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Effects of Zinc Sources and Levels on Zinc Bioavailability, Blood Parameters, and Nutrient Balance of Male Mink (*Neovison vison*)

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ABSTRACT

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The objective of this study was to investigate the effects of different sources and levels of zinc (Zn) on nutrient digestibility, plasma metabolites, and relative Zn bioavailability in male mink. Animals in the control group were fed a basal diet, consisting mainly of corn, soybean oil, meat and bone meal, and fish meal, with no Zn supplementation. Mink in the other 9 treatments were fed the basal diet supplemented with Zn from grade Zn sulfate ($ZnSO_4 \cdot 7H_2O$), Zn glycinate (ZnGly), or Zn pectin oligosaccharides (ZnPOS) chelate at concentrations of either 100, 300, or 900 mg Zn/kg dry matter. The results showed that zinc levels increased the AD of fat linearly ($P < 0.05$). The AD of fat in Zn-900 was higher ($P < 0.05$) than that of the control. Fecal Zn and urinary Zn were affected by dietary Zn addition ($P < 0.01$). Moreover, Zn supplementation increased Zn retention compared with the control group ($P < 0.05$). The N retention in ZnPOS was higher ($P < 0.05$) than that of the control. The effect of Zn level was linear ($P < 0.01$) for N retention. In addition, the activity of alkaline phosphatase was higher in groups supplemented with 900 mg/kg Zn ($P < 0.05$) compared with the control group. There were significant interactions ($P < 0.05$) among Zn sources on the activity of Cu-Zn superoxide dismutase (Cu-ZnSOD). Compared with $ZnSO_4$, relative bioavailability values were 148% and 173% for ZnGly and ZnPOS, respectively, based on Cu-ZnSOD activity. In conclusion, our data show that the relative bioavailability of ZnPOS was greater than that of $ZnSO_4 \cdot 7H_2O$ and ZnGly and Zn supplementation can enhance the Cu-ZnSOD of male mink, and mink can efficiently utilize ZnGly and ZnPOS.

Keywords: zinc pectin oligosaccharides chelate; nutrient digestibility; relative bioavailability

List of abbreviations: ZnPOS = zinc pectin oligosaccharides chelate, ZnGly = zinc glycinate, DM = dry matter, CP = crude protein, EE = ether extract, AD = apparent digestibility, ALP = alkaline phosphatase, ALB = albumin, ALT = alanine transaminase, TP = total protein, GGT = glutamyl transpeptidase, AST = aspartate aminotransferase, GLU = glucose, Cu-ZnSOD = Cu-Zn superoxide dismutase, GSH-Px = glutathione peroxidase

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As an essential component of several enzymes, zinc (Zn) plays important roles in various biological activities in animals (Swinkels et al. 1994). Zn deficiency causes numerous physical and pathological changes such as growth retardation, poor feathering, and decreased immunity to infection of several diseases (Star et al. 2012). For carnivores such cat, mink, and ferret, a high level of dietary zinc (50 to 100 mg/kg diet) is required for optimum fetal development compared to other animal species. The Zn requirement for mink is ca. 66 mg/kg diet (National Research Council 1982). Most often, the diet for mink can meet the requirement because it contains a large part of animal by-products or fish meal, which are rich in minerals. Moreover, Zn supplementation above the requirement has been shown to promote growth in humans and animals. Early work from our lab showed that dietary Zn and copper supplementation improves growth by increasing feed intake and improving fat digestibility in mink (Wu et al. 2015a). In recent years, organic Zn sources in the form of complexes or chelates have been considered as an alternative to inorganic Zn and have been increasingly used in broiler chickens (Huang et al. 2009). However, very little research comparing the effect of organic Zn to inorganic Zn in mink has been conducted.

The main objective of the present study was to evaluate the relative bioavailability of zinc glycinate (ZnGly) and zinc pectin oligosaccharides chelate (ZnPOS) compared to Zn from grade zinc sulfate ($ZnSO_4$), and the effects of the supplementation of these Zn sources on nutrient digestibility and blood biochemical indices.

