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Effect of microbial phytase supplement to feed for sows on apparent digestibility of P, Ca and crude protein and reproductive parameters in two consecutive reproduction cycles

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Summary

The effect of a phytase supplement to diet for sows during two reproduction cycles on P, Ca and protein digestibility as well as the reproductive traits was estimated on 36 crossbred sows. From mating to the 70th day of pregnancy the sows were kept in group cages, 4 animals in each cage. From the 71st to the 100th day of pregnancy sows were housed individually. At the 100th day of pregnancy sows were moved into the farrowing hall and kept individually. The same sows allocated to the same experimental groups were used in both reproduction cycles. In both cycles sows received the same feed mixtures. Diet was supplemented with calcium phosphate (group I positive control, PC) or phytase 125, 250, 375 or 10000 PU per 1 kg of mixture (in diets III, IV, V and VI respectively). Negative control (II – NC) was also used. Experimental feeds were fed to sows starting from mating until piglet weaning i.e. when piglets reached the 28th day of age. Digestibility studies were performed in two experimental periods: from day 71 to 97 of pregnancy (faeces collection on days 93-97 of pregnancy) and from day 11 to 25 of lactation (faeces collection on days 20-24). Digestibility of CP, Ca and P was the lowest in the NC group, both in the pregnant and lactating sows, and it was significantly improved by phytase supplement. The addition of 375 PPU of phytase improved P digestibility from 42.6 (PC) to 48.3% in the case of pregnant sows and from 48.0 to 52.9% in the case of lactating ones. The digestibility of Ca was improved from 31.6 to 37.2 and from 41.4 to 51.2%, respectively. The effect of phytase on crude protein digestibility was lower. It was found that phytase did not affect the sows' reproductive parameters in either production cycle, either in pregnant or lactating sows.

Keywords: sows, phytase, phosphorus, calcium, apparent digestibility

Cereals are the main component of feeds for pigs. It is known that phytates are the main phosphorus (P) storage form in their grains and it is not available for monogastric animals (20). An insufficient supply of P for pigs results in a significant loss of bones (14) and growth retardation (22). Especially during gestation and lactation large P quantities are needed (15).

If a feed with a high proportion of cereals is fed to pigs, large amounts of P are excreted in the faeces, which is a source of contamination for the environment (21). There is also a need for mineral supplementation, which increases the cost of production. The way of avoiding this inconvenience is supplementing the feed with phytase which degrades phytates and renders phytate-bound P nutritionally available to pigs (24).

There is a great deal of information on using phytase in feeding growing pigs (6, 23); data on using it in feeding sows are limited, though Männer and Simon (17) found effectiveness of phytase in pregnant and lactating sows comparable to that in growing pigs. Baidoo et al. (2) investigated the effects of phytase on P utilization and the lactation performance of sows allotted to treatments on day 100 of gestation. They found the coefficient of total tract apparent digestibility of total phosphorus, organic phosphorus, crude protein and organic matter significantly ($P < 0.01$) higher in experimental than in control sows. Also Kemme et al.

(11) found that the apparent total tract digestibility of Ca, Mg and total P was improved by a microbial phytase supplement but the effects depended on the stage of lactation. According to Liesegang et al. (15) a phytase supplement can be used to keep P in the diet at a lower level without negative consequences for sows' bone quality.

To check the potential toxic effect of high doses of phytase or its possible further positive effect which was found by Jongbloed et al. (9) the additional group receiving 10 000 PPU of enzyme was used in the present experiment.

Kemme et al. (10) found a decline in P and Ca digestibility with an increasing parity number and according to them this is unclear and needs further attention. Also according to Evarts et al. (5) the reproductive performance and mineral balance in sows are different in successive reproduction cycles; therefore in this experiment reproductive performance and crude protein, P, and Ca digestibility were checked in two consecutive parities.

