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Influence of feed enzymes on the content of mineral elements in sows milk and pigs blood plasma

Wpływ dodatku enzymów paszowych na zawartość składników mineralnych w mleku loch oraz osoczu krwi świń

Summary. The aim of this study was to analyze whether and to what extent the addition of enzymes hydrolyzing fractions of non-starch polysaccharides or degrading phytates in pigs feeding in the complete cycle (pregnant and lactating sows, piglets and fatteners) may affect the utilization of mineral elements. The study with pigs in the complete reproductive cycle was accomplished in five periods: pregnant sows, nursing sows, piglets, young fatteners, and fatteners. Four experimental groups were established in the experiment, including two controls: positive control (PC), where dicalcium phosphate additive was used as a source of phosphorus, and negative control (NC), where solely plant-based feed mixtures were the source of phosphorus. The other two groups were as follows: MP – in which pigs received the same feed mixture as in the NC group but supplemented with microbial phytase, and the EP group in which the animals were fed the same feed mixture as in the NC group but with the addition of a multi-enzyme preparation which included both microbial phytase and enzymes participating in the hydrolysis of non-starch polysaccharide fractions (xylanase, β-glucanase, cellulase). The addition of microbial phytase either alone or with the enzymes hydrolyzing the non-starch polysaccharide fractions contributed to increased contents of phosphorus, copper and zinc in sows' milk. In contrast, it did not evoke any significant changes in the content of calcium, magnesium, iron, or in that of protein, fat and lactose in the milk of sows. The feed enzymes contributed to a significant increase in the concentrations of minerals (except for magnesium) in blood plasma of piglets and fatteners, whereas so significant changes were observed in the blood plasma of sows.

Key words: pigs, feed enzymes, blood

INTRODUCTION

Monogastric animals, including livestock, are incapable of synthesizing both the enzymes hydrolyzing fractions of non-starch polysaccharides (e.g. cellulolytic enzymes, pectinases, xylanases, β-glucanase) nor phytases [Yin *et al*. 2001]. Hence, the addition of these enzymes to feeds is of significant importance [Omogbenigun *et al*. 2004]. The above-mentioned enzymes exert a variety of effects. For instance, as a result of degradation of saccharide molecules, the enzymes hydrolyzing fractions of non-starch polysaccharides (β-glucanase or xylanase) cause the loss of gel-forming ability of these compounds [Blaabjerg *et al*. 2010], whereas the action of phytase consists in catalyzing the detachment of inorganic orthophosphates from phytates, owing to which it releases bivalent elements chelated with them as well as proteins and saccharides [Shelton *et al*. 2005]. The efficacy of feed enzymes addition is especially tangible in the case of young animals. It is reflected in increased body weight gains and improved feet utilization as well as positively affects the health status of animals. This is due to, among other things, improved digestibility of nutrients and an increased nutritive value of low-calorific cereals [Varley *et al*. 2011].

Owing to the fact that both phytase and enzymes hydrolyzing the fractions of non-starch polysaccharides affect the improved absorption of, e.g., minerals, it seems interesting to answer the question whether and to what extent the addition of enzymes hydrolyzing non-starch polysaccharide fractions (endo-1,3(4)-β-glucanase-EC 3.2.1.6. and endo-1,4-β-xylanase -EC 3.2.1.8) or phytate-degrading enzymes (3phytase-EC 3.1.3.8) in swine feeding in the complete cycle (pregnant and lactating sows, piglets and fatteners) may affect the utilization of minerals.

MATERIAL AND METHODS

The experiment with pigs in the complete reproductive cycle was conducted in five periods: pregnant sows, nursing sows, piglets (12–30 kg of body weight), young fatteners (30–60 kg b.w.), and fatteners (60–90 kg b.w.). The experiment was carried out with wbp × pbz sows after the second and third lactation mated with Duroc boars.

Four experimental groups were established in the experiment, including two controls: positive control (PC) where dicalcium phosphate additive (10 g kg^{-1}) was used as a source of phosphorus, and negative control (NC) where solely plant-based feed mixtures were the source of phosphorus. The other two groups were as follows: MP group – in which pigs were receiving the same feed mixture as in NC group but supplemented with 500 PU kg^{-1} of microbial phytase, and EP group – in which the animals were fed the same feed mixture as in NC group but with the addition of a multi-enzyme preparation (0.1 g kg^{-1}) which included both microbial phytase and enzymes participating in the hydrolysis of non-starch polysaccharide fractions (xylanase, β-glucanase, cellulase).

