Effect of Elevated Fat and Protein Corn and Phytase on Nutrient Digestibility and Excretion in Pigs

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Introduction

The current concern of nutrient loading waterways and soils from livestock manure has increased awareness of methods to reduce excess nutrient excretion. The initial methods for nutrient reduction are simple diet manipulations to feed nearer the requirement of the pig. Further modifications have been made to increase digestibility of feedstuffs. The use of genetically modified corns and addition of microbial phytase are known to be effective methods for increasing nitrogen and phosphorus digestibility while reducing nutrient excretion. Two mutant corn hybrids containing the genes, *Lpa*-1 and *Lpa*-2, have 66% and 33% less total phytic acid phosphorus, resulting in greater phosphorus availability (Raboy and Gerbasi, 1996). Similar genetic selections have been made to increase protein and energy content of corn. Recently, an elevated fat and protein corn has been developed and has been combined with the low phytic acid gene to create an elevated fat and protein corn with high available phosphorus content.

The objective of this study was to determine the nutrient digestibility of two genetically enhanced corns with the addition of microbial phytase when fed to finishing pigs.

Materials and Methods

Experimental design. Twenty-four crossbred barrows (initial body weight=234 lb) were used in two replicates with 12 pigs per replicate (total of 6 pigs/trt) and housed in metabolism stalls for the total collection of feces and urine. Pigs had a three-day adaptation to the metabolism stalls and a five-day adaptation to treatment diets followed by a three-day total collection. Pigs were offered approximately 5 lb/d (3 × maintenance requirement; NRC, 1998) in two equal feedings (0600 and 1800 h) and had ad libitum access to water. Feed refusal was measured daily.

Dietary treatments. Pigs were blocked by weight and ancestry and randomly assigned to one of four dietary treatments. Diets included: 1) elevated fat and protein corn diet (EFP), 2) elevated fat and protein, high available phosphorus corn diet (EFP-HAP1), 3) diet 1 with 136 phytase units (PU)/lb, and 4) diet 2 with 136 PU/lb. All diets were balanced to 0.53% digestible lysine and 0.30% total phosphorus and to meet or exceed NRC (1998) requirements for all other nutrients (Table 1).

Statistical analysis. Data were analyzed as a factorial design of corn type and phytase supplementation and their interaction using ANOVA analysis in the GLM procedure of SAS (2000; SAS Inst. Inc., Cary, NC).

Sample analysis. Feces and urine were analyzed for dry matter (DM), ash, total nitrogen, ammonium nitrogen, total phosphorus, water soluble phosphorus (WSP), potassium, fecal pH and fecal volatile fatty acids (data not reported). Diets were analyzed for DM, ash, total nitrogen, total phosphorus, and WSP.

Results

Average beginning and ending pig weights were not different among treatments (Table 2). Dry matter intake was similar among treatments and averaged 3.94 lb/d (Table 2). Total wet feces excreted was reduced ($P < 0.03$) for pigs fed the EFP-HAP1 corn diets compared to pigs fed EFP corn diets. Phytase addition to the diet increased ($P < 0.03$) wet feces excreted 13% and 38% for pigs fed the EFP and EFP-HAP1 corn diets, respectively. The difference in the magnitude of increase in wet feces excreted with the addition of phytase to the EFP and EFP-HAP1 corn hybrids created a corn by phytase interaction ($P < 0.03$). The addition of the phytase enzyme tended ($P < 0.08$) to decrease fecal DM. Total feces excreted (DM basis) was reduced ($P < 0.05$) 22.5% when the EFP-HAP1 corn diets were fed compared to the EFP corn diets. Pigs fed the EFP-HAP1 corn treatments had approximately 4% greater ($P < 0.001$) DM digestibility than EFP corn treatments. Fecal pH was increased ($P < 0.01$) when pigs were fed the EFP-HAP1 corn diets, and there was a trend ($P < 0.07$) for a corn by phytase interaction due to the increase in fecal pH with the addition of phytase to the EFP corn type and a reduction in pH with the addition of phytase to the EFP-HAP1 corn type.

Nitrogen intake was not different among treatments (Table 3). Fecal nitrogen was reduced 22% ($P < 0.05$) for the EFP-HAP1 corn treatments compared to the EFP corn treatments. Phytase addition to either corn type tended ($P < 0.06$) to increase fecal nitrogen concentrations by 20%. Pigs fed the EFP-HAP1 corn treatments excreted greater ($P < 0.04$) urinary nitrogen than pigs fed the EFP corn diets, and phytase addition to either corn type tended ($P < 0.08$) to reduce urinary nitrogen excretion. However, total nitrogen excreted was not affected by dietary treatment. Nitrogen digestibility was 6% greater ($P < 0.01$) for pigs fed the EFP-HAP1 corn treatments than pigs fed the EFP corn treatments, and phytase addition to either corn type reduced ($P < 0.05$) nitrogen digestibility.

