Swine manure composition affects the biochemical origins, composition, and accumulation of odorous compounds¹,²

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ABSTRACT: Odors from swine production facilities are associated with the storage and decomposition of manure. Diet is linked to manure composition and will likely affect odor, but the microbial mechanisms responsible for manure decomposition and odor production are poorly understood. To identify the sources of odor during manure fermentation, substrates (starch, casein, and cellulose) were added to slurries of fresh swine manure, and the anaerobic accumulation of fermentation products and the consumption of substrates were measured relative to no addition of substrates. Volatile fatty acids and alcohols were the dominant fermentation products in all treatments. The total VFA concentration from starch treatment was greater \( (P < 0.001) \) than for all other treatments. Branched-chain VFA and aromatic compounds accumulated in all treatments, but accumulation in the casein treatments was greater \( (P < 0.001) \) than in all other treatments. Thus, addition of carbohydrate to swine manure slurries did not circumvent protein fermentation, as was previously observed in cattle manure slurries. Based on substrate loss, starch and protein fermentation were equivalent in all treatments, with losses of each exceeding 4% of the DM. Substrate additions had a limited effect on the overall accumulation of odor compounds in manure and on odor compound composition. Compared with the results of the earlier fermentation study of fresh cattle manure, swine manure fermentation produced less lactate and more products of protein fermentation (branched-chain VFA and aromatic ring compounds). We hypothesize that differences in manure organic matter composition between cattle and swine, a result of diet and digestion, select for bacterial communities that are adapted to the available substrate composition.

Key Words: Bacteria, Manures, Odors, Swine

Introduction

Manure odors are a complex mixture of VFA, alcohols, aromatic compounds, amides (including NH₃), and sulfides (O’Neill and Phillips, 1992; Hartung and Phillips, 1994) produced during digestion and subsequent manure storage. Microorganisms mediate odor compound production during the incomplete anaerobic fermentation of substrates in manures (Mackie et al., 1998). Aromatic compounds and VFA most closely correlate to swine odor (Zahn et al., 1997; 2001; Powers et al., 1999); therefore, limiting odor precursors (microbial substrates) in manures would limit odor emissions.

¹Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.
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manure slurry incubations over 5 wk. Results were compared to an earlier experiment of cattle feedlot manure and illustrated similarities and differences in the biochemical sources and microbial pathways for odor compound production in animal manures.

**Materials and Methods**

**Fecal Slurry Incubations and Analyses**

Fresh swine manure samples were collected from the floors of several adjacent pens at a farrow-to-finishing swine production facility during October 2001. We describe the samples as “manure” because the samples may have been contaminated with urine even though they appeared to be 100% feces. Animals (60 to 80 kg) were fed to achieve ad libitum intake of a corn/soybean meal finishing diet. The diet contained (as-fed basis) 85.20% corn, 11.07% soybean meal, 1.45% dicalcium phosphate, 0.75% calcium carbonate, 0.33% vegetable fat, 0.30% sodium chloride, 0.26% L-lysine, 0.20% trace mineral, 0.20% vitamin premix, 0.10% choline chloride, 0.06% methionine, 0.05% bacitracin methylene disalicylate (Alpharma, Fort Lee, NJ), and 0.03% threonine. The composition of trace mineral premix (per gram of DM) was 35.05% ferrous sulfate monohydrate, 1.77% copper sulfate pentahydrate, 2.61% manganese oxide, 9.62% zinc oxide, 0.033% sodium selenite, and 50.917% calcium carbonate. The composition (per gram of DM) of vitamin premix was 2,200 IU of vitamin A, 440 IU of vitamin D₃, 17.6 IU of vitamin E, 2.2 mg of vitamin K₂, 22 mg of niacin, 12.1 mg of d-pantothenic acid, 4.4 mg of riboflavin, and 0.022 mg of vitamin B₁₂. The calculated nutrient composition was 88.42% DM, 12.80% CP, 3.36% crude fat, 3.25% crude fiber, 0.65% calcium, 0.55% total P, 0.3% available P, 0.15% digestible cysteine, 0.6% digestible lysine, 0.26% digestible methionine, 0.11% digestible tryptophan, and 0.41% digestible Met + Cys. Metabolizable energy of the diet was 3.3 Mcal/kg.