The first experimental period covered sows with diagnosed pregnancy. Each group contained eight sows. During rearing, the piglets were kept with the sows in farrowing pens, whilst after the rearing the piglets from two farrows were grouped in one cage (four cages per group). The piglets were fed a pre-starter mixture for two weeks and then with a starter mixture. From each cage, four piglets were selected based on the analogs taking into account body weight and sex (2 gilts and 2 barrows), that during fattening were kept in pens (4 animals each).

In all studied group, contents of nutrients (except for phosphorus and calcium) in feed mixtures administered in the particular feeding periods were consistent with Swine

Feeding Standards [Normy żywienia świń 1993]. The contents of total phosphorus and calcium in feed mixtures for animals from PC group were also consistent with those recommendations. The feed mixtures for piglets and fatteners and for lactating sows were applied *ad libitum*, whereas these for pregnant sows were applied in doses at a constant access to drinking water. The percentage composition of experimental feed mixtures was presented in Table 1.

Table 1. Composition of full mixtures for pigs
Tabela 1. Skład recepturowy mieszanek pełnoporcjowych dla świń (%)

Components Składniki (%)	Mixtures/Mieszanka											
	pregnancy ciąża		lactation laktacja		prestarter prestarter		starter starter		grower grower		finisher finiszer	
	PC	NC	PC	NC	PC	NC	PC	NC	PC	NC	PC	v
Barley/Jęczmień	54.0	55.0	26.5	27.5	7.5	8.5	22.0	22.0	27.0	27.0	51.0	52.0
Maize Kukurydza	-	-	-	-	10.0	10.0	11.0	11.0	-	-	-	-
Triticale Pszenżyto	20.0	20.0	-	-	-	-	-	-	-	-	20.0	20.0
Wheat bran Otręby pszenne	15.0	15.0	10.0	10.0	-	-	-	-	5.0	5.0	10.0	10.0
Wheat/Pszenica	-	-	35.0	35.0	47.8	47.8	38.0	39.0	43.0	44.0	-	-
Fish meal, 65% Mączka rybna, 65%	-	-	-	-	8.5	8.5	2.0	2.0				
Rapeseed oil Olej rzepakowy	-	-	3.0	3.0	2.0	2.0	2.0	2.0	1.0	1.0	-	-
Post-extraction soybean meal Poekstrakcyjna śruta sojowa	6.0	6.0	20.0	20.0	18	18	20.0	20.0	20.0	20.0	15.0	15.0
Dicalcium phosphate Fosforan dwuwapniowy	1.0	-	1.0	-	1.0	-	1.0	-	1.0	-	1.0	-
Limestone Kreda pastewna	1.6	1.6	1.6	1.6	1.0	1.0	1.3	1.3	1.1	1.1	1.3	1.3
NaCl	0.4	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.4	0.4	0.2	0.2
Mineral-vitamin premix[a] Premiks mineral-no-witaminowy[a]	2.0	2.0	2.5	2.5	4.0	4.0	2.5	2.5	1.5	1.5	1.5	1.5
Total/Razem	100.0	100.0	100.0	100.0	100	100	100.0	100.0	100.0	100.0	100.0	100.0

[a] Mineral-vitamin premix contained, per 1 kg: Mg 13.5 g, Zn 3.01 g, Mn 2.5 g, Cu 0.5 g, Co 0.005 g, J 0.025 g, Se 0.015 g, vitamin A 650,000 U, vitamin E 2.5 g, vitamin K_3 0.05 g, vitamin B_1 0.05 g, vitamin B_2 0.125 g, vitamin B_6 0.1 g, vitamin B_{12} 0.0005 g, biotin 0.0025 g, calcium pantotenate 1 g, nicotinic acid 1 g, folic acid 0.02 g, choline 5 g, and maize meal – carrier.

