Manipulating Nitrogen in Pig Diets to Reduce Manure Nitrogen Excretion and Odors

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Introduction

The threat of odors emitted from pork production operations in some areas of the country has restricted growth of the industry and has created negative relations with residential neighbors. Odors from manure result from microbial decomposition of the organic matter and nutrients in undigested feed, and normal exogenous end products of cellular metabolism. Reducing nutrient excretions and controlling compounds creating the odors in manure are needed to significantly reduce odors emitted from pork production units. Minimizing nutrient excesses in diets, improving nutrient digestibility and utilization, and balancing nutrient levels to meet the needs of the pig and of the microflora in the digestive system are approaches needing evaluation as potential methods of odor control. Reducing the dietary crude protein level and supplementing with synthetic amino acids has reduced nitrogen excretion from pigs (Lenis, 1993). From 25 to 30% reduction of nitrogen in manure has been reported (Bridges, et al., 1994; Cromwell and Coffey, 1993; Jongbloed and Lenis, 1993; Hartung and Phillips, 1994), and theoretically, a nitrogen reduction of 40 to 50% is possible (Kirchgessner and Roth, 1991). Altering the ratio of nitrogen excretion in urine and feces is a potential means for reducing ammonia emissions. By reducing the nitrogen excretion in urine as urea, which is the primary precursor for ammonia volatilization, and shifting the nitrogen excretion into the feces, which is primarily in the form of bacterial protein, ammonia volatilization is reduced. The objectives of this study were to determine the sources and concentrations of odorous compounds in cecal contents, fresh manure and anaerobically stored manure from swine, and to determine the effects of dietary nitrogen manipulation on production of odorous compounds.

Materials and Methods

Three groups of four crossbred gilts (12 total), averaging 120 lb, were surgically cannulated in the cecum using standard procedures. The pigs were fed each of four diets in a 4x4 Latin Square designed experiment with three replicate trials. Dietary treatments were:

1. 10% crude protein, protein deficient diet;
2. 10% crude protein with four synthetic essential amino acids (lysine, threonine, tryptophan and methionine), amino acid supplemented diet;
3. 13% crude protein diet, standard commercial diet; and
4. 18% crude protein, protein excess diet.

All diets were corn-soy based, fortified with a vitamin and mineral premix and tylan. After a 2-week adaptation to each diet and placement in digestibility crates, cecal samples were collected on three separate days, four hours after feeding. Manure and urine samples were collected over a 24-hour period on three separate days. The manure and urine were mixed and initial manure samples were obtained; subsamples were used for 90-day anaerobic incubations. During the incubations, fresh manure was added three times per week, using typical manure production values for the flask volume. Separate gas samples were collected from the daily cecal and fresh manure samples. Gas samples were collected from anaerobic incubation flasks each week from 60 to 90 days after initiation of the study. Liquid matrix subsamples were acidified and analyzed for short chained volatile fatty acids (VFA). Dry matter, pH, ammonia and total nitrogen were assayed.

Results and Discussion

Results for cecal contents are given in Table 1. The pH and ammonia nitrogen concentrations were not affected by diet. However, total nitrogen concentrations were lower ($P<.05$) in pigs fed the deficient protein and amino acid supplemented diets, as compared to the standard and excess protein diets. From 17% to 20% less nitrogen was present with the amino acid supplemented diet compared to the higher protein diets. The dry matter content from pigs fed the standard and excess protein diets was lower ($P<.05$) than the other diets. Propionic and valeric acids were higher ($P<.05$) for pigs fed the standard diet compared to the other diets, except propionic concentrations were similar for the amino acid supplemented diet. On a molar percent basis, the lowest proportion of butyric acid in the total VFA concentrations was observed with the amino acid supplemented diet. The propionic acid concentrations and molar percentage proportion of the total VFA for pigs fed the excess protein were numerically lower than the other diets. Higher propionate levels in cecal contents favor more efficient energy utilization for the pig. Since ammonia concentrations were not changed by diet and total nitrogen was lower in the cecal contents, it appears that reduced protein degradation resulted.

