Dietary P Management To Reduce Soil P Loading From Pig Manure

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ABSTRACT

The potential use of phosphorus (P) based land application limits for animal manure has increased the importance of optimizing animal feed P management. The specific objectives of this study were to determine the impacts of using high available P (HAP) corn and phytase on 1) P uptake and excretion by young pigs, and 2) total P, PA-P, and water-soluble P (WSP) levels in fresh manure generated by these pigs during a seven day digestibility trial. Our results show that, compared to the control diet, P uptake may be increased approximately 30 percent using HAP corn or phytase alone, but up to more than 50 percent when both phytase and HAP corn are present in the diet. Manure P excretion decreased 21, 23, and 41 percent below the control diet for the phytase, HAP corn, and HAP corn + phytase diets, respectively. The experimental diets also increased water-soluble P and decreased phytic-acid P (PA-P) as a percentage of the total P in fresh manure relative to the control diet. However, due to the reduced mass of P excreted, the total mass of WSP was lowest in the HAP corn + Phytase diet. This study clearly shows that diet modifications can dramatically reduce P excretion by young pigs. Improved dietary P management strategies may be used to offset the increase in land needed for sustainable pork production if P-based land application regulations are implemented.

INTRODUCTION

The United States Environmental Protection Agency (USEPA) has identified agricultural non-point pollution as the major source of freshwater contamination that prevents attainment of the goals set forth by the Clean Water Act (Parry, 1998). The USEPA also states that nitrogen (N) and phosphorus (P) are the primary contaminants in lakes and estuaries and the third leading cause of pollution in rivers. Phosphorus is generally considered the limiting nutrient in freshwater ecosystems of the Eastern and Midwestern USA, and agricultural P inputs from runoff, erosion, and drainage can create conditions that trigger alga blooms, contribute to fish kills, and increase the cost of water treatment.

Animal manure is a major source of P in agricultural production systems. Livestock and poultry are relatively inefficient users of P, so approximately 75 percent of the P ingested is excreted in manure. The quantity of P generated annually in livestock and poultry manure in the USA is approximately two million tons (Sweeten, 1992) and is equal to the quantity of P fertilizer sold annually in the USA (Indiana Agricultural Statistics Service, 1998). Approximately 460 thousand tons of P are generated by pigs (*Sus scrofa*) annually (Sweeten, 1992), and the majority of this P is applied on land adjacent to the livestock production facilities.

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Most states regulate manure applications based on crop N needs. Repeated applications of manure based on crop N needs exceed crop P removal, resulting in soils with high extractable P levels. These soils can potentially release large quantities of soluble P and often show P movement below the crop root zone that may intercept tile lines and high seasonal water tables. Soluble P in runoff and agricultural drainage is essentially immediately available for aquatic organisms (Peters, 1981). In addition to soluble P, large amounts of P may be released when P-rich particles are eroded into surface waters. This sediment-bound P provides a long-term source of P in aquatic environments (Carignan and Kalff, 1980; Correll, 1998; Wildung et al, 1974).

Reducing soil P inputs is essential for reducing excessive P losses in agricultural runoff and drainage. This has become increasingly difficult for intensive livestock operations with limited land available for P removal by crops.

Corn (*Zea mays* L.) and soybean [*Glycine max.* (L.) Merr.] meal are the primary ingredients in pig diets. The predominant form of P in corn and soybean, phytic-acid (PA), largely cannot be hydrolyzed to available inorganic P by monogastric animals because they lack intestinal phytase. Therefore, pig diets are often supplemented with inorganic P to make up for P deficiencies.

Raboy and Gerbasi (1996) identified a non-lethal genetic mutation in corn that produced seed containing only about one-third the amount of PA-P compared to the non-mutated line, but due to higher levels of inorganic P, the mutated line contained similar total seed P. Pioneer Hi-Bred International, Inc. has developed high-available P (HAP) experimental corn hybrids using this trait (Ertl et al., 1998).