[a] Premiks mineralno-witaminowy zawierał w 1 kg: Mg 13,5 g, Zn 3,01 g, Mn 2,5 g, Cu 0,5 g, Co 0,005 g, J 0,025 g, Se 0,015 g, witamina A 650000 jm, witamina E 2,5 g, witamina K_3 0,05 g, witamina B_1 0,05 g, witamina B_2 0,125 g, witamina B_6 0,1 g, witamina B_{12} 0,0005 g, biotyna 0,0025 g, pantotenian wapnia 1 g, kwas nikotynowy 1 g, kwas foliowy 0,02 g, cholina 5 g, mączka kukurydziana – nośnik.

Conditions in the piggery corresponded to the recommended zoohygienic standards [Rokicki and Kolbuszewski 1996]. The animals were under constant surveillance of a veterinarian.

In each feeding period (pregnancy, lactation, prestarter, starter, grower, finisher) samples of feed mixtures were collected twice for analyses. In turn, milk was sampled for analyses on day 21 of lactation from all sows from each group. The sows were administered 2 ml of oxytocin, and then ca. 10 ml of milk were milked from the first eight breast nipples to vessels with a preservative (potassium dichromate). Blood samples were collected from the sows in the 14th week of pregnancy and in the third week of lactation, whereas in the case of fatteners – at the body weight of ca. 30, 60 and 90 kg. Blood was sampled to heparinized test tubes 10 ml in volume from the jugular vein under the supervision of a veterinarian.

Feed mixtures were assayed for contents of dry matter, crude ash, total protein, crude fibre and ether extract according to AOAC methods [2000] as well as for the content of total phosphorus according to the method by Fiske-Subarow [1925]. Contents of calcium, iron, copper, magnesium and zinc were determined with the atomic absorption spectrophotometry (AAS). The feed mixtures were also analyzed for the activity of phytase – according to Engelen *et al*. [1994], and for the content of phytate phosphorus – according to Oberleas [1971].

Samples of blood plasma and milk were determined for contents of minerals: calcium, magnesium, zinc, copper and iron with the AAS apparatus using the method of atomic absorption spectrometry. The content of total phosphorus (P) in blood plasma was assayed with the colorimetric method using monotests by Cormay company, whereas in milk – with the use of the Fiske-Subbarow method [1925]. Milk samples were additionally analyzed for the contents of: dry matter, total protein, crude fat, lactose and crude ash on a Milko-scan apparatus.

Digital data achieved were subjected to a statistical analysis, by determining mean values and standard errors of the means using Statistica ver.6.1 software. The significance of differences between means was determined with the one-way analysis of variance test ANOVA, with Duncan's multiple confidence interval, at significance levels of 0.05 and 0.01.

RESULTS AND DISCUSSION

The addition of feed enzymes to feed mixtures for pigs, poultry or fish may improve not only the availability of major nutrients but also of minerals [Sugiura *et al*. 2001, Jondreville *et al*. 2007]. As reported by Peter *et al*. [2001], the addition of microbial phytase may increase the availability of, primarily, phosphorus and calcium but also of other bivalent elements from feed mixtures for pigs. This allows reducing the addition of those elements to feed by at least 20% [Peter *et al*. 2001]. Hence, in the presented experiment, in feed mixtures for pigs receiving the addition of microbial phytase in diet (MP and EP groups) as well as in group II which was the negative control, the content of total phosphorus was reduced by ca. 30 ±5%, and that of calcium by ca. 22 ±5% (Tab. 2).

Table 2. Chemical composition and nutritive value of pig mixtures
Tabela 2. Zawartość składników w mieszankach dla świń

