Growth Performance, Phosphorus Balance, and Bioavailability of Phosphorus in Pigs Fed High Available Phosphorus Corn and Phytase

J. S. Sands[1], D. Ragland[2], and O. Adeola[1]
[1]Department of Animal Sciences, and [2]Veterinary Clinical Sciences, Purdue University

Abstract

Phytase has been shown to consistently improve the bioavailability of phytate phosphorus for pigs. However, only about 60 to 70% of the phytate P in a corn-soy diet is made available when supplemented with an optimal phytase dose. The use of high available P (HAP) should provide an additional strategy for improving the bioavailability of phytate P in pigs. In experiments 1 and 2, growth performance and utilization of P were compared in pigs fed high available P or normal corn with or without phytase. Weight gain and feed efficiency were expectedly depressed in the diet containing normal corn without phytase; supplementation with phytase improved these performance criteria. The addition of phytase to HAP corn diets produced a numerical improvement in weight gain. Supplementing the normal corn diet with phytase improved P digestibility and retention. Adding phytase to HAP corn gave a numerical increase in phosphorus digestibility and retention. Phosphorus digestibility and retention in HAP corn were increased 28% and 34%, respectively. The bioavailability of P in HAP and normal corn relative to mono-sodium phosphate was assessed in experiment 3. Estimates of P bioavailability from HAP and normal corn when plasma P was regressed on supplemental P intake was 46 and 33%, respectively.

Key words: Phosphorus, HAP corn, Phytase, Bioavailability, Nutrient retention, Pigs

Introduction

The biological availability of phosphorus (P) for young pigs in corn grain is less than 15% (Cromwell, 1992). About 70% of the total P in corn is in the form of phytate P and is unavailable to pigs. The efficacy of phytase for making available the phytate P present in plant-derived feed ingredients has been characterized in numerous studies (Lei et al., 1993; Mroz et al., 1994; Cromwell et al., 1995). The development of HAP corn provides an additional strategy for further increasing the availability of phytate P and reducing the environmental impact of P excretion. If used in conjunction with phytase, HAP corn should significantly reduce the amount of supplemental inorganic P required in the diet of growing pigs. The nutrient composition of HAP corn is similar to that of normal corn but the level of phytate phosphorus in the kernel is significantly lower in HAP corn (Ertl et al., 1998). A consequence of the reduced level of phytate in HAP corn is an increase in the bioavailability P (Spencer et al., 2000).

The objectives of the following experiments were to evaluate growth performance and P utilization in young pigs fed HAP or normal corn-soy diets with or without phytase and to assess the relative bioavailability of P in HAP corn compared to normal corn.

Materials and Methods

Experiment 1

The growth performance of 48 pigs offered each of four diets arranged in a 2×2 factorial of HAP or normal corn and phytase at 0 or 600 units per kg of diet were examined in the first

experiment. The diets were corn-soybean meal based and contained adequate amounts of all required nutrients (NRC 1998). The diets were formulated to contain 19.0% crude protein, 8000 kcal DE lb, 1.18% lysine, 0.72% Ca, and 0.41% P and contained no added inorganic P (Table 1). The average initial weight was 20.24 lbs and the pigs had unrestricted access to feed and water for 28 days. Body weights and feed intake were recorded weekly.

Experiment 2

In the second experiment, 6 pigs, individually housed in stainless-steel metabolism crates, received each of the four diets used in the first experiment to evaluate P digestibility. Pigs were fed in two equal feedings daily for a 5 d adjustment period followed by a 5 d period of total but separate collection of feces and urine.

Experiment 3

The bioavailability of P in HAP and normal corn relative to mono-sodium phosphate was assessed in a total of 96 pigs, fed 8 diets for 28 d in a randomized complete block design. The basal diet contained 57.0% cornstarch, 39.0% soybean meal, .30% salt, .18% limestone, .10% soybean oil and premixes that supplied adequate amounts of the required vitamins and minerals. The analyzed Ca and P content of the basal diet were 1.14 and .25% respectively. Reference and test diets were formulated by adding P as MSP, HAP or normal corn at 0, .075 and .15% to basal diet at the expense of cornstarch (Table 2).