The aim of this experiment was to estimate the effect of different phytase supplements to the sow feed mixture on the apparent digestibility of P, Ca and protein as well as on the reproductive parameters of pregnant and lactating sows in two reproduction cycles.

Material and methods

Thirty-six crossbred sows (Polish Landrace × Large White Polish) were allocated to 6 experimental groups. All sows had similar body weight before mating and they were after the 2nd parity. From mating to the 70th day of pregnancy the sows were kept in group cages, 4 animals in each cage. From the 71th to the 100th day of pregnancy sows were housed individually. At the 100th day of pregnancy sows were moved to the farrowing hall and kept individually. The same sows allocated to the same experimental groups were used in both reproduction cycles. All cages had concrete floors covered with straw. Sows received the same feed mixture (tab. 1) supplemented with dicalcium phosphate (I – PC – positive control), with no supplement (II – NC – negative control) and with no calcium phosphate but supplemented with phytase 125, 250, 375 or 10 000 PPU per 1 kg of feed (groups III-VI, respectively). Phytase (New Phytase, AB Enzymes GmbH, Darmstadt, Germany) was applied via premixtures to achieve calculated enzyme levels. Experimental feeds were fed to sows starting from mating until piglet weaning i.e. when piglets reached the 28th day of age. All sows received 2.4 kg of feed per day till the 100th day of pregnancy, 3.5 kg of feed daily from the 101st day to the end of pregnancy and 5.0-5.5 kg of feed per day from the 1st day after farrowing to weaning.

Tab. 1. Composition and nutrient contents of the experimental diets (%)

Components	Pregnant sows		Lactating sows	
	Control diet	Experimental diet	Control diet	Experimental diet
Corn meal	57.2	58.0	47.1	47.9
Oat meal	20.0	20.0	20.0	20.0
Dried sugar beet residue	10.0	10.0	5.0	5.0
Soybean meal	4.0	4.0	15.0	15.0
Rapeseed meal	6.0	6.0	10.0	10.0
Calcium carbonate	1.2	1.2	1.2	1.2
Dicalcium phosphate	0.8	–	0.8	–
Salt	0.3	0.3	0.4	0.4
Vitamin and trace element premix 0,5% *	0.5	0.5	0.5	0.5
Nutrient content per 1 kg:				
Dry matter, %	88.75	86.21	88.28	87.04
Metabolizable energy, MJ **	12.35	12.15	12.47	12.28
Crude protein , %	13.67	13.71	16.84	16.98
Digestible protein, %	10.31	10.34	13.03	13.32
Ether extract, %	2.99	3.08	3.39	3.48
Crude fiber, %	5.08	5.46	5.17	5.56
N-free extractives, %	61.95	59.61	58.65	56.07
P, g	4.60	3.72	5.06	4.14
P phytate ***	2.23	2.25	3.13	2.25
Ca, g	7.77	6.13	8.20	6.65

Explanations: * – vitamin-mineral premix used for pregnant sows – vitamin: A – 200 000 IU; D_3 – 20 000 IU; E –10.0 g; K_3 – 0.4 g; B_2 – 0.8 g; B_6 – 0.4 g; B_{12} – 0.004 g; pantothenic acid – 2.0 g; choline cloride – 50 g; folic acid – 0.2 g; nicotinic acid – 4.0 g; biotine – 0.03 g; magnesium – 8.0 g; manganese – 5.0 g; iodine – 0.2 g; zinc – 15.0 g; iron – 18.0 g; copper – 4.0 g; cobalt – 0.08 g; selenium – 0.04 g.
* vitamin-mineral premix used for lactating sows – vitamin: A – 240 000 IU; D_3 – 20 000 IU; E –10.0 g; K_3 – 0.4 g; B_2 – 0.8 g; B_{12} – 0.004 g; pantothenic acid – 2.0 g; choline cloride – 50 g; folic acid – 0.4 g; nicotinic acid – 4.0 g; biotine – 0.04 g; magnesium – 8.0 g; manganese – 10.0 g; iodine – 0.06 g; zinc – 14.0 g; iron – 16.0 g; copper – 4.0 g; cobalt – 0.1 g; selenium – 0.04 g.
** ME calculated according to the equation by Hoffmann and Schiemann (8)
*** Phytate P calculated value based on data by Eeckhout et al. (4)

