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Efficiency of phytase in growing-finishing pig feeding

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Summary

The effect of growing doses of phytase added to feed mixtures for growing pigs on their performance, carcass evaluation, meat quality and bone mineralization was evaluated on 144 pigs allocated to 6 experimental groups, 12 barrows and 12 gilts each. All animals were fed a standard feed mixture. In Group I (PC) the mixture was supplemented with calcium phosphate, Group II (NC) was fed the mixture with no supplement, while Groups III-VI were fed mixtures supplemented with 125, 250, 375 or 500 PPU/kg of phytase, respectively.

It was found that pigs receiving the highest dose of phytase had significantly better body weight gains than the NC group. There was no difference in feed conversion and carcass traits though animals receiving the lowest dose of the enzyme had the thinnest layer of backfat. The meat of all animals receiving feed without the P supplement, but especially of those from groups NC and III, had better water holding capacity index than that of the PC group. The highest alkaline phosphatase activity was found in the blood serum of the NC animals. There were also differences in bone wall thickness between NC and group VI receiving the highest dose of phytase. Bones of animals from the NC group had also the lowest yielding load as well as the Ca and P content in the bone cortex.

Keywords: phytase, pig feeding, meat quality, bone mineralization

Cereals are the basic constituents of feeds for farm animals. In feeds for pigs mainly wheat and barley are used. In these cereals phosphorus is present mostly in the form of phytates which constitute 65-80% of the total P (12) and are not readily available for pigs (17). Phosphorus is one of the essential minerals. It is necessary for bone formation and for many other metabolic functions. In order to meet animal requirements, feed is usually supplemented with inorganic salts of P. Another way is to render phytate-bound P nutritionally available for pigs by supplementing feed with phytase (4, 28).

Initially the animal experiments with phytase (14) gave good results but enzyme was too expensive to be used in practice. Now phytase is commercially produced and can be used in farm animal feeding. Phytase is successfully used in pig nutrition but results of experiments are inconsistent. While Silva et al. (24) found improved growing pig performance when phytase was added to feed, Powers et al. (18) did not find such a relationship. According to most experiments phytase improved P and Ca availability (12, 27) and according to some data also energy, protein and amino acid utilisation (13) though other experiments did not confirm this last information (16).

The objective of the present experiment was to study the effect of growing doses of phytase added to feed mixtures for growing pigs on the performance, carcass evaluation, meat quality and bone mineralization of fatteners.

Material and methods

The experiment was carried out on 72 barrows and 72 gilts allocated to 6 experimental groups. Animals originated from Polish Landrace × Polish Large White sows mated with a Duroc × Pietrain boar. Pigs were kept in pens (4 animals per pen), 4 pens per group under restricted feeding conditions (from 1.4 kg of feed per animal daily between 20-30 kg body weight to 3.2 kg between 80-115 kg BW). Group I (Positive Control – PC) received feed mixture 1 containing dicalcium phosphate, group II (Negative Control – NC) received feed mixture 2 with no phosphate added. Groups III-VI received feed mixture 2 supplemented with phytase preparation in the amounts of 125, 250, 375 or 500 PPU per kg of feed, respectively. Enzyme preparation (New Phytase) was produced by AB Enzymes Oy, Rajamäki. Composition of feed mixtures is given in tab. 1. Pigs were weighed every two weeks and feed consumption was monitored. After slaughter the right sides of carcasses were evaluated.

The content of basic nutrients in mixtures was determined according to standard methods (1). The calcium content of feeds was analysed by atomic absorption method (1) and the phosphorus content was estimated colorimetrically using the vanadate-molybdate method (1).

