THE EFFECTS OF REDUCING DIETARY CRUDE PROTEIN AND/OR ADDING CHICORY ON COMPOSITION AND ODOR OF STORED SWINE MANURE[1]

S.M. Hanni, J.M DeRouchey, M.D. Tokach, J.L. Nelssen, R.D. Goodband, S.S. Dritz[2], C.N. Groesbeck, M.G. Young, and K.R. Lawrence

Summary

A feeding study was conducted to compare nutrient excretion and odor analysis of pigs fed either a conventional corn-soybean meal diet, or a diet formulated to minimize nutrient excretion and odors through use of crystalline amino acids, phytase, and non-sulfur containing trace minerals. These diets (0.85% true digestible lysine), were fed to pigs (each initially 130 lb) with or without chicory, a feed ingredient speculated to reduce odors in swine waste.

Dietary treatments were arranged in a 2 x 2 factorial, with main effects of diet nutrient excretion potential (low or high) and chicory (0 or 10%). Twelve nonlittermate barrows were fed each of the four diets over four, 10-d periods in a replicated 4 × 4 Latin square design. Each pig was housed in a stainless steel metabolism cage (5 × 2 ft) designed to allow separate collection of urine and feces. Feces and urine were collected between the seventh and eleventh meals in order to measure nitrogen (N), sulfur (S), and phosphorus (P) intake, excretion, and retention. Feces and urine also were collected the last two days of each period and mixed into a 7.5% DM slurry for odor analysis at the University of Minnesota Olfactometry Laboratory. The 7.5% DM slurries were measured for pH, total solids (TS), total volatile solids (TVS), ammonia, total Kjeldahl nitrogen (TKN), hydrogen disulfide (H2S), percentage sulfur (sum of sulfur in air and slurry samples), and Ca, K, Mg, Na, and P. Air samples collected from the slurries were measured for H2S, intensity, and offensiveness.

Pigs fed diets formulated to reduce nutrient excretion and odor had a 20% and 34% reduction ($P<0.001$) in total N and P excretion, respectively, and a 33% reduction in urinary S excretion. The addition of chicory to the diet further reduced ($P<0.002$) N and P excretion by 10% and 14%, respectively. Pigs fed the diets formulated to reduce nutrient excretion and odor had lower ($P<0.001$) total pH, ammonia, sulfur dry weight percentage, and TKN in the slurry samples. However, H2S emission, odor intensity and offensiveness were not affected ($P<0.19$). These results indicate that formulating a diet to meet the needs of a pig, yet lower nutrient excretion by use of synthetic amino acids, phytase, non-sulfur-containing trace mineral premixes and the addition of chicory will reduce nutrient excretion in swine manure, but do not appear to affect the intensity or offensiveness of odors.

---

[1]The authors would like to thank the Kansas Center for Agricultural Resources and the Environment (KCARE) for funding of the experiment.

[2]Food Animal Health and Management Center.

(Key Words: Pigs, Chicory, Odor, Nutrient Excretion, Phytase)

Introduction

Concern about odor emissions and nutrients from livestock manure overloading the soil and entering waterways has become a major issue for the swine industry in the past few years. Several compounds are associated with the odor of swine manure: ammonia, amines, sulfur-containing compounds, volatile fatty acids, indole, skatole, phenols, alcohols, and carbonyls. Several nutrients – such as N, P, and S – in feed ingredients are not completely digested by pigs. These excess nutrients are then excreted as waste and deposited in lagoons or spread on nearby fields.

Several compounds associated with the odor and nutrient levels in swine manure have been altered through diet or microbial manipulation. It was shown that by adding 3% or 6% Jerusalem artichoke to the diet, swine manure had a sweeter, less sharp and pungent odor, and less of a skatole smell than pigs eating the control diet. The tuber of the Jerusalem artichoke is rich in the carbohydrate inulin, a fructose polymer. Chicory (Cichorium intybus) is also rich in inulin. These fructose polymers (fructooligosaccharides) have been shown to alter volatile fatty acid (VFA) patterns by increasing the population of bifidobacteria in the hindgut and thus reducing odor in feces. Research has also shown that adding 5% chicory to the diet significantly reduces skatole in manure of pigs fed a corn-soy diet. However, in this same study, added inulin had no effect on nitrogen-related odor.