For manure slurries, 0.8 kg of the fresh swine manure was blended in a Waring blender (New Hartford, CT) with 3.2 L of H₂O to form a 20% (wt/vol) manure slurry. The initial percentage weight composition of the swine manure composite was 27% DM, 22.6% OM, 0.9% non-ammonia nitrogen (NAN), 1.5% starch, and 11.6% NSP (methods of analyses described below). The slurry was equally divided into four blenders with four different substrate treatments (protein, starch, cellulose, and no addition). The substrate concentrations added to three different blenders were casein (Fisher Scientific, Fair Lawn, NJ) at 5 g/L, starch (Sigma, St. Louis, MO) at 2 g/L, and microcrystalline cellulose (J. T. Baker, Phillipsburg, NJ) at 6 g/L. The quantities of the additions were designed to increase the endogenous concentration of a particular substrate by 50%. Each sample was blended and approximately 190 mL of manure slurry was then added to five 250-mL flasks (five replicate flasks per manure/treatment). Flasks were gassed with N₂, stoppered to limit volatilization losses and ensure anaerobic conditions, and incubated at room temperature (20 to 25°C). Excess fermentation gas was vented though a needle into a water-filled test tube. Every day during the first week, slurries were mixed, and 8 mL was collected and distributed into three aliquots (4 mL for pH and substrates, 2 mL for fermentation products, and 2 mL for DM and OM determination). After the first week, samples were collected less frequently (twice to once per week). Manure slurry pH was analyzed immediately using a combination pH electrode, whereas the remaining manure parameters (substrates and fermentation products) were determined from frozen samples analyzed after the end of incubation. Details of the analyses have been previously described (Miller and Varel, 2001; 2002). Briefly, manure substrates, which included NAN, starch, and NSP, were analyzed in homogenized samples. Samples for NAN content, analogous to fermentable nitrogen (protein and nucleic acids), were made alkaline by the addition of 1 mL of 2 M NaOH and dried overnight at 100°C to remove free NH₃ before analysis using a Leco CN-2000 carbon/nitrogen analyzer (Leco, St. Joseph, MI). Drying under alkaline conditions removed 100% of NH₃ spiked into control manure samples (data not shown). Starch was measured as free glucose using the membrane-immobilized glucose oxidase enzyme system (YSI model 2700, Yellow Springs Instrument Co., Yellow Springs, OH) after overnight digestion with amyloglucosidase. Total polysaccharide was determined colorimetrically using the phenol-sulfuric acid reaction (Daniels et al., 1994), with NSP calculated as the difference between total polysaccharide and starch. Fermentation products (L-lactate, ethanol, propanol, isobutanol, butanol, pentanol, hexanol, acetate, propionate, isobutyrate, butyrate, isovalerate, valerate, isocaproate, caproate, heptanoate, caprylate, phenol, p-cresol, 4-ethyl phenol, indole, skatole, benzoate, phenylacetic, and phenylpropionate) were quantified in the liquid phase of the slurries using the YSI 2700 analyzer for L-lactate by immobilized L-lactate oxidase enzyme method, and a Hewlett Packard 6890 gas chromatograph (Agilent Technologies, Palo Alto, CA) equipped with flame ionization and mass selective detectors for all other products. Operating conditions used to separate and quantify the fermentation products by gas chromatography have been previously described (Miller and Varel, 2001; 2002).

**Odor Source and Substrate Conversion Calculations**

Two methods were used to describe the relative contribution of starch or NAN crude protein toward odor compound production in the slurries. The first method calculated the molar percentage of total VFA that was branched-chain VFA in our treatments and compared that percentage to the values reported by Smith and Macfarlane (1996; 1998), who found that purified human colonic bacteria grown anaerobically on protein as the sole carbon source produced up to 17% of the total
VFA as branched-chain VFA. The second method calculated the mass loss of starch and NAN crude protein and compared that mass loss to the mass gain of fermentation products in the flask during the incubation period. Percentage conversion of substrates to products was simply:

\[
100 \times \frac{\text{mass of accumulated products}}{\text{mass of substrates lost}}
\]

**Statistical Analyses**

Data were analyzed as a split-plot in time. The unit of observation was the flask \((n = 20;\) five replicate flasks per treatment) and there were no missing values. The model included effects of incubation day, treatment, flask \((treatment)\), and incubation day \(\times treatment\). Treatment was tested against the mean square of flask \((treatment)\). Differences between least squares means were tested with a protected \(t\)-test. Statistical analyses were conducted with the GLM procedure of SAS \((v. 7.0,\) SAS Inst., Inc., Cary, NC).

