Effects of a Solid-State Fermented Phytase on Phosphorus Utilization in Growing Pigs Fed Corn-Soybean Meal Diets: I. Growth Performance and Phosphorus Excretion

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Story in Brief

Forty-two barrows were used to determine the effects of the addition of a solid-state fermented phytase complex (Allzyme SSF; Alltech, Inc) to low phosphorus (P), corn-soybean meal diets on growth performance and P excretion. Pigs were allotted randomly to one of seven dietary treatments (6 pigs/trt). A basal diet consisted of corn and soybean meal and was adequate in all nutrients, except Ca and P. This diet contained .34% total P (.07% available P), all of which was provided by corn and soybean meal. Treatments were the basal, the basal plus monosodium phosphate (MSP) to provide .05, .10, and .15% added available P, and the basal plus enzyme to provide 250, 500, and 1,000 phytase units (PU)/kg. All diets were formulated to .95% total lysine and a Ca:total P ratio of 1.2:1. There were two 5-d total collection periods (d 10-15 and d 25-30) during the 33-d study. Daily gain and G:F increased with addition of MSP or SSF. However, ADFI was not affected by either addition of MSP or SSF. The addition of 500 or 1,000 PU/kg to the low P, corn-soybean meal diet increased ADG and G:F similar to that for pigs fed the highest level of MSP. Digestibility of dry matter, N, and energy were similar among treatments. Digestibility of P increased with addition of MSP or SSF. Compared to the basal diet, additions of SSF decreased P excretion by up to 45.4%. These data indicate that the addition of a solid-state fermented phytase improves growth performance and P utilization, and markedly reduces P excretion of pigs fed low P, corn-soybean meal diets.

Key Words: Pigs, Phytase, Excretion

Introduction

Phytate (myoinositol 1,2,3,4,5,6 hexa, dihydrogen phosphate) is the major form of P in cereal grains and oilseed meals (Reddy et al., 1982). Approximately 60 to 70% of the P in corn and soybean meal is in the form of phytate (NRC 1998). Unlike ruminant animals, monogastric animals, such as pigs and chicks, cannot utilize phytate due to the lack of endogenous phytase enzyme that cleaves phytic P (Peeler 1972). During the past decade, dietary phytases have been added to swine diets to improve P utilization, and ultimately, to decrease the amount of P excretion (Lei et al., 1993; Cromwell et al., 1995; O’Quinn et al., 1997). Many of the phytases used in the swine industry are produced by submerged microbial fermentation (SmF). Recently, solid-state fermentation (SSF) technology has been utilized as an alternative way to produce dietary phytase. Therefore, the purpose of this study was to determine the effects of the addition of a solid-state fermented phytase complex (Allzyme SSF; Alltech, Inc) to low P, corn-soybean meal diets on growth performance and P excretion in growing pigs.

Materials and Methods

A total of 42 crossbred barrows with an average BW of 19.9 kg were used in a 33-d study to investigate the effects of phytase addition on growth performance and P excretion of pigs fed corn-soybean meal based diets. Pigs were blocked by weight and randomly allotted to one of seven dietary treatments in a randomized complete block design. The corn-soybean meal based diets (Table 1) were fed as mash form. A basal diet consisted of corn and soybean meal and was adequate in all nutrients, except Ca and P. This diet contained .34% total P (.07% available P), all of which was provided by corn and soybean. Treatments were the basal, the basal plus monosodium phosphate (MSP) to provide .05, .10, and .15% added available P, and the basal plus enzyme to provide 250, 500, and 1,000 phytase units (PU)/kg. All diets were formulated to .95% total lysine and a Ca:total P ratio of 1.2:1.   All other nutrients met or exceed NRC (1998) standards except Ca and P. The Ca: total P ratio in all diets was 1.2:1.