Many of the compounds found to cause odor are related to the degradation of excess amino acids commonly found in diets. Research has shown that by reducing the dietary crude protein content by 4% and formulating the diet to meet the requirements for the first four limiting amino acids with crystalline amino acids, aerial ammonia concentrations could be reduced by 29%. The impact of crystalline amino acid supplementation with low-CP diets to reduce N excretion has been shown to range from 3.2 to 6.2%, depending on the weight of the pig, level of dietary CP reduction, and initial CP level in the control diet.

Our objective was to determine the effect of chicory supplementation on nutrient excretion and odor characteristics in stored manure. In addition, we evaluated several other technologies that are known to lower the odor and nutrient level of swine waste including: 1) use of low protein, amino acid-fortified diets; 2) use of nonsulfur-containing trace mineral premixes; and 3) use of phytase to lower the diets phosphorus level. The use of a combination of these technologies provides a model to test the effectiveness of chicory addition on nutrient excretion and emission of ammonia, sulfur, and other odor-causing compounds.

Procedures

Twelve nonlittermate barrows, each weighing approximately 130 lb, were used in a 4 × 4 replicated Latin square design. The Latin square consisted of four consecutive periods, with each period lasting 10 days. At the beginning of each period, pigs were weighed and randomly assigned to a dietary treatment, treatments then changed with every 10-d period so that each pig was fed all four of the experimental diets. All diets (Table 1) were formulated to provide 0.85% true digestible lysine and were fed in meal form. A typical, 18% CP corn-soybean meal diet was formulated with no crystalline L-lysine HCl or phytase (0.51% available P). This diet also used a trace mineral premix with the sulfur-containing form of the various trace minerals. We expected our formulation method of this diet to have high nutrient excretion in waste and potential for odor production. The other diet was formulated to reduce nutrient excretion and odor through the use of crystalline amino acids, added phytase, and a replacement of the sulfur-containing trace minerals with other forms. The typical (high nutrient excretion), or low protein (low nutrient excretion) diets were fed with none or 10% chicory added. Pigs were fed at 3% their body weight, divided equally among two feedings, with ad libitum access to water. We designed our experimental treatments such that by having high and low nutrient excretion and odor dietary treatments, we should be able to detect differences in nutrient excretion and odor. We could then evaluate the effectiveness of added chicory compared with the high or low nutrient excretion diets.

Pigs were housed in individual stainless steel metabolism crates design for separate collection of feces and urine. Each pig was allowed three days to adapt to the dietary treatments followed by a three-day collection period of feces and urine. Feces and acidified urine were collected twice daily and frozen until analysis. Then, on the final two days of each period, all feces and urine (non–acidified) were collected for the simulated anaerobic pit system. Simulated anaerobic pit systems are designed to mimic an anaerobic manure system, in which the manure can be analyzed for nutrient content and odor production. Feces and urine were collected twice daily and refrigerated until the end of the two-day collection period. After all feces and urine were collected, feces from pigs fed the same diets were blended and DM content was determined for the blended feces. Urine from pigs fed the same diets also was blended. The feces and urine were then blended together to form a 7.5% DM slurry for each treatment. From this slurry, 19 sub-samples were collected with the samples being one 2-L sample, and eighteen 50-ml aliquots. The samples were stored in separate plastic containers and labeled, then frozen until the completion of the four periods and shipped to the University of Minnesota Olfactometry Laboratory for odor and nutrient content analyses.

At the University of Minnesota, each 2-L sample was thawed and placed in a simulated anaerobic pit. The simulated anaerobic pits were then stored in an environmentally-controlled chamber with a constant temperature. A 50 ml aliquot (from the same original sample) was thawed and added to each simulated pit two times a week (Tuesday and Thursday) to feed the bacterial population. Nutrient and odor analysis was conducted on days 28 and 56.