Activity of alkaline phosphatese was determined colormetricall according to Rick (19). Meat colour was estimated

Tab. 1. Composition and nutritional value of feed mixtures

Ingredients	Fatteners 31-60 kg body weight		Fatteners 61-115 kg body weight	
	control positive (PC)	control negative (NC)	control positive (PC)	control negative (NC)
Barley	20.0	20.0	20.0	20.0
Maize	42.45	42.85	49.75	49.95
Oat	10.0	10.0	10.0	10.0
Soybean meal	10.0	10.0	5.0	5.0
Rapeseed meal	15.0	15.0	13.0	13.0
Salt	0.3	0.3	0.3	0.3
Fodder chalk	0.8	1.2	0.9	1.1
Premix PT-1[a]/PT-2[b]	0.5[a]	0.5[a]	0.5[b]	0.5[b]
Lys crystal	0.15	0.15	0.15	0.15
Dicalcium phosphate	0.8	–	0.4	–
1 kg of feed mixture contain:				
ME (MJ) *	12.43	12.55	12.43	12.50
Crude protein (%)	17.22	17.40	15.50	15.65
Crude fat (%)	3.03	3.25	3.44	3.38
Crude fiber (%)	5.58	5.50	5.20	5.48
Crude ash (%)	5.13	4.68	4.49	3.92
N-free extract (%)	58.62	58.57	59.58	59.69
Lys (g)	9.40	9.41	8.02	8.06
Met + Cys (g)	6.72	6.74	6.30	6.32
Ca (g)	8.30	8.10	7.10	7.00
Total phosphate (g)	5.20	4.60	4.80	3.80
P phytate **	3.06	3.07	2.87	2.88

Explanations: a – PT-1 premix composition: Vitamine: A – 1 600 000 IU; D_3 – 200 000 IU; E – 6.0 g; K_3 – 0.3 g; B_1 – 0.2 g; B_2 – 0.6 g; B_6 – 0.3 g; B_{12} – 0.002 g; Pantothenic acid – 2.0 g; Choline cloride – 40g; Folic acid – 0.04 g; Nicotinic acid – 3.0 g; Magnesium – 8.0 g; Manganese – 10.0 g; Iodine – 0.06 g; Zinc – 14.0 g; Iron – 20.0 g; Copper – 4.0 g; Cobalt – 0.04 g; Selenium – 0.04 g; complete limestone to 1000.0 g.
b – PT-2 premix composition: Vitamine: A – 1 600 000 IU; D_3 – 200 000 IU; E – 4.0 g; K_3 – 0.3 g; B_2 – 0.6 g; B_{12} – 0.002 g; Pantothenic acid – 1.6 g; Choline cloride – 40 g; Nicotinic acid – 2.0 g; Magnesium – 8.0 g; Manganese – 10.0 g; Iodine – 0.06 g; Zinc – 14.0 g; Iron – 10.0 g; Copper – 4.0 g; Cobalt – 0.04 g; Selenium – 0.04 g; complete limestone to 1000.0 g.
* – ME calculated by the equation of Hoffmann and Schiemann (15); ** – Phytate P calculated value based on data by Eeckhout et al. (5)

in the samples of *longissimus* muscle using the Minolta colorimeter after slaughter. Water holding capacity was estimated according to Grau and Hamm (7).

Femur bones were prepared, cleaned of soft tissues, weighed and stored frozen (–20°C) for analysis. Mechanical properties (breaking force, yielding load) in a three point bending test were determined using an Instron 4302 apparatus (a constant speed of head – 10 N per min.). Cortex thickness and circular were measured in the breaking places using an electronic slide calliper.

Statistical analysis of treatment effects was conducted by two-way analysis of variance (MANOVA) with comparison of means by Duncan's multiple range test at $p \leq 0.05$ and $p \leq 0.01$ levels of significance using the Statistica v 5.1 package.

Results and discussion

There was no significant differences in body weight gains of pigs except NC and group VI (receiving the highest dose of phytase) – 757 and 804 g per day, respectively (tab. 2). Feed conversion and results of carcass evaluation were also very similar in all experimental groups. According to many authors, phytase has no effect on body weight gains of pigs (18, 22). Helander and Partanen (9) found improved pig body weight gains but only when a low-phosphorus diet was used. Also Cromwell et al. (3) found better performance of pigs fed a low-phosphorus diet but only when the highest dose of phytase (750 U/kg) was given. This last result is similar to that obtained in the present experiment in which only the highest dose of phytase, and only compared to NC diet, gave significantly better body weight gains.

