Effects of Dietary Treatment on Odor and VOCs Emitted From Swine Manure

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Summary and Implications

Odor and volatile organic compounds (VOCs) emissions associated with swine production facilities are major concerns for the swine industry. Swine manure is one of the major sources of odor from swine operations. Odor control approaches include ration manipulation, improved manure treatment processes, capture and treatment of odorous gases, and improved dispersion. This study was conducted to investigate the effects of a low level of crude protein and low sulfur content in diets of young swine on odor and VOCs emissions from the headspace of swine manure. Small pigs in metabolic stalls were fed twice daily over 28 days with diets containing either 19.36 % crude protein, 7.06 % cellulose and 2,296 mg/kg sulfur (diet B) or 17.83 % crude protein, 6.82 % cellulose and 1,772 mg/kg sulfur (diet H). Three replicate trials were conducted and three pigs were used for each diet. All excreted manure (feces and urine) were collected daily after morning feeding and added to the manure storage vessel designed to hold waste from the same growing pig. Gas samples were collected from the headspace of manure storage container using 85 µm Carboxen/PDMS SPME fibers at the end of each trial and three replicate gas samples were collected for each pig. All samples were analyzed simultaneously for chemicals and odors on a GC-MS-olfactometry system. Statistical analyses were performed to determine the effects on diets on target odorous chemicals and odor. A total of 40 compounds belonging to 14 chemical classes were identified in the headspace of swine manure. A subset of 14 odorous compounds responsible for the characteristic odor of swine manure were selected for statistical analyses. The lower sulfur and crude protein diet was associated with reduced methanethiol (p=0.0686), dimethyl sulfide (p=0.0006), 2,4-dithiapentane (p<0.00001), acetone (p=0.0003), toluene (p=0.0133), 4-methyl phenol (p=0.0745), 4-ethyl phenol (p=0.00004) and skatole (p=0.0002). The total odor (p=0.0262) and some characteristic odors caused by specific gases were also significantly reduced, i.e. 'sewer' (H_2S) (p=0.0014), 'acetic' (acetic acid) (p=0.00001), 'skunky' (2,4-dithiapentane) (p=0.0261), 'onion' (dimethyl trisulfide) (p=0.0122) and phenolic' (4-ethyl phenol) (p=0.0168).

Introduction

Air pollution and odor nuisance problems have become a major challenge for the livestock production. Swine production facilities are associated with the increased frequency of odor-related complaints compared to other species. Malodors from swine operations arise from urine and feces, feed, and animal bodies. The most significant source of odor is from the excreta of swine and their decomposition during collection, handling, storage, and spreading.

Swine industry diets contain a larger amount of proteins than the animals require. Only a proportion of dietary protein is used for growth or other production activities of the animal. Proteins and their metabolites in the excreta are precursors for odor formation. Feed management can affect the composition of swine manure, especially with respect to N. There is abundant literature on the impact of the reduction of dietary protein supply to swine on the reduction of N excretion and ammonia emissions. However, limited research has been done on the impact of feeding a reduced crude protein (CP) and amino-acid (AA)-supplemented diet on reducing odorous compounds. Hobbs (1996) reported reductions of VFAs and branched-chain VFAs, 4-methyl phenol, indole and skatole in manure from pigs fed low-protein diets (14 and 13% CP for grower and finisher diets, respectively) compared to high-protein diets (21 and 19% CP for grower and finisher diets, respectively). Sutton et al. (1998) used a low sulfur premix and a low protein diet and reported 63% reduction in mercaptans. However, Sutton et al. (1999) also reported no differences in phenolics or sulfur-containing compounds in feces from pigs fed 10, 13, or 18% CP diets. Moreover, Otto et al. (2003) reported an increase in total VFA concentration in the manure and a tendency to increase odor offensiveness from pigs fed reduced CP and AA-supplemented diets, while Shriver et al. (2003) reported lower VFA concentration. The effects of dietary protein levels on odor in the above-mentioned studies were inconsistent. Different sampling and sample preparation methods might partly contribute to this inconsistency.

The objective of this research was to qualitatively evaluate the effectiveness of feeding reduced CP by supplements of AA and lowering dietary sulfur content on odor and VOCs emission from swine manure headspace.

Materials and Methods

Three replicate trials were conducted in this study. Table 1 shows the composition of the diets. In each trial, three pigs were used for each diet and three replicate gas samples were collected for each pig. Small pigs (3 pigs/diet) were fed twice daily over 28 days with diets. Over the 39-d feeding period, average initial and final BW were 8.7 and 24.8 kg, respectively, with an average daily feed consumption of 628 g/d. During the last week of the experiment, samples of headspace gas emitted from swine manure in the manure tanks were collected by using 85 µm Carboxen/PDMS SPME fiber (Supelco, Bellefonte, PA) for 10 min extraction at room temperature (~21 ºC). SPME fiber was inserted into the headspace of swine manure tank through a sampling port with green septa.