Components Składniki	Mixtures/Mieszanka											
	pregnancy ciąża		lactation laktacja		prestarter prestarter		starter strater		grower grower		finisher finiszer	
	PC	NC	PC	NC	PC	NC	PC	NC	PC	NC	PC	NC
Dry matter, g kg^{-1}/Sucha masa, g kg^{-1}	859.3	855.2	867.6	861.3	873.5	872.3	868.4	861.0	860.6	857.1	854.5	852.3
EM[1], MJ kg^{-1}	11.9	11.9	12.5	12.5	12.8	12.8	12.2	12.4	12.1	12.2	11.9	12.0
Protein (N × 6.25), g kg^{-1} Białko (N × 6,25), g kg^{-1}	137.1	136.7	182.0	181.7	187.3	188.5	189.7	190.4	179.6	178.9	160.3	158.5
Ether extract, g kg^{-1} Ekstrakt eterowy, g kg^{-1}	25.5	24.9	53.0	53.4	53.1	53.2	44.8	44.9	36.0	36.3	26.6	26.9
Crude fibre, g kg^{-1} Włókno surowe, g kg^{-1}	54.9	55.3	45.1	45.8	30.6	30.8	37.6	38.8	41.8	42.5	46.0	46.3
Crude ash, g kg^{-1}/Popiól surowy, g kg^{-1}	59.6	49.8	65.1	54.8	77.2	67.3	67.5	57.9	58.0	48.4	61.4	51.7
Total phosphorus, g kg^{-1} P ogólny, g kg^{-1}	6.3	4.5	6.2	4.4	7.3	5.3	5.7	3.8	6.0	4.1	6.2	4.4
Phytate P, g kg^{-1}/P fitynowy, g kg^{-1}	3.2	3.2	3.2	3.2	4.2	4.2	2.7	2.7	3.0	3.0	3.1	3.1
Calcium, g kg^{-1}/Wapń, g kg^{-1}	8.6	6.6	9.5	7.5	10.1	8.0	8.1	6.1	7.3	5.2	8.1	6.1
Magnesium, g kg^{-1}/ Magnez, g kg^{-1}	1.5	1.5	1.8	1.8	1.6	1.6	1.5	1.5	1.7	1.7	1.5	1.5
Copper, mg kg^{-1}/Miedź, mg kg^{-1}	14.5	14.5	18.2	18.1	15.1	15.0	15.5	15.4	12.8	13.0	12.9	12.8
Zinc, mg kg^{-1}/Cynk, mg kg^{-1}	88.9	88.1	103.2	103.3	90.8	90.8	84.7	84.5	71.9	71.6	75.0	74.5
Iron, mg kg^{-1}/Żelazo, mg kg^{-1}	72.1	71.9	89.4	89.3	96.4	95.5	78.0	78.0	80.7	80.5	83.7	83.9
[1]Activity of native phytase, PU kg^{-} [1]Aktywność fitazy natywnej, PU kg^{-1}	1008.5	1005.0	579.6	595.1	390.1	400.0	406.4	410.0	555.0	560.0	790.9	803.8

[1]Metabolizable energy corrected for zero nitrogen balance – MEN (kcal/kg) = 14.7 × CP + 32.9 × EE + 17.2 × starch + 14.9 × sugars
[1]Energia metaboliczna skorygowana na zerowy bilans azotu – MEN (kcal/kg) = 14,7 × CP + 32,9 × EE + 17,2 × skrobia + 14,9 × cukry

As demonstrated by Grela and Kumek [2002], the improvement of availability and digestibility of mineral elements is reflected in, among other things, their increased contents in colostrum and milk of sows. This has been confirmed in the reported study, where the addition of feed enzymes (MP and EP groups) contributed to a significant increase in the contents of phosphorus, copper and zinc by, respectively, ca. 21%, 37% and 12% as compared to the MP group (Tab. 3). The results achieved are mainly due to the activity of microbial phytase, because its key task is to decompose phytates, which are salts of phytic acid (myo-inositol hexa-dihydrogen phosphate) that occur in plant-based feeds [Mosenthin and Broz 2010, Cowieson *et al*. 2006, Jondreville *et al*. 2007]. It is likely that the enzymes hydrolyzing fractions of non-starch polysaccharides (EP group) contributed to the occurrence of conditions that facilitated the action of microbial phytase. Such a dependency was, however, not observed in respect of the contents of calcium, magnesium nor iron. The addition of feed enzymes had no significant effect on protein, fat and lactose contents in milk of the sows, either (Tab. 3).