The EFP corn type reduced ($P < 0.0001$) urinary ammonium nitrogen concentrations (Table 3), and the EFP-HAP1 corn type tended ($P < 0.08$) to have reduced fecal ammonium nitrogen. Total ammonium nitrogen excretion was reduced 9% ($P < 0.01$) when pigs were fed the EFP corn diets compared to the EFP-HAP1 corn diets.

Phosphorus intake was not affected by corn type or phytase inclusion in the diet (Table 4). Fecal phosphorus and fecal phosphorus as a percent of fecal DM were reduced (51% and 36%, respectively; $P < 0.0001$) when pigs were fed the EFP-HAP1 corn treatments compared to the EFP corn treatments. However, the EFP-HAP1 corn type increased ($P < 0.0001$) urinary phosphorus excretion, and phytase inclusion in the diet also increased ($P < 0.005$) urinary phosphorus excretion. Total phosphorus excreted was 39% lower ($P < 0.0001$) for pigs fed the EFP-HAP1 corn diets compared to pigs fed the EFP corn diets. Total phosphorus excreted was reduced when phytase was added to the EFP corn diet, but was increased when phytase was added to the EFP-HAP1 corn diets, creating a tendency for a corn by phytase interaction ($P < 0.09$). Pigs fed the EFP corn treatments had lower phosphorus digestibility (31.9% vs. 65.8%; $P < 0.001$) than pigs fed EFP-HAP1 corn diets. The EFP-HAP1 diets had increased phosphorus absorbed, retained and retained as a percent of intake ($P < 0.01$). Phosphorus retained as a percent of absorbed was decreased ($P < 0.03$) when pigs were fed diets with phytase. Fecal WSP concentration was not affected by dietary treatment (Table 4). Phytase addition to either corn treatment tended ($P < 0.06$) to increase total WSP excretion.

Fecal potassium excretion (Table 5) was decreased ($P < 0.02$) 26% by the EFP-HAP1 corn diets compared to EFP corn diets. Phytase supplementation increased fecal potassium excretion by 35% ($P < 0.002$). Urinary potassium concentration was reduced ($P < 0.02$) when phytase was added to either corn type. Potassium digestibility was increased ($P < 0.04$) in EFP-HAP1 corn diets (12%) compared to EFP corn diets. Phytase inclusion reduced potassium digestibility 10% when added to either corn type ($P < 0.04$).

Discussion

Corn hybrids genetically enhanced to contain more available phosphorus and the use of the phytase enzyme are two potential dietary modifications to increase nutrient availability in swine diets. Pigs fed the EFP-HAP1 corn had lower fecal DM excretion than pigs on the EFP corn treatments, resulting in the approximately 4% greater DM digestibility. Phytase increased wet feces excretion and tended to reduce fecal percent DM, which may be a result of the slightly increased DM intake when pigs were fed treatments containing phytase.

The increased nitrogen digestibility when pigs were fed the EFP-HAP1 corn hybrid compared to the EFP corn hybrid suggests that the HAP gene inclusion is successfully freeing some bound amino acids for utilization by the pig. The reduction in urinary ammonium nitrogen in pigs fed the EFP corn treatments is likely the result of the reduced nitrogen digestibility, causing less urine to be absorbed and reducing nitrogen excreted in the urine.

Fecal phosphorus concentration was reduced when the EFP-HAP1 treatment was compared to the EFP treatment, indicating the increased availability of phosphorus with the low phytic acid genetic manipulation. Urinary phosphorus increased linearly when the EFP corn type was combined with the HAP gene and further increased with the addition of phytase to both corn types. This suggests that the manipulations made here are effective at increasing phosphorus availability for absorption. The increases in urinary phosphorus would indicate that the dietary available phosphorus requirements of the pigs were exceeded with the corn hybrids with the HAP gene. The reduction in total phosphorus excreted (39%) when the EFP-HAP1 corn was compared to the EFP corn, while lower than some previously reported values, does reflect the greater phosphorus digestibility and retention with the more available phosphorus corn hybrid. The addition of the HAP gene to the EFP corn type resulted in a greater increase in phosphorus digestibility as well as a greater increase in phosphorus retention as a percent of intake than the addition of phytase to the EFP diet. This may be expected, as the potential for release of phytic bound phosphorus from the Lpa corn mutation is 33-66%, while phytase is typically found to increase phosphorus availability only 25-30%.

The addition of the HAP gene to the EFP corn variety resulted in increased potassium digestibility. Phytase addition, however, decreased potassium digestibility when added to either corn type.

