Digestibility of Several Known Dietary Manipulations Used in Combination to Reduce Nutrient Excretion in Pigs

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Introduction

The concern associated with the effect of excess nutrient excretion on the environment, as well as odor emissions, continues to grow as suburban communities are beginning to develop in many rural areas. Historically, livestock operations have served as a source of balancing nutrients for cropland which in turn can be recycled back to the animal through grain sources. With the large increase in use of commercial fertilizers and the intensification of livestock production, nutrients are being concentrated to a smaller land mass and present the potential for runoff and leaching of nutrients such as nitrogen (N), phosphorus (P), and potassium (K). It is predicted that agricultural practices in the Mississippi River Basin contribute approximately 2-3 lbs of nitrogen per agricultural acre to the Mississippi River each year. The fertilizer value of this lost nitrogen is valued at $410 million. (CAST, June 1999). Not only does this lost nitrogen have the potential to accumulate and cause low dissolved oxygen levels in waterways, it is a great loss of fertilizer to the farmer. Similarly, phosphorus can pollute waterways through soil erosion and sedimentation.

It has been well documented that manipulation of dietary components can significantly increase nutrient utilization and therefore reduce nutrient excretion in growing pigs. In a previous growth trial at Purdue University conducted by Kendall et al. (2000), pigs were housed in environmentally controlled rooms with separate pits and fed a low crude protein (CP) high-available phosphorus (HAP) corn diet with synthetic amino acids, 5% soybean hulls, 0.05% phytase, and reduced mineral sulfates. The combination diet resulted in lower aerial ammonia concentrations, as well as lower total and ammonium nitrogen in pit manure contents. There was also a 53% reduction in P content of manure. To further analyze the nutrient utilization of these diets by growing pigs, a digestibility trial using similar diets was conducted to determine the effect of dietary manipulations used in combination on nutrient excretion in feces and urine.

Procedures

Twelve crossbred barrows (initial BW = 212 lbs) were blocked by weight and randomly assigned to one of three dietary treatments. All diets (Table 1) were formulated to provide 0.48% digestible lysine (Lys) and are as follows:

1) Standard 13.1 % CP corn-soy diet, 0.23% available P (CTL)
2) 11.5% CP corn-soy diet, 0.15% Lys-HCl, 0.26% available P (AA)
3) 8.25% CP diet with 5% soybean hulls, HAP corn, 0.05% phytase, reduced mineral sulfates, 0.40% Lys-HCl, and 0.16% available P (HRP).

Pigs were adapted to metabolism stalls and dietary treatments for seven days followed by a three day total feces and urine collection. Feces and acidified urine were collected twice daily and frozen at -4°F (-20°C) until analysis. Pigs were fed three times maintenance levels (NRC, 1988), approximately 5 lbs/d , divided equally among three feedings and had ad libitum access to water.

Feces and urine were analyzed for dry matter (DM), pH, nitrogen (N), ammonium N (AMM), total phosphorus (TP), water soluble phosphorus (WSP), potassium (K), and volatile fatty acids (VFA). Dry matter was determined after drying feed and fecal samples at 203°F (95°C) for 24 hours and pH was measured using a calibrated glass electrode pH meter. Nitrogen was determined using micro-Kjeldahl techniques, phosphorus was determined colorimetrically, potassium was determined using atomic absorption, and VFAs were determined by gas chromatography.

Data were analyzed using the GLM procedure of SAS and means were separated using the probability of difference at $P < .05$.

Results and Discussion

Dry matter intake and total fecal DM excreted (Table 2) were not different between treatments. Dry matter digestibility was 88.7%, 88.3%, and 87.9% for the CTL, AA and HRP diets, respectively, and was not affected by treatment. Fecal pH was also not affected by dietary treatment. Total manure excreted (as-is) was reduced 44% ($P < .05$) when the HRP diet was fed compared to the CTL diet (Table 3). This reduction can be attributed to the decreased ($P < .10$) urine excretion by those pigs fed the HRP diet compared to the CTL diet. Pigs fed reduced CP diets likely had decreased water intake, therefore creating less manure slurry volume.