Table 3. Milk composition of sows
Tabela 3. Skład mleka loch

Components/Składniki	Feeding groups/Grupa doświadczalna				SEM
	PC	NC	MP	EP	
Dry matter, g kg^{-1}/ Sucha masa, g kg^{-1}	189.2	183.4	191.7	191.6	6.12
Crude ash,g kg^{-1}/ Popiół surowy, g kg^{-1}	7.15	7.19	7.28	7.35	0.12
Crude protein,g kg^{-1}/ Białko surowe, g kg^{-1}	50.55	49.74	52.68	52.23	2.02
Fat, g kg^{-1}/ Tłuszcz, g kg^{-1}	69.48	68.94	68.10	67.94	1.12
Lactose, g kg^{-1}/ Laktoza, g kg^{-1}	52.61	50.71	54.00	54.35	1.31
Phosphorus, mg kg^{-1}/Fosfor, mg kg^{-1}	1202.2a	1005.4b	1222.2a	1218.7a	15
Calcium, mg kg^{-1}/Wapń, mg kg^{-1}	1534.1	1400.6	1601.6	1584.8	31
Magnesium, mg kg^{-1}/ Magnez, mg kg^{-1}	89.42	88.77	90.68	91.00	1.99
Copper, mg kg^{-1}/Miedź, mg kg^{-1}	1.41c	1.17b	1.61a	1.60a	0.06
Zinc, mg kg^{-1}/ Cynk, mg kg^{-1}	7.51ab	7.17b	8.12a	7.96a	0.78
Żelazo, mg kg^{-1}/ Iron, mg kg^{-1}	2.33	2.17	2.51	2.55	0.03

a, b – values in the same rows with different letters differ significantly at $p \leq 0.05$
a, b – wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

Contents of all mineral elements determined in blood plasma of the sows, both in the period of pregnancy and lactation, as well as in blood plasma of all pigs over the entire fattening period complied with reference values [Winnicka 2008, Frendship and Henry 1996, Klem *et al*. 2010].

In blood plasma of pregnant sows receving the addition of phytase and enzymes hydrolyzing non-starch polysaccharide fractions in the diet (EP group), a significant increase was noted in the content of magnesium and copper as compared to NC group, whereas in the period of lactation the addition of feed enzymes (groups: MP and EP) caused an increase only in calcium level. An insignificant effect of the experimental additives on contents of minerals in blood plasma of the sows, either during pregnancy or lactation, might result from their utilization for the needs of a foetus or for milk production.

Table 4. Microelements contents (P, Ca, Mg) in swine blood plasma
Tabela 4. Zawartość mikroelementów (P, Ca, Mg) w osoczu krwi świń

Specification Wyszczególnienie	Technological group Grupa technologiczna	Feeding groups Grupa doświadczalna				SEM
		PC	NC	MP	EP	
P mmol l^{-1}	pregnancy/ciąża lactation/laktacja	2.24 2.04	1.78 1.70	1.96 1.88	2.25 1.95	0.014 0.015
	$\bar{x}$	2.14	1.74	1.92	2.10	0.017
	starter/starter grower/grower finisher/finiszer	2.34ab 2.26 2.16b	2.03b 2.11 1.75b	2.27ab 1.94 2.15b	2.52a 2.19 2.89a	0.002 0.004 0.011
	$\bar{x}$	2.25ab	1.96b	2.12ab	2.53a	0.012
Ca mmol l^{-1}	pregnancy/ciąża lactation/laktacja	2.07 2.09ab	1.94 1.91b	1.97 2.30a	2.04 2.45a	0.013 0.018
	$\bar{x}$	2.08	1.93	2.14	2.25	0.014
	starter/starter grower/grower finisher/finiszer	2.63b 2.35ab 2.44a	2.14c 2.05b 2.06b	2.87a 2.41a 2.49a	3.10a 2.67a 2.63a	0.026 0.031 0.021
	$\bar{x}$	2.47a	2.06b	2.59a	2.80a	0.022
Mg mmol l^{-1}	pregnancy/ciąża lactation/laktacja	0.97ab 1.07	0.87b 0.94	1.07a 1.21	1.12a 1.19	0.007 0.013
	$\bar{x}$	2.08	1.93	2.14	2.25	0.016
	starter/starter grower/grower finisher/finiszer	1.01 1.09 1.01	0.94 1.00 0.92	1.14 1.16 1.05	1.08 1.17 1.14	0.008 0.017 0.005
	$\bar{x}$	1.04	0.95	1.12	1.13	0.007

a, b – values in the same rows with different letters differ significantly at $p \leq 0.05$
a, b – wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

Quite a different picture may be seen in respect of minerals content assayed in blood plasma of piglets and fatteners. The addition of microbial phytase alone (MP group) or together with the enzymes hydrolyzing the non-starch polysaccharide fractions (EP group) evoked a significant increase in the levels of calcium, copper and zinc in blood plasma of the pigs as compared to the control group (NC). An increased concentration of phosphorus in blood plasma was noted only in the case of pigs receiving a complex of feed enzymes in their feed mixture (EP group).

