Effects of Manure Storage Time and Filling Scheme on Odor and Headspace Analysis Using Simulated Manure Storage Pits

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Summary and Implications

Swine manure was stored in 2-liter simulated manure storage vessels for up to 91 d. Manure was added to the vessels by using one of two filling schemes. Vessels were filled either completely on day 0 (SF) or received a 1/10-volume addition each week (200 ml) for 10 wk (WF). Weekly, headspace gases were collected for analysis by an electronic nose and gas chromatography. Once weekly, headspace gases were adsorbed to cotton swatches for odor evaluation by human panelists. Vessel contents were collected when vessels were terminated (between 56 and 91 d) and analyzed for composition. Findings indicate that filling mode and length of manure storage influenced manure components. Solids content was greater in WF vessels. Although total nitrogen did not change with storage time, NH_4-N increased with time, likely due to conversion of organic nitrogen to inorganic nitrogen. Headspace gas content was influenced by both storage time and filling scheme although not all analytes were affected similarly. Length of storage time did impact odor score. A prediction equation developed from headspace analytes reflected odor scores moderately ($R^2 = 0.18$). Development of an equation based on the chemical composition of the manure following storage did not improve predictive capability ($R^2 = 0.20$). Correlation of the electronic nose response to odor score was similar ($r = 0.20$). However, the prediction equation developed from headspace gas constituents predicted electronic nose response well ($R^2 = 0.76$). Results suggest that manure management practices may be modified to address odor potential. Instrumental methods continue to require further development before they become practical tools for odor assessment.

Introduction

As animal production becomes more concentrated and urban areas expand into formerly rural areas, malodor is of increasing importance. Malodors are generally considered nuisance pollutants but are regulated by some states (6). Malodors are produced by the microbial breakdown of undigested feed components in an anaerobic environment (8); potentially a mismanaged lagoon, or an earthen or formed manure storage structure. The storage process has a direct impact on the intensity and character of the odors produced (7). However, the mechanism of formation and the composition of odor is not well defined (3). Gas chromatography-mass spectrometry analysis of air samples associated with swine manure storage has identified more than 200 compounds present in the samples (5). Research is needed to investigate the production and composition of malodor as it pertains to manure handling and storage. Manure storage likely has a significant impact on odor as it develops. Alteration of manure storage and handling may be one way to decrease malodor production at these facilities, creating less of a problem for producers and their neighbors.

Quantifying the intensity of the malodor produced is a subjective process. The measurement of odor is specific to each human and an individual's response may change each time the odor is encountered, making it difficult to apply a value to the intensity and offensiveness of the smell (11). Each person also has a specific odor threshold, the lowest value in which an odor can be detected making it difficult to determine what is considered offensive and intense (10). The intensity of smell is also dependent on the gender and age of the person. Females often have a better sense of smell than males do. As a person ages, they lose their sense of smell so that by the time they are 80 only 28% of their sensory nerves remain (11). Humans also suffer from odor fatigue. This enhances the difficulty in assessing the intensity and offensiveness of odors that are encountered after other odors are detected (11). Methods are now being devised to replicate the human sense of smell. However, at this time, the human nose can detect odorants at concentrations in the ppb and ppt range (11), whereas instrumental detection limits are often in the ppm and ppb range.

Alternatives to human assessment may be desirable for regulatory evaluation of odors. Identification of compounds most highly correlated to odor and development of a prediction equation that characterizes malodor potential is one approach to providing such an alternative. Furthermore, development of instrumental methods may also play a role. The electronic nose is one instrument currently studied to replicate the human sense of smell. Data evaluating the electronic nose's potential for use with livestock odors are lacking. Although a widely used application in the food and beverage industry, some food odor trials have demonstrated difficulty in replicating previously collected data (9). The specific objectives of this study were as follows:

1. Evaluate changes in malodor, and associated air composition, as influenced by manure storage time.
2. Quantify the compositional and odor intensity differences that occur when manure is undisturbed compared with weekly additions of manure.
3. Compare the odor intensity scores, as determined by human panelists, with chemical and instrumental analyses.