Pigs receiving phytase had a slightly bigger loin eye area than those from the PC group but these differences were not statistically significant (tab. 3). Significant differences were found only in terms of backfat thickness.

Lack of differences in the results of carcass evaluation in this study is in accordance with the results of Harper et al. (8) and Walz and Pallauf (26) and could be due to restricted feeding. Shelton et al. (21) found a lower dressing percentage and increased backfat thickness in pigs fed reduced Ca and P diet when compared to pigs fed a diet with phytase. No such relation between NC and other groups was found in this experiment. In the present experiment only the tendency towards bigger loin eye area in pigs fed higher doses of phytase was observed but these differences were not statistically significant. Similar results were found by Harper et al. (8).

There were no differences in meat quality in terms of its colour and acidity, which is in accordance with the results obtained by Shelton et al. (23) (tab. 4). Meat pH measured 45 minutes after slaughter varied from 6.27 to 6.45 and measured after 24 h cooling varied from 5.49 to 5.56. Water holding capacity was significantly lower in animals from the NC group and those receiving the lowest dose of phytase when compared to the PC group. The meat of animals receiving no phosphate (NC) and receiving phytase (groups III-VI) had better water holding capacity than that from the PC group.

In an experiment by the same authors (23) a phytase supplement levelled drip loss of meat of pigs fed a Ca and P deficient diet to that of the control group. Also in this experiment the NC group and the one fed the lowest amount of phytase had the lower water holding capacity index which was slightly raised by enzyme addition.

Alkaline phosphatase activity was the highest in the blood of animals from the NC group. Significant differences were found between this treatment and the groups receiving 125 or 250 PPU of phytase per kg of feed. The highest activity of alkaline phosphatase, enzy-

Tab. 2. Pig performance

Parameters	Groups						Sex		SEM
	I – PC	II – NC	III – NC	IV – NC	V – NC	VI – NC	Gilts	Barrows	
Initial BW, kg	29.9	30.7	30.2	31.4	31.2	29.5	30.0	31.0	0.354
Final BW, kg	115.0	116.0	116.0	115.6	115.3	114.5	115.1	115.1	0.361
Fattening days	112	113	112	108	106	106	113^{B}	107^{A}	0.912
Average daily weight gain in fattening periods (g):									
31-60 kg	630	623	632	640	648	657	625^{a}	651^{b}	5.246
61-115 kg	869	867	891	882	900	923	870^{a}	907^{b}	8.435
31-115 kg	761^{ab}	757^{a}	773^{ab}	779^{ab}	792^{ab}	804^{b}	761^{A}	794^{B}	5.779
Average feed conversion per 1 kg of body weight gain (kg):									
31-60 kg	3.24	3.20	3.13	3.09	3.02	3.09	3.19	3.06	0.038
61-115 kg	3.42	3.48	3.50	3.45	3.42	3.22	3.49	3.34	0.049
31-115 kg	3.35	3.38	3.37	3.32	3.26	3.26	3.38	3.27	0.031

Explanations: values in the same rows with different letters differ significantly a, b – $p \leq 0.05$, A, B – $p \leq 0.01$

Tab. 3. Carcass analysis

Carcass parameters	Groups						Sex		SEM
	I – PC	II – NC	III – NC	IV – NC	V – NC	VI – NC	Gilts	Barrows	
BW at slaughter, kg	114.50	114.40	114.30	114.80	115.70	114.90	114.80	114.70	0.326
Cold dressing yield, %	79.10	78.70	78.70	79.00	78.30	78.90	78.70	78.80	0.138
Meat in primal cuts, kg	24.73	25.53	24.77	24.56	24.54	25.23	25.00	24.78	0.212
Meatiness of carcass, %	54.65	54.97	54.85	54.66	54.58	55.85	55.90	53.95	0.483
Loin eye area, cm^2	51.61	52.26	53.60	53.59	53.59	53.87	53.56	52.61	0.705
Backfat of 5 meas., cm	3.02^{b}	2.78^{ab}	2.64^{a}	3.00^{b}	3.00^{b}	2.81^{ab}	2.79	2.96	0.046
Backfat in point C, cm	1.45	1.40	1.46	1.47	1.47	1.38	1.34^{a}	1.53^{b}	0.039
Liver, kg	1.90	1.87	1.88	1.93	1.92	1.84	1.87	1.91	0.020