Samples were analyzed on a MDGC-MS-O system (Microanalytics, Round Rock, TX) for simultaneous chemical and sensory analyses.

Results and Discussion

A total of forty-eight compounds were identified from the headspace of swine manure. Among those compounds only several chemical groups contributed to the offensive odor of swine manure, including short-chain VFAs, volatile sulfur compounds, and phenolic and indolic compounds. Fourteen compounds responsible for swine odor belonging to those groups were selected for comparison of the effects of the low CP dietary treatment, including seven sulfides, one VFAs, two phenols and two indoles. Two additional compounds (acetone and toluene) were included in the target compounds as well since they showed significant difference between control and treatment. Sulfur-containing compounds are major contributors to the offensive odor associated with swine manure. One of the purposes of this study was conducted to determine if reduced dietary sulfur content would lead to reduced sulfur compounds and odor emissions from swine manure. In this study, two different dietary sulfur levels were used, i.e. 2296 mg/kg for diet B and 1772 mg/kg for diet H, respectively. Seven sulfide compounds were identified from the headspace of swine manure, i.e. H2S, methanethiol, dimethyl sulfide, dimethyl disulfide, 2,4-dithiapentane, dimethyl trisulfide and dimethyl tetrasulfide. Decreasing the sulfur and crude protein content in diet correspondingly reduced methanethiol (p=0.0686), dimethyl sulfide (p=0.0006), dimethyl disulfide (p=0.2696), dimethyl trisulfide (p=0.1777), dimethyl tetrasulfide (p=0.7873), 2,4-dithiapentane (p<0.00001), acetic acid (p=0.6323), acetone (p=0.0003), toluene (p=0.0133), 4-methyl phenol (p=0.0745), 4-ethyl phenol (p=0.00004) and skatole (p=0.0002). However, the mean amounts of H_2S (p=0.0686) and indole (p=0.6958) increased with reduce crude protein and sulfur.

Twelve characteristic odors responsible for swine odor were selected for further evaluation of the effectiveness of low dietary CP and sulfur content on swine odor including ‘Sewer’ (H2S), ‘Sewer, Foul’ (Methanethiol), ‘Foul, Onion’ (Dimethyl sulfide), ‘Buttery’ (Diacetyl), ‘Acidic’ (Acetic acid), ‘Mercaptan’ (Dimethyl disulfide), ‘Skunky’ (2,4-Dithiapentane), ‘Onion’ (Dimethyl trisulfide), ‘Burnt’ (Guaiacol), ‘Barnyard’ (4-Methyl phenol), ‘Phenolic’ (4-Ethyl phenol), ‘Barnyard’ (Skatole). Among those corresponding compounds, two compounds, i.e. diacetyl and guaiacol, were not present in chemical analysis, however, the odors caused by these two compounds were recorded by panelist. On one hand, this result was due to the very low concentration of diacetyl and guaiacol in the headspace of swine manure below the detecction limit of MS detector. On the other hand, the odor detection thresholds of these compounds were very low, i.e. 4.4 ug/l for diacetyl and 3-21 ug/l for guaiacol, so even they could not be identified by GC-MS, they could still be identified by human nose. It is noteworthy that utilizing human nose as a detector is more sensitive than MS detector in this regard.

Average reduction of total odor for three trials with low dietary CP and sulfur was 19%. The reduction rate for the total odor for #1 trial was -8.5% with a slightly generation. However, there were 30% and 34% reduction rates for #2 and #3 trials, respectively. Most of the offensive odors were controlled by dietary treatment except ‘sewer’ (H2S) for #1 trial, ‘acetic’ (acetic acid) and ‘barnyard’ (4-methyl phenol). Surprisingly, ‘barnyard’ (4-methyl phenol, p-cresol) was dramatically generated for trial #1 and #3. *p*-Cresol showed slightly significant reduction for the three trials. This result was probably due to the generation of m-cresol which was co-eluted with p-cresol and caused the similar odor to p-cresol, i.e. ‘barnyard, fecal, piggy’. Statistical analysis for odor showed total odor had a significant reduction (p=0.0262) and some characteristic odors also had a significant reduction, i.e. ‘sewer’ (H2S) (p=0.0014), ‘acetic’ (acetic acid) (p=0.00001), ‘skunky’ (2,4-Dithiapentane) (p=0.0261), ‘Onion’ (Dimethyl trisulfide) (p=0.0122) and phenolic’ (4-Ethyl phenol) (p=0.0168). Compared with chemical analysis, there were two odorants that showed consistent significant reductions for both chemicals and odors including ‘skunky’ (2,4-dithiapentane) and ‘phenolic’ (4-ethyl phenol).