Materials and Methods

Simulated manure storage pits. Swine manure was collected weekly from a grow-finish building with sloping concrete floors. Urine was able to drain away, resulting in a product that was approximately 22% total solids (TS). Collected manure was stored in a simulated manure storage pit, constructed of PVC pipe (10.2 cm wide by 31.1 cm tall, 2-liter operating volume). When full, 4.4 cm of headspace was provided between the manure surface and the top of the storage vessel. The storage unit was sealed with a screw on lid that fit into a female PVC adapter. A valve was located on top of the lid to allow fermented air to escape into a balloon. Manure storage vessels were filled by one of two schemes each in duplicate. One scheme filled the storage vessel in a single addition (SF); the other scheme operated with a 1/10 volume addition each week (200 ml; WF) for a 10-wk period. New vessels were initiated weekly to provide a staggering of storage times available for evaluation. To fill a storage vessel completely in a single manure addition (SF), a 1-kg sample of fresh swine manure was mixed with 1 liter of distilled water. This product was then transferred to the manure storage vessel and sealed. This process continued once weekly for 6 wk, resulting in a total of 12 SF manure storage vessels (6 weeks in duplicate). All SF vessels continued to operate until project termination on April 25, 2001 thereby allowing for up to 91 d of storage for the vessels filled on d 0. In the case of the weekly fill storage units (1/10 volume addition each week; WF), 200-ml of a 1:1 mixture of swine manure and distilled water was added to each manure storage vessel weekly until full (10 wk). The 200 ml samples were formulated from a single collection of the swine manure and frozen until needed. All WF storage vessels were terminated April 4, 2001 when the WF units started on January 23, 2001 (day 0) reached 70-d storage time. At the time of termination of each vessel a homogenous 200-ml subsample was collected and frozen for future analyses.

Odor evaluation. Once weekly a 10.2-cm^2 cotton bandage was taped inside the cap of each manure storage vessel to allow odors to adsorb to it overnight. These bandages were then used for odor assessment by untrained, volunteer, human panelists following placement of the bandages into screw-top glass jars (12,13). A triangular forced-choice procedure was used. Panelists were asked to identify which sample in a set of three contained a bandage that smelled differently than the other two (blanks) and score that sample for intensity by using a scale of 1 (barely perceptible) to 10 (very intense). If the panelist could not correctly select the jar containing the exposed bandage, a score of 0 was given to that sample. To reduce odor fatigue, weekly odor panels contained between 12 and 20 different sets of samples despite that as many as 34 storage vessels were operational. Vessels were selected for inclusion in the odor panel evaluations such that as many "days stored - filling scheme" combinations as possible were included in each weekly panel session. The weekly odor panels were conducted from wk 2 (day 7) of the project until the termination of the project at day 91, resulting in 12 odor panels. However, after day 70 of the study only the SF vessels remained operational.

Participants were required to provide their age group (over or under age 35) and their gender to establish whether these two factors had an effect on the odor score assigned to samples. To eliminate as much variance between panelists as possible, panelists were required to adhere to a set of posted rules. Panelists recorded the exact order in which testing of the samples occurred to determine whether odor fatigue affected the odor scores.

