures (premixes): zinc oxide (group I – control) and zinc-glycine (group II – experimental).

Before the experiment commenced, all feed mixture components were subjected to chemical analyses in order to determine the content of the primary nutrients and mineral components, i.e. calcium, sodium [AOAC, 2000] and phosphorus [Fick *et al*., 1979] as well as zinc after wet mineralization of the samples using Zeiss AAS-3 spectrometer [AOAC, 2000]. The results of the analyses allowed for the determination of the nutritive value of the concentrate mixtures for the chickens (Table 1).

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TABLE 1. Composition (%) and nutritive value of mixtures.

Item		Starter	Grower	Finisher
Maize	%	24.75	20.0	30.0
Wheat	%	35.0	42.0	38.3
Soybean meal 46%	%	32.0	29.3	23.5
Dicalcium phosphate	%	1.7	1.5	1.2
Salt (NaCl)	%	0.25	0.25	0.25
Soybean oil	%	4.0	4.8	5.0
Limestone	%	1.3	1.15	0.75
Premix*	%	1.0*	1.0*	1.0*
Nutritive value				
Metabolizable energy	kcal x kg^{-1}	3000	3080	3160
Metabolizable energy	MJ x kg^{-1}	12.84	12.88	13.22
Crude protein	%	22.00	19.75	18.45
Crude fibre	%	2.50	2.50	2.50
Lysine	%	1.20	1.17	1.05
Methionine	%	0.54	0.52	0.48
Methionine + Cystine	%	0.92	0.88	0.81
Tryptophan	%	0.25	0.22	0.21
Treonine	%	0.78	0.73	0.65
Total calcium	%	0.87	0.82	0.70
Available phosphorus	%	0.46	0.42	0.35
Total sodium	%	0.16	0.15	0.16
Zinc – Zn	mg x kg-1	79.71	71.03	76.40

*According to the adopted scheme for the experiment, the premixes contained zinc in the form of zinc oxide (gr. I) and Zn-glycine (gr. II).

In the day 21 and 42 of the experiment, the chickens were weighed and the feed intake quantity as well as mortality were recorded. In this way, the birds' body weight and feed conversion rate were measured.

At the end of the experiment, on day 42 of rearing, 12 birds (6 cockerels and 6 hens) were randomly selected for blood sampling, killing and dissection. Ther dressing percentage, gutted carcass mass and the percentage of breast and leg muscles and thick flanks were measured. Samples from breast and leg muscles, livers and kidneys and thigh bones including the joint tissues prepared from the carcass were analysed. The qualitative parameters were expressed in% of the total mass of each carcass.

The following parameters were determined for the breast and leg muscles: dry matter [AOAC 934.01, 2000], crude protein [AOAC 981.10, 2000] and fat according to the applicable Polish Standard [PN–73/A-8211]. After wet mineralization of the samples using nitric acid, the content of zinc was determined in the muscles, liver, kidneys and thigh bones as well as in the serum of the blood of the birds using plasma spectrometer with mass detection using the VARIAN ICP-MS instrument. The breast and leg muscles were subjected to a sensory analysis following PN-ISO 6564:1999 using the multiple comparison method using a 5 grade scale to evaluate the following properties: colour, taste, smell, tenderness and juiciness.

All data obtained in the course of the experiment were statistically analysed using the t-student test and a single-factor analysis of variation and the relevance of the differences was estimated applying the Duncan's multiple range test in STATISTICA 6.0 program.

RESULTS AND DISCUSSION

The results related to broiler chicken performance are presented in Table 2.

The body weight of the chickens receiving zinc oxide form a mineral and vitamin mixture (group I) on day 21 of their life was lower by approximately 2% compared to the chickens that received zinc-glycine (group II). On day 42 the birds that received zinc oxide from a mineral and vitamin mixture (group I) had a higher ($p\leq0.05$) body weight. Feed conversion rate on day 21 and 42 in either group under comparison was similar and corresponded to the birds' body weight. Lower mortality was observed in the group of chickens that received Zn-glycine from all-mash than in the birds from the control group (Table 2).

