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Zinc as a feed supplement and its impact on plasma cholesterol concentrations in breeding cocks

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Abstract

The aim of this work was to verify the impact of feed supplemented with selected inorganic and organic zinc compounds on the total cholesterol concentrations and other blood plasma indices in breeding cocks. A total of 250 RIR 05 breeding cocks, 9 weeks old, were used. The cocks were divided into 5 groups of 50 animals each (four experimental groups and one control group). Cocks were fed a commercial feed mixture specifically for breeding cocks, containing 30.4 mg·kg^{-1} of zinc. The feed for experimental groups of cocks was fortified to 100 mg Zn·kg^{-1}: zinc sulphate in first group, zinc oxide in second group, fodder yeast (Minvital Zn) in third group and Bioplex Zn in fourth group. Blood samples for biochemical examination were taken from the basilic vein. The contents of total cholesterol (Chol), total proteins (TP), glucose (Glu), aspartate aminotransferase (AST), alanine aminotransferase (ALT), calcium (Ca), phosphorus (P) and magnesium (Mg) in blood plasma were spectrophotometrically measured using a biochemical analyser, Cobas EMira, and commercial kits (Biovendor a.s., Czech Republic). In the 15th week of age, third and fourth groups showed a significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$) decrease of total cholesterol in blood plasma compared to the control. In the 20th and 25th week of age, all of the experimental groups showed a significantand highly significant ($P \leq 0.01$) decrease of total cholesterol in blood plasma compared to the control. Other monitored indices (total proteins, glucoses, aspartate aminotransferase, alanine aminotransferase, calcium, phosphorus and magnesium) did not reveal any significant changes between the experimental and the control groups. The presented work provides the first available experimental evidence regarding the impact of zinc supplementation on the cholesterol levels in blood plasma of breeding cocks.

Supplementation, biochemical indices, zinc oxide, zinc sulphate, organic zinc forms

Zinc is one of the trace elements necessary for the healthy development and functioning of living organisms. However, in tissue, its concentrations are not high. It is stated that the adult human body contains only 2–3 grams of zinc (Folin et al. 1994), with 90% of it deposited in muscle tissue and bones. The other 10% can be found in the prostate, liver, digestive tract, kidneys, skin, lungs, brain, heart and pancreas (Lichten and Cousins 2009). On the cellular level, 30–40% of the zinc is located in the nucleus, 50% in cytosol, and the rest in the membrane (Vallee and Valchuj 1993). Zinc is necessary for the proper functioning of many enzymatic systems, and the insulin system is probably the most important one. It also plays a significant role in various peptidases, esterases and dehydrogenases. It influences the immune system, DNA synthesis, cell proliferation, protein synthesis and the incorporation of iron into the haemoglobin. A deficiency of zinc can cause abnormal mental and physical growth in children. A zinc deficiency in adults can lead to weight loss, slower healing of wounds and memory deterioration (Wuehler et al. 2005). The recommended daily intake for pregnant women in the Czech Republic is 14 mg

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(Hronek 2004). For men, the U.S. Food and Drug Administration (FDA) recommends a daily intake of 15 mg.

The European Commission issued Regulation No. 1334/2003, which limits the maximum tolerable zinc levels in feed mixtures for livestock at 150 $mg \cdot kg^{-1}$, and in animal breeding at 250 $mg \cdot kg^{-1}$. Many authors have demonstrated the impact of zinc supplementation within several indices of the internal environment in birds (Kucuk et al. 2003; Sahin et al. 2005), mammals and humans (Gatto and Samman 1995; Hughes and Samman 2006). Its significance has also been stated in relation to various metabolic disorders as well as several diseases, such as Ischemic Heart Disease (IHD), dyslipidemia, hypertension, diabetes mellitus and obesity (Truswel 2003).

The aim of this work was to verify the impact of feed supplemented with selected inorganic and organic zinc compounds on total cholesterol levels and other blood plasma indices in breeding cocks.