Headspace composition. Concurrent with panelist evaluation, headspace analysis was conducted weekly on each manure storage vessel even if the vessel was not represented in the panel session. To collect a headspace sample for analysis by using gas chromatography-mass spectrometry (GC-MS), a solid phase microextraction (SPME) fiber (Supelco SPME Portable Field Sampler; 75-µm-thick partially crosslinked carboxen/polydimethylsiloxane phase material, Supelco, Bellefonte, PA) was placed in the valve at the top of the cap on each storage vessel and exposed for 20 min to allow compounds to equilibrate between the ambient air and the phase coating. A Hewlett Packard 6890 Plus II gas chromatograph coupled to a 5973 mass selective detector (Agilent Technologies, Inc., Wilmington, DE) was used to identify and quantify odorous compounds. Compounds present in the standard solutions, and, therefore, potentially quantified are depicted in Table 1. Headspace composition also was evaluated weekly using a CyraNose-320 electronic nose (Cyrano Sciences, Pasadena, CA) consisting of 32 polypyrrole sensors. The sampling device on the electronic nose was placed in the valve at the top of the cap on each storage vessel and an air sample analyzed by the electronic nose. Data from the electronic nose was then downloaded from the instrument to an Excel spreadsheet.

Chemical analysis. Total solids (TS) content was analyzed on the subsample of each vessel that had been collected on its termination date. A portion of the collected sample was weighed into a porcelain crucible and dried at 105_ C (2). Chemical oxygen demand (COD; Hach EPA-approved Method 8000; Hach Company, Loveland, CO) of each vessel's contents was determined. Total Kjeldahl nitrogen and ammonia nitrogen (1) content was determined to compare how total nitrogen and ammonia nitrogen content was related to the final odor score of each vessel.

A portion of the subsample that was collected from each vessel at the time of project termination was centrifuged and supernatant exposed for 20 min to a SPME fiber. The fiber was then analyzed by GC-MS for odorous compounds present in the sample after its given storage period.

Statistical analyses. Odor concentration, electronic nose response, and air composition were evaluated statistically using the mixed procedure of SAS, version 6.01. To analyze treatment effects (filling scheme and days stored), vessel served as the experimental unit in the incomplete randomized block design. Fixed variables included vessel nested within filling scheme, filling scheme, the interaction of days stored and filling scheme, and panelist. Storage time (d) was treated as a continuous independent variable to look at dose-response relationships. Stepwise regression procedures were used to generate an odor prediction equation from quantified air analytes, which were considered, initially, as cubic terms. The GC-MS results were used to predict panelist response and were compared with the electronic nose response. Correlation procedures were used to relate human panelist response to electronic nose response. Simple correlations between individual odorants and odor score were determined.

Results and Discussion

Manure storage time and vessel filling effects. By using the statistical model described previously, no differences between duplicate vessels were found for odor, headspace analyses or compositional analyses of contents at termination. In addition, vessel differences were not observed indicating that each vessel produced similar results when treated similarly regarding storage time of manure and filling scheme (SF or WF). Filling scheme did result in differences in odor scores assigned to the cotton swatches ($P = 0.008$). Figure 1 illustrates that SF vessels produced greater odor scores than WF vessels initially. Days stored was a significant factor in determining odor ($P = .002$). A significant interaction between filling scheme and days stored ($P = 0.01$) resulted. This was due to differences in odor score trends for the two filling schemes. Odor scores increased with time in the WF vessels ($P < 0.05$). In the SF vessels, after an initial spike in odor during the first week of storage, odor scores decreased up to d 49 ($P < 0.05$), followed by no change in scores from d 49 to d 91 ($P > 0.05$). Table 2 numerically depicts odor scores for vessels filled by each filling scheme at each weekly interval of storage time.