Digestibility studies were performed in two experimental periods: from day 71 to 97 of pregnancy (faeces collection on days 93-97 of pregnancy) and from day 11 to 25 of lactation (faeces collection on days 20-24). During faeces collections the floor was not bedded with straw. Faeces from each sow were collected twice a day and frozen at –20°C. Each part was mixed and mean samples were analyzed. Apparent phosphorus, calcium, and nitrogen digestibility was calculated using chromium oxide as an indigestible marker. It was added to feed at 0.3 % (w/w) level. The calcium and chromium contents in feeds and faeces were determined by the atomic absorption spectrophotometry procedure (FAAS Avanta Sigma) and the phosphorus content was estimated colorimetrically using the vanadate-

-molybdate method (1). The analysis of crude protein, crude fiber and dry matter in feeds and faeces was performed using standard methods AOAC (1).

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

Results and discussion

Phytase did not affect the sows' body weight between mating and weaning of piglets in either production cycle (tab. 2). Feed utilization per 1 weaned piglet was similar in all groups except NC where it was 16% higher than in the PC group.

A low level of P in the feed mixture for the NC group resulted in a lower number of piglets born and raised to the 28th day of age in both reproduction cycles (tab. 2). The difference in the number of piglets in a litter between the NC group (9.3 piglets) and groups III and VI (11.3 piglets) was statistically significant ($P < 0.05$). Phytase had no significant effect on the piglets' body weight gains. There was no adverse effect of phytase at its highest dose (10 000 PPU · kg^{-1}).

In the experiment by Lyberg (16) the low P diet positively affected the number of piglets born but negatively affected the piglet mortality at birth, resulting in no differences in the number of live-born piglets between the low and high P diets. In this experiment the P deficient diet for pregnant sows (NC) resulted in the lowest number of piglets born in a litter. It was possibly due to a lower content of P in the diet. Reduced litter size when gestating sows were fed with low P diets was found also by Kornegay et al. (13), who researched the effect of P content in sow diets during five consecutive reproduction cycles. A higher amount of digestible P as a result of phytase supplementation with a feed mixture for pregnant sows made it possible to achieve a number of born piglets similar or higher than in the control group obtaining fodder phosphate in the feed (PC). Similar results were obtained by Jongbloed et al. (9), who used similar doses of phytase (750; 1000; and 10 000 PPU).

The body weight of born piglets was the highest ($P < 0.05$) when the supplement of 250 PPU · kg^{-1} was added. This difference vanished, however, during the further part of the experiment and body weights of all piglets at weaning were similar. These results approximately correspond to those found by Kemme et al. (10) in their experiment on a phytase supplement: they found no difference in piglets' birth weight and growth rate before weaning. Also Baidoo et al. (2) found that litter sizes and litter weights at weaning were not influenced by a reduction of inorganic phosphorus and by a concomitant supplementation of phytase.

Apparent crude protein digestibility was the lowest in pregnant sows fed the mixture with no supplement (tab. 3) and the differences between this and other groups were statistically significant ($P < 0.05$). The digestibility of Ca and P was also the lowest in the NC group and it was significantly improved by the phytase supplement. The digestibility of P was high already when the lowest dose 125 PPU/kg of phytase was used. It was also significantly higher in the second than in the first production cycle but there was no such difference in the lactating sows.