Microbial phytase has been shown to increase the utilization of PA-P and reduce manure P excretion in pigs (Simons et al., 1990; Cromwell et al., 1993; Adeola et al., 1995). Based on results from phytase studies, dietary inorganic P supplementation may be reduced 30 to 50 % and still maintain optimum performance.

We are currently evaluating several strategies to minimize P losses from soil to water. The specific objectives of this research paper were to determine the impacts of HAP corn and phytase supplemented diets on the 1) mass of total P excreted by young pigs, and 2) total P, PA-P, and water-soluble P (WSP) levels in fresh manure generated by these pigs during a seven day digestibility trial.

MATERIALS AND METHODS

Feed Analyses

Total P was determined in feed samples by digestion with concentrated H_2SO_4 and 30% H_2O_2. PA-P was determined according to Raboy, et al. (1984). Total P fed and PA-P fed were calculated from the concentrations in the feeds and the cumulative mass of each diet fed during the experiment.

Pig Digestibility Trial

Twenty-four feeder pigs (15-20 kg) were used in two one-week digestibility trials (12 pigs per trial). Each animal was randomly selected to receive one of four corn-soybean meal diets arranged in a 2 x 2 factorial of corn type (normal or HAP corn) and phytase (600 units g^{-1}) supplementation (+ or -). Each diet was formulated to meet NRC (1988) requirements for all nutrients except P. Each pig was housed individually in a stainless steel metabolism crate (.83-m x .71-m) that allowed for separate collection of feces and urine. Carmine Red (Fisher Scientific, Inc.) was used as a non-digestible marker to determine the beginning and end of the feeding trial.

Manure Collection And Analyses

All feces produced by each animal were collected daily, weighed, and immediately frozen. All urine was collected daily into 28% formaldehyde, the volume measured, and a 20% aliquot was frozen until subsequent analysis. Upon completion of the digestibility trial, feces were composited within crates and homogenized in a mechanical mixer. A 100 g subsample was removed, frozen and lyophilized. Percent moisture was determined from the mass of manure before and after lyophilization. The lyophilized samples were ground with a mortar and pestle to pass a 1mm sieve.

Samples of fresh, lyophilized manure from each animal were analyzed for water-soluble P [WSP; manure:double deionized H_2O, 1:100, shaken 24 hours at 120 epm (50 % head space), with 0.1 ml chloroform added to suppress microbial activity], PA-P (Raboy, et al., 1984), and total P (250 mg manure:5 ml concentrated H_2SO_4, at 220° C, with sequential additions of 30% H_2O_2 until the solution was clear). Water extracts were centrifuged at 19,800 x g for 25 minutes and the supernatant was filtered through Whatman #42 filter paper. Total P in the water extracts was determined by the same method as the whole manure, except that a 5-ml aliquot of extract was used instead of the 250-mg whole manure sample. Phosphorus concentration in all extracts was determined colorimetrically according to the method of Murphy and Riley (1962).

Phosphorus used and P excreted were calculated from total P analyses. Phosphorus used was the difference between total P fed and total P excreted. Values are presented as a percentage of P fed. Increase in P used and decrease in P excreted was calculated as the percent above or below the control, respectively.

RESULTS AND DISCUSSION

Animal performance was not affected by diet during this digestibility trial (data not presented). However, data collected from four-week animal performance trials will be used to better assess growth rates, and bone, tissue, and blood P levels.

Feed Analyses

Total P and PA-P data for the four diets used in this study are presented in Table 1. Total P levels were similar for each diet and would be considered marginally P deficient (NRC, 1988). Approximately 70 percent of the total P in the control and phytase diets was PA-P, but the diets containing HAP corn were less than 50 percent PA-P. This represents a 30-35 percent reduction in PA-P as a result of using HAP corn. Total P provided to the animals during the seven-day trial was approximately 10.5 g and did not differ significantly ($p = 0.05$) among the diets.

