Effects of Low Phytic Acid Corn, Low Phytic Acid Soybean Meal and Phytase on Nutrient Excretion and Nutrient Digestibility in Pigs

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Introduction

Environmental concerns associated with animal agriculture are of the utmost interest to producers and regulators alike. In December 2002 the United States Environmental Protection Agency is scheduled to release new regulations that will attempt to guide manure management practices for all production levels of animal agriculture. A proposed component of the new regulations is to require a comprehensive nutrient management plan to establish a nutrient balance on each animal production unit. Within the past thirty years our animal producers have changed from small, diversified farms to larger, more concentrated operations, with a greater mass of nutrient outputs located at one site. In addition to this, the use of commercial fertilizer has steadily increased while manure has gained the perception as a "waste problem" instead of beneficial soil fertilizer and constituent. Thus, it becomes increasingly important to maximize nutrient uptake by the animal in an effort to reduce total nutrient output to the environment and in establishing a whole farm nutrient balance.

About 85% of the phosphorus (P) in a normal corn-soybean meal diet fed to swine is not utilized because it is bound as phytate phosphate (Veum et al., 2001). Swine lack the digestive enzyme phytase, which is responsible for the release of the bound P from the phytate inositol ring; therefore, large amounts of inorganic P are commonly supplied to swine diets in an attempt to meet the P requirements of the developing pig. However, when diets are supplemented with inorganic P, large amounts of P that are unavailable to the pig (bound to phytate) are excreted and, if not properly managed, could have potential detrimental consequences on the environment. In addition to negative impacts of poorly managed P to the environment, nitrogen (N) and organic matter also threaten ground and surface water contamination with ill effects such as hypoxia, algae blooms and low dissolved oxygen levels. The objective of this study was to evaluate the effects of feeding low phytic acid (LPA) corn, LPA soybean meal and the Phytase enzyme on P digestibility and excretion with grower pigs.

Experimental Procedures

Forty-eight barrows, 24 per replicate (initial body weight = 100 lbs) were blocked by weight and ancestry and randomly assigned to one of eight dietary treatments in a $2 \times 2 \times 2$ factorial arrangement with all possible diet combinations of LPA corn, LPA soybean meal, normal (NRM) corn, NRM soybean meal, and supplemental phytase (Table 1). Phytase was added to diets at 226 phytase units (PU)/lb of feed and diets were formulated to provide 0.38% total P with the phytase enzyme replacing cornstarch in the control diet. Pigs were adapted to metabolism crates and dietary treatments for seven days followed by a three-day total collection of urine and feces. Feces and acidified urine were collected twice daily and frozen at -4ºF until analysis. Pigs were fed three times maintenance levels (NRC 1998), approximately 3.7 lb/d, divided equally between two feedings (0700 and 1700 h) and had ad libitum access to water.

Feces and urine were analyzed for dry matter (DM), pH, total N, ammonium N (NH_4), total P, water-soluble phosphorus (WSP), and K. Dry matter was determined after drying feed and fecal samples at 203ºF for 24 hours and pH was measured using a calibrated glass electrode pH

meter. Nitrogen was determined by using micro-Kjeldahl techniques, phosphorus was determined using colormetric procedures, and potassium was determined by atomic absorption spectrometry. Feed samples were analyzed for crude protein, total lysine, calcium, phosphorus, and potassium by University of Missouri experiment station chemical laboratories.

Results and Discussion

Total fecal DM excreted, %DM of feces, and %DM digested were not different among treatments in this experiment (Table 2). Furthermore, we saw no difference between treatments for as-is feces, urine, and total manure produced. However, pigs consuming LPA soybean meal consumed less total DM than pigs fed NRM soybean meal ($P < 0.03$), 3.21 vs. 3.30 lb/d respectively. In addition, pigs fed diets containing phytase consumed less DM per day ($P < 0.016$) than those without phytase inclusion, 3.20 vs. 3.30 g/d respectively. Pigs fed LPA corn in diets had a higher overall fecal pH ($P < 0.047$) than those fed NRM corn, 5.7 vs. 5.6.