On the day of odor and nutrient analysis, each simulated pit was agitated, and a 100 ml sample was pipetted from the simulated pit. Air samples were taken by placing the 100 ml samples into glass flasks, and covering the flask with a rubber stopper with an inlet and outlet. Charcoal-filtered nitrogen gas was moved over the headspace of the flask at a rate 1.5L/min for 50 minutes in order to purge existing gases. After 50 minutes, a 10-L Tedlar bag was attached to the outlet and filled using a vacuum box.

The air samples were then analyzed for odor units using dynamic olfactometry and total reduced sulfur (TRS) concentration using a Jerome® meter. Each 100 ml sample was then analyzed for total solids (TS), pH, total volatile solids (TSV), total nitrogen (tN), ammonium nitrogen ($NH3 – N$), total sulfide, and total minerals.

Results and Discussion

The volume of nutrients excreted through urine and feces is an important environmental concern. If the land base for manure application and storage capacity is limited, decreasing manure and nutrient outputs becomes a crucial issue to a swine operation. In our study, there were no differences ($P>0.19$) in fecal wet weight or fecal dry weight between pigs fed any of the four dietary treatments (Table 2). However there was a nutrient excretion level by chicory interaction ($P<0.03$) for fecal dry matter percentage. This difference in percentage fecal DM appears to be partially due to the slightly higher (3% increase; P<0.001) DM intake for pigs fed diets formulated to reduce odor and nutrient excretion. Including chicory in the diet also appears to increase the moisture content of the feces, as evidenced by lower fecal dry matter for pigs fed diets including chicory. Pigs fed the diets formulated to reduce odor and nutrient excretion excreted 7% less (P<0.03) urine than pigs fed the conventional corn-soybean meal diets, while the addition of chicory further reduced (P<0.001) urine output by 13%. The reduction in urine output could have been affected by the amount of water intake. We did not measure water intake in our study, but all pigs were offered water ad libitum. It appears that including chicory in the diet alters the route of excretion for water to decrease excretion in the urine and increase excretion in the feces. Pigs fed low nutrient excretion diets had higher (P<0.01) ADFI than pigs fed the high nutrient excretion diets. The difference in intake is a result of feeding the pigs 3% of their body weight instead of feeding a constant level during each stage. Neither diet formulation method nor added chicory affected DE, ME, or DE as a percentage of gross energy of the diet.

There was a nutrient excretion level by chicory interaction (P<0.001) for N intake. As expected, pigs fed the diets formulated to reduce nutrient excretion and odor had decreased N intake compared to pigs fed the high protein diets. The reduction of N intake between the two formulation methods was due to a 22% reduction in CP by the use synthetic amino acids. The interaction occurred because the addition of chicory to the low nutrient excretion diet decreased N intake 16% whereas there was no change in N intake when adding chicory to the conventional corn-soybean diet. The reason for this anamoly is two-fold. First, pigs fed the low nutrient excretion diet without chicory had higher total feed intake, as discussed earlier. Second, the low nutrient excretion diet without chicory had a higher analyzed protein content than expected, leading to higher calculated N intake.

Total N excretion was reduced by 20% (P<0.001) when pigs were fed diets formulated to reduce nutrient excretion and odor. Added chicory further reduced (P<0.03) total N excretion by 10% and 14% for pigs fed the diets formulated for low nutrient excretion and the conventional corn-soybean meal diets, respectively. Similar to total N excretion, urinary N excretion was reduced 36% (P<0.001) for pigs fed diets formulated for lower nutrient excretion and odor. The addition of chicory reduced (P<0.01) urinary N level by 17% and 13% in pigs fed the diets formulated for lower nutrient excretion and the conventional corn-soybean meal diets, respectively. Fecal N excretion tended to be numerically higher (P>0.09) with the addition of chicory. Other research has shown that when a fermentable carbohydrate (such as chicory) is added, increase in fecal N excretion and a decrease in urinary nitrogen are often observed. A nutrient excretion level by chicory interaction (P<0.008) was observed for nitrogen retention (g/day). Adding chicory reduced N retention when added to the diets formulated to decrease nutrient excretion, but increased N retention in pigs fed the conventional corn-soybean meal diets. As the diets were formulated closer to the pigs' amino acid requirements with the use of synthetic amino acids, there was a 15% improvement (P<0.001) in N retention (%) for pigs fed the diets formulated for low nutrient excretion and odor.