In this experiment, pigs were individually housed in metabolic chambers in an environmentally-controlled room. The chambers were specially designed for the total, but separate collection of feces, urine, and wasted feed. Each chamber has a galvanized steel mesh floor and one stainless steel self-feeder and one nipple waterer. Beneath the floor, a five-quart plastic container was used to collect urine. All pigs were allowed ad libitum access to feed and water. During two 5-d collection periods (d 10-15 and d 25-30), feces were collected every morning from the 1-mm screen under the chamber. The collected feces were immediately weighed and frozen (-20°C) until the samples were analyzed. At the same time, refused feed also was collected and weighed. Dry matter content of diets and feces was determined by drying at 100°C for 24 h (AOAC, 1990). Nitrogen content was determined by the Kjeldahl procedure (AOAC, 1990) by automated analyzer (FOSS Tecator, 2020 Digestor, 2400 Kjeltec Analyzer; Hoganas, Sweden). Total phosphorus content was determined by a gravimetric quinolinium molybdophosphate method (AOAC, 1990).

Data were analyzed as a randomized complete block design using procedures described by Steel et al. (1997) with initial BW as the blocking criterion. The model included the effects of block (rep), treatment, and block × treatment (error). The model for digestibility included the effects of block (rep), treatment, period and treatment × period. The effects of MSP supplementation were tested for linearity and curvilinearity using orthogonal polynomial contrasts. For the four levels of phytase, polynomial coefficients for unequally spaced treatments were generated by the ORPAL matrix function of the IML procedure of SAS. In all cases, pig served as the experimental unit.

Table 1. Composition of experimental diets, as-fed basis

	Diet						
Total P, %	.34	.39	.44	.49	.34	.34	.34
Available P, %	.07	.12	.17	.22	.07	.07	.07
SSF phytase, PU/kg	0	0	0	0	250	500	1,000
Corn	72.07	72.07	72.07	72.07	72.07	72.07	72.07
Soybean meal	25.25	25.25	25.25	25.25	25.25	25.25	25.25
Corn starch	1.16	.78	.39	.00	1.14	1.11	1.06
Monosodium phosphate	.00	.21	.43	.66	.00	.00	.00
Limestone	.82	.99	1.16	1.32	.82	.82	.82
Sodium chloride	.25	.25	.25	.25	.25	.25	.25
Vitamin & mineral premix[a]	.25	.25	.25	.25	.25	.25	.25

Antibiotic	.20	.20	.20	.20	.20	.20	.84
SSF phytase[b]	.00	.00	.00	.00	.03	.05	.10
Calculated analysis							
Ca, %	.41	.47	.53	.59	.41	.41	.41
Total P, %[c]	.34	.39	.44	.49	.34	.34	.34
Available P, %	.07	.12	.17	.22	.07	.07	.07
Added phytase activity, PU/kg	0	0	0	0	250	500	1,000

[a] Provided the following per kg of diet: 5,506 IU of vitamin A, 551 IU of vitamin D, 33 IU of vitamin E, 3.6 mg of vitamin K (as menadione), 221 mg of biotin, 137 mg of choline, 33.04 mg of niacin, 24.78 mg of panthothenic acid (as d-pantothenate), 5.51 mg of riboflavin, 27.55 mg of vitamin B12, 1.66 mg of folacin, 100 mg of Zn, 2 mg of Mn, 100 mg of Fe, 10 mg of Cu, .30 mg of I, and .30 mg of Se.

[b] Solid-state fermented phytase (Allzyme® SSF; Alltech, Inc) contains 1,000 PU/g of product.

[c] Analyzed total P were 0.37, 0.43, 0.48, 0.52, 0.37, 0.37, and 0.37 %, respectively.

Results and Discussion

Growth performance. There was a linear effect ($P<.03$) of the addition of MSP on average daily gain and gain:feed (Table 2). Among the pigs fed diets with SSF phytase, ADG was linearly increased ($P<.05$) as SSF phytase increased from 0 to 1,000 units/kg. Adding 1,000 PU/kg of SSF phytase to the basal diet increased ADG and gain:feed by 17% and 9%, respectively. Average daily feed intake for 33 d was not affected ($P>.29$) by addition of MSP or SSF phytase. Compared to pigs fed the basal diet, ADG ($P<.03$) and gain:feed ($P<.08$) were greater for pigs fed SSF phytase-supplemented diets.