Explanations: values in the same rows with different letters differ significantly a, b – $p \leq 0.05$

Tab. 4. Meat quality and alkaline phosphatase in blood serum

Parameters	Groups						Sex		SEM
	I – PC	II – NC	III – NC	IV – NC	V – NC	VI – NC	Gilts	Barrows	
Water holding capacity index, %	26.4^{b}	23.0^{a}	23.3^{a}	24.0^{ab}	25.8^{ab}	24.2^{ab}	24.62	24.28	0.381
Meat colour (Hunter scale):									
– lightness	46.28	47.01	45.58	46.04	46.99	45.06	46.49	46.49	0.302
– saturation in red	12.76^{ab}	12.47^{ab}	12.28^{a}	12.41^{ab}	12.95^{b}	12.68^{ab}	12.59	12.59	0.082
– saturation in yellow	2.98	2.99	2.70	2.84	3.19	2.70	2.95	2.95	0.072
pH 45 min after slaughter	6.29	6.37	6.44	6.31	6.27	6.36	6.32	6.36	0.025
pH after 24 h cooling	5.48	5.57	5.51	5.50	5.50	5.55	5.51	5.52	0.016
Alkaline phosphatase in blood serum, U/L	240^{bcAB}	270^{cB}	192^{aA}	214^{abAB}	248^{bcAB}	242^{bcAB}	225	243	6.498

Explanations: values in the same rows with different letters differ significantly a, b, c – $p \leq 0.05$, A, B – $p \leq 0.01$

me which is a good marker of bone turnover (2), found in the NC group could be due to the low level of P in feed (20). A higher plasma alkaline phosphatase activity in pigs with low P concentration was found also by Stahl et al. (25). On the other hand, in contrast to the results of this experiment, Gentile et al. (6) found plasma alkaline phosphatase activity inversely correlated with dietary phytase doses.

There were also differences in bone wall thickness between NC and group VI receiving the highest dose of

Tab. 5. Some characteristics of the femur bone

Parameters	Groups						Sex		SEM
	I – PC	II – NC	III – NC	IV – NC	V – NC	VI – NC	Gilts	Barrows	
Fresh weigth, g	346	328	331	327	332	343	332	337	2.940
Length, cm	21.62	21.28	21.27	21.29	21.48	21.51	21.52	21.30	0.079
Circular, cm	7.83	7.79	7.88	7.77	7.81	7.89	7.86	7.80	0.041
Wall thickness, mm	4.74^{ab}	4.40^{a}	4.59^{ab}	4.51^{ab}	4.51^{ab}	4.80^{b}	4.53	4.66	0.048
Breaking force, kN	5.79	5.21	5.32	5.97	5.37	5.60	5.62	5.46	0.108
Yielding load, kN	3.74^{b}	2.83^{a}	3.14^{ab}	3.54^{ab}	3.12^{ab}	3.37^{ab}	3.40	3.18	0.099
Ca content (% in cortex dry matter)	254.1^{abAB}	247.8^{aA}	254.5^{abAB}	258.1^{bcBC}	258.4^{bcBC}	263.6^{cC}	255.5	256.7	1.112
P content (% in cortex dry matter)	124.9^{b}	121.9^{a}	125.5^{b}	125.1^{b}	124.1^{ab}	124.2^{ab}	124.8	123.8	0.402