MATERIAL AND METHODS

The animal protocol for this experiment was approved by the Animal Care Committee of the Institute of Special Animal and Plant Sciences of the Chinese Academy of Agricultural Sciences (CAAS). Animals were maintained and processed in accordance with the CAAS Guide for the Care and Use of Laboratory Animals.

Animals, diets, and management. One hundred and twenty 16-week-old male black mink with initial body weight (BW) 1.87 ± 0.15 kg were randomly assigned to 9 treatments in a 3 × 3 factorial design + 1 control group (n = 12 for each group) based on average age and mean BW. All animals were fed a basal diet (without Zn supplementation) for a 10-day adaption period before the study. Animals in the control group were fed the basal diet and those in treatment groups were fed the control diet supplemented with either $ZnSO_4 \cdot 7H_2O$, ZnGly (22% Zn by calculation), or ZnPOS at 100, 300, or 900 mg Zn/kg. The source of ZnPOS that consists of α-(1,4)-linked POS units was obtained from the Feed Research Institute, Chinese Academy of Agricultural Sciences, and the content of Zn in the ZnPOS was 7% by calculation. The basal diet consisted of corn, meat, fish meal and bone meal, and soybean oil, with no added Zn in the premix and was formulated to meet the Zn requirements of growing mink (Wu et al. 2015b). Zn content in the control diet was 65.18 mg/kg by analysis. The concentration of Zn was achieved using a nutrient composition table. The actual analyzed Zn contents in the experimental diets were 185.42, 359.22, and 970.39 mg/kg DM, respectively, for three $ZnSO_4$ groups; 176.16, 370.23, and 966.18 mg/kg DM, respectively, for three ZnGly groups; and 177.81, 360.97, and 980.79 mg/kg DM, respectively, for three ZnPOS groups. The composition and chemical analysis of the basal diet are shown in Table 1. Mink were housed individually in conventional cages (60 cm long × 40 cm wide × 50 cm high) with additional attached nest boxes (30 cm long × 40 cm wide × 30 cm high) in two-row sheds. The diet was fed in liquid form that was made by mixing feed ingredients and water in a 1 : 3 ratio which is commonly used in mink industry and is ideal for growing mink. Diets were given twice a day at 7:30 and 15:30 h. Drinking water (< 0.01 mg Zn/l by analysis) was available *ad libitum*.

Sample collections and measurements. On day 20 of the experiment, ten male mink from each treatment were randomly selected and housed individually in metabolism cages for 4 days of the digestive and nitrogen balance trial to study the effects of Zn on the nutrient digestibility. Plastic bottles and trays were used to collect urine and feces, respectively, to avoid metal contamination. According to the volume of urine, 10 ml 10% H_2SO_4 (10% v/v) was added to the urine collection bottles and five drops of methylbenzene were added to prevent nitrogen loss. Urine samples were stored at −20°C until analysis. Fecal and feed samples were dried in a forced-air drying oven at 65°C and then ground to pass a 40-mesh sieve. At the end of the experiment, 10 ml of blood was taken

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Table 1. Ingredients and nutrient composition of the basal diet (%, air-dried basis)

Item	Content
Ingredients (% diet)	
Extruded corn	24.5
Soybean meal	26
Corn gluten meal	6
Fish meal	13.4
Bone meat meal	15.5
Cheese meal	5
Lysine	0.5
Methionine	0.5
NaCl	0.2
Premix[1]	1
Pectin oligosaccharides[2]	1.1
Glycinate[3]	0.3
Soybean oil	6
Total	100
Nutrient composition	
Metabolizable energy (MJ/kg)[4]	18.61
Crude protein	32.84
Crude fat	14.81
Carbohydrate	38.16
Crude fibre	1.79
Lysine	1.43
Methionine	1.06
Crude ash	8.17
Zinc (mg/kg)	65.18
Copper (mg/kg)	105.23