Table 2. Effects of monosodium phosphate and solid-state fermented phytase on growth performance of pigs fed low P, corn-SBM based diets[a]

	Diet							
Total P, %	.34	.39	.44	.49	.34	.34	.34	
Available P, %	.07	.12	.17	.22	.07	.07	.07	
SSF phytase, PU/kg	0	0	0	0	250	500	1,000	SE
d 0- 33								
ADG, kg [bcd]	.635	.671	.743	.720	.691	.742	.741	.027
ADFI, kg	1.47	1.43	1.54	1.47	1.47	1.55	1.52	.05
Gain:feed [bc]	.45	.47	.48	.49	.47	.48	.49	.01

[a] Least squares means for 6 pigs/trt, [b] Linear effect of added monosodium P ($P<.05$), [c] Linear effect of added phytase ($P<.05$), [d] None vs SSF phytase ($P<.01$)

Excretion and digestibility. There was no interaction between treatment and period ($P>.50$); thus, the data were pooled across period. Excretion and absorption of dry matter, energy and nitrogen were not affected ($P>.10$) by either the addition of monosodium phosphate or SSF phytase (Table 3). Among the pigs fed MSP, the amount of P excreted (g/d) was similar but P excretion based on the proportion of P intake was decreased ($P<.01$) by addition of monosodium phosphate. For the pigs fed SSF phytase, the amount of P excreted via feces decreased (linear, $P<.01$) as SSF phytase increased. Also, supplementation of SSF phytase linearly decreased P excretion expressed as a percentage of intake ($P<.01$). Compared to the basal diet, P excretion via feces was reduced by 23% and 46% with addition of 500 and 1,000 PU/kg, respectively.

Also, digestibility of P was improved linearly (P<.01) from 44% to 70% when SSF phytase was added up to 1,000 PU/kg of diet.

Table 3. Effects of monosodium phosphate and solid-state fermented phytase on nutrient digestibility of pigs fed low P, corn-SBM based diets[a] (DM basis)								
	Diet							
Total P, %	.34	.39	.44	.49	.34	.34	.34	
Available P, %	.07	.12	.17	.22	.07	.07	.07	
SSF phytase, PU/kg	0	0	0	0	250	500	1,000	SE
Phosphorus								
Intake, g/d	5.50	6.02	7.66	7.66	5.49	5.83	5.68	.21
Feces, g/d[c]	3.06	2.98	3.42	3.00	2.48	2.36	1.68	.15
Absorbed, g/d[bcd]	2.43	3.16	4.24	4.66	3.02	3.48	4.01	.15
Excretion, %[bcd]	55.9	50.3	44.2	39.2	45.2	40.5	29.5	1.6
Digestibility, %[bcd]	44.1	49.7	55.8	60.7	54.8	59.5	70.5	1.6
DM, Energy, and N								
DM digestibility, %	88.1	87.6	87.3	88.3	87.9	88.6	88.2	.44
Energy digestibility, %	86.9	86.2	85.8	87.2	86.5	87.2	86.1	.63
N digestibility, %	83.8	82.7	82.6	84.1	83.1	85.3	84.0	.67

[a] Least squares means for 6 pigs/trt, [b] Linear effect of MSP (P<.01), [c] Linear effect of SSF phytase (P<.01), [d] None vs SSF phytase (P <.01).

Implications

The addition of solid-state fermented phytase to the low P, corn-soybean meal diets improved growth performance and phosphorus digestibility of growing pigs. This study indicates that the solid-state fermentation method used to produce this enzyme can be used as an alternative way to produce microbial dietary phytase. Addition of 1,000 PU/kg to low P, corn-soybean meal based diets resulted in 46% reduction in P excretion without affecting growth performance of growing pigs.

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