Tab. 2. Results of sows and piglets' performance

Reproduction performance	Groups						Cycle		SEM	Interaction
	I-PC	II-NC	III	IV	V	VI	1	2		
BW at mating, kg	198	202	206	207	210	192	201	205	4.352	ns
BW at farrowing, kg	214	226	230	228	235	208	220	226	4.552	ns
BW at weaning, kg	198	205	209	208	216	193	203	207	4.375	ns
BW loss during lactation, kg	16	21	21	20	19	15	17	19	1.279	ns
Barren period, days	9.7	8.8	7.8	6.3	7.8	9.7	–	–	0.548	ns
Average feed utilization per 1 weaned piglet, kg/sow	26.1	31.2	27.1	27.6	28.5	26.8	28.4	27.4	0.652	ns
Weight of whole litters born, kg	15.70	14.20	15.86	16.40	14.29	15.52	14.90	15.81	0.361	ns
Litter size, No	10.58^{ab}	9.33^{a}	11.33^{b}	10.33^{ab}	10.50^{ab}	11.33^{b}	10.36	10.78	0.222	ns
BW of piglet, kg	1.49^{ab}	1.53^{ab}	1.40^{ab}	1.59^{b}	1.36^{a}	1.37^{a}	1.44	1.47	0.027	ns
Weight of whole litters at the 28th d, kg	62.20	55.08	57.17	59.70	57.79	60.21	56.20	61.18	1.288	ns
BW of weaned piglet at the 28th d, kg	6.31	6.57	5.88	6.29	6.04	5.94	6.05	6.29	0.109	ns
Average BWG of piglet 1-28 d, g/d	179	187	166	174	173	169	171	178	3.745	ns
Feed intake 1-28 day, kg/piglet	0.79	0.87	0.76	0.76	0.81	0.78	0.75^{a}	0.84^{b}	0.020	ns
Number of weaned piglets per litter per sow, No	10.00^{ab}	8.50^{a}	9.92^{ab}	9.58^{ab}	9.42^{ab}	10.17^{b}	9.36	9.83	0.210	ns
Dead piglets percentage, %	5.48	8.90	12.45	7.26	10.29	10.24	9.65	8.81	–	

Explanations: a, b – mean values in the same row with different letters differ significantly at $P \leq 0.05$

Tab. 3. Apparent digestibility coefficients in pregnant and lactating sows (%)

Estimated nutrients	Groups						Cycle		SEM	Interaction
	I-PC	II-NC	III	IV	V	VI	1	2		
pregnant sows										
Protein	75.4^{bAB}	72.9^{aA}	75.4^{bAB}	76.6^{bB}	75.8^{bAB}	76.4^{bB}	75.6	75.2	0.323	ns
Ca	31.6^{bAB}	23.5^{aA}	31.8^{bAB}	36.8^{bcB}	37.2^{bcB}	40.2^{cB}	34.1	32.9	1.070	ns
P	42.6^{B}	34.2^{A}	45.6^{B}	48.5^{B}	48.3^{B}	48.7^{B}	40.3^{A}	49.0^{B}	1.016	ns
lactating sows										
Protein	77.4^{abAB}	76.4^{aA}	78.0^{abcAB}	79.3^{bcB}	79.4^{cB}	79.1^{bcB}	79.4^{B}	77.1^{A}	0.310	ns
Ca	41.4^{bB}	32.9^{aA}	47.8^{cBC}	48.6^{cBC}	51.2^{cC}	50.8^{cC}	45.7	45.3	1.089	ns
P	48.0^{B}	40.6^{A}	50.5^{B}	51.4^{B}	52.9^{B}	53.7^{B}	48.5	50.5	0.900	ns

Explanations: a, b, c – mean values in the same row with different letters differ significantly at $P \leq 0.05$; A, B, C – mean values in the same row with different letters differ significantly at $P \leq 0.01$