Nitrogen digestibility (Table 3) was not different among treatments at 82.8%, 81.4%, and 75.2% for the CTL, AA and HRP diets, respectively. Fecal nitrogen as a percent of total fecal DM excretion was decreased 23% and 20% ($P < .05$) for the AA and HRP diets, respectively, when compared to the CTL diet. Urinary nitrogen (g/d) had a similar response, with a 41% reduction ($P < .05$) when the AA diet was fed and was further reduced by another 28% ($P < .05$) when the HRP diet was fed compared to the AA diet. The combination of these reductions resulted in a 37% reduction ($P < .05$) in total nitrogen excreted with the AA diet compared to the CTL diet and a 55% reduction ($P < .05$) when the HRP diet was fed compared to the CTL diet. Although nitrogen absorbed ($P < .05$) and nitrogen retained (numerical) were lower for the AA and HRP diets compared to the CTL diet, nitrogen retained as a percent of that absorbed was increased 30% ($P < .05$) when the HRP diet was fed compared to the CTL diet. Fecal ammonium N was 29% and 27% lower ($P < .05$) for the AA and HRP diets, respectively, compared to the CTL diet. Urinary AMM and total AMM excreted tended to be lower ($P < .10$) for the HRP diet compared to the CTL diet. The reduction in nitrogen excretion with the AA and HRP diets are a result of the synthetic amino acid addition allowing for a more ideal amino acid ratio with the lower dietary CP and better utilization of dietary nitrogen. The soybean hull addition to the HRP diet may also be enhancing microbial utilization of nitrogen in the lower gut reducing ammonium nitrogen excretion.

Phosphorus excretion (Table 4) in feces and urine was reduced 62% and 68% ($P < .05$), respectively, when the HRP diet was fed compared to the CTL diet. These reductions combined to reduce total P excretion by 63% ($P < .05$) when pigs were fed the HRP diet compared to the CTL diet. The percent P digested was numerically increased with the addition of synthetic amino acids and further increased with the HRP diet. Phosphorus retained as a percent of absorbed tended to be higher for the HRP diet (83.4% vs. 67.4%) compared to the CTL diet ($P < .10$). Reduction in phosphorus excretion with the HRP diet can be principally attributed to the feeding of a higher available phosphorus corn source plus the activity of supplemental phytase making phosphorus more available for utilization. Water soluble P in the feces was highest at 1.19% of total fecal DM excreted for the AA diet even though the AA diet had 32% ($P < .05$) less WSP intake compared to the control diet. The HRP diet had the lowest WSP in feces and as a percent of fecal DM. Total WSP was reduced 41% ($P < .05$) when the HRP diet was compared to the CTL and AA diets.

Potassium digestibility (Table 5) was not different among treatments at 78.2%, 72.5%, and 69.5% for the CTL, AA, and HRP diets, respectively. Fecal K was not affected by diet, while urinary K was decreased 44% and 62% ($P < .05$) when the AA and HRP diets were fed, respectively, compared to the CTL diet. Total K excreted was reduced 31% and 46% when the AA and HRP diets were fed, respectively, compared to the CTL diet. Potassium retained as a percent of absorbed was 20.1% higher ($P < .05$) for the HRP diet compared to the control diet.

The gross energy (GE) of the diets (Table 6) was approximately 1750 kcal/lb and was not different among treatments. Fecal GE was 13% higher ($P < .05$) for pigs fed the HRP diet compared to the CTL diet, however digestible energy (DE) was not different among treatments. Digestible energy as a percent of total GE intake was 88%, 87%, and 86% for the CTL, AA, and HRP diets, respectively, and was not different among treatments. There was no effect of diet on urinary energy although the HRP diet had numerically lower total urinary energy. This is a result of the tendency for less urine volume ($P < .10$) with the HRP treatment due to the low crude protein content of the diet. The lower urinary energy allowed for greater ($P < .05$) kilocalories per pound of metabolizable energy (ME) when the HRP diet (1424 kcal/lb) was fed compared to the CTL diet (1294 kcal/lb). Metabolizable energy as a percent of GE intake, however, was not different among treatments (75.8%, 78.6%, and 79.8% for the CTL, AA, and HRP diets, respectively).

Total volatile fatty acid production (Table 7) was highest in the CTL diet with a 15% reduction ($P < .05$) in VFAs when AA diet was compared to the CTL diet. The lower fecal VFA concentration from pigs fed the AA diet are a result of lower acetate ($P < .10$), and numerically lower butyrate, isovalerate, and valterate. The HRP diet also tended ($P < .10$) to have lower acetate production when compared to the CTL diet. However, the short duration of feeding the experimental diets may not have allowed enough time to fully shift the hind gut microflora to see the expected increase in VFA production with the 5% soybean hull inclusion in the HRP diet.

As an aide to pork producers, the manure and nutrient excretion values observed in this study are included in English units in Table 8. This data is critical for future planning and for establishing estimates of nutrient excretion for manure management plans using these diet modifications.