No works have been found in available literature that would address the effect of multi-enzyme preparations on the contents of mineral elements in milk as well as blood of pigs. However, Jongbloed *et al.* [1997] paid attention to an increased concentration of iron in blood plasma of sows in groups administered microbial phytase and commercial multi-enzymatic preparation (containing microbial phytase and enzymes hydrolyzing the non-starch polysaccharide fractions). In turn, in a study by Kim *et al.* [2005] analyses were made to determine the impact of 1,4-β-xylanse (4000 U g^{-1}) and phytase (4100 U g^{-1}), administered separately or together, on the digestibility of nutrients, calcium and phosphorus in piglets. It demonstrated that the joined addition of enzymatic preparations had a significant effect on the increased digestibility of calcium and phosphorus. In turn, increased contents of minerals in milk of sows receiving the addition of microbial phytase alone were demonstrated in investigations by Czech *et al*. [2004], Grela *et al*. [2000] as well as Grela and Kumek [2002]. The results achieved indicate better absorption of such elements as: phosphorus, calcium, copper, iron and zinc from feed mixtures owing to the effect of microbial phytase on chelate complexes of phytic acid [Pallauf *et al*. 1994]. A research conducted by Czech *et al*. [2004] also confirm the beneficial effect of microbial phytase on contents of mineral elements in colostrum, milk and blood plasma of sows. Similar findings were reported by Liesegang et al. [2005]. According to Grela *et al*. [2000], the addition of microbial phytase caused a significant increase in the contents of phosphorus ($p \leq 0.05$) and zinc ($p \leq 0.01$) in colostrum and milk of investigated sows.

Table 5. Microelements contents (Cu, Zn, Fe) in swine blood plasma
Tabela 5. Zawartość mikroelementów (Cu, Zn, Fe) w osoczu krwi świń

Specification Wyszczególnienie	Technological group Grupa technologiczna	Feeding groups Grupa doświadczalna				SEM
		PC	NC	MP	EP	
Cu μmol l^{-1}	pregnancy/ciąża	26.54b	24.89c	27.57ab	29.33a	0.22
	lactation/laktacja	25.73	24.34	25.73	26.14	0.26
	$\bar{x}$	26.14ab	24.62b	26.65ab	27.74a	0.21
	starter/starter	26.09b	24.26b	27.41a	28.13a	0.25
	grower/grower	27.08ab	24.69b	28.98a	30.08a	0.23
	finisher/finiszer	25.32	24.44	26.16	26.44	0.17
	$\bar{x}$	26.16ab	24.46b	27.52a	28.22a	0.20
Zn μmol l^{-1}	pregnancy/ciąża	19.41	18.71	17.70	19.61	0.33
	lactation/laktacja	25.10a	22.71b	22.25b	21.80b	0.32
	$\bar{x}$	22.26	20.71	19.98	20.71	0.25
	starter/starter	24.51b	20.02c	24.27b	27.93a	0.31
	grower/grower	20.71b	15.09c	19.58b	24.01a	0.44
	finisher/finiszer	19.67b	17.15c	17.96bc	22.50a	0.51
	$\bar{x}$	21.63b	17.42c	20.60b	24.81a	0.33
Fe μmol l^{-1}	pregnancy/ciąża	20.59	18.03	21.56	22.09	0.02
	lactation/laktacja	18.66	17.57	17.06	17.24	0.21
	$\bar{x}$	19.63	17.80	19.31	19.67	0.20
	starter/starter	21.88b	19.56b	25.85a	25.42a	0.15
	grower/grower	22.22b	20.09c	22.11b	26.57a	0.27
	finisher/finiszer	25.12a	21.04b	26.04a	26.77a	0.17
	$\bar{x}$	23.07ab	20.23b	24.67ab	26.25a	0.13

a, b, c – values in the same rows with different letters differ significantly at $p \leq 0.05$
a, b, c – wartości w wierszach oznaczone różnymi literami różnią się istotnie przy $p \leq 0,05$

CONCLUSIONS

The addition of microbial phytase either alone or with the enzymes hydrolyzing the non-starch polysaccharide fractions contributed to increased contents of phosphorus, copper and zinc in sows' milk. In contrast, it did not evoke any significant changes in contents of calcium, magnesium, iron, nor in these of protein, fat and lactose in the milk of sows.