Phosphorus (P) intake was reduced 26% (P<0.001) for pigs fed the diets formulated for low nutrient excretion and odor compared to the conventional corn-soybean meal diets. The addition of chicory to the diet decreased (P<0.001) P intake an additional 13% and 10% for pigs fed the diets formulated for lower nutrient excretion and those fed the conventional corn-soybean meal diets, respectively. A nutrient excretion level by chicory interaction (P<0.002) was observed for total P excreted and fecal P excreted. This appeared to be a result of a low level of P excreted in the diets formulated for lower nutrient excretion and odor. A further reduction was seen when chicory was added to this diet. Urinary P excretion was not affected ($P<0.08$) by dietary nutrient excretion level or the addition of chicory. Phosphorus retention (g/d and %) was increased when pigs were fed diets formulated for low nutrient excretion and odor but increased in those fed the conventional corn-soybean meal diets (nutrient excretion level by chicory interaction, $P<0.002$).

Sulfur (S) intake decreased with the addition of chicory to diets formulated to lower nutrient excretion and odor, but increased in the conventional corn-soybean meal diets (nutrient excretion level by chicory interaction, $P<0.001$). However, pigs fed the diets formulated to reduce nutrient excretion and odor had a lower S intake ($P<0.001$) than pigs fed the conventional corn-soybean meal diets. The diets formulated to reduce nutrient excretion and odors were created with a nonsulfur-containing trace mineral premix and DL-methionine to minimize S intake. When the diets were analyzed for S, diets formulated to reduce nutrient excretion and odor with chicory had a lower level of S than the conventional corn-soybean meal diet. Urinary sulfur excretion was 33% lower ($P<0.001$) for pigs fed diets formulated to reduce nutrient excretion and odor. There was no effect ($P<0.18$) of nutrient excretion level, chicory level, or chicory by nutrient excretion interaction for total S excreted, or fecal S excreted. A nutrient excretion level by chicory interaction ($P<0.001$) for S retention was expressed on a g/d or percentage of S intake basis. The addition of chicory reduced S retention for pigs fed diets formulated to lower nutrient excretion and odor, and increased S retention for pigs fed conventional corn-soybean meal diets.

The odor and other response criteria for the 7.5% DM slurry from individual dietary treatments were analyzed on d 28 and 56 of storage (Tables 3 and 4). In general, the magnitude of results changed over time (Table 4), but few dietary treatments changed by day of storage interactions.

Slurry pH was decreased ($P<0.01$) for pigs fed diets formulated to lower nutrient excretion compared with those fed the conventional corn-soybean meal diets. The differences in pH observed may be because of the lower urinary N excretion. A reduction ($P < 0.04$) of total solids occurred when chicory was added to diets, which may be due to the lower percentage DM excreted by pigs fed diets containing chicory.

Manure slurry ammonium nitrogen (NH3 – N) and TKN were reduced ($P<0.01$) 18% and 15%, respectively for pigs fed diets formulated to lower nutrient excretion and odor. The difference in NH3 – N and TKN levels between the two methods of formulation was due to lower nitrogen input and better retention of nitrogen with the use of synthetic amino acids in diets formulated for lower nutrient excretion and odor. The addition of chicory did not have an effect ($P>0.84$) on the NH3 – N or TKN in the slurry.

There were no differences in ($P>0.19$) H2S in the air samples measured by the Jerome meter or measured in the slurry sample. The percentage S dry weight was reduced ($P<0.001$) by 21% when pigs were fed with the diets formulated to lower nutrient excretion, due to the use of non–S containing trace mineral premix and DL-methionine. However, added chicory tended to increase ($P<0.08$) percentage S in the slurry on a dry weight basis.