Analyses of the vessel contents at each weekly interval of storage time, and for each filling scheme, indicates that biological processing of the stored manure likely occurred to a lesser extent when the manure was added all at once (SF) rather than incrementally over a 10-wk period (WF). Solids content of the SF vessels was less than in WF vessels after equivalent storage time (Table 3). Solids degradation followed a linear decline with storage time in the SF vessels ($P < 0.05$) whereas no trend was observed in the WF vessels. The lack of a trend was probably to the weekly addition of manure containing 11% TS to the WF vessels. No trend for COD content was observed for either filling scheme (Table 3). Similarly, no significant trend over storage time was observed for TKN content of the manure (Table 3), indicating that N was conserved in the vessels. The NH_4-N content depicted a linear increase with storage time for both SF and WF vessels (Table 3). This trend was likely due to the breakdown of organic N to an inorganic form over time. Although it was expected that some N would be lost as NH_3 each week when the vessels were opened for headspace analyses, the stability of TKN suggests that this loss was minimal. The NH_4-N content, given equivalent storage time was greater in the SF vessels ($P < 0.001$) perhaps due to less volatilization of NH_3 because manure was not added weekly, thereby decreasing the mixing of the manure. Filling scheme influenced the following manure analytes acetic acid, isobutyric acid, butyric acid, isovaleric acid, valeric acid, 4-methylphenol, 4-ethylphenol, indole, dodecane, tridecane, and tetradecane (Table 4, $P < 0.05$). Manure storage time influenced manure concentrations of propionic acid, valeric acid 4-ethylphenol, indole, and 3-methylindole (Table 5, $P < 0.05$).

Headspace composition via GC-MS indicated that filling scheme and manure storage time influenced concentrations of some analytes ($P < 0.05$). Least squares means of the influenced analytes are depicted in tables 6 and 7. Filling scheme influenced headspace concentrations of propionic acid, butyric acid, valeric acid, phenol, 4-methylphenol, decane, nonanal, and undecane (Table 6, $P < 0.05$). Storage time affected headspace concentration of propionic acid, butyric acid, valeric acid, nonanal, undecane, dodecane, dimethyl disulfide, pentane, and nonane (Table 7, $P < 0.05$).

Instrumental and chemical relationships to odor. Pearson correlation coefficients between individual odorants analyzed in vessel headspace gas and odor scores assigned to exposed cotton swatches are depicted in Table 8. Of the 32 analytes that could be quantified, only 22 analytes were identified frequently enough to generate correlation coefficients. When comparing air constituents to odor dilution threshold values Gralapp et al. (4) also observed correlations of magnitude similar to those found in this study. The compounds identified by Gralapp et al. (4) as best correlated to odor were similar. Gralapp et al. (4) found that 3-methylphenol ($r = 0.23$) and 2,6-*bis* dimethylethylphenol ($r = 0.14$) were two of the most important analytes. Gralapp et al. (4) did not, however, consider sulfides which, based on this work, appear to be important (Table 8). Observed correlations were low relative to correlations observed in previous studies (8) where manure constituents were correlated to odor scores rather than correlating headspace constituents to odor score. In the current study strong correlations between odor score and specific constituents of the manure were observed. These correlations are depicted in Table 9.

In addition to determining simple correlations between odor score and analyte concentration in the headspace, a prediction equation was developed incorporating identified analytes as cubic terms. A reduced model was then developed leaving significant cubic terms in the model and incorporating nonsignificant cubic terms as quadratic or linear terms. The resultant equation accounted for 18% of the variation

associated with predicting odor score (R^2 = 0.18). Others have observed prediction coefficients much greater using an odor scoring system (8, R^2 = 0.64) with a similar number of observations. In this study, the equation was developed based on 267 observations compared with 266 observations in the study by Powers et al. (8). The equation developed by Powers et al. (8) considered primarily VFAs rather than a broad spectrum of compounds such as those considered in this study. Powers et al. (1997) used manure contents to predict odor rather than headspace gas constituents. In the current work, use of vessel content analyses as predictors of odor accounted for 22% of the variation (R^2 = 0.22) compared with the R^2 = 0.18 observed when headspace gas constituents were used in equation development. Gralapp et al. (4) developed a prediction equation by using 16 analytes found in air samples that accounted for 27% of the variation observed (R^2 = 0.27, n = 72). To try to improve odor prediction capability by GC-MS analyses of the current study, only VFAs were included in a second analysis. In this case, the predictive capability decreased slightly to R^2 = 0.16 suggesting that the VFAs may, in fact, represent the most important components of odor response. However, simple correlations between headspace gases and odor scores do not support this idea.