Manure Analyses

Data showing P use and excretion for the seven-day digestibility trial are presented in Table 2. Phosphorus use, or uptake, by the feeder pigs in this trial was relatively high, with an average of 44 percent for the control diet up to 67 percent for the HAP corn + phytase diet. The P used increased 27, 30, and 53 percent above the control for the phytase, HAP corn, and HAP corn + phytase diets, respectively, and reduced P excretion from 20 to 40 percent below the control. It should be noted that the "P used" data in Table 2 is not meant as a measure of P bioavailability, but rather the P unaccounted for in the manure analyses. Further analysis of blood, tissue, and bone samples would better reflect actual P uptake. Factors including feed spilled by the animals and individual pig metabolism could potentially affect these data.

Table 1. Total phosphorus and phytic-acid phosphorus (PA-P) contents of the four diets used in the feeding trial.

Diet	Total P	PA-P	Percent PA-P
	------- $g\ kg^{-1}$ -------		(of total P)
Control	3.84	2.71	70.7
Phytase	3.79	2.73	71.9
HAP Corn	3.89	1.78	45.8
HAP Corn + phytase	3.53	1.76	49.8

Table 2. Total phosphorus uptake and excretion as influenced by the four diets used in the feeding trial.

Diet	P used	P excreted	Increase in P used	Decrease in P excreted
	-- % of total P fed --		% above / below control	
Control	44.0 c	56.0 a	---	---
Phytase	56.0 b	44.0 b	27	21
HAP Corn	57.1 b	42.9 b	30	23
HAP Corn + phytase	67.1 a	32.9 c	53	41

Means followed by the same letter are not significantly different ($p = 0.01$) according to Duncan's Multiple Range Test.

Table 3 shows the data for PA-P excreted in manure as a percentage of total P fed and PA-P fed. Also shown is the percent decrease in PA-P as a percentage of total P fed and PA-P fed. The results indicate that, based on the percentage of total P fed, the HAP corn and phytase diets decreased PA-P approximately 50%, while the HAP corn + phytase diet decreased PA-P nearly 70% below the control. The decreases in PA-P excreted as a percentage of PA-P fed show that phytase has a major effect on the amount of PA-P excreted. The phytase and HAP corn + phytase diets showed decreases of 48% and 70% below the control, respectively, while the HAP corn diet alone only decreased about 26% below the control.

Differences in manure P composition were also observed among the four diets. Data showing water-soluble P, PA-P, and residual P [total P - (WSP + PA-P)] as a percentage of total manure P are illustrated in Figure 1. No distinction was made between water-soluble inorganic P and organic P because water-soluble organic P levels were below detection limits. The WSP fraction comprised 56, 64, 73, and 67 percent of total manure P in the control, phytase, HAP corn, and HAP corn + phytase treatments, respectively. However, due to the reduced mass of P excreted, the total mass of WSP was lowest in the HAP corn + Phytase diet. Phytic-acid P levels were highest in the control diet (15 percent of total manure P) and lowest in the HAP corn + phytase diet (6 percent of total manure P). No significant differences in residual P ($p = 0.05$) were observed among the diets.

Anderson et al. (1974) reported that organic P, especially PA-P, is more strongly sorbed in soils and may depress the sorption of inorganic P. Anderson and Arlidge (1962) showed that PA-P can actually desorb soil P. The presence of significant quantities of PA-P in manure could potentially increase P dissolution in runoff or movement to subsurface horizons that may intercept tile lines or high seasonal water tables. Therefore, if less PA-P is excreted in manure, it may be possible to reduce the potential movement of manure P applied to soil. Studies are currently in process to determine the impact of storage on manure P distribution.

Table 3. Phytic-acid phosphorus excretion as influenced by the four diets used in the feeding trial.

Diet	PA-P excreted		Decrease in PA-P excreted	
	% of total P fed	% of PA-P fed	% below control (of total P fed)	% below control (of PA-P fed)
Control	8.66 a	12.26 a	-----	-----
Phytase	4.58 b	6.37 bc	47	48
HAP Corn	4.15 b	9.06 ab	52	26
HAP Corn + phytase	1.85 c	3.71 c	79	70

Means followed by the same letter are not significantly different (p = 0.01) according to Duncan's Multiple Range Test.