Nitrogen digestibility, fecal N, urinary N, and total N excreted (Table 3) were not significantly different between treatments. However, N absorbed was significantly higher ($P < 0.0003$) for diets containing no phytase than for those with phytase inclusion, 46.9 vs. 43.3 g/d respectively. In addition, N retained was higher for pigs fed diets without phytase ($P < 0.009$) compared to those diets with phytase inclusion, 26.3 vs. 23.5 g/d respectively. These increases are predominantly due to the increased overall DM and N intake of pigs fed diets without phytase as demonstrated by no detectable differences among treatments for N retained as a % of intake and N retained as % absorbed. Ammonium N excreted in the feces was significantly higher ($P < 0.005$) for pigs fed diets containing LPA soybean meal compared to NRM soybean meal, 1.90 vs. 1.53 g/d respectively.

Fecal phosphorus excretion (Table 4) was reduced 10% for pigs fed LPA corn vs. NRM corn, 2.87 vs. 3.22 g/d ($P < 0.05$), 17% for pigs fed LPA soybean meal vs. NRM soybean meal, 2.74 vs. 3.34 g/d ($P < 0.001$), and 18% for pigs fed phytase vs. non-phytase diets, 2.74 vs. 3.35 g/d ($P < 0.02$). In addition to these main effects, there were additive benefits of reduced P excretion which were a 28% reduction for pigs fed LPA corn and LPA soybean meal vs. NRM corn and NRM soybean meal, 2.51 vs. 3.47 g/d ($P < 0.0001$), and a 43% reduction for pigs fed LPA corn, LPA soybean and phytase vs. NRM corn and NRM soybean meal without phytase, 2.13 vs. 3.76 g/d ($P < 0.0001$). No significant differences were detected among treatments for urinary P excretion. Total P excretion values, therefore, correspond to fecal P excretion numbers. Phosphorus digestibility was, increased 21% for pigs fed diets containing LPA corn vs. NRM corn, 48.3 vs. 39.9% ($P < 0.01$);16% for pigs fed LPA soybean meal vs. NRM soybean meal, 47.3 vs. 40.9% ($P < 0.007$); 22% for pigs fed phytase vs. on-phytase diets, 48.5 vs. 39.7% ($P < 0.008$); and 78% for pigs fed LPA corn, LPA soybean meal, and phytase vs. NRM corn, NRM soybean meal; and no phytase, 60.2 vs. 33.9% ($P < 0.0001$) respectively. Phosphorus retained as a % of intake was significantly increased for pigs fed LPA corn vs. NRM corn, 46.5 vs. 38.3% ($P < 0.01$). LPA soybean meal fed pigs also demonstrated an increase in P retained as a % of intake, 45.3 vs. 39.5% ($P < 0.07$), as well as phytase fed pigs vs. non-phytase diets, 46.6 vs. 38.2% ($P < 0.01$). Corn type and soybean meal type had no significant effect on WSP excreted across all treatments. However, pigs fed phytase diets excreted less total WSP than those without phytase inclusion, 1.96 vs. 2.29 g/d ($P < 0.024$).

Potassium excreted in the feces (Table 5) was significantly less for pigs fed LPA corn vs. NRM corn, 0.73 vs. 1.01 g/d ($P < 0.0003$) and for pigs fed LPA SBM ($P < 0.05$). No significant differences were detected for K excretion in urine or for total K excretion among the dietary treatments. However, K digestibility was significantly increased for LPA corn fed pigs vs. NRM corn fed pigs, 94.8 vs. 92.7% ($P < 0.0002$). In addition K retained as a % of intake also tended to

increase for pigs fed LPA corn vs. NRM corn, 73.1 vs. 70.9% ($P < 0.10$). No significant differences were detected among all treatments for K retained as % absorbed.