Acknowledgements

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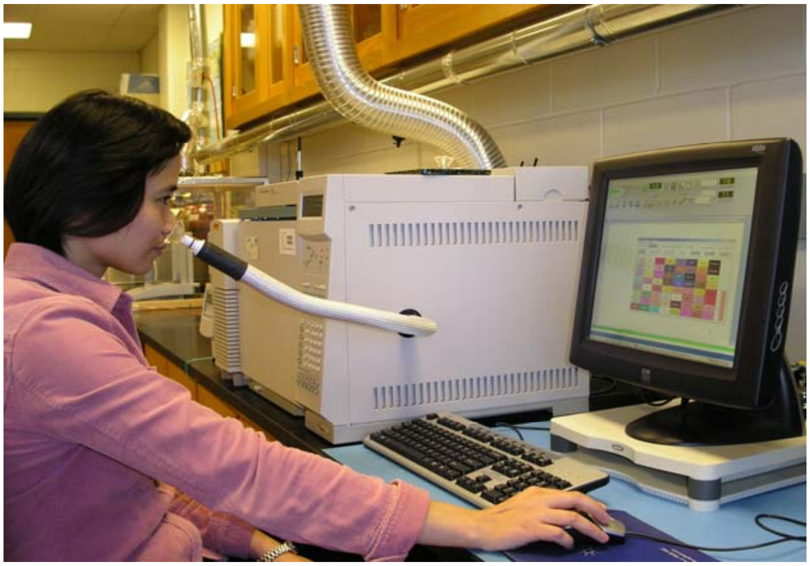
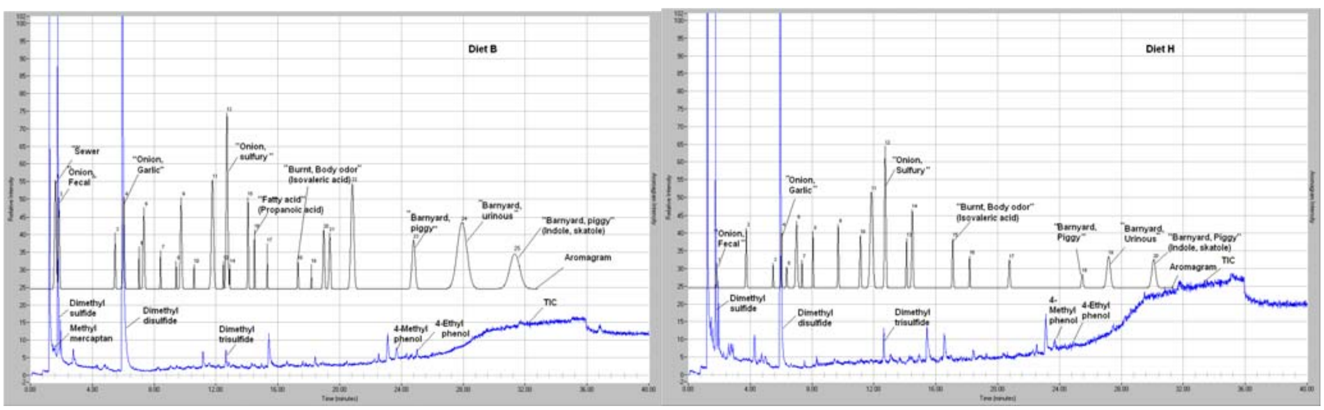


Figure 1. Panelist evaluates odors emitted from swine manure simultaneously with chemical analysis.



Part A **Part B**

Figure 2. Comparison of aromagram and chromatogram of diet B (Part A) and diet H (Part B) by using HS-SPME-GC-MS-O.

Table 1 Composition of experimental diets.

Ingredient, %	Standard	Test
Corn	53.58	58.42
Soybean meal	26.84	22.18
Dried whey	5.00	5.00
Soybean hulls	10.00	10.00
Animal fat	.90	.79
Dicalcium phosphate	1.80	-
Defluorinated phosphate	-	1.99
Limestone	.58	
Sodium chloride	.35	.35
Vitamin mix	.30	.30
Choline chloride-60	.15	-
Trace mineral mix-standard	-	.15
Trace mineral mix-test	.07	.07
L-lysine HCl	.25	.40
L-threonine	.07	.14
L-tryptophan	-	.02
DL-methionine	.10	.14
L-valine	-	.05
Calculated composition		
Crude protein, %	19.36	17.83
Sulfur, mg/kg	2296	1772