Effects of a Solid-State Fermented Phytase on Phosphorus Utilization in Growing Pigs Fed Corn-Soybean Meal diets: II. Bone Traits and Tissue Accretion Rates

J.S. Park, S.D. Carter, J.D. Schneider, and T.B. Morillo

Story in Brief

A 33-d experiment using 42 barrows was conducted to determine the effects of a solid-state fermented phytase complex (Allzyme SSF; Alltech, Inc) addition to low phosphorus (P), corn-soybean meal diets on bone traits and tissue accretion rates. Pigs were randomly allotted 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. At the end of the 33-d study, all pigs were killed and the femurs and metacarpals and metatarsals (MM) were extracted. The remainder of the carcass was ground for ash and P analyses. Bone breaking strength and ash (%) increased with increasing MSP or SSF. Based on average BS and ash, addition of 250, 500, or 1,000 PU/kg was equivalent to 0.066, 0.120, and 0.140% available P, respectively. For the carcass, the contents (%) and accretion rates of water, protein, and fat were not affected by either MSP or SSF. The content (%) and accretion of P and ash increased with addition of MSP and SSF. The increase in bone strength and carcass P associated with increasing SSF was similar to that for MSP addition. These data indicate a solid-state fermented phytase improves P utilization in growing pigs fed low P, corn soybean meal diets.

Key Words: Pigs, Phytase, Bone Strength

Introduction

Approximately 60 to 70% of the P in corn and soybean meal is the form of phytate (NRC 1998), Pigs can not utilize phytate due to the lack of endogenous phytase enzyme that cleaves phytic P (Peeler 1972). Previous studies have reported that dietary phytase improves P bioavailability resulting in a reduction in 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 (SmF). Recently, solid-state fermentation (SSF) technology has been utilized as an alternative method 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 bone traits and tissue accretion rates in growing pigs and to estimate phosphorus equivalency of SSF phytase.

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 bone strength and tissue accretion rates 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 dietary composition of the experimental diets has been reported in the companion paper (Park et al., 2003). Briefly, the corn-soybean meal based diets were fed as mash form. The basal 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. All other nutrients met or exceed NRC (1998) standards except Ca and P.

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.

At the start of the experiment, 6 pigs were initially killed for the determination of initial body composition. At the end of the experiment, all pigs were weighed and slaughtered. Frozen carcasses were ground through a 64-mm screen by a commercial meat grinder (Auto Grinder, Model 801GHP, Astria, OR). Carcass sub-samples were freeze-dried (Virtis Freezemobile 12SL;gardiner, NY) before grinding through a Wiley Mill (1-mm screen). Nitrogen content of the carcasses 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). Also, at the end of the experiment, metacarpals, metatarsals and femurs were collected for a bone breaking test. Bone breaking strength was determined using an Instron testing machine. Breaking strength is defined as the amount of force (kg) required to fracture the bone.

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 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.

Results and Discussion

Bone characteristics. For bone breaking strength, the addition of monosodium phosphate to the basal diets increased (linear, $P<.01$) breaking strength of the metacarpals, metatarsals, and femurs (Table 1). When SSF phytase was added, bone (metacarpal, metatarsal and femurs) breaking strength also increased (linear, $P<.01$). Metacarpal-metatarsal and femur breaking strengths of pigs fed the diets with monosodium phosphate and SSF phytase were regressed based on total P and available P intake. Compared to the basal diet, pigs fed diets containing SSF phytase had higher bone breaking strength and ash ($P<.01$). For physical characteristics of the bone, the weight of metacarpal (P<.06), metatarsal (P<.01), and femurs (P<.01) were increased by addition of MSP. Also, the addition of SSF phytase increased (linear, P<.01) bone weights (metacarpal, metatarsal, and femurs). The diameter of femurs was increased by the addition of MSP (P<.02) or SSF phytase (P<.04). Ash content in metacarpal increased with increased (linear, P<.01) level of MSP or SSF phytase.