Implications

This study suggests that the feeding of any combination of LPA corn, LPA soybean meal, and phytase can significantly improve P digestibility while dramatically decreasing P excretion. In addition, the feeding of LPA corn can reduce fecal K excretion while improving overall K digestibility. The modifications of commercial swine diets with LPA corn, LPA soybean meal, and or phytase can significantly improve P utilization and thus reduce the potential negative impacts of swine production on the environment.

References

Veum, T. L., D. R. Ledoux, V. Raboy, and D. L. Ertl. 2001. Low-Phytic Acid Corn Improves Nutrient Utilization for Growing Pigs. J. Anim. Sci. 79: 2873-2880.

Table 1. Ingredient composition of experimental diets

Corn type	**Normal**				**Low Phytic Acid (LPA)**			
Soybean meal type	**Normal**		**LPA**		**Normal**		**LPA**	
Phytase, PU/lb	**0**	**226**	**0**	**226**	**0**	**226**	**0**	**226**
Ingredients, %								
Corn	69.27	69.27	69.27	69.27	--	--	--	--
LPA Corn	--	--	--	--	69.27	69.27	69.27	69.27
Soybean Meal, 48%	28.0	28.0	--	--	28.0	28.0	--	--
LPA Soybean Meal	--	--	28.0	28.0	--	--	28.0	28.0
Limestone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Animal Fat	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin Premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Trace Mineral Premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Selenium 600 premix	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Phytase enzyme (600 PU/g)	--	0.083	--	0.083	--	0.083	--	0.083
Corn Starch	0.083	--	0.083	--	0.083	--	0.083	--
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis								
Lysine, %	1.026	1.026	1.026	1.026	1.026	1.026	1.026	1.026
Ca, %	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
P, %	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387

Table 2. Effect of normal and low phytic acid (LPA) corns and soybean meals, with or without phytase, on dry matter (DM) digestibility and excretion

Corn type	Normal				LPA					Main effects		
Soybean meal type	Normal		LPA		Normal		LPA		Std.	Probability, P <		
Phytase, PU/lb	0	226	0	226	0	226	0	226	Err.	Corn	SBM	Phy.
Response												
Intake, lb/d as-is[ac]	3.68	3.71	3.66	3.31	3.64	3.63	3.70	3.58	29.3	0.288	0.033	0.024
Diet, % DM	90.0	90.2	90.0	89.7	90.1	89.9	90.1	90.0	0.019	0.953	0.967	0.988
DM intake, lb/d[ac]	3.31	3.34	3.29	2.98	3.28	3.26	3.33	3.23	26.4	0.288	0.033	0.024
Feces, lb/d as-is	0.96	0.97	1.15	0.93	0.92	1.14	1.19	1.09	51.3	0.338	0.218	0.706
Feces, % DM	42.5	41.0	38.6	40.7	39.1	35.9	38.4	37.4	0.025	0.120	0.530	0.703
Feces, lb/d DM	0.40	0.39	0.43	0.38	0.36	0.39	0.45	0.39	13.7	0.873	0.261	0.297
DM, % digested	87.9	88.2	86.9	87.3	89.1	87.9	86.6	87.9	0.866	0.664	0.095	0.748
Feces, pH[b]	5.47	5.78	5.61	5.55	5.71	5.65	5.71	5.75	0.070	0.047	0.967	0.254

[a] Interactions = Corn × SBM; P < 0.03.

[b] Interactions = Corn × SBM × Phytase; P < 0.02.

[c] Interactions = SBM × Phytase; P < 0.01.