There were several reductions for Ca, K, Mg, Na, and P when diets were closely formulated to meet the needs of the pig. Ca, Na, and P were reduced ($P<0.001$) due to the use of lower crude protein diets formulated with phytase. Calcium, P, and Mg were further reduced ($P<0.001$) with the use of chicory. The reduction in the mineral content of the slurry, because of diet formulation and the use of chicory, will help to reduce the buildup of minerals in the soil and surrounding waters due to land application.

There were no differences ($P>0.22$) for odor intensity or odor offensiveness among dietary treatments. This implies that formulation technique, including crystalline amino acids, phytase, nonsulfur-containing trace mineral premixes, and the addition of chicory had no effect on reducing the relative offensiveness of swine manure odors.

From d 28 to d 56, pH of the simulated anaerobic pits was reduced ($P<0.01$) by 3%. The addition of the 50 ml aliquots each week to the simulated pits simulated the addition each day in a hog facility. These additions increase both the number of bacteria and the amount of nutrients (proteins) in the slurry. As the bacteria population increase the amount of proteins that are broken down also increase, which cause a decrease in slurry pH.

The addition of the 50 ml aliquots to the simulated pits twice a week was intended to maintain a 7.5% DM slurry. However from d 28 to d 56, there was a reduction ($P<0.01$) of percentage total solids. This reduction of solids was due to the bacterial population breakdown of nutrients.

From d 28 to d 56, manure slurry NH3 – N and TKN increased ($P<0.001$) 23% and 18%, respectively. The difference in NH3 – N and TKN levels between d 28 and d 56 was due to the increase in slurry, which added nutrient high in nitrogen.

When the air samples collected off of the slurry were tested by the olfactometry panelist, odor intensity was scored lower ($P<0.001$) for d 56. This reduction was not seen for either the formulation methods or interaction with chicory. Because of the lack of interaction seen between the formulation methods, we concluded that this reduction is not due to treatment but instead due to scoring of the panelist or reduction in other odor compounds over time.

Implications

Using formulation techniques, such as reducing the CP in a diet with the use of synthetic amino acids, using nonsulfur-containing trace mineral premixes, adding phytase to the diet, and the inclusion of chicory, may have added benefits to the environment. The diets formulated to lower nutrient excretion and odor reduced total and urinary nitrogen excretion, while chicory helped reduce fecal nitrogen by 5%. Phosphorus was reduced by 34% with the addition of phytase in the diet, while sulfur was reduced 33% due to the use of nonsulfur-containing trace mineral and the addition of DL–methionine. The addition of chicory at 10% of the diet was also beneficial in reducing the amount of P and N excreted in this study. Pigs fed the diets formulated to reduce nutrient excretion and odor had lower total pH, ammonia, sulfur dry weight percentage, and TKN in the slurry samples. However, H2S emission, odor intensity and offensiveness were not affected. The diet formulation alteration and addition of chicory did not have a negative affect on growth performance while reducing the excretion levels of the pig. These diet alterations may provide a method to further reduce the level of odor and nutrients leaving the swine farm.

Table 1. Diet Composition (As-fed Basis)