Pimentel *et al.* [1991] in their experiment consisting in supplementation of broiler chickens feed with zinc-methionine and zinc oxide in various amounts discovered that the birds' body weight did not depend of the zinc form used, but on the quantity of this element in the feed. Świątkiewicz *et al.* [2001] in their experiment consisting in supplementation of various quantities of zinc to broiler chickens (10, 20 and 40 mg x kg^{-1} of mixture) in the form of organic bonds (Zn complex with amino-acids – ZnAA) found that the body weight was slightly higher while the feed conversion rate was lower in comparison with the group of birds that were given zinc sulphate in the mixture. An experiment carried out by Ferket & Qureshi [1992], in which broiler turkeys were given Zn-methionine and Mn-methonine with the feed achieved a more efficient feed conversion ($p\leq0.05$) and a lower death rate compared to the group of birds that were given feed containing zinc sulphate or zinc oxide. A higher body weight and a lower feed conversion rate were a result of an experiment by Johnson [1998] in which the chickens were given mineral and vitamin mixtures containing organic forms of zinc, namely zinc-methionine, a zinc and methionine and lysine complex and the ZnAA amino-acid

TABLE 2. Production yield of broiler chickens...

Item		Feeding groups	
		I zinc oxide	II Zn-glycine
Body weight (g)			
21 day of life	$\bar{x}\pm$sd	726±59.8	740±46.2
	(%)	100	+1.93
in 42 day of life	$\bar{x}\pm$sd	2456a±236.8	2378b±189.9
	(%)	100	-3.18
Feed conversion (kg kg BW^{-1})			
1-21	$\bar{x}\pm$sd	1.34±0.15	1.36±0.12
	(%)	100	+1.49
22-42	$\bar{x}\pm$sd	1.98±0.19	1.94±0.22
	(%)	100	-2.02
Mortality	(%)	7.78	4.44

a, b – significant differences at $p\leq0.05$

complex. Lower mortality was observed among the chickens, particularly in the group receiving the amino-acid zinc complex. This is also confirmed in the results of the researcher's study (Table 2). Kidd *et al.* [1992] on the other hand proved that the survivability of hens from the parent flock of hen broilers fed with feed containing Zn-methionine and zinc oxide was similar and did not depend on the form of the chemical bond of this microelement in the feed.

The results of the post-slaughter analysis of the birds are presented in Table 3.

Prior to killing, the body weight of the chickens from the group receiving Zn-glycine from the concentrate mixture was by 3.17% lower compared to the birds from the control group (ZnO). The gutted carcass mass was slightly higher in the birds receiving Zn-glycine in the feed (Table 3).

The use of an organic form of zinc, *i.e.* Zn-glycine in the all-mash concentrate mixture resulted in a 4.15% increase of the dressing percentage of the birds compared to the dressing percentage of the chickens from the group that received zinc oxide from the mixture (Table 3). In comparison with the birds fed with a mixture containing zinc oxide, the birds receiving an amino-acid chelate of zinc, *i.e.* Zn-glycine, displayed a higher share of breast and leg muscles as well as thick flanks in the gutted carcass by 4.02, 3.79 and 8.59% respectively. Bonomi *et al.* [1993a, b] in their experiment consisting in supplementing broiler chickens and turkey broiler with amino-acid chelates of Zn, Cu, Mn and Fe noted a higher by 2.0 and 2.61% respectively dressing percentage of the carcass and a higher by 2.7 and 5.69% respectively percentage of meat compared to the group of birds receiving inorganic forms of these microelements. Johnson [1998] in an experiment in which broiler chickens were given organic forms of chemical bonds of zinc, *i.e.* Zn-methionine, Zn-methionine, Zn-lysine complex and an amino-acid zinc complex proved the positive influence of these forms of bonds of zinc upon the percentage of breast muscles in the carcass.

The results related to the chemical composition of breast and leg muscles of broiler chickens are presented in Table 4.

TABLE 3. Result of post-slaughter analysis.

Item		Feeding groups	
		I zinc oxide	II Zn-glycine
Body weight prior to killing (g)	$\overline{x}\pm$sd	2490±222.3	2411±187.7
	(%)	100	-3.17
Gutted carcass mass (g)	$\overline{x}\pm$sd	1875±231.8	1900±202.8
	(%)	100	+1.33
Dressing percentage (%)	$\overline{x}\pm$sd	75.43±8.30	78.56±6.07
	(%)	100	+4.15
Share of muscles (%)			
breast	$\overline{x}\pm$sd	21.37±2.14	22.23±2.06
	(%)	100	+4.02
leg	$\overline{x}\pm$sd	32.48±4.93	33.71±4.70
	(%)	100	+3.79
Share of thick flanks (%)	$\overline{x}\pm$sd	10.25a±0.74	11.13b±0.71
	(%)	100	+8.59

a, b – significantly differences at p≤0.05

TABLE 4. Chemical composition of muscles (%).