[1]contents per kg of premix composition: vitamin A palmitate 10 000 IU, vitamin B_1 thiamine hydrochloride 6 mg, vitamin B_2 riboflavin 8 mg, vitamin B_6 pyridoxine hydrochloride 3 mg, vitamin D cholecalciferol 2000 IU, vitamin E acetate 60 IU, vitamin B_{12} cobalamin 0.1 mg, vitamin K menadione 1 mg, vitamin C sodium ascorbate 400 mg, nicotinic acid 40 mg, vitamin B_5 niacin 12 mg, biotin 0.2 mg, folic acid 0.8 mg, choline 300 mg, Fe 82 mg, Mn 120 mg, Cu 1 mg, I 0.5 mg, Co 0.4 mg, Se 0.2 mg

[2]additional amount of zinc glycinate (ZnGly): ZnGly 100: 0.29% + extruded corn 0.01%; ZnGly 300: 0.22% + extruded corn 0.08%; ZnGly 900: 0% + extruded corn 0.3%; others: 0.3% + extruded corn 0%

[3]additional amount of pectin oligosaccharides (ZnPOS): ZnPOS 100: 1.05% + extruded corn 0.05%; ZnPOS 300: 0.8% + extruded corn 0.3%; ZnPOS 900: 0% + extruded corn 1.1%; others: 1.1% + extruded corn 0%

[4]calculated values, others were values analyzed based on air-dried samples

via the toe clip from mink in the morning after overnight fasting for determining concentrations of serum Zn and other biological parameters. Blood samples were centrifuged at 3000 *g* for 10 min to collect serum and stored at –20°C until analysis (Liu et al. 2015).

Chemical analysis. The nutrient contents of feed, feces, and urine were analyzed by the methods of the Association of Official Analytical Chemists (AOAC 2003). Dry matter (DM) of diets and fecal samples was quantified by drying feed or fecal samples at 105°C to constant weight (Method 930.15; AOAC 2003). Nitrogen was measured by FOSS Kjeltec 8400 (FOSS, Sweden) and crude protein was calculated as N × 6.25. Crude fat in feces and feed was determined by diethylether extraction-submersion method (Liu et al. 2015). Zn contents in feed, feces, and serum were determined using atomic absorption spectrophotometry (novAA 400 P; Analytik Jena AG, Germany). The activities of aspartate aminotransferase (AST), serum alanine transaminase (ALT), glucose (GLU), and alkaline phosphatase (ALP), and the contents of serum total protein (TP), albumin (ALB), and glutamyltransferase (GGT) were analyzed by an automatic biochemistry analyzer Hitachi 7020 (Hitachi High Technologies, Inc., Japan) with kits being supplied by the Nanjing Jiancheng Bioengineering Research Institute, China. Zn dependent enzyme activities of serum Cu-Zn superoxide dismutase (Cu-ZnSOD) were measured using commercially available assay kits purchased from the Nanjing Jiancheng Bioengineering Research Institute (Wu et al. 2015b). The apparent digestibility (AD) of nutrients and energy was calculated as follows (Wu et al. 2014):

$$AD = (A - B)/A \times 100$$

where:
A = nutrient intake from feed
B = nutrient excretion in feces

Statistical analysis. All data were expressed as means ± SEM and analyzed as a 3 × 3 + 1 factorial experiment based on a completely randomized design using the General Linear Model (GLM) procedure of the SAS software (Statistical Analysis System, Version 9.13, 2002). Data were analyzed as repeated measures with a model containing source, level, and source × level. Serum Cu-ZnSOD was used to estimate relative Zn bioavailability from

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ZnGly and ZnPOS, using $ZnSO_4$ as the standard source, by multiple linear regression and a slope ratio method. Linear and quadratic effects due to Zn levels were determined. $P < 0.05$ was considered significant and P-value in the range of 0.05–0.10 was considered a trend.

