Effects of a Solid-State Fermented Phytase on Growth Performance, Bone Traits and Phosphorus Digestibility of Growing Pigs Fed Corn-Soybean Meal Diets Containing Wheat Middlings

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A total of 24 barrows was used in a 35-d study to determine the effects of the addition of a solid-state fermented phytase complex (Allzyme SSF; Alltech, Inc) to low available P, corn-soybean meal (SBM) diets containing 20% wheat middlings (WM) on growth performance, bone traits, and P utilization. Pigs were blocked by weight and ancestry, and randomly allotted to one of four dietary treatments (6 pigs/trt). A basal diet consisted of corn, SBM, and WM (20%) and was adequate in all nutrients, except available P. This diet contained .50% total P (.13% avail. P), all of which was provided by corn, SBM, and WM. Diets 2 and 3 were the basal plus SSF to provide 250 and 500 phytase units (PU)/kg, respectively. The positive control diet (PC) was corn-SBM-based with 20% corn starch (.50% total P, .24% available P). All diets were formulated to .77% digestible lysine and a Ca:total P of 1.2:1. Pigs were housed individually with ad libitum access to feed and water. There were two 5-d periods (d 10-15 and d 25-30) for collection of feces and urine. Phytase did not affect ADG or ADFI, but increased G:F. Digestibility of P increased with SSF addition, resulting in a 10% reduction in P excretion for pigs fed 500 PU/kg. Bone breaking strength and ash (%) increased with SSF phytase. However, pigs fed PC had higher ADG, G:F, bone strength and ash compared to those fed diets containing WM. These data indicate that the addition of a solid-state fermented phytase improves P utilization of corn-soybean meal diets containing wheat middlings for growing pigs.

Keyword: Pigs, Phytase, Bone

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). Pigs cannot utilize phytate due to the lack of endogenous phytase enzyme that cleaves phytic P (Peeler 1972). Addition of dietary phytase improves P utilization and decreases P excretion (Lei et al., 1993; Cromwell et al., 1995; O'Quinn et al., 1997). Many of the phytases are produced by submerged microbial fermentation. Recently, solid-state fermentation (SSF) has been utilized to produce dietary phytase. A previous study in our lab (Park et al., 2003) reported that the addition of SSF phytase to low P, corn-soybean based diets improves P bioavailability, growth performance, and bone traits. The objectives were to determine the effects of the addition of a solid-state fermented phytase complex to low P, corn-soybean meal diets containing wheat middlings on growth performance, digestibility, and bone traits in growing pigs.

Materials and Methods

Animals, Diets, and Treatment. A total of 24 crossbred barrows with an average BW of 20 kg were used in a 35-d study to investigate the effects of addition of SSF phytase (Allzyme SSF; Alltech, Inc) on digestibility and growth performance of growing pigs fed corn-soybean meal based diets containing 20% wheat middlings. Pigs were blocked by initial body weight and randomly allotted to one of four dietary treatments in a randomized complete block design. There were 6 replications per treatment.

The experimental diets (Table 1) were fed as mash form. The basal diet was corn-soybean meal based with 20% wheat middlings (WM). This diet contained .77% apparent digestible lysine, .50% total P, .13% available P, and 3,262 kcal/kg ME. Diets 2-3 were as Diet 1 with addition of 250 and 500 phytase units/kg of diet. Diet 4 was a corn-soybean meal-based diet (positive control; PC) that contained .50 % total P and .25 % available P and wheat middlings was replaced with corn starch. All experimental diets were formulated based on apparent ileal digestible lysine. All other nutrients met or exceed NRC (1998) standards. 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. All diets were fed in meal form.

Collection and Analyses. 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 placed in plastic bags and stored 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). At the end of experiment, all pigs were slaughtered and femurs were collected. The metacarpals and metatarsals were collected from the feet after autoclave for 5 min at 121°C and 15 psi. All carcasses were stored at –20°C. Bone breaking strength was determined by an Instron testing machine (Model TM, Instron, Canton, MA). Bones were placed on 3.5 cm and 8.5 cm spaced support for metacarpal and metatarsal, and femurs respectively. Breaking strength is defined as the amount of force (kg) required to fracture the bone.

Statistical Analyses. 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 x treatment (error). The effects of phytase supplementation were tested for linearity and curvilinearity using orthogonal polynomial contrasts. Also, comparisons between the positive control (PC) and diets containing wheat middlings (WM) were performed. In all cases, pig served as the experimental unit.