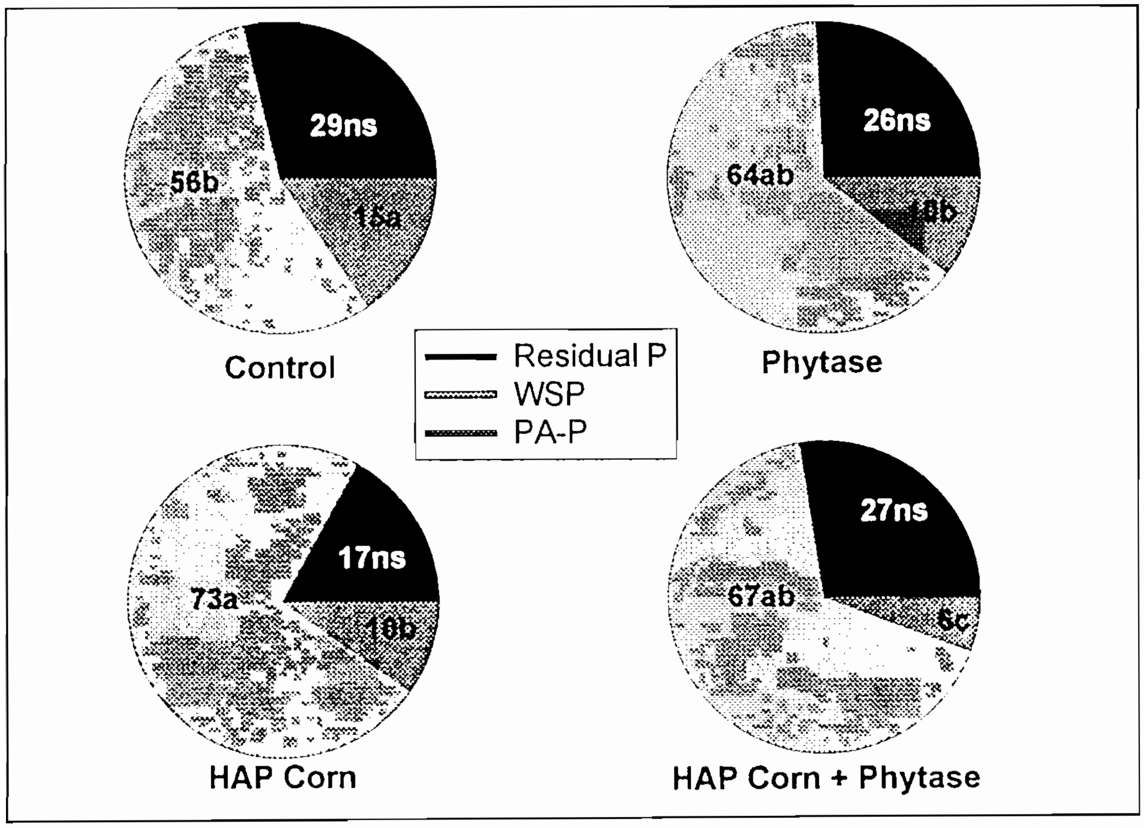

Figure 1. Fractions of water-soluble P (WSP), phytic-acid P (PA-P), and residual P as a percentage of total P excreted in manure from the four diets used in the digestibility trial. Means followed by the same letter are not significantly different (p = 0.01) according to Duncan's Multiple Range Test.

CONCLUSIONS

Our results show that, compared to control diets, manure P excretion by young pigs may be reduced by approximately 20 percent by using either phytase or HAP corn. However, potential reductions in manure P excretion of 40 percent may be possible if both phytase and HAP corn are used. The experimental diets also reduced PA-P in fresh manure, which may impact potential P movement in soils.

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