RESULTS

Nutrient digestibility. Neither the Zn source nor the Zn level affected crude protein (CP), DM or ash digestibility (Table 2, $P > 0.05$). Zn source and level significantly affected apparent fat digestibility ($P < 0.05$). Compared to the control, the AD of fat was higher in Zn-Gly and ZnPOS ($P < 0.05$), and in Zn-900 ($P < 0.05$). Furthermore, the effect of Zn level on apparent fat digestibility was linear ($P < 0.05$).

Nitrogen balance. The Zn intake and Zn retention increased linearly ($P < 0.05$) with the level of Zn (Table 3). Fecal Zn and urinary Zn were affected by dietary Zn supplementation ($P < 0.05$). Zn supplementation increased Zn retention compared with the control group ($P < 0.05$). Nitrogen intake and urinary excretion N were not affected by either Zn source or level ($P > 0.05$). The N retention in ZnPOS was higher ($P < 0.05$) than that of the control. Additionally, the effect of Zn level was linear ($P < 0.05$) for N retention.

Blood biological parameters. Serum Zn concentrations were influenced by dietary Zn levels (Table 4, $P < 0.05$). However, there were no differences in serum Zn concentrations among Zn sources ($P > 0.10$). Serum AST and GLU activities were not affected by either Zn sources or levels ($P > 0.10$). Compared to the control, the activity of ALP was higher in Zn supplemented groups ($P < 0.05$). In addition, the activity of ALP was higher in 900 mg Zn/kg ($P < 0.05$) compared to the control. Zn supplementation had no effect on the concentration of serum ALB, TP, and GGT ($P > 0.10$). The effect of Zn levels was linear ($P < 0.05$) for the activity of ALP.

Activities of antioxidant enzymes. The activities of glutathione peroxidase (GSH-Px) were not affected by dietary treatments (Table 5). Compared to the control, the activity of total SOD was higher in groups supplemented with 900 mg/kg Zn ($P < 0.05$). There were significant interactions ($P < 0.05$) between Zn sources on the activity

Table 2. Effects of dietary Zn source and level on diet DM, CP, fat, and ash digestibility of mink

Item	Control	Zn source			Zn level (mg/kg)				SEM	*P*-value		
		$ZnSO_4$	ZnGly	ZnPOS	0	100	300	900		source	level	linear	quadratic
ADFI (g)	71.70	76.41	73.62	69.24	71.70	72.46	75.84	70.42	1.14	0.32	0.17	0.93	0.75
DM (%)	63.66	63.54	64.09	66.26	63.66	65.17	65.20	64.52	1.28	0.10	0.35	0.39	0.35
CP (%)	54.98	56.40	59.84	62.40	56.45	59.13	61.36	57.16	2.06	0.06	0.39	0.18	0.16
Fat (%)	69.26^{b}	71.83^{ab}	73.85^{a}	72.63^{a}	69.26^{b}	72.32^{ab}	72.90^{ab}	75.09^{a}	3.33	0.75	0.02	0.04	0.47
Ash (%)	28.64	28.11	27.06	28.35	28.64	29.71	28.30	27.94	0.57	0.27	0.13	0.35	0.18

DM = dry matter, CP = crude protein, $ZnSO_4$ = zinc sulfate, ZnGly = zinc glycinate, ZnPOS = zinc pectin oligosaccharides chelate, ADFI = average feed intake
^{a,b}means with different superscripts within a column differ significantly ($P < 0.05$); data are expressed as Least Squares Means with pooled SEM; $n = 10$ per treatment

Table 3. Effects of dietary Zn source and level on Zn and N absorption and retention of mink