Chemical and Statistical Analysis

Fecal and urinary P were analyzed spectrophotometrically and plasma P by a colorimetric procedure. Statistical analysis was performed by the general linear model procedures of SAS (SAS, 1996). Data from experiments 1 and 2 were analyzed as randomized complete block designs with a 2×2 factorial arrangement of treatments. In experiment 3, common-intercept, multiple linear regression and slope-ratio assay (Finney, 1978) were used to estimate P bioavailability.

Results and discussion

Growth Performance

Weight gain and feed efficiency were expectedly depressed with the phytase-unsupplemented normal corn diet; and supplementation with 600 units of phytase/ kg improved ($P < .05$) these performance criteria (Table 3). Weight gain and feed efficiency of pigs was superior ($P < .05$) with HAP compared to those fed normal corn diets. The addition of phytase to HAP corn diets produced a numerical improvement in weight gain and feed efficiency. These results are consistent with observed responses in phytase supplemental pigs fed corn-soybean meal diets (Lei et al., 1993; Cromwell et al., 1995; Kornegay and Qian, 1996). Plasma P was lowest when a normal corn phytase-unsupplemented diet was fed (Figure 1). Adding phytase at 600 units/kg to normal corn diets led to a significant improvement ($P < .05$) in plasma P. Plasma inorganic P level of pigs fed HAP corn was higher ($P < .05$) than those fed normal corn; an indication that the P from HAP corn is more bioavailable. As seen in studies with phytase, consuming a HAP corn-soybean meal diet, improved ($P < .05$) weight gain, feed efficiency, and plasma P compared to normal corn without phytase (Table 3).

Phosphorus Balance

Supplementing the normal corn-based diet with 600 phytase units per kg improved (P < .05) P digestibility and retention from 39 and 36%, respectively to 55 and 53%, respectively (Table 4). Phosphorus digestibility (53%) and retention (50%) in HAP corn diet were higher (P < .05) than those of normal corn diet (39 and 36%, respectively). Feeding HAP corn with phytase gave a numerical increase in phosphorus digestibility (58%) and retention (51%) compared to HAP without phytase (53.49 and 41.75, respectively). The amount of P absorbed from the HAP corn diet was 30% higher than the amount absorbed from the normal corn diet. Fecal excretion of P was highest (P < .05) from pigs on the normal corn-based diet without phytase. Addition of phytase to either HAP or normal corn diets resulted in numerically lower fecal P output. Urinary P output was reduced with the HAP corn and phytase diet compared to a HAP corn without phytase diet. These results demonstrate that increases in available P and reduction of fecal and urinary P excretion with the addition of phytase can also be achieved by the use of HAP corn.

Phosphorus Bioavailability

Plasma inorganic P concentration responded linearly (P < .05) to supplemental P level (Figure 2). The common-intercept, multiple linear regression equation of supplemental P intake on plasma P was Y = 21.99 + 40.91 (MSP) + 19.83 (HAP) + 13.47 (NORMAL). Estimates of P bioavailability from HAP and normal corn when plasma P was regressed on supplemental P intake were 46 and 33%, respectively.

Implications

- High available phosphorus corn effectively increases the bioavailability of P for pigs.
- Genetic reduction of phytate in feed ingredients provides an effective strategy for improving P utilization in pigs.
- The potentially detrimental impact of manure P on the environment is reduced when HAP corn and or phytase are use in the diet of young pigs.
- The use of both HAP corn and phytase at the levels used in this study led to further improvements in P digestibility and retention, and reduced P excretion by growing pigs.