Table 1. Effects of monosodium P and solid-state fermented phytase on bone characteristics 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
Breaking strength, kg								
Metacarpal[cehi]	38.2	46.9	54.1	69.2	48.9	59.5	63.7	2.3
Metatarsal[cegi]	33.2	45.6	56.3	70.1	48.1	59.2	67.2	3.7
Femur[cehi]	113.6	140.5	196.8	236.4	164.1	212.5	219.6	10.2
Metacarpal ash, %[cegi]	47.37	48.91	50.33	52.51	49.57	51.49	52.21	.57
Metacarpal ash, g[cehi]	2.10	2.33	2.71	3.11	2.57	2.95	2.99	.08
Bone weight, g								
Metacarpal [bf]	64.2	58.7	64.8	67.3	60.9	65.8	65.2	1.7
Metatarsal [cei]	73.0	75.2	78.4	83.9	77.9	81.3	82.7	1.7
Femur [cej]	159.3	159.1	167.7	181.6	161.5	177.7	180.4	3.6
Femur diameter, mm [bd]	19.2	19.5	19.4	20.8	19.4	20.6	20.5	.4

[a]Least squares means for 6 pigs/trt, [b] Linear effect of monosodium P (P<.05), [c] Linear effect of monosodium P (P<.01), [dLinear] effect of SSF phytase (P<.05), [e] Linear effect of SSF phytase (P<.01), [f] Quadratic effect of monosodium P (P<.05), [g] Quadratic effect of SSF phytase (P<.05), [h] Quadratic effect of SSF phytase (P<.01), [I] None vs SSF Phytase (P<.01), [j] None vs SSF Phytase (P<.05).

Carcass composition and accretion. For the carcass composition (Table 2), the percentages of water, protein (N × 6.25) and fat were not affected (P>.10) by addition of MSP or SSF phytase. However, percentage of ash and P were increased (linear, P < 0.01) by addition of MSP or SSF phytase. Accretion rates (g/d) of water, protein, and fat were similar among the dietary treatments (P > 0.10). However, the accretion rate of P and ash increased (linear, P < 0.01) as MSP or SSF phytase increased. The accretion rate of P and ash were greater (P < 0.01) for pigs fed diets with SSF phytase than that for pigs fed the basal diet.

Table 2. Effects of monosodium P and solid-state fermented phytase on carcass composition and tissue accretion rate for growing pigs fed low P, corn-SBM based diets[a]

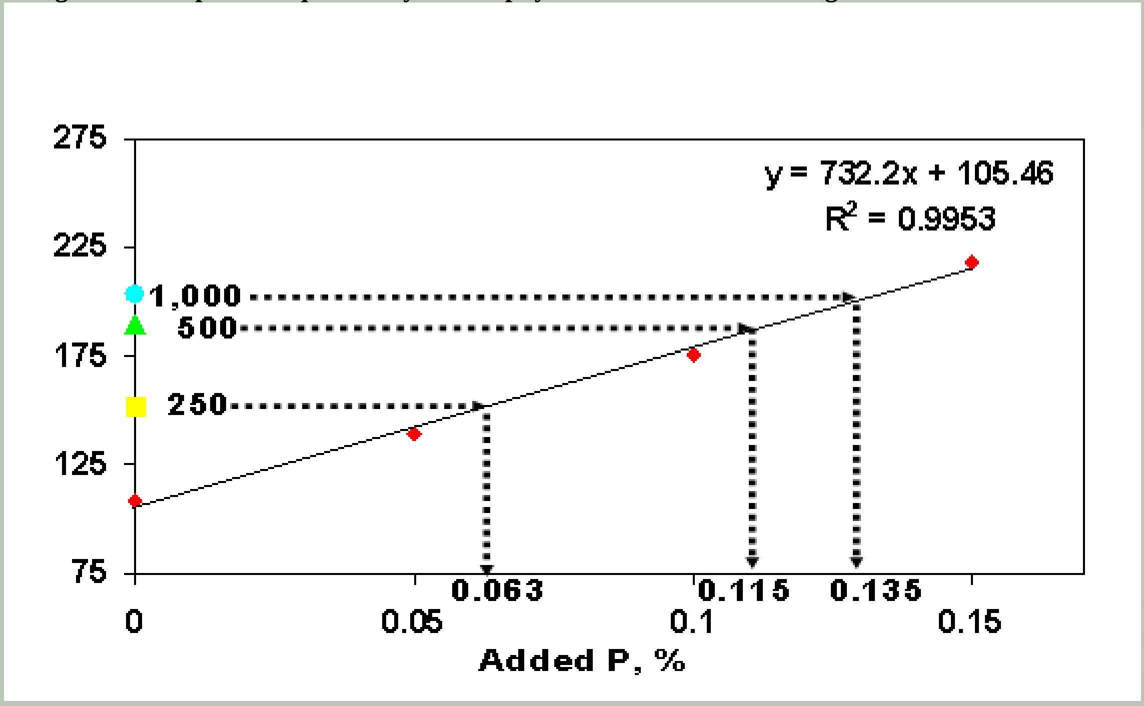
Total P, %	.34	.39	.44	.49	.34	.34	.34	
Available P, %	.07	.12	.17	.22	.07	.07	.07	
SSF phytase, PU/kg	0	0	0	0	250	500	1,000	SE