Implications

This study suggests that feeding a HAP corn source in a reduced CP diet supplemented with synthetic amino acids and adding 5% soybean hulls and phytase will reduce total N excretion as well as fecal AMM excretion in growing pigs. The data also supports the findings of Kendall et al. (2000) with a dramatic reduction of 63% in total P excretion. Lastly, there is some indication that fecal K excretion can be reduced with the HRP diet and VFA production decreased when a low CP diet with supplemental amino acids is fed. Altering of commercial swine diets to contain some of the dietary manipulations included here should not only alleviate some of the potential environmental impacts currently drawing concerns, but should also allow for more ideal application rates of nutrients to cropland.

References

Kendall, D. C., B. T. Richert, A. L. Sutton, K. A. Bowers, C. T. Herr and D. Kelly. 2000. Effects of Dietary Manipulation on Pig Performance, Manure Composition, Hydrogen Sulfide and Ammonia Levels in Swine Buildings. Purdue University Swine Day Report. p. 152.

Interpretive Summary: *Gulf of Mexico Hypoxia: Land and Sea Interactions.* June 1999. Council for Agricultural Science and Technology. Report 134.

Table 1. Ingredient composition of experimental diets

Ingredient, %	CTL	AA	HRP*
Corn	83.64	87.80	--
High-available P corn	--	--	90.47
SBM-48%	13.03	8.71	--
Soybean hulls	--	--	5.00
Yellow swine grease	1.00	1.00	2.34
Dicalcium Phos.	0.95	1.10	--
Limestone	0.93	0.79	1.18
Salt	0.25	0.25	0.25
Purdue Swine Vit. Premix1	0.10	0.10	0.10
Purdue Swine TM Premix2	0.05	0.05	--
Low Sulfur TM Premix3	--	--	0.05
Natuphos	--	--	.05
Se 600 Premix	0.05	0.05	0.05
Lysine-HCl	--	0.15	0.40
L-Threonine	--	--	0.072
L-Tryptophan	--	--	0.040
Calculated Composition			
ME (Kcal/lb)	1533	1532	1534
Crude protein, %	13.1	11.5	8.25
Lysine, %	.61	.60	.57
Calcium, %	.60	.60	.50
Phosphorus, %	.50	.50	.26
Available Phosphorus, %	.23	.26	.16
Potassium, %	.56	.48	.36
Digestable amino acids			
Lysine, %	.477	.477	.477
Threonine, %	.355	.335	.300
Methionine + Cysteine, %	.394	.379	.300
Tryptophan, %	.102	.076	.080
Isoleucine, %	.420	.404	.270
Analyzed composition			
Crude protein, %	11.91	9.09	7.45
Total Phosphorus, %	0.60	0.59	0.33
Total Potassium, %	0.78	0.67	0.58

*HRP = Reduced crude protein diet with 5% soyhulls, high-available P corn, phytase and reduced mineral sulfates

[1] Provides per lb. of diet: 1100 IU Vitamin A, 110 IU D3, 8 IU Vitaman E, .365 mg Menadione, .006 mg B12, 1.28 mg Riboflavin, 4.0 mg Pantothenic Acid, 6.0 mg Niacin

[2] Provides per lb. of diet: 44 ppm Zn, 44 ppm Fe, 5.45 ppm Manganese, 4.1 ppm Cu, .167 ppm I

[3] Iron carbonate replacing ferrous sulfate, zinc oxide replacing zinc sulfate, manganese oxide replacing manganese sulfate, and copper chloride replacing copper sulfate formulated to provide equal quantities of available minerals

Table 2. Effect of diet on dry matter (DM) digestibility

Diet[a]	**CTL**	**AA**	**HRP**	**CV**
Intake, g/d as-is	2639.4	2367.3	2285.6	11.99
Diet, % DM	87.82	89.56	89.58	--
DM intake, g/d	2318.0	2120.1	2047.4	12.01
Feces, g/d as-is	778.1	700.5	747.9	24.93
Feces, % DM	33.29	35.28	33.92	11.20
Total feces DM excreted, g/d	257.91	245.09	245.65	20.53
DM, % digested	88.78	88.30	87.85	3.23
Feces, pH	6.45	6.46	6.54	2.12

[a] CTL = 13.1% CP standard corn-soy; AA = 11.5% CP with synthetic Lys; HRP = 8.25% CP high-available P corn based diet with synthetic amino acids, 5% soyhulls, phytase and reduced mineral sulfates