The feed enzymes contributed to a significant increase in the concentrations of minerals (except for magnesium) in blood plasma of piglets and fatteners, whereas so significant changes were not observed in the blood plasma of sows.

REFERENCES

AOAC, 2000. Official Methods of Analysis. International, 17th Ed., AOAC Inter., Gaithersburg, MD, USA.

Blaabjerg K., Carlsson N.G., Hansen-Møller J., Poulsen H.D., 2010. Effect of heat-treatment, phytase, xylanase and soaking time on inositol phosphate degradation *in vitro* in wheat, soybean meal and rapeseed cake. Anim. Feed Sci. Technol., 162, 3–4, 123–134.

Cowieson A.J., Acamovic T., Bedford M.R., 2006. Using the precision-feeding bioassay to determine the efficacy of exogenous enzymes-A new perspective. Anim. Feed Sci. Technol. 129, 1–2, 149–158.

Czech A., Grela E.R., Klebaniuk R., Bil T., 2004. Zawartość Mg, P i Ca w mleku i osoczu krwi loch żywionych paszą z dodatkiem fitazy mikrobiologicznej. J. Element. 9(4), 569–577.

Engelen A.J., Vander Heeft F.C., Randsdorp P.H.G., Smit E.L.C., 1994. Simple and rapid determination of phytase activity. J. ADAC Int. 77, 760–765.

Fiske C.H., Subbarow Y., 1925. The colorimetric determination of phosphorus. J. Biol. Chem. 66(2), 375–400.

Friendship R.M., Henry S.C., 1996. Cardiovascular system, haematology and clinical chemistry. (In:) Diseases of swine, Eds. Leman A.D., Straw B.E., Mengeling W.L., D'Allaire S., Taylor D.J., Iowa State Univ. Press, USA, 3–11.

Grela E.R, Kumek R., 2002 Wpływ dodatku fitazy i kwasu mrówkowego na wzrost prosiąt oraz skład siary i mleka loch. Med. Wet. 58(5), 375–377.

Grela E.R., Kumek R., Lipiec A., 2000. The influence of microbial phytase and citric acid in sow feeding on mineral components availability during pregnancy and lactation. Proceedings of the International Symposium on phytase in animal nutrition „Phytase in animal nutrition", 8–9 June, Lublin, 56–60.

Jondreville C., Schlegel P., Hillion S., Chagneau A.M., Nys Y., 2007. Effects of additional zinc and phytase on zinc availability in piglets and chicks fed diets containing different amounts of phytates. Liv. Sci. 109, 1–3, 60–62.

Jongbloed A.W., Kemme P.A., Mroz Z., Van Diepen H.T.M., 1997. Efficacy, use and application of microbial phytase in pig production: a review. Biotechnology in the Feed Industry. Proceeding of Alltech's 16th Annual Symposium., Edited by T.P. Lyons and K. A. Jacques, 111–129.

Kim J.C., Simmins P.H., Mullan B.P., Pluske J.R., 2005. The effect of wheat phosphorus content and supplemental enzymes on digestibility and growth performance of weaner pigs. Anim. Feed Sci. Technol. 118, 1–2, 139–152.

Klem T.B., Bleken E., Morberg H., Thoresen S.I., Framstad T., 2010. Hematologic and biochemical reference intervals for Norwegian crossbreed grower pigs. Vet. Clin. Pathol. 39(2), 221–226.

Liesegang A., Loch L., Bürgi E., Risteli J., 2005. Influence of phytase added to a vegetarian diet on bone metabolism in pregnant and lactating sows. J. Anim. Physiol. Anim. Nutr. 89, 3–6, 120–128.

Mosenthin R., Broz J., 2010. Mineral digestibility and environmental issues. Efficacy and interactions of phytases. Liv. Sci. 134, 1–3, 258–260.

Normy żywienia świń, 1993. IFiŻZ PAN, Omnitech Press, Warszawa.

Oberleas D., 1971. The determination of phytate and inositol phosphates. [In:] Methods of biochemical analysis. D. Glick (ed.), Wiley and Sons, New York.

Omogbenigun F.O., Nyachoti C.M., Slominski B.A., 2004. Dietary supplementation with multienzyme preparations improves nutrient utilization and growth performance in weaned pigs. J. Anim. Sci. 82, 1053–1061.