Implications

This study suggests that feeding genetically enhanced corn types to pigs can be beneficial in reducing nutrient excretion. It is important, however, to account for the increased availability of specific nutrients in the enhanced corn variety to avoid exceeding the nutrient requirement of the pigs, which encourages greater nutrient excretion from the urinary component. Lastly, the use of the phytase enzyme with HAP corn may not be needed or have little benefit compared to its effectiveness in diets containing normal corn hybrids.

References

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Table 1. Ingredie nt composition of experimental diets

Ingredient, %	**EFP[a]**	**EFP+PHY**	**EFP-HAP1**	**EFP-HAP1+PHY**
EFP corn	93.42	93.37	--	--
EFP-HAP1 corn	--	--	93.42	93.37
Phytase enzyme[b]	--	0.05	--	0.05
Soy concentrate	5.00	5.00	5.00	5.00
Limestone	0.85	0.85	0.85	0.85
Salt	0.25	0.25	0.25	0.25
Vit. Premix[c]	0.25	0.25	0.25	0.25
TM Premix[d]	0.20	0.20	0.20	0.20
Lysine-HCl	0.03	0.03	0.03	0.03
Calculated Composition				
Crude protein, %	12.53	12.53	12.53	12.53
Calcium, %	0.35	0.35	0.35	0.35
Phosphorus, %	0.30	0.30	0.30	0.30
Available Phosphorus, %	0.04	0.04	0.17	0.17
Digestable amino acids				
Lysine, %	0.53	0.53	0.53	0.53
Threonine, %	0.40	0.40	0.40	0.40
Methionine + Cysteine, %	0.43	0.43	0.43	0.43
Tryptophan, %	0.10	0.10	0.10	0.10
Isoleucine, %	0.41	0.41	0.41	0.41
Analyzed composition				
Crude protein, %	11.67	11.87	11.74	10.86
Total Phosphorus, %	0.34	0.35	0.29	0.31
Total Potassium, %	0.51	0.50	0.42	0.45

[a]EFP=Elevated fat and protein corn; EFP-HAP1=Elevated fat and protein, high available phosphorus corn.
[b]Provided 136 phytase units/lb.
[c]Vitamins per lb of diet: 2570 IU A, 275 IU D, 20 IU E, 0.9 mg Menadione, 15.9 mg B12, 3.2 mg Riboflavin, 9.98 mg Pantothenic Acid, 14.9 mg Niacin.
[d]Provides per lb of diet: 66 ppm Zn, 8.16 ppm Fe, 8.16 ppm Manganese, 6.12 ppm Cu, 0.24 ppm I, 0.14 ppm Se.

Table 2. Pig initial and ending weights and the effect of elevated fat and protein corn hybrids and phytase on dry matter (DM) digestibility

Corn Hybrid[a]	EFP		EFP-HAP1			Probability, P <		
Phytase, PU/lb	0	136	0	136	SE	Corn	Phytase	Corn ´ Phy.
Average initial wt., lb	234	236	234	236	2.38	0.73	0.49	0.99
Average final wt., lb	237	235	239	241	2.65	0.13	0.99	0.44
Intake, lb/d as-is	4.32	4.32	4.57	4.77	0.336	0.32	0.77	0.78
Diet, % DM	88.59	89.20	87.34	87.84	--	--	--	--
DM intake, lb/d	3.83	3.86	3.99	4.19	0.298	0.42	0.71	0.79
Feces, lb/d as-is	1.06	1.22	.654	1.06	0.119	0.03	0.03	0.03
Feces, % DM	38.58	36.83	42.91	36.41	2.20	0.39	0.08	0.29
Total feces DM excreted, lb/d	0.409	0.441	0.286	0.374	0.045	0.05	0.20	0.53
DM, % digested	89.21	88.41	92.94	91.13	0.830	0.001	0.13	0.55
Feces, pH	5.44	5.53	5.91	5.70	0.077	0.0007	0.46	0.07
Urine, gal/d as-is	.796	.951	.856	1.02	0.129	0.62	0.23	0.97
Total manure excreted, lb/d as-is	7.71	9.16	7.80	9.57	1.11	0.82	0.16	0.89

[a] EFP = elevated fat and protein corn; EFP-HAP1 = elevated fat and protein, high available phosphorus corn.

Table 3. The effect of elevated fat and protein corn hybrids and phytase on nitrogen digestibility and NH_4-N excretion