Item	Control	Zn source			Zn level (mg/kg)				SEM	*P*-value			
		$ZnSO_4$	ZnGly	ZnPOS	0	100	300	900		source	level	linear	quadatic
Zn intake (mg/day)	4.71[b]	34.91[a]	36.04[a]	37.14[a]	14.71[d]	20.27[c].	31.13[b]	64.59[a]	1.41	0.29	< 0.01	< 0.01	< 0.01
Zn in feces (mg/day)	3.95[b]	25.59[a]	23.06[a]	24.38[a]	8.95[c]	12.33[b]	18.46[b]	42.46[a]	0.39	0.54	< 0.01	< 0.01	< 0.01
Zn in urine (mg/day)	0.04[c]	0.284[b]	0.38[a]	0.264[b]	0.04[b]	0.251[a]	0.343[a]	0.33[a]	0.09	0.02	0.01	0.03	0.07
Zn retention (mg/day)	0.57[c]	9.18[b]	12.16[a]	12.53[a]	5.27[c]	7.09[c]	12.19[b]	21.73[a]	0.02	0.01	< 0.01	0.02	< 0.01
N intake (g/day)	3.61	3.91	3.71	3.49	3.61	3.65	3.88	3.49	0.07	0.15	0.32	0.34	0.36
N in feces (g/day)	1.328[b]	1.59[ab]	1.73[a]	1.25[b]	1.32	1.37	1.65	1.25	0.52	0.05	0.19	0.70	0.82
N in urine (g/day)	1.27	1.11	0.96	1.05	1.27	1.02	1.30	1.05	0.09	0.29	0.13	< 0.01	0.53
N retention (g/day)	0.31[a]	0.32[ab]	0.32[ab]	0.33[b]	0.31[a]	0.32[a]	0.33[b]	0.34[b]	0.11	0.34	0.01	< 0.01	0.001

$ZnSO_4$ = zinc sulfate, ZnGly = zinc glycinate, ZnPOS = zinc pectin oligosaccharides chelate

[a–d]means with different superscripts within a column differ significantly ($P < 0.05$); data are expressed as Least Squares Means with pooled SEM; $n = 10$ per treatment

Table 4. Effects of dietary Zn source and level on blood biological parameters of mink

Item	Control	Zn source			Zn level (mg/kg)				SEM	*P*-value			
		$ZnSO_4$	ZnGly	ZnPOS	0	100	300	900		source	level	linear	quadratic
Zn (μmol/l)	94.67[b]	152.37[a]	149.25[a]	164.39[a]	94.67[c]	107.57[b]	161.43[a]	186.17[a]	2.68	0.11	< 0.01	0.05	0.10
AST (u/l)	116.40	121.19	88.32	131.66	116.40	145.59	114.21	93.79	1.47	0.11	0.14	0.36	0.23
GLU (mmol/l)	6.04	5.90	5.67	6.45	6.047	6.12	4.98	7.13	0.81	0.36	0.05	0.12	0.05
ALP (u/l)	110.48[b]	120.23[a]	126.71[a]	130.09[a]	110.48[b]	118.93[b]	121.81[ab]	134.20[a]	5.17	0.82	0.02	< 0.01	0.33
ALB (g/l)	47.91	39.71	44.05	41.90	47.91	44.10	41.02	41.38	3.77	0.27	0.14	0.07	0.18
TP (g/l)	82.84	71.68	77.92	72.04	82.84	77.40	72.26	72.37	0.31	0.47	0.33	0.311	0.18
GGT (u/l)	9.40	16.72	14.84	15.98	9.40	15.46	17.45	14.53	0.64	0.53	0.25	0.25	0.30

AST = aspartate aminotransferase, GLU = glucose, ALP = alkaline phosphatase, ALB = albumin, TP = total protein, GGT = glutamyl transpeptidase, $ZnSO_4$ = zinc sulfate, ZnGly= zinc glycinate, ZnPOS = zinc pectin oligosaccharides chelate

[a–c]means with different superscripts within a column differ significantly ($P < 0.05$); data are expressed as Least Squares Means with pooled SEM; $n = 12$ per treatment