Table 3. Effect of diet on nitrogen digestibility and NH_4-N excretion

Diet[f]	**CTL**	**AA**	**HRP**	**CV**
Feces, g/d as-is	778.1	700.5	747.9	24.93
Urine, ml/d as-is	3552.0[d]	2470.8[de]	1658.5[e]	46.65
Total manure excreted, g/d as-is	4330.1[a]	3171.3[ab]	2406.4[b]	35.12
N				
Intake, g/d[g]	50.298[a]	34.442[b]	27.228[c]	11.72
Feces, g/d	8.584	6.331	6.628	27.45
Feces, % DM excreted	3.31[a]	2.55[b]	2.66[b]	11.04
Urine, g/d	23.615[a]	13.983[b]	7.960[c]	18.11
Urine, %	.756	.696	.502	40.83
Total N excreted, g/d	32.199[a]	20.314[b]	14.588[c]	13.73
N, % digested	82.815	81.444	75.211	8.35
Absorbed, g/d	41.714[a]	28.111[b]	20.600[b]	15.80
Retained, g/d	18.099	14.128	12.641	37.99
Retained, % intake	35.086	40.880	45.505	26.84
Retained, % absorbed	42.116[a]	50.161[ab]	59.917[b]	21.80
NH_4-N				
Feces, g/d	1.8307[a]	1.3029[b]	1.3354[b]	21.82
Urine, g/d	2.7042[d]	1.584[de]	0.8650[e]	79.48
Total NH_4-N excreted, g/d	4.535[d]	2.887[de]	2.200[e]	47.80

[abc] Differing superscripts within a row indicate significance at $P < .05$
[de] Differing superscripts within a row indicate significance at $P < .10$
[f] CTL = 13.1% CP standard corn-soy; AA = 11.5% CP with synthetic Lys; HRP = 8.25% CP high-available P corn based diet with synthetic amino acids, 5% soyhulls, phytase and reduced mineral sulfates
[g] Intakes calculated using actual feed intakes and analyzed N values

Table 4. Effect of diet on phosphorus digestibility

Diet[f]	CTL	AA	HRP	CV
Feces, g/d as-is	778.1	700.5	747.9	24.93
Urine, ml/d as-is	3552.0	2470.8	1658.5	46.65
Total manure excreted, g/d as-is	4330.1[a]	3171.3[ab]	2406.4[b]	35.12
P				
Intake, g/d[g]	15.942[a]	13.939[a]	7.512[b]	11.72
Feces, g/d	8.565[a]	7.134[a]	3.275[b]	25.82
Feces, % DM excreted	3.306[a]	2.903[b]	1.323[c]	6.96
Urine, g/d	2.1022[a]	1.6255[ab]	0.6824[b]	44.67
Urine, %	0.060[ab]	0.070[a]	0.041[b]	24.54
Total P excreted, g/d	10.667[a]	8.760[a]	3.958[b]	22.33
P, % digested	45.866	48.266	56.106	27.36
Absorbed, g/d	7.377[d]	6.805[de]	4.237[e]	34.75
Retained, g/d	5.275	5.180	3.554	45.90
Retained, % intake	32.403	36.856	46.955	35.75
Retained, % absorbed	67.374[d]	76.018[de]	83.367[e]	14.88
WSP[h]				
Intake, g/d	5.178[a]	3.504[b]	2.171[c]	11.72
Feces, g/d	2.451[de]	2.906[d]	1.983[e]	26.79
Feces, % DM excreted	0.960[ab]	1.185[a]	0.797[b]	14.64
Total WSP (feces and urine), g/d	4.55[a]	4.53[a]	2.67[b]	15.47

[abc] Differing superscripts within a row indicate significance at $P < .05$

[de] Differing superscripts within a row indicate significance at $P < .10$

[f] CTL = 13.1% CP standard corn-soy; AA = 11.5% CP with synthetic Lys; HRP = 8.25% CP high-available P corn based diet with synthetic amino acids, 5% soyhulls, phytase and reduced mineral sulfates