Corn Hybrid[a]	EFP		EFP-HAP1			Probability, P <		
Phytase, PU/lb	0	136	0	136	SE	Corn	Phytase	Corn ´ Phy.
Nitrogen								
Intake, g/d[b]	36.60	37.25	38.95	37.56	2.85	0.65	0.90	0.73
Feces, g/d	5.83	6.89	4.22	5.72	0.650	0.05	0.06	0.74
Feces, % DM excreted	3.21	3.51	3.25	3.36	0.190	0.75	0.30	0.62
Urine, g/d	15.79	12.95	16.49	16.11	0.857	0.04	0.08	0.17
Total N excreted, g/d	21.62	19.84	20.71	21.84	1.14	0.64	0.78	0.22
N, % digested	83.60	80.78	89.31	84.91	1.71	0.01	0.05	0.65
Absorbed, g/d	30.77	30.36	34.74	31.83	2.64	0.32	0.54	0.64
Retained, g/d	14.99	17.41	18.25	15.72	2.43	0.75	0.98	0.32
Retained, % intake	39.31	44.43	46.24	41.65	4.04	0.61	0.95	0.25
Retained, % absorbed	46.60	54.83	51.69	49.02	4.39	0.94	0.54	0.23
NH_4-N								
Feces, g/d	1.10	1.22	0.829	1.05	0.121	0.08	0.18	0.68
Urine, g/d	1.52	1.40	2.06	2.24	0.103	0.0001	0.80	0.16
Total NH_4-N excreted, g/d	2.62	2.62	2.89	3.29	0.157	0.008	0.23	0.21

[a]EFP = elevated fat and protein corn; EFP-HAP1 = elevated fat and protein, high available phosphorus corn.
[b]Intakes calculated using actual feed intakes and analyzed N values.

Table 4. The effect elevated fat and protein corn hybrids and phytase on phosphorus digestibility

Corn Hybrid[a]	EFP		EFP-HAP1			Probability, P <		
Phytase, PU/lb	0	136	0	136	SE	Corn	Phytase	Corn ´ Phy.
Phosphorus								
Intake, g/d[b]	6.64	6.80	5.96	6.74	0.504	0.48	0.36	0.55
Feces, g/d	4.62	4.27	1.84	2.53	0.309	0.0001	0.60	0.11
Feces, % DM excreted	2.53	2.18	1.51	1.51	0.127	0.0001	0.20	0.18
Urine, g/d	0.063	0.318	0.469	0.784	0.090	0.0001	0.005	0.75
Urine, %	0.002	0.010	0.017	0.020	0.003	0.0002	0.06	0.42
Total P excreted, g/d	4.68	4.59	2.31	3.31	0.313	0.0001	0.17	0.09
P, % digested	28.97	34.76	69.20	62.45	4.86	0.0001	0.92	0.21
Absorbed, g/d	2.02	2.54	4.12	4.22	0.456	0.0005	0.51	0.65
Retained, g/d	1.96	2.22	3.65	3.43	0.450	0.004	0.96	0.60
Retained, % intake	27.95	29.43	61.44	51.02	5.23	0.0001	0.40	0.27
Retained, % absorbed	97.14	78.00	88.86	81.56	5.25	0.78	0.03	0.35
WSP[c]								
Feces, g/d	1.92	2.13	1.27	1.83	0.355	0.19	0.29	0.62
Feces, % DM excreted	1.08	1.04	1.01	1.11	0.175	0.99	0.85	0.70
Total WSP (feces + urine), g/d	1.99	2.45	1.74	2.62	0.340	0.90	0.06	0.55

[a]EFP = elevated fat and protein corn; EFP-HAP1 = elevated fat and protein, high available phosphorus corn.
[b]Intakes calculated using actual feed intakes and analyzed P values.
[c]WSP = Water soluble phosphorus.

Table 5. The effect of elevated fat and protein corn hybrids and phytase on potassium digestibility

Corn Hybrid[a]	EFP		EFP-HAP1			Probability, P <		
Phytase, PU/lb	0	136	0	136	SE	Corn	Phytase	Corn ´ Phy.
Potassium								
Intake, g/d[b]	10.07	9.81	8.79	9.77	0.741	0.38	0.64	0.41
Feces, g/d	2.84	3.34	1.74	2.83	0.316	0.02	0.02	0.36
Feces, % DM excreted	1.56	1.69	1.40	1.66	0.123	0.46	0.13	0.59
Urine, g/d	3.86	4.22	4.01	4.49	0.620	0.74	0.51	0.92
Urine, %	0.128	0.116	0.123	0.116	0.002	0.32	0.002	0.37
Total K excreted, g/d	6.70	7.56	5.75	7.32	0.741	0.43	0.12	0.64
K, % digested	71.03	64.35	80.38	71.18	3.61	0.04	0.04	0.73
Absorbed, g/d	7.24	6.47	7.05	6.93	0.711	0.85	0.54	0.65
Retained, g/d	3.37	2.25	3.04	2.45	0.724	0.93	0.25	0.72
Retained, % intake	32.06	20.77	34.69	25.83	6.85	0.56	0.16	0.86
Retained, % absorbed	44.51	30.10	42.46	35.91	8.52	0.83	0.23	0.65

[a]EFP = elevated fat and protein corn; EFP-HAP1 = elevated fat and protein, high available phosphorus corn.
[b]Intakes calculated using actual feed intakes and analyzed K values.