Table 5. Effects of dietary Zn source and level on antioxidant status of mink

Item	Control	Zn source			Zn level (mg/kg)				SEM	*P*-value			
		$ZnSO_4$	ZnGly	ZnPOS	0	100	300	900		source	level	linear	quadratic
T-SOD	109.42	110.41	116.28	117.09	109.42[b]	111.99[b]	113.53[b]	118.19[a]	0.90	0.21	0.03	0.04	0.39
Cu-ZnSOD	52.42[c]	62.03[b]	65.41[a]	66.68[a]	52.42[d]	58.89[c]	66.51[b]	68.99[a]	6.21	0.52	0.01	< 0.01	0.25
GSH-Px	313.70	325.60	330.33	339.11	313.70	323.28	336.14	332.14	11.56	0.41	0.54	0.13	0.31

T-SOD = total superoxide dismutase, Cu-ZnSOD = Cu-Zn superoxide dismutase, GSH-Px = glutathione peroxidase, $ZnSO_4$ = zinc sulfate, ZnGly = zinc glycinate, ZnPOS = zinc pectin oligosaccharides chelate

[a–d]means with different superscripts within a column differ significantly ($P < 0.05$); data are expressed as Least Squares Means with pooled SEM; $n = 12$ per treatment

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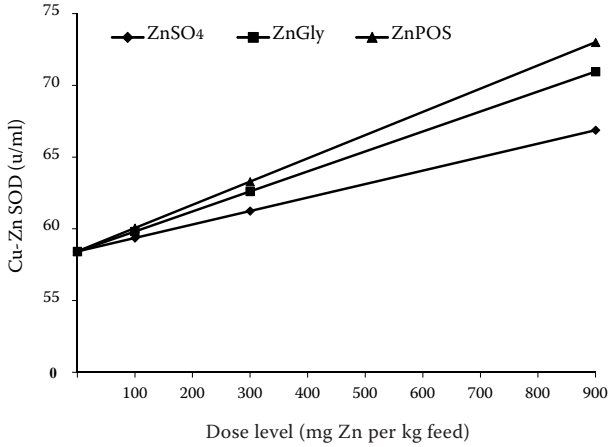

Figure 1. Linear regression of the activity of Cu-Zn superoxide dismutase (Cu-Zn SOD) on supplemental Zn intake and relative bioavailability of Zn

$ZnSO_4$ = zinc sulfate, ZnGly = zinc glycinate, ZnPOS = zinc pectin oligosaccharides

Y = 58.4281 + 0.00939*X1 + 0.01392*X2 + 0.01620*X3; R^2 = 0.6520, SE = 0.35 for X1, X2, and X3. Values on the *x* axis are based on analyzed values for Zn in the diets. Relative Zn bioavailability: $ZnSO_4$ = 100%, ZnGly = 148%, ZnPOS = 173%

of Cu-ZnSOD. Cu-ZnSOD activity tended to be affected by dietary zinc (P = 0.065). In addition, the effect of Zn level was linear (P < 0.05) for Cu-ZnSOD activity.

Relative bioavailability values. Bioavailabilities of ZnGly and ZnPOS relative to $ZnSO_4$ were estimated based on Cu-ZnSOD levels using multiple linear regression and a slope ratio method (Figure 1). Bioavailabilities for ZnPOS and ZnGly were 173 and 148%, respectively, relative to 100% for $ZnSO_4$ (P < 0.05).

DISCUSSION

Results obtained in this study suggest that both ZnPOS and ZnGly are more bioavailable than zinc sulfate. The estimated bioavailability was 173% and 148% for ZnPOS and ZnGly, respectively, compared with zinc sulfate (100%) based on Cu-ZnSOD activity. The fact that organic zinc source, such as ZnGly, had a significantly higher bioavailability than zinc sulfate has been reported by others (Cao et al. 2000; Rider et al. 2010). Yenice et al. (2015) have shown that organic Zn increases the bioavailability of Zn compared with inorganic sources. Although the exact mechanism for the increased bioavailability of ZnPOS was unclear and still needs further study, several hypotheses have been proposed for the higher bioavailability of organic minerals than inorganic minerals. Schlegel and Windisch (2006) showed that pectin oligosaccharides chelate can form a complex with minerals and promotes absorption of minerals into living organisms by simply mixing it with feed for oral use. Wang et al. (2016) have demonstrated that the supplementation of ZnPOS is optimal in improving the utilization of dietary DM and CP, which is consistent with the present findings.