Similarly to the pregnant sows also in the lactating sows (tab. 3) all digestibility coefficients were lowest in the NC group. In comparison to this group, the lowest supplement of phytase in the feed for the lactating sows significantly improved the digestibility of all estimated components ($P < 0.01$) except crude protein. In comparison to the PC group, the digestibility of Ca in the lactating sows was significantly ($P < 0.05$) improved when 125 PPU · kg^{-1} of mixture was added. Further significant improvement of Ca digestibility ($P < 0.01$) was found after an addition of 375 PPU and higher amounts of phytase. The improvement of P digestibility in comparison to the PC group was not statistically significant even when 10 000 PPU of phytase was added (48.0 and 53.7%, respectively). In the lactating sows protein digestibility in the first cycle was significantly higher (79.4 and 77.1%, respectively) but there was no distinct difference in the digestibility of Ca and P. There are not many papers on the digestibility of nutrients in sows obtaining a feed supplemented with phytase, though its effect on the digestibility of P (24) and some other nutrients (18) in growing pigs is known.

Kemme et al. (10) found a substantially enhanced digestibility of P in pregnant and lactating sows. In this experiment the digestibility of P was the lowest in the phosphorus-deficient group (NC) in both pregnant and lactating sows. There was a tendency for improving P digestibility in the sows receiving phytase but the differences were not significant. An improvement of P digestibility in sows after supplementing their feed with phytase was found by Liesegang et al. (15) but the differences were also not significant, which was probably due to the high standard error. The authors did not know the reason for this high variation. In the present experiment the digestibility of P in pregnant sows was the only nutrient estimated whose digestibility was different in the first and the second production cycle. This difference is hard to explain. A similar improvement of P digestibility in a later period of the experiment was also found by Kemme et al. (11). According to these authors the effects of phytase supplementation depend on the pig's physiological status. A higher digestibility of P and Ca found in lactating than in pregnant sows could be due to a higher absorption of these elements during lactation.

Phytase can also improve Ca digestibility. Such improvement in lactating sows was found by Kemme et al. (11). In the present experiment phytase improved Ca digestibility in both the pregnant and lactating sows. In the first case the difference between the first three groups and groups receiving the highest supplements of enzyme (IV-VI) was significant ($P < 0.01$). In the lactating sows a significant difference was found between the PC and groups V and VI. Unlike phosphorus digestibility, there was no difference in Ca digestibility between the first and second production cycles.

There was no difference in crude protein digestibility between the NC and PC groups whereas the phytase supplement ≥ 250 PPU · kg^{-1} mixture improved it in both the pregnant and lactating sows. It is in accordance with the results obtained by Kemme et al. (11) and Baidoo et al. (2). Grela and Czech (7) found a slight improvement in the digestibility of some amino acids after supplementing sows' feed with this enzyme. The effect of phytase on protein metabolism was found by Shelton et al. (23). In their experiment this supplement changed plasma urea N concentration. An increased efficiency of protein retention by the addition of phytase was reported by Ketaren et al. (12). It is possible that such an improvement of protein digestibility indicates that phytate-protein bindings are to some extent cleaved by phytase, or, by reducing phytic acid level, its inhibiting effect on proteases was reduced (3, 19).

The supplementation of diet for pregnant and lactating sows with phytase significantly improves crude protein, phosphorus and calcium apparent digestibility. There was no significant effect of phytase supplementation on sow performance and piglet rearing indices in comparison to sows fed with mixtures containing fodder phosphate.