The response of each of the 32 sensors in the electronic nose was compiled and analyzed by Principal Component Analysis. Following, the generated principal component was correlated to the odor score producing a Pearson correlation coefficient of r = 0.20. The results of this study were similar to those observed by Gralapp et al. (4, r = 0.18) where an AromaScan electronic nose was used. Similar to observations by Gralapp et al. (4), the electronic nose response correlated well to the prediction equation developed using all analytes identified (R^2 = 0.76).

Panelist effects. Panelist was a significant determinant of odor score ($P < 0.05$) due to individual variation in sensitivity and previous exposure to livestock odors. Analysis of panelist characteristics indicated that although gender did not influence odor score, age group was significant. Across genders the least squares mean for odor score of all 3735 observations was 4.15. Females assigned a score of 4.14, whereas males assigned a score of 4.16. The least squares mean of odor score across all 3735 observations was 4.42 for panelists under the age of 35 and 3.88 for panelists over the age of 35. Other similar studies also have found that sensitivity declines with age (8). Thirty-six of the 63 panelists were under the age of 35.

It did appear that a carryover effect did occur in this study. One panel session contained 20 sets of odor samples, however, most contained between 12 and 16 sets of samples. Further analysis found that the carryover effect was male-dependent but strong enough to result in a significant effect across all observations. The gender dependency may, however, relate to physiological differences in odor perception and sensitivity. A similar number of males and females participated in the study. Of the 63 total panelists that participated, 29 were female.

Conclusions

The results of this study support the idea that odor is dependent on manure management and storage time. Loading properties of manure into storage facilities influenced perceived odor as well as odor properties over time. Nutrient composition of the manure was influenced by storage time and, to a lesser extent, filling scheme. The results suggest that VFAs may have been the most influential class of compounds related to odor. However, 4-methylphenol and dimethyl disulfide were the specific compounds that best correlated to odor score. Although our instrumental results were similar to that found in other studies, continued work is needed if a chemical or instrumental approach is to be used to predict odor nuisance potential.

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Table 1. Odorants included in stock standard solutions for quantification by gas chromatography-mass spectrometry.

Odorant		
Acetic acid	Decane	Carbon disulfide
Propanoic acid	Undecane	Dimethyl disulfide
Isobutyric acid	Dodecane	Ethanethiol
Butyric acid	Pentane	Propanethiol
Isovaleric acid	µ-Butyrolactone	Butanethiol
Valeric acid	Nonanal	Methylamine
Phenol	1-Decene	Dimethylamine
3-Methylphenol	Tridecane	Diethylamine
4-Methylphenol	Tetradecane	Triethylamine
2-Ethylphenol	Nonane	Indole
3-Ethylphenol		2-Methylindole
4-Ethylphenol		3-Methylindole
2,6-Bis(1,1-dimethylethyl)phenol		4-Methylindole

Table 2. Least squares means of odor score of manure storage vessel contents filled by one of two modes and stored for varying days.

Mode	Single fill	Weekly fill
Days Stored	Odor Score	
0	3.86	3.42
7	5.29	3.71
14	5.25	3.57
21	4.96	4.12
28	5.12	4.54
35	4.97	4.76
42	5.16	4.35
49	4.81	4.95
56	4.79	4.75
63	4.53	4.67
70	4.60	4.58
77	4.48	
84	4.52	
91	5.03	