Nutrient excretion level:	Low[c]		High[d]	
Ingredient, % — Chicory, %:	0	10	0	10
Corn	81.15	70.90	71.65	61.45
Soybean meal, 46.5% CP	16.55	16.85	25.90	26.25
Chicory	--	10.00	--	10.00
Monocalcium phosphate, 21% P	0.23	0.23	0.65	0.65
Limestone	0.97	0.88	1.17	1.06
Salt	0.35	0.35	0.35	0.35
Vitamin premix[a]	0.13	0.13	0.13	0.13
Trace mineral premix[b]	0.13	0.13	0.13	0.13
L-Tryptophan	0.01	0.01	--	--
L-Threonine	0.08	0.09	--	--
L-Lysine HCl	0.30	0.30	--	--
DL-Methionine	0.05	0.07	--	--
Phytase[e]	0.08	0.08	--	--
Total	100.00	100.00	100.00	100.00
Calculated analysis.				
Total Lysine, %	0.95	0.95	0.97	0.97
True digestible lysine, %	0.85	0.85	0.85	0.85
True digestible amino acid ratios, %				
Isoleucine:lysine	61	60	79	78
Leucine:lysine	150	142	176	168
Methionine:lysine	32	34	31	30
Met & Cys:lysine	60	60	65	62
Threonine:lysine	63	63	69	68
Tryptophan:lysine	17	17	22	22
Valine:lysine	71	70	89	88
Metabolizable energy, Mcal/kg	3.35	3.35	3.33	3.32
Protein, %	14.6	14.3	18.1	17.9
Ca, %	0.50	0.50	0.67	0.66
P, %	0.39	0.38	0.52	0.51
Available P equiv, %	0.21	0.21	0.21	0.21
Chemical analysis				
Crude protein, %	16.47	14.90	18.53	18.75
P, %	0.39	0.35	0.55	0.50
S, %	0.16	0.14	0.17	0.19
Gross energy, Mcal/kg	3.99	4.01	4.03	3.99

[a]Provided the following per kilogram of complete diet: vitamin A, 11,023 IU; vitamin D3, 1,653 IU; vitamin E, 44 IU; menadione (menadione bisulfate complex), 4.4 mg; vitamin B12, 0.04 mg; riboflavin, 9.9 mg; pantothenic acid, 33 mg; and niacin, 55 mg.
[b]Provided the following per kilogram of complete diet: Mn, 40 mg; Fe, 165 mg, Zn, 165 mg, Cu, 17 mg, I, 0.3 mg; and Se, 0.3 mg.
[c]Trace mineral premix formulated with: zinc oxide, ferric chloride, manganese oxide, cupric chloride, and calcium iodate and sodium selenite.
[d]Trace mineral premix formulated with: zinc sulfate, ferrous sulfate, manganese sulfate, cupric sulfate, calcium iodate, and sodium selenite.
[e]Provided 300 FTU/kg of feed (Natuphos® 600).

Table 2. The Effects of Reducing Dietary Crude Protein and Adding Chicory on Nutrient Availability[a]

Items	Nutrient level:	Low		High			P< value		
	Chicory, %:	0	10	0	10	SED	Nutrient level	Chicory	Interaction
Fecal									
Wet weight excreted, g		1,390	1,425	1,344	1,432	83	0.74	0.30	0.66
DM, %		33	29	31	29	0.5	0.02	0.001	0.03
Dry weight excreted, g		458	414	416	417	23	0.24	0.19	0.19
Urine excreted, ml		7,254	5,946	7,471	6,838	347	0.03	0.001	0.18
Feed									
ADFI, g/d		1823	1,783	1,746	1,738	18	0.001	0.08	0.23
Digestible energy, %		86	87	87	88	1	0.13	0.16	0.40
Digestible energy, Mcal/kg		3.44	3.50	3.52	3.49	---	---	---	---
Metabolizable energy, Mcal/kg		3.32	3.39	3.37	3.35	---	---	---	---
Nitrogen									
Intake, g		111.3	99.2	123.9	126.2	1.3	0.001	0.001	0.001
Total excreted, g		49.0	43.5	68.2	62.6	3.5	0.001	0.03	0.99
Urinary excreted, g		36.0	30.1	54.5	48.0	3.4	0.001	0.01	0.92
Fecal excreted, g		13.0	13.4	13.7	14.6	0.8	0.09	0.23	0.68
Retention, g		62.3	55.7	55.6	63.6	3.6	0.82	0.80	0.008
Retention, %		56.3	56.1	45.1	50.8	3.3	0.001	0.25	0.21
Phosphorus									
Intake, g		14.8	13.0	20.0	17.9	0.2	0.001	0.001	0.25
Total excreted, g		8.8	6.1	11.2	11.1	0.6	0.001	0.002	0.005
Urinary excreted, mg		1.6	2.8	3.1	2.5	0.7	0.20	0.53	0.08
Fecal excreted, g		8.8	6.0	11.2	11.1	0.6	0.001	0.002	0.005
Retention, g		6.0	7.0	8.8	6.8	0.6	0.004	0.26	0.002
Retention, %		40.3	53.4	43.6	38.5	3.7	0.03	0.13	0.001
Sulfur									
Intake, g		6.0	5.1	6.2	6.8	0.1	0.001	0.03	0.001
Total excreted, g		2.2	2.1	2.1	2.2	0.1	0.87	0.61	0.19
Urinary excreted, mg		59.7	58.3	88.1	86.2	9.2	0.001	0.80	0.98
Fecal excreted, g		2.1	2.0	2.0	2.1	0.1	0.86	0.59	0.18
Retention, g		3.8	3.0	4.1	4.6	0.1	0.001	0.05	0.001
Retention, %		64.0	59.0	66.4	67.5	1.9	0.001	0.17	0.03