Item		Feeding groups	
		I zinc oxide	II Zn-glycine
Breast muscles			
Dry matter	$\overline{x}\pm$sd	29.77±0.21	30.07±0.82
	(%)	100	+1.01
Crude protein	$\overline{x}\pm$sd	23.02±0.14	22.38±0.97
	(%)	100	-2.78
Crude fat	$\overline{x}\pm$sd	2.68a±0.22	3.04b±0.51
	(%)	100	+13.43
Leg muscles			
Dry matter	$\overline{x}\pm$sd	28.90±0.50	29.72±2.85
	(%)	100	+2.84
Crude protein	$\overline{x}\pm$sd	18.60±0.36	18.76±1.41
	(%)	100	+0.86
Crude fat	$\overline{x}\pm$sd	6.50a±0.17	7.81b±1.50
	(%)	100	+20.15

a, b – significantly differences at p≤0.05

The amino-acid chelate of zinc with glycine added to all-mash for broiler chickens contributed to an increase of the content of fat by 13.43% (p≤0.05) and dry matter by 1.01% in the breast muscles, while the protein content decreased by 2.78%. The fat content in the leg muscles of the birds from this group was higher (p≤0.05) than in the birds from the group fed with concentrate mixture containing zinc oxide. A slightly higher content of dry matter and protein was also found in this type of muscles.

Table 5 provides the results related to zinc content in selected soft tissues, thigh bone and in blood serum of the chickens.

TABLE 5. Zinc content in selected soft tissues, thigh bone (mg x kg of fresh tissue^{-1}) and in blood serum (μmol/L) of broiler chickens.

Item		Feeding groups	
		I zinc oxide	II Zn-glycine
Breast muscles	$\overline{x}\pm$sd	19.06A±1.01	21.14B±1.34
	(%)	100	+10.91
Leg muscles	$\overline{x}\pm$sd	14.42A±0.77	15.80B±1.12
	(%)	100	+9.57
Liver	$\overline{x}\pm$sd	25.71a±2.54	29.37b±2.87
	(%)	100	+14.24
Kidneys	$\overline{x}\pm$sd	19.47±1.90	19.85±1.42
	(%)	100	+1.95
Thigh bone	$\overline{x}\pm$sd	154.2a±31.75	176.0b±37.52
	(%)	100	+14.14
Blood serum	$\overline{x}\pm$sd	2.46±0.26	2.09±0.33
	(%)	100	-15.04

a, b – significantly differences at p≤0.05; A, B– highly significantly differences at p≤0.01

A significantly higher content of zinc ($p \leq 0.01$) in the breast and leg muscles, 21.14 and 15.8 mg Zn/kg of fresh tissue respectively, was found in the birds fed with all-mash containing zinc in the form of amino-acid chelate, *i.e.* Zn with glycine (group II), while in with the group of chickens receiving zinc oxide (group I) these figures were as follows: 19.06 and 14.4 mg Zn/kg of fresh tissue. The content of zinc in the liver was higher ($p \leq 0.05$) in the chickens receiving Zn-glycine from the feed, whereas the content of this element in the kidneys of the chickens from either group was similar (Table 5). In the chickens that were given Zn-glycine in the mixture the content of zinc in the thigh bone was significantly higher ($p \leq 0.05$), while the level of this element in the blood serum was slightly lower (Table 5).

The higher content of zinc in the breast and leg muscles, liver, and the thigh bone of the chickens receiving Zn-glycine from the mineral-vitamin mixture proves a better bioavailability of this microelement from the organic forms of bonds than from its inorganic forms. According to some authors [Baker *et al.*, 1995] and the Opinion of the Scientific Commitette for Animal Nutrition on the Use of Zinc of Feeding Stuffs [2003], a clear indication of biological availability of zinc are: the content of this element in the liver, melethionine activity, accumulation of zinc in the bones and the level of zinc in blood serum as the method of estimation of availability of this element in live animals.