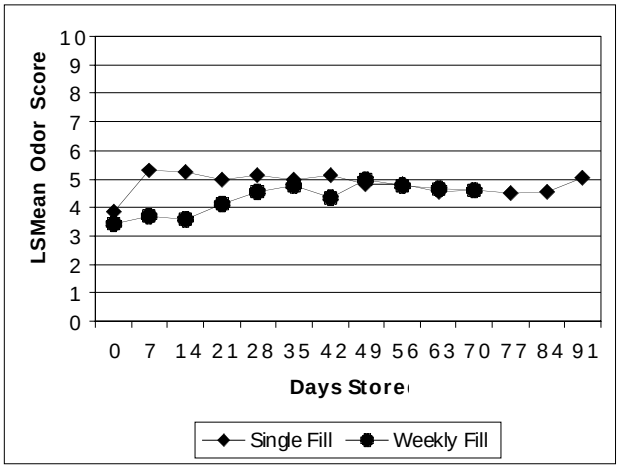

Figure 1. Least square means of odor scores assigned to cotton swatches after exposure to manure stored for various lengths of time in vessels filled using one of two filling schemes.

Table 3. Least squares means of manure composition from storage vessels.

Mode	Days stored	TS,%	COD, g/l	TKN, % DM	NH_4-N, % DM
Single fill	56	10.27	114.6	0.55	0.27
	63	8.56	106.5	0.50	0.27
	70	8.16	99.6	0.48	0.25
	77	7.82	108.3	0.52	0.29
	84	6.68	95.7	0.51	0.31
	91	7.43	133.0	0.58	0.31
Weekly fill	0	11.01	114.5	0.52	0.11
	7	11.86	130.8	0.55	0.14
	14	11.28	118.9	0.54	0.17
	21	9.65	114.9	0.53	0.16
	28	10.04	116.8	0.53	0.22
	35	10.29	117.4	0.52	0.20
	42	9.89	114.7	0.53	0.21
	49	9.33	115.5	0.51	0.23
	56	9.38	105.6	0.51	0.24
	63	9.47	120.7	0.51	0.30
	70	8.89	108.6	0.54	0.28

Table 4. Least squares means of swine manure analyte concentrations that were influenced by filling scheme of simulated 2 liter storage vessels.

Odorant concentration (µM)	Single fill (2 liter)	Weekly addition (200 ml per week for 10 wk)
Acetic acid	821.43	4520.05
Iso-butyric acid	55.03	2.35
Butyric acid	1050.62	327.21
Iso-valeric acid	28.33	8.20
Valeric acid	427.12	49.24
4-Methylphenol	28.84	5.91
4-Ethylphenol	0.38	0.66
Indole	0.73	0.95
Dodecane	22.99	55.46
Tridecane	25.86	63.13
Tetradecane	42.53	78.83

Table 5. Least squares means of swine manure analyte concentrations that were influenced by storage time (d) in simulated 2 liter storage vessels.

Odorant concentration (uM)							
			Days Stored				
	0	7	14	21	28	35	42
Propionic acid	745.75	2461.89	958.56	757.61	879.06	135.58	304.39
Valeric acid	38.86	57.32	27.12	18.52	22.88	48.85	48.86
4-ethylphenol	0.06	0.00	0.00	0.00	0.49	0.00	0.44
Indole	0.09	0.00	0.00	0.00	0.39	0.00	0.14
3-methylindole	0.22	0.05	0.07	0.00	0.30	0.16	0.19
Days stored	49	56	63	70	77	84	91
Propionic acid	365.80	788.85	491.63	723.99	460.61	241.40	144.52
Valeric acid	28.69	142.03	290.11	380.19	746.58	101.05	340.92
4-Ethylphenol	0.58	0.74	0.95	1.501	0.64	0.76	0.17
Indole	1.02	1.10	2.19	1.61	0.80	2.14	0.46
3-Methylindole	0.19	0.60	0.66	0.63	0.47	2.67	0.42

Table 6. Least squares means of analyte headspace concentrations that were influenced by filling scheme of simulated 2 liter manure storage vessels.

Odorant concentration (ppm)	Single fill (2 liter)	Weekly addition (200 ml/wk for 10 wk)
Propionic acid	0.2171	0.0818
Butyric acid	0.0329	0.0106
Valeric acid	0.0056	0.0025
Phenol	0.0020	0.0010
4-Methylphenol	0.0017	0.0004
Decane	0.1018	0.0737
Nonanal	0.1381	0.1087
Undecane	0.1758	0.1579

Table 7. Least squares means of analyte headspace concentrations that were influenced by manure storage time (d) of simulated 2 liter manure storage vessels.