Results for fresh manure are given in Table 2. The amino acid supplemented diet reduced ($P<.05$) pH, ammonia nitrogen and total nitrogen compared to the other diets. Dry matter level was higher for pigs fed the amino acid supplemented diet, and dry matter was decreased with increasing dietary crude protein ($P<.05$). Ammonia nitrogen, on a dry matter basis, was reduced 25%, 28% and 40% ($P<.05$) with the amino acid supplemented diet as compared to the deficient, standard and excess protein diets, respectively. Total nitrogen, on a dry matter basis, was reduced 20%, 28% and 42% ($P<.05$) with the amino acid supplemented diet as compared to the deficient, standard and excess protein diets, respectively. The only changes in volatile fatty acid concentrations were reduced propionic, butyric and valeric acid concentrations for pigs fed the excess protein diet ($P<.05$). Reduced levels of ammonia and total nitrogen in fresh manure compared to cecal contents suggested that much of the ammonia and total nitrogen reaching the colon was used for further bacterial growth and less was absorbed for excretion in urine. Similarly, less volatile fatty acids were excreted in fresh manure and proportionally were used more efficiently by the pig and/or the intestinal bacteria.

Similar responses to the diets were evident during the anaerobic incubation of the manures (Table 3). The pH of manure from pigs fed the amino acid supplemented diet was lower ($P<.05$) than the other diets. Ammonia and total nitrogen concentrations were significantly lower for pigs fed the amino acid supplemented diet, followed by incremental increases in nitrogen compounds for the deficient, standard and excess protein diets. Ammonia nitrogen concentrations on a wet basis were reduced by 32%, 43% and 56% (P<.05) with the amino acid supplemented diet as compared to the deficient, standard and excess protein diets, respectively. Similarly, total nitrogen levels were reduced by 29%, 43% and 55% (P<.05) with the amino acid supplemented diet as compared to the deficient, standard and excess protein diets, respectively.

Total volatile fatty acid concentrations were highest with the standard diet, with a very high proportion of acetic acid. Conversely, volatile fatty acids were reduced with the deficient and excess protein diets. This response reflects a similar trend in the fresh manure from pigs fed the excess protein, but is not similar to VFA production in the manure from pigs fed the deficient protein diet. Therefore, it appears that there was insufficient nitrogen in the deficient diet to promote microbial decomposition in the anaerobically stored manure. Also, there was an imbalance in the C:N ratio or insufficient carbohydrate in the excess protein diet to promote enhanced microbial decomposition. Although the reduced pH in the amino acid supplemented diet was not solely due to increased VFA, the lower pH and less ammonia and total nitrogen excretion suppressed ammonia volatilization from stored manure. Also, reduced microbial metabolism and growth were evident from the lowered VFA production in manure from the amino acid supplemented diet compared to the standard diet.

Analysis of gas collected from cecal contents has identified ethanol, propanol, butanol, n-propyl acetate, dimethyl disulfide, dimethyl sulfide, s-methyl propanethionate, 2-butanone, and the ethyl esters of propanoic acid and butanoic acid (Table 4). Similar compounds were identified in gas collected from fresh manure at relatively lower concentrations, but with ethanol, propanol, dimethyl disulfide and 2-butanone as the primary organic compounds (Table 5). Prevalent concentrations of ethanol, propanol, dimethyl sulfide, dimethyl disulfide, and carbon disulfide were observed in gas collected from anaerobically stored manures (Table 6). Further studies need to be conducted to discern specific metabolic microbial pathways creating these compounds and to develop means to reduce specific sulfide compounds which cause odors.