Materials and Methods

A total of 250 RIR 05 breeding cocks, aged 9 weeks were selected for the experiment. The cocks were analogically divided (according to their live weight) into 5 groups (four experimental groups P1-P4 and one control group C) of 50 animals each, and were located in the experimental stable of the Department of Nutrition, Zootechnics and Zoohygiene, Faculty of Veterinary Hygiene and Ecology, University of Veterinary and Pharmaceutical Sciences Brno. The temperature in the experimental stable was 15–18 °C and the lighting schedule was as follows: 10^{th} to 19^{th} week, 8 h of light; 9 h in the 20^{th} week, 10 h in the 22^{nd} week and each following week 0.5 h of light was added until the 25^{th} week. Cocks were fed a commercial feed mixture specifically for cock breeding (supplier ZZN Pelhřimov, Czech Republic), containing 30.4 $mg \cdot kg^{-1}$ of zinc (Zn – C). The feed was fortified to 100 mg $Zn \cdot kg^{-1}$ for the experimental groups: zinc sulphate ($ZnSO_4$; Sigma-Aldrich., Czech Republic) for group P1, zinc oxide (ZnO, Sigma-Aldrich) for group P2, fodder yeast Minvital Zn (Vitex, Biocel Paskov a.s., Czech Republic) for group P3 and Bioplex Zn (Alltech, USA) for group P4. The nutritional content of the feed mixture was verified analytically, and contained the following nutrients: ME_N 11.6 $MJ \cdot kg^{-1}$, crude protein 145.8 $g \cdot kg^{-1}$, threonine 4.8 $g \cdot kg^{-1}$, methionine 2.7 $g \cdot kg^{-1}$, lysine 6.6 g $g \cdot kg^{-1}$ and arginine 9.9 $g \cdot kg^{-1}$, fat 38.3 $g \cdot kg^{-1}$, fibre 58.9 $g \cdot kg^{-1}$, starch 435.6 $g \cdot kg^{-1}$, ash 105.6 $g \cdot kg^{-1}$, phosphorus 6.2 $g \cdot kg^{-1}$ and magnesium 5.28 $g \cdot kg^{-1}$, sodium 1.5 $g \cdot kg^{-1}$.

In the 10^{th}, 15^{th}, 20^{th} and 25^{th} week of the experiment, 10 cocks from each group were randomly selected. Blood samples for biochemical examination were taken from the basilic vein. The concentrations of total cholesterol (Chol), total proteins (TP), glucose (Glu), aspartate aminotransferase (AST), alanine aminotransferase (ALT), calcium (Ca), phosphorus (P) and magnesium (Mg) in blood plasma were spectrophotometrically measured using a biochemical analyser, Cobas EMira, and commercial kits (Biovendor a.s., Czech Republic).

The results were processed using statistical software Unistat 5.1.; ANOVA was used to evaluate the data. Differences between the experimental and control groups at a significance level of $P \leq 0.05$ were considered significant, and $P \leq 0.01$ as highly significant.

Results

The experimental groups at 10 weeks age of breeding cocks did not reveal any significant changes in total cholesterol and other blood plasma indices when compared to the control group (Table 1).

At 15 weeks old the groups which were given the organic zinc forms P3 (Minvital) and P4 (Bioplex), showed a significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$) decrease of total cholesterol in their blood plasma compared to control group. Other blood plasma indices in the experimental groups did not reveal any significant changes compared to the control group (Table 1).

In the 20^{th} and 25^{th} week of age, cocks of all experimental groups showed a highly significant ($P \leq 0.01$) decrease of total cholesterol concentrations in the blood plasma compared to control group, regardless of the zinc form that had been supplemented. Other indices monitored in the experimental groups did not reveal any significant changes compared to the control group (Table 1).