[g] Intakes calculated using actual feed intakes and analyzed P values

[h] WSP = Water soluble phosphorus

Table 5. Effect of diet on potassium digestibility

Diet[c]	CTL	AA	HRP	CV
Feces, g/d as-is	778.1	700.5	747.9	24.93
Urine, ml/d as-is	3552.0	2470.8	1658.5	46.65
Total manure excreted, g/d as-is	4330.1[a]	3171.3[ab]	2406.4[b]	35.12
K				
Intake, g/d[d]	20.51[a]	15.76[b]	13.14[b]	11.75
Feces, g/d	4.43	4.31	3.94	21.93
Feces, % DM excreted	1.73	1.75	1.61	11.46
Urine, g/d	10.24[a]	5.74[b]	3.91[b]	28.75
Urine, %	0.31	0.26	0.24	20.46
Total K excreted, g/d	14.67[a]	10.05[b]	7.85[b]	15.76
K, % digested	78.19	72.45	69.47	10.21
Absorbed, g/d	16.08[a]	11.46[b]	9.20[b]	17.61
Retained, g/d	5.84	5.71	5.30	34.51
Retained, % intake	28.10	36.40	39.60	27.09
Retained, % absorbed	35.99[b]	51.13[ab]	56.09[a]	25.00

[ab] Differing superscripts within a row indicate significance at $P < .05$
[c] CTL = 13.1% CP standard corn-soy; AA = 11.5% CP with synthetic Lys; HRP = 8.25% CP high-available P corn based diet with synthetic amino acids, 5% soyhulls, phytase and reduced mineral sulfates
[d] Intakes calculated using actual feed intakes and analyzed K values

Table 6. Effect of diet on energy digestibility

Diet[f]	CTL	AA	HRP	CV
Intake, lb/d	5.81	5.21	5.03	11.99
GE of feed, kcal/lb[g]	1708.87	1751.39	1786.51	--
Total energy intake, kcal/d	9934.62	9132.39	8993.78	12.05
Feces, lb/d	0.57	0.54	0.54	20.53
GE of feces, kcal/lb	2070.51[a]	2167.61[a]	2349.12[b]	4.52
Total fecal energy, kcal/d	1174.49	1168.35	1274.84	21.45
DE kcal/lb[g]	1503.50	1522.77	1528.10	3.84
DE, % of GE intake	88.08	87.04	85.63	3.81
Urine, ml/d	3552.0[d]	2470.8[de]	1658.5[e]	46.65
GE of urine, kcal/ml	0.33	0.31	0.32	11.25
Total urine energy, kcal/d	1221.14[d]	800.71[de]	523.30[e]	56.76
ME kcal/lb[g]	1294.35[a]	1374.54[ab]	1423.91[b]	5.48
ME, % of GE intake	75.82	78.57	79.79	5.55

[ab] Differing superscripts within a row indicate significance at $P < .05$
[de] Differing superscripts within a row indicate significance at $P < .10$
[f] CTL = 13.1% CP standard corn-soy; AA = 11.5% CP with synthetic Lys; HRP = 8.25% CP high-available P corn based diet with synthetic amino acids, 5% soyhulls, phytase and reduced mineral sulfates
[g] GE = Gross energy, DE = Digestible energy, ME = metabolizable energy

Table 7. Fecal volatile fatty acid production (VFA) in response to dietary treatment

Diet[f]	**CTL**	**AA**	**HRP**	**CV**
VFA, mmol/L				
Acetate	89.65[d]	74.84[e]	75.80[e]	11.78
Propionate	25.96	24.83	25.53	16.01
Isobutyrate	2.94	2.58	3.03	22.18
Butyrate	19.14	15.05	18.25	19.59
Isovalerate	3.23	2.87	3.07	31.17
Valerate	3.25	2.87	3.07	31.17
Total	144.17[a]	121.93[b]	128.85[ab]	9.25

[ab] Differing superscripts within a row indicate significance at P < .05
[de] Differing superscripts within a row indicate significance at P < .10
[f] CTL = 13.1% CP standard corn-soy; AA = 11.5% CP with synthetic Lys; HRP = 8.25% CP high-available P corn based diet with synthetic amino acids, 5% soyhulls, phytase and reduced mineral sulfates

Table 8. Total nutrients excreted per pig

Diet[a]	**CTL**	**AA**	**HRP**
Total feces, lb/d as-is	1.71	1.54	1.65
Total urine, gal/d as-is	0.938	0.652	0.438
Total manure, lb/d as-is	9.54	6.99	5.30
Total N excreted, lb/d	0.071	0.045	0.032
Total P excreted, lb/d	0.023	0.019	0.009
Total K excreted, lb/d	0.032	0.022	0.017

[a] CTL = 13.1% CP standard corn-soy; AA = 11.5% CP with synthetic Lys; HRP = 8.25% CP high-available P corn based diet with synthetic amino acids, 5% soyhulls, phytase and reduced mineral sulfates