Implications

Based upon this study, reducing the crude protein level of pig diets and supplementing with essential amino acids to meet the pig’s lean tissue production significantly reduced total nitrogen excretion and ammonia concentrations, and altered the concentrations and ratios of selected volatile fatty acids in fresh manure. Similar more pronounced results were observed with anaerobically stored manures. Current standard diets often meet the nutritional needs of the pig for the most limiting amino acids, but exceed other amino acids requirements, resulting in excessive nitrogen excretions. Degradation of these excess proteins could result in production of obnoxious odors. By reducing the crude protein level of a typical corn-soy based diet and balancing with essential amino acids, there was more efficient nitrogen utilization by the pig, and less excretion of nitrogenous compounds and odors in manures. Direct measurement of aerial ammonia concentrations from the incubation flasks supported this observation. If the cost of adding additional synthetic amino acids is not too prohibitive, the manipulation of nitrogen in the diet may be a practical method of reducing the land necessary for manure application (based on nitrogen loading rates) and reduction of ammonia into the atmosphere.

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Table 1. Effect of diet on pH, nitrogen components and volatile fatty acids in cecal contents.[1]

Diet	pH	DM	NH_3-N	TKN[2]	Volatile Fatty Acids[3], mmole/L						
(% CP)		%	%DM	%DM	Ac	Pro	iBut	But	iVal	Val	Total
Deficient (10)	5.56	14.4^{a}	0.282	2.40^{b}	69.6	37.6^{b}	0.60^{ab}	16.0	0.99	4.76^{bc}	129.6
Suppl. (10+AA)	5.56	15.1^{a}	0.281	2.32^{b}	68.9	39.7^{ab}	0.68^{a}	16.2	1.73	5.82^{b}	133.1
Standard (13)	5.53	13.2^{b}	0.286	2.79^{a}	68.7	41.2^{a}	0.65^{ab}	17.7	1.14	7.13^{a}	136.6
Excess (18)	5.56	12.5^{b}	0.309	2.88^{a}	71.2	36.5^{b}	0.55^{b}	17.5	1.18	4.25^{c}	131.3

[1] Different letter superscripts within a column indicate means are significantly different (P<.05).
[2] Total Kjeldahl nitrogen.
[3] Volatile fatty acids: acetic (Ac), propionic (Pro), isobutyric (iBut), butyric (But), isovaleric (iVal), valeric (Val).

Table 2. Effect of diet on pH, nitrogen components and volatile fatty acids in fresh manure.[1]

Diet	pH	DM	NH_3-N	TKN[2]	Volatile Fatty Acids[3], mmole/L						
(% CP)		%	%DM	%DM	Ac	Pro	iBut	But	iVal	Val	Total
Deficient (10)	7.80^{a}	17.3^{ab}	3.47^{b}	7.40^{b}	39.4	18.6^{a}	1.42	10.4^{a}	1.99	3.38^{ab}	75.2
Suppl. (10+AA)	7.33^{b}	18.4^{a}	2.61^{c}	5.90^{c}	37.7	20.2^{a}	1.45	11.3^{a}	2.63	3.38^{ab}	76.5
Standard (13)	7.84^{a}	16.0^{b}	3.61^{b}	8.16^{b}	36.8	18.3^{a}	1.40	10.5^{a}	1.96	4.02^{a}	73.0
Excess (18)	8.13^{a}	12.9^{c}	4.35^{a}	10.13^{a}	37.2	14.6^{b}	1.37	8.4^{b}	1.98	3.04^{b}	66.6

[1] Different letter superscripts within a column indicate means are significantly different (P<.05).
[2] Total Kjeldahl nitrogen.
[3] Volatile fatty acids: acetic (Ac), propionic (Pro), isobutyric (iBut), butyric (But), isovaleric (iVal), valeric (Val).

Table 3. Effect of diet on pH, nitrogen components and volatile fatty acids in anaerobically stored manure.[1]

Diet (% CP)	pH	DM %	NH_3-N mg/L	TKN[2] mg/L	Volatile Fatty Acids[3], mmole/L Ac	Pro	iBut	But	iVal	Val	Total
Deficient (10)	7.58^a	5.40^b	4375^c	5631^c	8.4	0.69	1.51	1.51	3.35	0.18	15.64
Suppl. (10+AA)	6.94^b	6.47^a	2986^d	4026^d	10.0	1.34	4.17	21.15	5.27	2.91	45.32
Standard (13)	7.80^a	5.64^b	5239^b	7012^b	82.5	4.44	3.52	2.61	3.94	0.00	96.99
Excess (18)	7.97^a	5.75^b	6789^a	8912^a	13.0	1.76	3.35	0.31	3.88	0.00	22.33

[1] Different letter superscripts within a column indicate means are significantly different (P<.05).
[2] Total Kjeldahl nitrogen.
[3] Volatile fatty acids: acetic (Ac), propionic (Pro), isobutyric (iBut), butyric (But), isovaleric (iVal), valeric (Val).