Odorant concentration (ppm)							
Days stored	0	7	14	21	28	35	42
Propionic acid	0.0693	0.4919	0.3433	0.1928	0.2079	0.1399	0.0967
Butyric acid	0.0073	0.0711	0.0420	0.0290	0.0386	0.0082	0.0391
Valeric acid	0.0014	0.0072	0.0068	0.0087	0.0048	0.0027	0.0067
Nonanal	0.2430	0.2652	0.2642	0.0663	0.0611	0.0170	0.0424
Undecane	0.3528	0.3626	0.2755	0.1333	0.0994	0.0060	0.0082
Dodecane	0.1983	0.2165	0.1801	0.0848	0.0923	0.0276	0.0277
Dimethyl disulfide	0.0045	0.0355	0.0421	0.3092	0.3135	0.3387	0.3020
Pentane	0.9829	0.9088	2.3790	0.7320	0.6421	0.3684	0.1186
Nonane	0.0187	0.0094	0.0198	0.0100	0.0061	0.0000	0.0125
Days stored	49	56	63	70	77	84	91
Propionic acid	0.0105	0.0371	0.0131	0.0856	0.1495	0.1495	0.1495
Butyric acid	0.0024	0.0073	0.0044	0.131	0.0218	0.0218	0.0218
Valeric acid	0.0000	0.0008	0.0007	0.0024	0.0041	0.0041	0.0041
Nonanal	0.0756	0.0625	0.0939	0.1245	0.1987	0.2281	0.0147
Undecane	0.0633	0.0534	0.1248	0.2069	0.2319	0.3814	0.0348
Dodecane	0.0294	0.0531	0.0759	0.0797	0.0944	0.1426	0.1164
Dimethyl disulfide	0.5898	0.8459	0.7847	0.4457	1.1097	0.4465	1.5191
Pentane	0.2235	0.0714	0.0918	0.1285	0.2182	0.2142	0.2142
Nonane	0.0331	0.0224	0.0278	0.0440	0.1707	0.1179	0.0029

Table 8. Pearson correlation coefficients between odor score and headspace chemical analyses.

Compound	Correlation coefficient (r)	Compound	Correlation coefficient (r)
Acetic acid	0.05	Decane	0.01
Propionic acid	0.15	Undecane	0.03
Isobutyric acid	-0.12	Dodecane	0.05
Butyric acid	0.14	Nonane	0.01
Isovaleric acid	0.05	1-Decene	0.07
Valeric acid	0.15	Tridecane	0.08
Phenol	0.02	Tetradecane	0.05
4-Methylphenol	0.24	Indole	-0.02
3-Methylphenol	0.05	2-Methylindole	-0.02
2,6-Bis(dimethylethyl)phenol	0.14	3-Methylindole	-0.02
Carbon disulfide	0.07		
Dimethyl disulfide	0.22		

Table 9. Pearson correlation coefficients between odor score and chemical analytes in swine manure.

Compound	Correlation coefficient (r)	Compound	Correlation coefficient (r)
Chemical oxygen demand	-0.15	4-methylphenol	-0.02
Total Kjeldahl nitrogen	-0.13	3-methylphenol	-0.40
Ammonium nitrogen	0.46	4-ethylphenol	0.60
Total solids	-0.44	Indole	0.42
Acetic acid	-0.02	3-methylindole	0.28
Propionic acid	-0.32	Undecane	0.17
Isobutyric acid	-0.21	Dodecane	0.15
Butyric acid	-0.29	Tridecane	0.23
Isovaleric acid	-0.01	Tetradecane	0.28
Valeric acid	-0.06	Dimethyl disulfide	-0.03
Phenol	0.03		