Pallauf J., Rimbach G., Pippig S., Schindler B., Most E., 1994. Effect of phytase supplementation to a phytase-rich died based on wheat, barley and soya on the bioavailability of dietary phosphorus, calcium, magnesium, zinc and protein in piglets. Agribiol. Res. 47(1), 39–48.

Peter C.M., Parr T.M., Parr E.N.,Webel D.M., Baker D.H., 2001. The effects of phytase on growth performance, carcass characteristics, and bone mineralization of late-finishing pigs fed maize-soyabean meal diets containing no supplemental phosphorus, zinc, copper and manganese. Anim. Feed Sci. Technol. 94, 199–205.

Rokicki E., Kolbuszewski T., 1996. Higiena zwierząt. Fundacja „Rozwój SGGW", Warszawa.

Shelton J.L., LeMieux F.M., Southern L.L., Bidner T.D., 2005. Effect of microbial phytase addition with or without the trace mineral premix in nursery, growing, and finishing pig diets. J. Anim. Sci. 83, 376–385.

Sugiura S.H., Gabaudan J., Dong F.M., Hardy R.W., 2001. Dietary microbial phytase supplementation and utilization of phosphorus, trace minerals and protein by rainbow trout (Oncorhynchus mykiss (Walbaum) fed soybean meal diets. Aquacult. Res. 32, 583–592.

Varley P.F., Flynn B., Callan J.J., O'Doherty J.V., 2011. Effect of phytase level in a low phosphorus diet on performance and bone development in weaner pigs and the subsequent effect on finisher pig bone development. Liv. Sci. 138, 1–3, 152–158.

Winnicka A., 2008. Wartości referencyjne podstawowych badań laboratoryjnych w weterynarii. Wyd. SGGW, Warszawa.

Yin Y.L, Baidoo S.K., Schulze H., Simmins P.H., 2001. Effects of supplementing diets containing hulless barley varieties having different levels of non-starch polysaccharides with ß-glucanase and xylanase on the physiological status of the gastrointestinal tract and nutrient digestibility of weaned pigs. Liv. Prod. Sci. 71, 97–107.

Streszczenie. Celem pracy było przeanalizowanie, czy i na ile dodatek enzymów hydrolizujących frakcje polisacharydów nieskrobiowych lub rozkładających fityniany w żywieniu świń w pełnym cyklu (lochy w okresie ciąży i laktacji, warchlaki oraz tuczniki) może wpłynąć na wykorzystanie składników mineralnych. Badania na świniach w pełnym cyklu reprodukcyjnym zostały zrealizowane w pięciu okresach: lochy prośne, lochy karmiące, prosięta, tuczniki młodsze oraz tucz końcowy. W doświadczeniu utworzono cztery grupy doświadczalne, w tym dwie kontrolne: pozytywną (KP), w której zastosowano jako źródło fosforu dodatek fosforanu dwuwapniowego oraz kontrolę negatywną (KN), w której źródłem fosforu były wyłącznie pasze roślinne. Świnie w grupie FM otrzymywały mieszankę jak w grupie KN, ale uzupełnioną fitazą mikrobiologiczną, a zwierzęta w grupie PE żywiono również mieszanką tak jak w grupie KN, ale z dodatkiem preparatu wieloenzymatycznego, w skład którego wchodziły zarówno fitaza mikrobiologiczna, jak i enzymy uczestniczące w hydrolizie frakcji polisacharydów nieskrobiowych (ksylanaza, β-glukanaza, celulaza). Dodatek fitazy mikrobiologicznej czy fitazy mikrobiologicznej łącznie z enzymami hydrolizującymi frakcje polisacharydów nieskrobiowych przyczynił się do wzrostu zawartości fosforu, miedzi i cynku w mleku loch. Nie spowodował natomiast znaczących zmian w zawartości wapnia, magnezu oraz żelaza, a także białka, tłuszczu i laktozy w mleku loch. Enzymy paszowe przyczyniły się do znaczącego wzrostu zawartości składników mineralnych (z wyjątkiem magnezu) w osoczu krwi prosiąt i tuczników, nie zanotowano natomiast tak istotnych zmian w osoczu krwi loch.

Słowa kluczowe: świnie, enzymy paszowe, krew