Explanations: values in the same rows with different letters differ significantly a, b, c – $p \leq 0.05$, A, B, C – $p \leq 0.01$

phytase (tab. 5). The bones of animals from the NC group had also the lowest yielding load and Ca and P content in the bone cortex. Increasing level of phytase additive raised the amount of Ca deposited in the femur bone. It is known that the effect of phytase supplement is most apparent in bone metabolism (13, 24) but its effects depend on the origin of enzyme. Jakob et al. (10) found improved bone mineralization (higher content of P and Ca) using one preparation of phytase but no such effect was observed when another preparation was used. Also in the present experiment a higher content of Ca in the bone cortex of pigs receiving higher doses of phytase was found. In the case of the P content the differences were not so significant. It is not in accordance with the results by Shelton et al. (23) who found no difference in the Ca and P content between PC, NC and groups supplemented with phytase. The improvement of bone strength (breaking force) after supplementing feed with phytase was not observed in the present experiment. Similar results were obtained by Cromwell et al. (3).

From the obtained results it may be concluded that increasing phytase levels in diets from 0 to 500 PPU/kg improves pig body weight gains but has no effect on carcass traits. Phytase can improve the water holding capacity of meat but only in animals receiving a phosphorus deficient diet. In high doses phytase can also increase the Ca content in bones.