Table 1. Biochemical indices of the blood plasma of cocks 10–25 weeks old (mean ± SD)

	Biochemical indices							
	Chol (mmol·l^{-1})	TP (g·l^{-1})	Glu (mmol·l^{-1})	AST (µkat·l^{-1})	ALT (µkat·l^{-1})	Ca (mmol·l^{-1})	P (mmol·l^{-1})	Mg (mmol·l^{-1})
10th week								
C	3.19	31.48	14.92	0.80	0.019	2.62	2.03	0.78
	± 0.884	± 3.098	± 1.213	± 0.041	± 0.005	± 0.189	± 0.174	± 0.054
P1	2.79	31.41	14.89	0.84	0.027	2.72	1.99	0.80
	± 0.523	± 4.712	± 0.992	± 0.047	± 0.014	± 0.226	± 0.113	± 0.052
P2	2.99	32.25	14.34	0.85	0.025	2.62	1.99	0.77
	± 0.468	± 4.845	± 0.706	± 0.059	± 0.013	± 0.208	± 0.129	± 0.045
P3	2.65	33.28	15.23	0.82	0.028	2.60	1.97	0.79
	± 0.241	± 5.590	± 1.282	± 0.034	± 0.013	± 0.186	± 0.182	± 0.063
P4	2.72	34.40	15.18	0.87	0.016	2.63	2.00	0.81
	± 0.283	± 4.870	± 0.796	± 0.034	± 0.005	± 0.279	± 0.230	± 0.042
15th week								
C	3.30	30.07	12.27	0.77	0.081	2.62	2.76	0.85
	± 0.467	± 3.504	± 1.165	± 0.074	± 0.016	± 0.122	± 0.550	± 0.053
P1	2.92	31.90	12.67	0.76	0.171	2.57	2.37	0.81
	± 0.377	± 3.191	± 0.721	± 0.041	± 0.288	± 0.193	+ 0.362	± 0.079
P2	2.97	29.96	12.92	0.75	0.088	2.60	2.56	0.86
	± 0.278	± 2.879	± 1.191	± 0.032	± 0.025	± 0.158	± 0.531	± 0.065
P3	2.84 *	29.81	12.00	0.77	0.075	2.57	3.28	0.89
	± 0.362	± 2.690	± 1.235	± 0.039	± 0.021	± 0.122	± 0.888	± 0.054
P4	2.02 **	29.78	12.92	0.77	0.072	2.57	2.44	0.82
	± 0.502	± 2.095	± 0.805	± 0.046	± 0.024	± 0.092	+ 0.440	± 0.069
20th week								
C	3.44	31.07	12.68	0.75	0.091	2.63	1.88	0.90
	± 0.412	± 5.416	± 1.023	± 0.080	± 0.027	± 0.129	± 0.539	± 0.056
P1	2.65 **	30.11	12.98	0.71	0.063	2.70	1.58	0.91
	± 0.429	± 5.427	± 1.228	± 0.086	± 0.043	± 0.137	± 0.263	± 0.062
P2	2.23 **	30.40	13.14	0.70	0.102	2.57	1.62	0.88
	± 0.418	± 1.519	± 0.604	± 0.084	± 0.030	± 0.159	± 0.258	± 0.058
P3	2.14 **	30.17	12.71	0.76	0.102	2.60	1.65	0.92
	± 0.215	± 4.011	± 1.004	± 0.172	± 0.029	± 0.119	± 0.158	± 0.072
P4	2.02 **	33.21	13.07	0.72	0.086	2.82	1.84	0.90
	± 0.138	± 5.204	± 1.002	± 0.073	± 0.013	+ 0.278	± 0.702	± 0.060
25th week								
C	3.25	31.96	13.30	1.10	0.08	2.58	1.66	0.95
	± 0.462	± 7.548	± 1.126	± 0.1405	± 0.029	± 0.162	± 0.544	± 0.081
P1	2.20 **	35.28	12.95	1.05	0.17	2.70	1.29	0.93
	± 0.426	± 3.505	± 0.714	± 0.1085	± 0.202	± 0.122	± 0.360	± 0.033
P2	2.22 **	33.41	12.74	1.09	0.076	2.82	1.42	0.91
	± 0.346	± 4.817	± 1.132	± 0.082	± 0.038	± 0.132	± 0.473	± 0.080
P3	2.17 **	30.11	12.47	0.94	0.138	2.62	1.70	0.95
	± 0.591	± 4.414	± 1.391	± 0.221	± 0.182	± 0.186	± 0.501	± 0.032
P4	2.19 **	32.80	12.94	0.99	0.062	2.75	1.49	0.92
	± 0.392	± 4.833	± 1.617	± 0.141	± 0.033	± 0.133	± 0.270	± 0.054