The apparent digestibilities of CP and ether extract (EE) in the present study were slightly lower compared with values in other digestive and balance trials with mink (Wu et al. 2015a). This is likely due to the difference in feed types and composition of diets between those trials and our experiment. It has been found that in another fur animal species, the Arctic fox, nutrients from diets composed of animal meals were characterized by low digestibility than components of fresh feed (Gugolek et al. 2010). In this study, a dry diet, which is widely used in China, was used for its stable nutrient contents. This could explain the relatively low nutrient digestibility in our experiment. Another factor influencing the digestibility of nutrients is the dietary protein and the proportion of plant-based feeds. As all treatments were fed diets with similar nutrient contents except for Zn, the differences in nutrient digestibility were mainly caused by dietary Zn concentrations. Our results indicate that Zn supplementation had no effects on DM and CP in mink. These results are similar to the findings of Wu et al. (2015a) that there was no influence of dietary zinc and copper on DM and CP in young male mink. In this experiment, the AD of crude fat was greatly improved by dietary Zn addition. It is possible that dietary Zn concentrations enhanced digestibility of fat by stimulating activities of the fat metabolism-related enzymes. Liu et al. (2011) suggested that dietary Zn supplementation improved Zn status and resulted in promoting antioxidant ability and activities and gene expressions of fat metabolism-related enzymes of broilers. Similar results have been reported in mink (Bleavins et al. 1983) and nursery pigs (Hill et al. 2014). Cho et al. (2015) found that dietary supplementation with ZnO increased nutrient digestibility. In the present study, N retention was

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increased with the increase in dietary Zn levels, which is in agreement with Shinde et al. (2006). Little is known about the effects of dietary Zn on N balance in mink but information is available for hen and chickens. It was reported that dietary Zn supplementation increased total N retention in laying hens (Kim and Patterson 2005). Zn was also shown to stimulate N retention in chickens (Mohanna and Nys 1999).

One of the important findings of the present study is that the organic sources of Zn, ZnGly, and ZnPOS increased Zn absorption. Similar results have been reported in other studies (Star et al. 2012; Sirri et al. 2016). How and to what degree the Zn absorption is affected by organic Zn form may depend on other interacting factors including the degree of chelation and the ratio of ligand to the minerals (Thomason et al. 1976). Yu et al. (2010) found that the chelation of zinc by low molecular weight ligands leads to the formation of a soluble complex that can increase Zn absorption. The activity of ALP was greatly increased by Zn addition regardless of sources in this study which is in agreement with other studies (Sun et al. 2005; Rocha et al. 2015). The Cu-ZnSOD, in which Zn is an integral part, is an important antioxidant defense in nearly all living cells exposed to oxygen (Paz Matias et al. 2014). Rao et al. (2016) found that supplementation of organic form of Zn increased SOD. Similarly, the results from our study also indicated that Zn supplementation increased the activity of Cu-ZnSOD. In our research the Cu-ZnSOD bioavailability was similar to that of Zn found by Fischer et al. (1991), who reported that Cu-Zn activity was decreased in the low-Zn group and was significantly elevated in the high-Zn group. In agreement with the findings of the present study, Dimitrova et al. (2005) also found that the activity of Cu-ZnSOD elevated with Zn supplementation in the diet.

CONCLUSION

The result of this feeding trial demonstrated that organic ZnPOS had a higher bioavailability than ZnGly or inorganic zinc sulfate. Additionally, this study also indicated a clear dose-response relationship between dietary zinc and Cu-Zn superoxide dismutase in mink with increased Cu-Zn superoxide dismutase upon Zn supplementation. We conclude that ZnPOS can be used by the feed industry as an alternative source of supplemental Zn.

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