Johnson [1998] in an experiment on broiler chickens proved that feeding premixes containing organic forms of chemical bonds of zinc, *i.e*. Zn-methionine and an amino-acid zinc complex resulted in an increase of the content of zinc in the bones and blood serum by 21.2, 28.9%, 24.4 and 27.6% respectively compared to the content of this element in the tissues of the birds receiving zinc sulphate from the premix. Pimentel *et al.* [1991] in an experiment consisting in feeding broiler chickens with feed containing zinc-methionine and zinc oxide proved that the content of this microelement in the bones, liver and pancreas does not depend on the form of chemical bonds of zinc, but rather on the level of this element in the diet.

The results of sensory evaluation of the meat form the breast and leg muscles of broiler chickens are presented in Table 6.

Although the organic and inorganic forms of chemical bonds of zinc present in the mineral and vitamin mixtures did not actually influence the overall results of the sensory evaluation of meat from the breast muscles of broiler chickens, the meat from the breast muscles of the chickens fed with a concentrate mixture containing zinc-glycine had a slightly better colour, taste and smell, although it was at the same time less juicy and tender than the meat of the birds from the group receiving zinc oxide from the feed. The overall results of the sensory evaluations of the meat from the leg muscles were, on the other hand, slightly lower, as were the remaining parameters and its tenderness was significantly lower ($p \leq 0.05$) than the parameters of the meat from the leg muscles of the chickens fed with feed containing zinc oxide (Table 6).

In the available literature there is no data concerning the influence of the quantity and form of zinc in the diet of farm stock, including broiler chickens, upon the results of the sensory evaluation of meat.

TABLE 6. Results of sensory evaluation of chicken meat (pts).

Item	Feeding groups	
	I zinc oxide	II Zn-glycine
Breast muscles		
Colour	4.29 ±0.51	4.43 ±0.51
Taste	4.14 ±0.60	4.21 ±0.61
Flavour	4.32 ±0.58	4.43 ±0.43
Tenderness	4.36 ±0.46	4.18 ±0.58
Juiciness	4.25 ±0.61	4.00 ±0.62
Total note	4.21 ±0.64	4.21 ±0.47
Leg muscles		
Colour	4.07 ±0.73	4.04 ±0.63
Taste	4.32 ±0.58	4.14 ±0.69
Flavour	4.29 ±0.73	4.21 ±0.70
Tenderness	4.57a ±0.39	4.21b ±0.47
Juiciness	4.54 ±0.41	4.22 ±0.47
Total note	4.39 ±0.59	4.25 ±0.51

a, b – significantly differences at $p \leq 0.05$

CONCLUSIONS

The results of the biological evaluation of the use of inorganic (ZnO) as well as organic (Zn-glycine) forms of zinc in chicken feeding allow for the formulation of the following conclusions as regards the group of broiler chickens receiving Zn-glycine from feed:

• drop of body weight and feed conversion rate were at similar levels;

• lower mortality;

• increased percentage of breast and leg muscles and thick flanks in the carcass and a higher dressing percentage at the same time;

• increased content of fat in the breast and leg muscles;

• increased content of zinc in the breast and leg muscle, liver, kidneys and the thigh bone.

As far as chickens are concerned, better bioavailability of zinc from Zn-glycine contributes to a reduction in environmental emission of this element. Products of animal origin with an increased content of zinc are decent sources of this element in human diet.

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WPŁYW STOSOWANIA RÓŻNYCH ZWIĄZKÓW CYNKU W MIESZANKACH DLA KURCZĄT RZEŹNYCH NA JEGO BIODOSTĘPNOŚĆ ORAZ SKŁAD CHEMICZNYCH I JAKOŚĆ MIĘSA

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W badaniach na kurczętach rzeźnych oceniono biodostępność cynku z nieorganicznych (ZnO) i organicznych (Zn-glicyny) form połączeń tego pierwiastka. Zastosowana w mieszankach Zn-glicyna obniżyła masę ciała i śmiertelność kurcząt, a zużycie paszy na 1kg przyrostu masy ciała było podobne w obu grupach. Zwiększył się natomiast udział mięśni piersiowych, udowych i skrzydeł w tuszce, a tym samym wydajność rzeźna kurcząt, którym w paszy podawano Zn-glicynę. Odnotowano również wzrost zawartości tłuszczu w mięśniach piersiowych i udowych oraz wyższą zawartość cynku w mięśniu piersiowym i udowym, wątrobie, nerkach, a także kości udowej.