[a]Values are means of 12 barrows (59 to 207 kg) over four periods with 3 pigs per treatment per period.

Table 3. The Effects of Reducing Dietary Crude Protein and Adding Chicory on Odor Quality[a]

	Nutrient level:	Low		High			P< value			
Item	Chicory, %:	0	10	0	10	SED	Day	Nutrient level	Chicory	Interaction
pH		8.4	8.2	8.6	8.6	0.11	0.01	0.01	0.17	0.34
Total solid, %		9.4	8.8	9.3	8.8	0.38	0.01	0.78	0.04	0.87
Total volatile solid, %		6.4	6.4	6.5	6.0	0.30	0.08	0.54	0.37	0.26
NH3-N, mg/L		4,495	4,763	5,757	5,527	490	0.001	0.01	0.96	0.48
Total Kjeldahl nitrogen, mg/L		6,014	6,722	7,876	7,046	414	0.001	0.001	0.84	0.02
H2S, ppm		1.0	1.7	0.7	1.0	2.01	0.36	0.19	0.24	0.64
H2S Air, ppm		0.6	0.8	1.2	1.0	0.50	0.44	0.34	0.97	0.59
Sulfur dry weight, %		68.5	78.2	91.5	95.1	5.0	0.06	0.001	0.08	0.41
Ca, ppm		70,453	30,891	44,115	43,577	4,366	0.01	0.04	0.001	0.001
K, ppm		18,352	21,649	22,932	22,517	2,659	0.49	0.16	0.45	0.33
Mg, ppm		6,224	5769	7,697	5,904	694	0.29	0.12	0.03	0.19
Na, ppm		5,190	4,565	4,024	3,913	520	0.54	0.02	0.33	0.49
P, ppm		10,273	8,637	15,179	12,245	1,171	0.57	0.001	0.01	0.44
Intensity		5.0	4.9	5.2	5.0	0.21	0.001	0.22	0.36	0.80
Offensives		-2.7	-2.9	-3.0	-2.8	0.33	0.96	0.67	0.96	0.52

[a]Values are means of 16 samples with four samples per treatment over two sampling periods.

Table 4. The Effects of Storage Time on Manure Slurry and Odor[a]

	Day			P< value
Items	28	56	SED	Day
pH	8.57	8.35	0.11	0.01
Total solid, %	9.50	8.65	0.38	0.01
Total volatile solid, %	6.51	6.13	0.30	0.08
NH3-N, mg/L	4,483	5,788	490.33	0.001
Total Kjeldahl nitrogen, mg/L	6,243	7,586	413.95	0.001
H2S, ppm	1.30	0.90	2.01	0.36
H2S Air, ppm	1.04	0.76	0.50	0.44
Sulfur dry weight, %	79.7	87.0	5.0	0.06
Ca, ppm	51,698	42,820	4366	0.01
K, ppm	22,021	20,704	2659	0.49
Mg, ppm	6,663	6,134	694	0.29
Na, ppm	4,538	4,308	520	0.54
P, ppm	11,823	11,344	1171	0.57
Intensity	6.0	4.0	0.21	0.001
Offensives	-2.8	-2.8	0.33	0.96

[a]Values are means of 16 samples with four samples per treatment over two sampling periods.