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Table 1. Composition of experimental diets used in experiments 1 & 2

Corn[1]	**HAP**		**NORMAL**	
Phytase PU/ kg[a]	**0**	**600**	**0**	**600**
Ingredient %				
HAP Corn	63.15	63.15	0	0
Normal Corn	0	0	63.15	63.15
Soybean Meal	28.00	28.00	28.00	28.00
Whey	5.00	5.00	5.00	5.00
White grease	1.00	1.00	1.00	1.00
Limestone	1.45	1.45	1.45	1.45
Salt	0.35	0.35	0.35	0.35
Vitamin premix[b]	0.25	0.25	0.25	0.25
Trace mineral premix[c]	0.13	0.13	0.13	0.13
Selenium premix[d]	0.05	0.05	0.05	0.05
Mecadox[e]	0.13	0.13	0.13	0.13
Lysine HCL	0.10	0.10	0.10	0.10
Corn Starch	0.40	0.30	0.40	0.30
Phytase (600 PU/ g)[f]	_	1.0	_	1.0
Analyzed nutrient composition				
DE, kcal/ lb	1,974	1,983	1,967	1,972
Protein, %	21	20	19	19
Ca, %	0.73	0.71	0.73	0.73
P, %	0.39	0.35	0.38	0.38

[a]One phytase unit is calculated as the amount of enzyme that liberates 1 µmol of inorganic phosphorus per minute from sodium phytate at pH 5.5 and 37°C

[b]Provided per kg of diet: vitamin A, 6,108 IU; vitamin D_3, 600 IU; vitamin E, 23 IU; menadione sodium bisulfate, 1.2 mg; vitamin B_{12}, 31 µg; riboflavin, 6 mg; d-panthothenic acid, 22.5 mg; niacin, 35 mg

[c]Provided per kg of diet: Cu, 10 mg; Fe, 100 mg; Mn, 27.5 mg; I 1.4 mg

[d]Provided per kg of diet: Se, 300 µg

[e]Provided 28 mg carbadox per kg of diet

[f]One per gram of premix supplies 600 phytase units per kilogram of diet

[1]NORMAL= Normal corn; HAP = high available phosphorus corn

Table 2. Structure of dietary treatments (Exp. 3)

P source	Basal		MSP[a]		HAP[a]		NORMAL[a]	
Diet	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Total P	0.250	0.250	0.325	0.400	0.325	0.400	0.325	0.400
Added P	0	0	0.075	0.150	0.075	0.150	0.075	0.150

[a]MSP = monosodium phosphate; HAP = high available phosphorus corn; NORMAL = Normal corn

Table 3. Growth performance of pigs fed HAP or normal corn with or without phytase supplementation in experiment 1[a]

Corn	HAP		NORMAL		
Phytase PU/ kg	**0**	**600**	**0**	**600**	**SD**
Weight gain, lb/d[bc]	1.08[d]	1.14[d]	0.946[e]	1.06[d]	0.125
Feed Intake, lb/d	2.02	1.97	1.88	2.03	0.328
Gain: Feed[b]	0.55[de]	0.58[d]	0.51[e]	0.53[de]	0.062
N	11	12	12	12	

[a]HAP = high available phosphorus corn; NORMAL = normal corn
[def]Least square means of treatment effects with different superscripts significantly different at P < .05
[bc]Main effect of corn at P < .05
[c]Main effect of phytase at P < .05

Table 4. Phosphorus balance of pigs fed HAP or normal corn with or without phytase in experiment 2[a]

Corn	HAP		NORMAL		
Phytase PU/ kg	**0**	**600**	**0**	**600**	**SD**
Intake, g/ d	2.19[b]	1.98[d]	2.15[bc]	2.12[bc]	0.07
Fecal, g/ d	1.02[c]	0.84[c]	1.32[b]	0.95[c]	0.21
Urinary, g/ d	0.26[b]	0.15[c]	0.24[bc]	0.21[bc]	0.07
Absorbed, g/ d	1.17[b]	1.14[b]	0.82[c]	1.16[b]	0.19
Retained, g/ d	0.92[b]	1.00[b]	0.60[c]	0.96[b]	0.21
Digested, %	53.49[b]	58.13[b]	38.65[c]	55.10[b]	9.31
Retained, %	41.75[b]	50.63[b]	27.65[c]	45.18[b]	10.07
N	6	6	6	6	