Table 3. Effect of normal and low phytic acid (LPA) corns and soybean meals, with or without phytase, on nitrogen digestibility, excretion, and NH_4-N excretion

Corn type	Normal				LPA					Main effects		
Soybean meal type	Normal		LPA		Normal		LPA		Std.	Probability, P <		
Phytase, PU/lb	0	226	0	226	0	226	0	226	Err.	Corn	SBM	Phy.
Response												
Feces, as is, lb/d	0.96	0.97	1.15	0.93	0.92	1.14	1.19	1.09	51.3	0.338	0.218	0.706
Urine, as is, gal/d	1.09	1.09	0.090	1.18	1.08	1.12	1.24	1.27	596.1	0.322	0.669	0.381
Total manure, as is, lb/d	10.01	9.99	8.62	10.69	9.90	10.46	11.43	11.59	596.4	0.265	0.625	0.437
Nitrogen												
Intake, g/d[abcd]	54.9	53.6	56.3	46.9	52.1	50.5	58.1	55.4	0.946	0.105	0.048	0.0001
Feces, g/d[c]	7.4	7.2	9.5	7.5	6.7	9.8	10.0	8.7	1.11	0.250	0.165	0.859
Urine, g/d	21.0	19.6	18.8	20.3	19.5	19.5	23.1	19.7	1.34	0.579	0.536	0.377
Total N excreted, g/d[e]	28.4	26.8	28.4	27.7	26.3	29.3	33.1	28.3	1.60	0.209	0.141	0.388
N digestibility, %	86.5	86.6	83.1	84.0	87.1	80.7	82.9	84.4	1.99	0.374	0.260	0.480
Absorbed, g/d[ad]	47.5	46.4	46.7	39.4	45.3	40.7	48.2	46.7	1.27	0.827	0.774	0.0003
Retained, g/d[ad]	26.5	26.8	27.9	19.1	25.8	21.2	25.0	27.0	1.43	0.744	0.745	0.009
Retained, % intake[d]	48.4	50.2	49.7	40.7	49.3	42.0	43.1	49.0	0.027	0.463	0.335	0.249
Retained, % absorbed[d]	55.8	58.0	59.7	48.4	56.8	51.9	51.9	57.9	2.67	0.642	0.544	0.297
NH_4-N												
Feces, g/d[c]	1.46	1.64	1.96	1.54	1.47	1.57	2.37	1.72	0.172	0.288	0.005	0.114
Urine, g/d	1.52	1.38	1.40	1.31	1.65	1.40	1.55	1.53	0.135	0.183	0.680	0.196
Total NH_4-N, g/d	2.98	3.02	3.36	2.85	3.12	2.96	3.92	3.25	0.219	0.100	0.043	0.043

[a]Interactions = Corn × SBM; P < 0.05.
[b]Interactions = Corn × Phytase; P < 0.05.
[c]Interactions = SBM × Phytase; P < 0.05.
[d]Interactions = Corn × SBM × Phytase; P < 0.05.
[e]Interactions = Corn × SBM × Phytase; P < 0.06.

Table 4. Effect of normal and low phytic acid (LPA) corns and soybean meals, with or without phytase, on phosphorus digestibility, excretion, and water soluble phosphorus (WSP) excretion

Corn type	Normal				LPA					Main effects		
Soybean meal type	Normal		LPA		Normal		LPA		Std.	Probability, P <		
Phytase, PU/lb	0	226	0	226	0	226	0	226	Err.	Corn	SBM	Phy.
Response												
Feces, as is, lb/d	0.96	0.97	1.15	0.93	0.92	1.14	1.19	1.09	51.3	0.338	0.218	0.706
Urine, as is, gal/d	1.09	1.09	0.090	1.18	1.08	1.12	1.24	1.27	596.1	0.322	0.669	0.381
Total manure, as is, lb/d	10.01	9.99	8.62	10.69	9.90	10.46	11.43	11.59	596.4	0.265	0.625	0.437
Phosphorus												
Intake, g/d[abc]	5.68	5.72	5.32	4.66	5.63	5.60	5.54	5.37	0.097	0.009	0.0001	0.005
Feces, g/d	3.76	3.17	3.27	2.68	3.48	2.97	2.90	2.13	0.238	0.038	0.001	0.0007
Urine, g/d	0.07	0.06	0.10	0.11	0.07	0.11	0.08	0.12	0.024	0.480	0.154	0.263
Total P excreted, g/d	3.83	3.23	3.37	2.79	3.55	3.07	2.98	2.25	0.233	0.041	0.001	0.0008
P digestibility, %	33.8	44.6	38.7	42.5	38.3	46.8	47.9	60.2	4.38	0.010	0.048	0.007
Absorbed, g/d[c]	1.92	2.55	2.05	1.98	2.15	2.59	2.64	3.24	0.231	0.002	0.301	0.019
Retained, g/d[c]	1.85	2.50	1.95	1.87	2.08	2.48	2.56	3.12	0.228	0.003	0.376	0.023
Retained, % intake[d]	32.7	43.5	36.8	40.2	36.9	44.7	46.4	57.9	4.31	0.010	0.069	0.009
Retained, % absorbed[d]	96.2	97.5	93.9	92.1	96.6	95.7	97.1	96.2	1.52	0.175	0.110	0.632
WSP												
Feces, g/d	2.36	2.03	2.29	1.87	2.01	2.06	2.16	1.50	0.193	0.142	0.240	0.017
Total WSP excreted, g/d	2.43	2.09	2.39	1.98	2.09	2.17	2.24	1.62	0.193	0.165	0.317	0.024