Table 1. Composition of Basal Diet (as-is)

	WM0	WM250	WM500	PC
Total P, %	.50	.50	.50	.50
Available P, %	.13	.13	.13	.25

Phytase, PU/kg	0	250	500	0
Corn	55.01	55.01	55.01	55.01
Soybean meal	22.89	22.89	22.89	22.89
Wheat middling	20.00	20.00	20.00	--
Corn Starch	.05	.025	--	19.41
Calcium phosphate (dicalcium)	--	--	--	1.02
Limestone	1.34	1.34	1.34	.78
Sodium chloride	.25	.25	.25	.25
Vitamin & mineral premix [a]	.25	.25	.25	.25
Antibiotic	.20	.20	.20	.20
Lysine-HCL	0	0	0	.11
L-Threonine	0	0	0	.02
SSF Phytase [b]	0	.025	.05	0
Calculated analysis				
Ca, %	.60	.60	.60	.60
Total P, %	.50	.50	.50	.50
Available P, %	.13	.13	.13	.25
Added phytase activity, PTU/kg of diet	0	250	500	0

[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 B_{12}, 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.

Results and Discussion

Growth performance. Pigs fed the positive control diet had greater ($P<.01$) ADFI and ADG compared to those fed diets containing WM. Addition of SSF phytase to diets containing 20% WM did not affect ADG or ADFI ($P>.22$), but it increased G:F (linear, $P<.04$).

Table. 2 Effects of SSF phytase on growth performance[a]

	WM0	WM250	WM500	PS	
Total P, %	.50	.50	.50	.50	
Available P, %	.13	.13	.13	.25	
Phytase, PTU/kg	0	250	500	0	SE
ADG, g [c]	590	629	637	746	26
ADFI, g [c]	1,263	1,286	1,294	1,453	46
Gain/feed, g/kg [bc]	467	470	491	515	8

[a] Least squares means for 6 pigs/trt, [b] Linear effect of SSF phytase ($P<.05$), and [c] WM vs PC ($P<.01$)

Digestibility. Dry matter digestibility (Table 3) was not affected ($P>.01$) by addition of SSF phytase. However, digestibility (Table 3) of P increased (linear, $P<.03$) with SSF addition, resulting in a 10% reduction in P excretion for pigs fed 500 PU/kg.

Table 3. Effects of SSF phytase on nutrient digestibility of pigs fed low P, corn-SBM based diets containing wheat middlings [ab] (DM basis)

	WM0	WM250	WM500	PS	

Total P, %	.50	.50	.50	.50	
Available P, %	.13	.13	.13	.25	
Phytase, PTU/kg	0	250	500	0	SE
Dry matter					
Intake, g/d [e]	1196	1179	1231	1521	52
Feces, g/d [e]	216	205	224	157	9
Digestibility, % [e]	82.0	82.6	81.7	89.6	.5
Phosphorus					
Intake, g/d	6.66	6.71	6.87	8.97	.28
Feces, g/d [c]	4.17	3.89	3.77	3.52	.15
Digestibility, % [de]	37.2	41.9	44.3	60.3	1.9
[a] Least squares means, [b] Data were pooled (no period x treatment interaction), [c] Linear effect of SSF phytase (P < .05), [d] Linear effect of SSF phytase (P<.01), and [e] WM vs CS (P<.01)					

Bone characteristics. Bone breaking strength of the metacarpals and metatarsals (Table 3) and femurs was increased (linear, P<.01) by addition of SSF. Also, metacarpal ash content (%) increased (linear, P<.01) with SSF phytase. Pigs fed diets containing PC had greater (P<.01) bone strength and bone ash compared to those fed diets containing WM.

Table 3. Effects of solid-state fermented phytase on bone characteristics of pigs fed low P, corn-SBM based diets containing wheat middlings [a]					
	WM0	WM250	WM500	PS	
Total P, %	.50	.50	.50	.50	
Available P, %	.13	.13	.13	.25	
Phytase, PTU/kg	0	250	500	0	SE
Breaking strength, kg					
Metacarpalcd	41.6	47.5	52.2	69.1	2.6
Metatarsalcd	33.3	43.8	45.9	67.9	3.3
Femurbc	140.2	171.1	177.5	256.3	12.2
Averagecd	71.7	87.5	91.9	130.1	4.9
Metacarpal ash, %[cd]	71.7	87.5	91.9	130.1	4.9
Metacarpal ash, g[bc]	2.2	2.3	2.4	3.0	.1
[a] Least squares means for 6 pigs/trt, [b] Linear effect of SSF phytase (P<.05), [c] Linear effect of SSF phytase (P<.01), and [d] WM vs CS (P<.01)					

Implications

The addition of a solid-state fermented phytase to low P, corn-soybean meal based diets containing 20% wheat middlings improved feed efficiency and bone strength of pigs. The amount of daily P excretion was reduced by 9.6% by the addition of SSF phytase. Because wheat middlings contain relatively high phytase activity, the magnitude of response to dietary phytase was lower than that previously observed for corn-soybean meal diets. These data indicate that the addition of a solid-state fermented phytase improves P utilization of corn-soybean meal diets containing wheat middlings for growing pigs.

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