[a]HAP = high available phosphorus corn; NORMAL = Normal corn
[bcd]Least square means of treatment effects with different superscripts differ significantly at P < .05

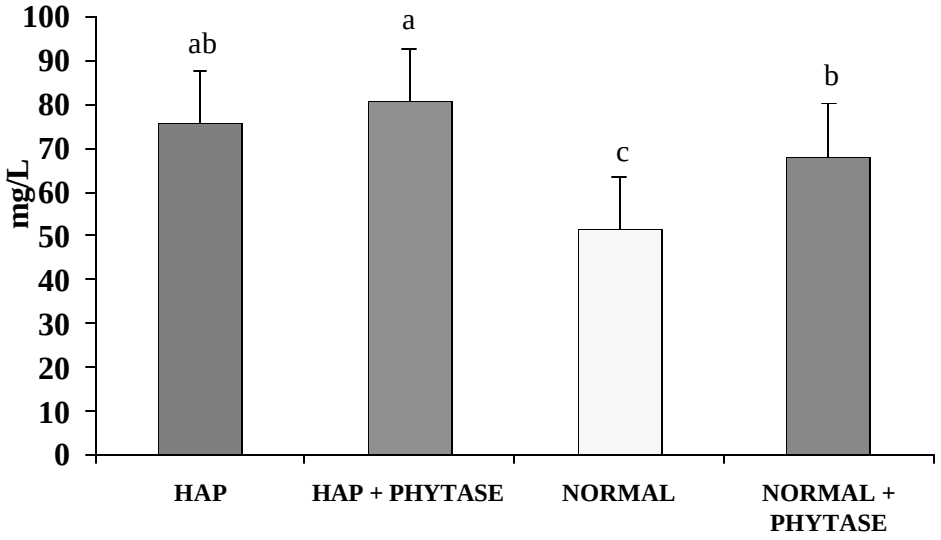

Figure 1. Plasma P (mg/L) of pigs fed HAP or NORMAL corn with or without phytase. HAP= high available P corn, NORMAL = normal corn

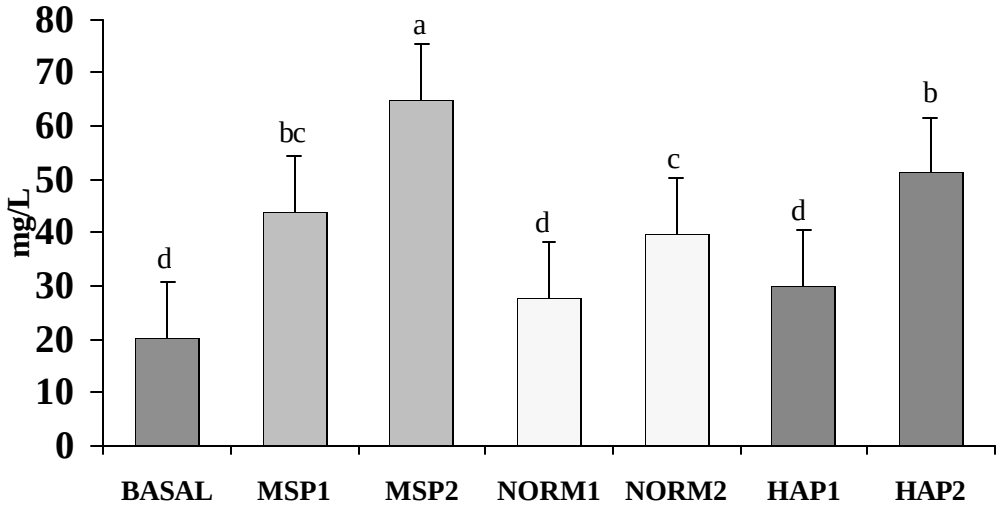

Figure 2. Plasma P concentration of pigs supplemented with P at 0.75 and 1.5 g/kg as MSP, HAP or normal corn. HAP= high available P corn, NORM= normal corn and MSP= monosodium phosphate