*$P \leq 0.05$, **$P \leq 0.01$, Chol – cholesterol; TP – total proteins; Glu – glucose; AST – aspartate aminotransferase; ALT – alanine aminotransferase; Ca – calcium, P – phosphorus; Mg – magnesium

C1 – control group, P1 - zinc sulphate ($ZnSO_4$), P2 - zinc oxide (ZnO), P3 - Minvital Zn, P4 - Bioplex Zn.

Discussion

A great part of published works dealing with the influence of zinc on the internal environment and the biochemical indices of blood and health disorders has its origin in the area of human medicine. A placebo-controlled, double-blind randomized trial, which included 3,640 humans, was performed. It revealed that concentrations of plasma cholesterol are influenced by zinc (ZnO) supplementation (80 mg.day^{-1}), either alone or in combination with copper or vitamins (Gensler et al. 2002). The decrease of cholesterol levels in blood plasma was also achieved in older populations, where zinc intake or serum zinc concentrations are lower than recommended, and they were provided zinc supplements in the amount of 20–53 mg·day^{-1} (Boukaiba et al. 1993).

The above results are supported by data from many researches in the area of veterinary medicine. The anti-atherogenic effect of zinc in hypercholesterolemic rabbits was reported (Ren et al. 2006; Rashtchizadeh et al. 2008). Zinc deficiency caused increased plasma lipid levels and an increased risk of cardiovascular diseases in LDL receptor knock-out mice. Mice with zinc-deficient diets exhibited increased cholesterol and triglycerides levels in blood plasma (Reiterer et al. 2005). Bolkent et al. (2006) proved the protective effect of zinc supplementation on lipid metabolism indices (total lipids, cholesterol, HDL-cholesterol) in laboratory rats with streptozotocin-induced type 1 diabetes.

In our study, a significant decrease in the levels of total cholesterol in the blood plasma of breeding cocks was found in case of feed mixtures supplemented with zinc, to the amount of 100 mg·kg^{-1} in all the used forms of zinc (organic and inorganic). Our results confirmed previous findings, which proved the positive impact of zinc on lipid metabolism indices. Herzig et al. (2009) proved that there was a significant decrease of plasma cholesterol in their experiment involving the administering of high amounts of zinc to chicken broilers. Aksu et al. (2010) also reported the decrease of total and LDL cholesterol, combined with the increase in HDL cholesterol in chickens' blood plasma, when the feed mixtures were supplemented with organic complexes of zinc, copper and manganese. However, Kucuk et al. (2008) did not confirm any significant changes in the concentrations of total cholesterol, triglycerides and glucose when supplementing 30 mg of Zn per 1 kg of a feed mixture.

A significant decrease of the concentrations of total cholesterol in blood plasma of breeding cocks was found in case of supplementing feeding mixtures with zinc to the amount of 100 mg·kg^{-1} in all used forms (organic and inorganic). It confirms the previous findings, which prove the positive impact of zinc on the lipid metabolism indices. The faster onset of the effects of organic zinc forms, after two weeks of administering, is most likely connected with the higher biological availability of elements bound in organic compounds compared to inorganic forms (Cao et al. 2003; Mantovani et al. 2010; Petrovic et al. 2010).

The impact of zinc on other monitored blood plasma indices in breeding cocks was not found in our study; the similar results were obtained by Bonham et al. (2003). The presented work provides the first available experimental evidence regarding the impact of zinc supplementation on the cholesterol concentrations in blood plasma of breeding cocks.

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