Carcass composition, %								
Water	63.57	64.48	63.14	64.02	64.88	62.44	63.51	0.52
Protein (N × 6.25)	18.91	18.65	19.02	18.76	18.64	19.06	19.07	0.26
Fat	15.63	14.64	15.85	14.75	15.35	16.37	15.04	0.64
Ash [bce]	1.88	2.09	2.36	2.45	2.13	2.37	2.47	0.07
P [bce]	0.33	0.37	0.41	0.46	0.38	0.41	0.44	0.01
Accretion rate, g/d								
Water	256.0	271.0	290.8	280.3	273.6	280.4	276.0	12.5
Protein (N × 6.25)	132.2	128.5	142.5	133.6	131.5	141.3	137.0	5.2
Fat	106.5	96.5	116.4	100.9	104.6	119.0	104.8	8.5
Ash [bcde]	10.6	12.4	16.3	16.2	13.1	16.0	16.3	0.7
P [bcde]	1.46	1.77	2.33	2.63	1.88	2.32	2.44	0.13

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

Phosphorus equivalency. To estimate the phosphorus equivalency of SSF phytase, bone strength and ash of pigs fed the basal diet and the three levels of MSP were regressed against added available phosphorus to generate a standard curve. Bone strength and ash of pigs fed the three levels of SSF phytase also were plotted against added available P. The P equivalency was then estimated from the standard curve for each level of dietary phytase (Figure 1).

Figure 1. Phosphorus equivalency of SSF phytase based on bone strength and bone ash content



The addition of SSF phytase improved bone strength, bone ash, and P accretion rate. Based on the average response in bone traits, phosphorus equivalency of SSF phytase was estimated

(Table 3). Addition of 250, 500 and 1,000 PU/kg were equivalent to .07% .11% and .14% available P, respectively.

Table 3. Improvements of P digestibility by addition of solid-state fermented phytase in corn-SBM based diets

	SSF Phytase, PU/kg		
Item	250	500	1,000
Available P intake, %	39.9	53.4	59.1
Unavailable P made available by phytase, %	24.3	41.4	46.6
Available P liberated by phytase, g/d	.96	1.74	1.94
Equivalent to available P in diet, %	.07	.11	.14

Implications

The addition of solid-state fermented phytase (1,000 PU/kg) to low P, corn-SBM based diets increased bone strength and bone ash content of growing pigs. In the companion paper, addition of SSF phytase reduced the excretion of P by 46% with similar growth performance to that of pigs were supplemented with MSP. The addition of SSF phytase (1,000 PU/kg) was equivalent to 0.14 % P. These data indicate that the amount of P in the corn-soybean meal diets for growing pigs can be reduced with SSF phytase supplementation.

Literature Cited

AOAC. 1990. Official Methods of Analysis (16th Ed.). Association of Official Analytical Chemists, Arlington, VA.

Cromwell et al. 1995. J. Anim. Sci. 73: 449.

Cromwell et al. 1995. J. Anim. Sci. 73: 2000.

Lei et al. 1993. J. Anim. Sci. 71:3368.

NRC. 1998. Nutrient Requirements of Swine. 10th ed. National Academy Press, Washington, DC.

O'Quinn et al. 1997. J. Anim. Sci. 75:1299.

Peeler. 1972. J. Anim. Sci. 35:695.

Reddy et al. 1982. Advances in Food Research. P 1-92.

Steel, R.D.G. et al. 1997. Principle and Procedures of Statistics: A Biometrical Approach. 3rd ed. McGraw-Hill Publishing Co., New York.

Acknowledgments

The authors thank Alltech, Inc., (Nicholasville, KY) and USDA-CSREES (Federal Initiative Grant) for partial financial support and James Pierce (Alltech, Inc.) for technical assistant as well as providing the SSF Phytase used in this experiment.