[a]Interactions = SBM × Phytase; $P < 0.01$.
[b]Interactions = Corn × SBM × Phytase; $P < 0.05$.
[c]Interactions = Corn × SBM; $P < 0.05$.
[d]Interactions = Corn × SBM; $P < 0.08$.

Table 5. Effect of normal and low phytic acid (LPA) corns and soybean meals, with or without phytase, on potassium digestibility and excretion

Corn type	Normal				LPA					Main effects		
Soybean meal type	Normal		LPA		Normal		LPA		Std.	Probability, P <		
Phytase, PU/lb	0	226	0	226	0	226	0	226	Err.	Corn	SBM	Phy.
Response												
Feces, as is, lb/d	0.96	0.97	1.15	0.93	0.92	1.14	1.19	1.09	51.3	0.338	0.218	0.706
Urine, as is, gal/d	1.09	1.09	0.090	1.18	1.08	1.12	1.24	1.27	596.1	0.322	0.669	0.381
Total manure, as is, lb/d	10.01	9.99	8.62	10.69	9.90	10.46	11.43	11.59	596.4	0.265	0.625	0.437
Potassium												
Intake, g/d[acdf]	14.7	14.3	14.3	12.0	13.6	13.7	14.3	14.2	0.246	0.624	0.038	0.0004
Feces, g/d	1.01	1.11	1.02	0.91	0.93	0.73	0.69	0.56	0.103	0.0003	0.047	0.243
Urine, g/d	3.32	2.71	2.89	3.06	2.67	3.25	2.96	3.17	0.254	0.925	0.856	0.626
Total K excreted, g/d	4.34	3.81	3.91	3.98	3.60	3.98	3.67	3.73	0.270	0.167	0.547	0.992
K digestibility, %[e]	93.13	92.24	92.85	92.44	93.17	94.66	95.18	96.03	0.732	0.0002	0.118	0.617
Absorbed, g/d[bcdf]	13.70	13.19	13.26	11.12	12.64	12.94	13.59	13.59	0.246	0.039	0.206	0.002
Retained, g/d[acef]	10.37	10.49	10.37	8.06	9.97	9.68	10.64	10.42	0.297	0.099	0.229	0.003
Retained, % intake[b]	70.53	73.44	72.65	67.00	73.54	70.80	74.56	73.52	0.019	0.101	0.909	0.132
Retained, % absorbed[a]	75.73	79.66	78.24	72.40	78.92	74.84	78.33	76.58	1.86	0.621	0.501	0.151

[a]Interactions = Corn x SBM x Phytase; P < 0.03.
[b]Interactions = Corn x SBM x Phytase; P < 0.06.
[c]Interactions = Corn x SBM; P < 0.0001.
[d]Interactions = Corn x Phytase; P < 0.0005.
[e]Interactions = Corn x Phytase; P < 0.085.
[f]Interactions = SBM x Phytase; P < 0.008.