Table 4. Effect of diet on relative organic compound concentrations in headspace air from cecal contents.

	Diet (% CP)			
Compound	Deficient (10)	Suppl. (10+AA)	Standard (13)	Excess (18)
	relative percent of peak area			
Ethanol	21.8	16.6	17.8	15.4
Propanol	10.9	10.2	10.9	10.7
Butanol	5.8	4.2	6.4	6.6
Pentanol	2.0	2.0	2.0	1.0
n-Propyl acetate	5.3	5.6	5.9	7.3
Propanoic acid, ethyl ester	5.7	5.4	4.2	5.8
Butanoic acid, ethyl ester	4.5	4.2	3.0	7.0
Pentanoic acid, ethyl ester	1.3	4.7	3.0	3.0
Ethanethioic acid, s-methyl ester	4.5	5.5	9.3	5.5
Dimethyl sulfide	2.8	0.0	3.5	4.0
Dimethyl disulfide	5.9	4.8	6.8	7.0
S-methyl propanethionate	6.5	4.2	7.0	5.7
2-Butanone	2.0	3.0	0.0	0.0

Table 5. Effect of diet on relative organic compound concentrations in headspace air from fresh manure.

	Diet (% CP)			
Compound	Deficient (10)	Suppl. (10+AA)	Standard (13)	Excess (18)
	relative percent of peak area			
Ethanol	11.0	13.9	13.2	22.6
Propanol	9.0	7.5	9.6	11.8
Butanol	3.2	3.8	3.8	2.7
Pentanol	1.3	2.3	0.0	5.0
n-Propyl acetate	0.0	3.0	0.0	2.5
Propanoic acid, ethyl ester	6.0	3.5	0.0	3.5
Butanoic acid, ethyl ester	0.0	0.0	0.0	1.0
Ethanethioic acid, s-methyl ester	9.0	8.0	3.7	5.0
Dimethyl sulfide	4.5	2.0	7.0	3.0
Dimethyl disulfide	11.2	17.0	13.4	14.3
S-methyl propanethionate	4.0	6.7	7.0	2.0
Dimethyl sulfoxide	1.0	0.0	3.0	0.0
2-Butanone	9.7	7.3	5.8	8.6
2-Pentanone	6.5	2.0	2.7	4.8
Methyl iso-butyl ketone	0.0	2.0	0.0	0.0
Acetal-aldehyde	2.0	0.0	0.0	0.0

Table 6. Effect of diet on relative organic compound concentrations in headspace air from anaerobically stored manure.

	Diet (% CP)			
Compound	Deficient (10)	Suppl. (10+AA)	Standard (13)	Excess (18)
	relative percent of peak area			
Ethanol	10.7	6.5	16.0	2.7
Propanol	2.8	8.0	6.0	2.0
Butanol	6.6	0.0	0.0	0.0
n-Propyl acetate	4.0	4.0	5.0	3.0
Ethanethioic acid, s-methyl ester	0.0	1.0	4.0	3.5
Dimethyl sulfide	7.2	8.0	15.5	8.0
Dimethyl disulfide	12.0	14.3	11.0	10.3
Dimethyl sulfoxide	1.0	1.0	11.0	7.0
Carbon disulfide	11.2	10.3	10.7	14.0
2-Butanone	3.0	4.0	10.0	2.0
2-Pentanone	0.0	2.0	0.0	0.0
Methyl iso-butyl ketone	1.5	1.5	2.0	0.0