References

1. AOAC: Association of Official Analytical Chemists. Official Method of Analysis. Arlington VA, USA 1990.
2. *Avbersek-Luznik I., Gmeiner Stopar T., Marc J.*: Activity of mass concentration of bone-specific alkaline phosphatase as a marker of bone formation. Clin. Chem. Lab. Med. 2007, 45, 1014-1018.
3. *Cromwell G. L., Lindemann L. D., Monegue H. J.*: Effects of phytase in low Ca, low P diets on performance and bone strength of finishing pigs. J. Anim. Sci. 1997, 75, Suppl. 1, Abstr 69.
4. *Czech A.*: Efektywność fitazy w żywieniu zwierząt. Medycyna Wet. 2007, 63, 1034-1039.
5. *Eeckhout W., De Paepe M.*: Total phosphorus, phytae-phosphorus and phytase activity in plant feedstuffs. Anim. Feed sci. Technol. 1994, 47, 19-29.
6. *Gentile J. M., Roneker K. R., Crowe S. E., Pond W. G., Lei X. G.*: Effectiveness of an experimental consensus phytase in improving dietary phytate-phosphorus utilization by weanling pigs. J. Anim. Sci. 2003, 81, 2751-2757.
7. *Grau R., Hamm R.*: Eine einfache Methode zur Bestimmung der Wasserbindung im Muskel. Naturwissenschaften 1953, 40, 29.
8. *Harper A. F., Kornegay E. T., Schell T. C.*: Phytase supplementation of low--phosphorus growing-finishing pig diets improves performance, phosphorus digestibility, and bone mineralization and reduces phosphorus excretion. J. Anim. Sci. 1997, 75, 3174-3186.
9. *Helander E., Partanen K.*: Effect of phosphorus level and microbial phytase supplementation on the performance and bone mineralization in pigs. Acta Acric. Scand. Ser. A, Animal Sci. 1997, 47, 159-167.
10. *Jakob S., Maillard R., Nore O., Geraert P. A.*: Efficacy of new phytase preparation on phosphorus and calcium digestibility and on bone mineralization in weanling piglets. J. Anim. Sci. 2002, 80, Suppl. 1, Abstr. 1376.
11. *Liesegang A., Loch L., Bürgi E., Risteli J.*: Influence of phytase added to a vegetarian diet on bone metabolism in pregnant and lactating sows. J. Anim. Physiol. Anim. Nutr. 2005, 89, 120-128.
12. *Liu K., Peterson K. L., Raboy V.*: Comparison of the phosphorus and mineral concentration in bran and abraded kernel fractions of a normal barley (Hordeum vulgare) cultivar versus four low phytic acid isolines. J. Agric. Food Chem. 2007, 55, 4453-4460.
13. *Mroz Z.*: Phytase does improve energy, protein, and amino acid utilization. J. Anim. Sci. 2002. 80, Suppl. 1, Abstr. 217.
14. *Nelson T. S., Shieh T. R., Wodzinski R. J., Ware J. H.*: The availability of phytate phosphorus in soybean meal before and after treatment with a mold phytase. Poult. Sci. 1968, 47, 1842-1848.
15. Normy Zywienia świń. Wartość pokarmowa pasz. Instytut Fizjologii i Żywienia Zwierząt PAN 1993, 87.
16. *Park J. S., Carter S. D., Schneider J. D., Morillo T. B.*: Effects of a solid-state fermented phytase on growth performance and phosphorus excretion of growing pigs fed corn-soybean meal diets. J. Anim. Sci. 2003, 81, Suppl. 2, Abstr. 140.
17. *Pointillart A., Fontaine N., Tomasset M.*: Phytate phosphorus utilization and intestinal phosphatases in pigs fed low phosphorus: wheat or corn diets. Nutr. Rep. Intern. 1984, 29, 473-483.
18. *Powers W. J., Fritz E. R., Fehr W., Angel R.*: Total and water soluble phosphorus excretion from swine fed low-phytate soybeans. J. Anim. Sci. 2006, 84, 1907--1915.
19. *Rick W.*: Klinische Chemie und Mikroskopie. 6th edition Springer Verlag, Berlin 1990, p. 294.
20. *Schanler R. J., Abrams S. A., Sheng H. P.*: Calcium and phosphorus deficiencies affect mineral distribution in neonatal miniature piglets. Am. J. Clin. Nutr. 1991, 54, 420-424.
21. *Shelton J. L., Southern L. L., Bidner T. D.*: Effect of phytase on growth performance, plasma metabolites, carcass traits, and pork quality in growing-finishing pigs. J. Anim. Sci. 2003a, 81, Suppl. 2, Abstr. 144.
22. *Shelton J. L., Southern L. L., Bidner T. D., Persica M. A., Braun J., Cousins B., McKnight F.*: Effect of microbial phytase on energy availability, and lipid and protein deposition in growing swine. J. Anim. Sci. 2003b, 81, 2053-2062.
23. *Shelton J. L., Southern L. L., LeMieux F. M., Bidner T. D., Page T. G.*: Effects of microbial phytase, low calcium and phosphorus, and removing the dietary trace mineral premix on carcass traits, pork quality, plasma metabolites, and tissue mineral content in growing-finishing pigs. J. Anim. Sci. 2004, 82, 2630-2639.
24. *Silva H. O., Fialho E. T., Lima J. A. F., Murgas L. D. S., de Freitas R. T. F.*: Utilization of phytase in diets for growing pigs – ileal AA digestibility, performance and mineral excretion. J. Anim. Sci. 2004, 82, Suppl. 1, Abstr. T51.
25. *Stahl C. H., Roneker K. R., Pond W. G., Lei X. G.*: Effects of combining three fungal phytases with a bacterial phytase on plasma phosphorus status of weanling pigs fed a corn-soy diet. J. Anim. Sci. 2004, 82, 1725-1731.
26. *Walz O. P., Pallauf J.*: The effect of the combination of microbial phytase and amino acid supplementation of diets for finishing pigs on P and N excretion and carcass quality. Arch. Tierernähr. 2003, 57, 413-428.
27. *Woyengo T. A., Sands J. S., Guenter W., Nyachoti C. M.*: Nutrient digestibility in growing pigs fed wheat-based diets supplemented with phytase and xylanase alone or in combination. J. Anim. Sci. 2007, 85, Suppl. 2, Abstr. 82.
28. *Zimmermann B., Lantzsch H.-J., Mosenthin R., Biesalski H. K., Drochner W.*: Additivity of the effect of cereal and microbial phytases on apparent phosphorus absorption in growing pigs fed diets with marginal P supply. Anim. Feed Sci. Technol. 2003, 104, 143-152.

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