References

1. *AOAC.*: Association of Official Analytical Chemists. Official Methods of Analysis. 15th edn, Arlington, VA 1990.
2. *Baidoo S. K., Yang Q. M., Walker R. D.*: Effects of phytase on apparent digestibility of organic phopsphorus and nutrients in maize-soya bean meal based diets for sows. Anim. Feed Sci. Technol. 2003, 104, 133-141.
3. *Caldwell R. A.*: Effect of calcium and phytic acid on the activation of trypsinogen and the stability of trypsin. J. Agric. Food Chem. 1992, 40, 43-46.
4. *Eeckhout W., De Paepe M.*: Total phosphorus, phytae-phosphorus and phytase activity in plant feedstuffs. Anim. Feed sci. Technol. 1994, 47, 19-29.
5. *Evarts H., Jongbloed A. W., Dekker R. A.*: Calcium, magnesium and phosphorus balance of sows durin lactation for therr parities. Livest. Prod. Sci. 1998, 55, 109-115.
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. *Grela E. R., Czech A.*: The influence of microbial phytase on the total and ileal digestibility of amino acids and their content in sow carcasses. Rocz. Nauk. Zoot. 2004, 31, 67-75.
8. *Hoffmann L., Schiemann, Von der Kalirie* zum Joule: Neue Größenbeziehungen bei Messungen des Energieumsatzes und bei der Berechnung von Keunzahlen der energetischen Futterbewertung. Arch. Tiernähr. 1980, 30, 733-742.
9. *Jongbloed A. W., Diepen J. Th. M., Kemme P. A., Broz J.*: Efficacy of microbial phytase on mineral digestibility in diets for gestating and lactating sows Livest Prod. Sci 2004, 91, 143-155.
10. *Kemme P. A., Jongbloed A. W., Mroz Z., Beynen A. C.*: The efficacy of Aspergillus niger phytase in rendering phytate phosphorus available for absorption in pigs is influenced by pig physiological status. J. Anim. Sci. 1997a, 75, 2129-2138.
11. *Kemme P. A., Radcliffe J. S., Jongbloed A. W., Mroz Z.*: The effects of sow parity on digestibility of proximate components and minerals during lactation as influenced by diet and microbial phytase supplementation. J. Anim. Sci. 1997b, 75, 2147-2153.
12. *Ketaren P. P., Batterham E. S., Dettman E. B.*: Phosphorus studies in pigs. 3. Effect of phytase supplementation on the digestibility and availability of phosphorus in soya-bean meal for growing pigs. Br. J. Nutr. 1993, 70, 289--311.
13. *Kornegay E. T., Thomas H. R., Meacham T. N.*: Evaluation of dietary calcium and phosphorus for reproducing sows housed in total confinement on concrete in dirt lots. J. Anim. Sci. 1973, 37, 2, 493-500.
14. *Liesegang A., Burgi E., Sassi M. L., Risteli J., Wanner M.*: Influence of vegetarian diet versus a diet with fishmeal on bone in growing pigs. J. Vet. Med. Physiol. Pathol. Clin. Med. 2002, 49, 230-238.
15. *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. Phys. Anim. Nutr. 2005, 89, 120-128.
16. *Lyberg K.*: Phosphorus in pig diets. Acta Universitatis Agriculturae Sueciae. 2006, 13, 7-37.
17. *Männer K., Simon O.*: Effectiveness of microbial phytase in diets of sows during gestation and lactation. J. Anim. Feed Sci. 2006, 15, 199-211.
18. *Mroz Z., Jongbloed A. W., Kemme P. A.*: Apparent digestibility and retention of nutrients bound to phytate complexes as influenced by microbial phytase and feeding regimen in pigs. J. Anim. Sci. 1994, 72, 226-132.
19. *Nair V. C., Laflamme J., Duvnjak Z.*: Production of phytase by Aspergillus ficuum and reduction of phytic acid content in canola meal. J. Sci. Food Agric. 1991, 54, 355-365.
20. *Pallauf J., Rimbach G.*: Nutritional significance of phytic acid and phytase. Arch. Anim. Nutr. 1997, 50, 301-319.
21. *Poulsen H. A.*: Phosphorus utilization and excretion in pig production. J. Environ. Qual. 2000, 29, 24-27.
22. *Schiemann R., Hennig A., Jentsch W., Ludke H.*: The effect of phosphorus supply on the energy metabolism of growing swine. Arch. Tierernähr. 1993, 43, 17-25.
23. *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 depesotion in growing swine. J. Anim. Sci. 2003, 81, 2053-2062.
24. *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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