**Results and Discussion**

*Accumulation of Odor Compounds and Fermentation Products in Manure Slurries*

Substrate addition affected the accumulation of VFA, branched-chain VFA, and aromatic ring compounds (Figure 1). Volatile fatty acids accumulated in all treatments during the first 3 wk \((P < 0.001)\), but the total VFA accumulated varied between treatments (Figure 1A). The starch treatment had greater \((P < 0.001)\) maximum VFA content than all other treatments. Protein and cellulose treatments did not affect \((P \geq 0.156)\) VFA accumulation relative to the no-addition treatment.

Branched-chain VFA \((\text{isobutyrate, isovalerate, and isohexanoate})\) and aromatic ring compounds \((\text{phenols, indoles, and benzoates})\) are associated with manure odors and have very low odor thresholds \((\text{Zahn et al., 2001})\). The accumulation of both groups of compounds varied between treatments but produced a similar pattern (Figure 1B, C). Branched-chain VFA and aromatic compounds accumulated in all treatments \((P < 0.001)\), but the greatest accumulation of these compounds occurred in the protein treatment compared with all other treatments \((P < 0.001)\). The starch amendment accumulated more branched-chain VFA than the no-addition treatment \((P = 0.032)\), whereas no difference was observed between the cellulose treatment and the no-addition treatment \((P = 0.592)\).

Although the concentration of many odorous compounds increased during the incubation, the molar composition \((\text{moles/100 moles})\) of the dominant fermentation products changed very little during the incubation (Table 1). The VFA pool was largely dominated by short, straight-chain VFA \((\text{acetate, propionate, and butyrate})\), which initially comprised 91.5% of the total VFA pool.

![Figure 1. Concentrations of total VFA (sum of acetate, propionate, isobutyrate, butyrate, isovalerate, valerate, isocaproate, and caproate), branched-chain VFA (sum of isobutyrate, isovalerate, and isocaproate), and aromatic compounds (sum of phenol, cresol, 4-ethyl phenol, indole, skatole, benzoate, phenylacetate, and phenylpropionate) during incubation of swine manure slurries. The SE of the least squares means \((n = 5)\) for total VFA \(= 3.1\), for total branched-chain VFA \(= 0.31\), and for total aromatics \(= 0.21\). The ANOVA for treatment \(\times\) incubation time differed at \(P < 0.001\), with the exception of total VFA \((P = 0.461)\), which differed by treatment \((P < 0.001)\).}
The percentage of short, straight-chain VFA remained the greatest contributor in the total VFA pool throughout the incubation, but by the end, had decreased in all treatments ($P < 0.005$). By the end of incubation, the starch treatment had a greater proportion of short, straight-chain VFA than the protein treatment ($P < 0.005$). Of the three compounds in the short, straight-chain pool, acetate initially comprised a higher molar percentage of the total VFA pool than propionate and butyrate. By the end of incubation, acetate had decreased ($P < 0.005$) in the no-addition and protein treatments, but it was still the dominant VFA in all the fecal slurries. The percentage of butyrate and propionate either decreased or remained unchanged. The increase in percentage of valerate and branched-chain VFA in all treatments (except branched-chain VFA in the starch treatment) likely accounted for the decreases in short, straight-chain VFA. Substrate addition compared with the no-addition treatment had little effect on the final VFA composition, with the exception of the protein amendment, where the percentage of branched-chain VFA increased relative to straight short-chain VFA. Thus, we concluded that substrate availability in the swine manure affects both the molar concentration of odorous chemical compounds and, depending on the substrate, the final composition of odorous compounds. Furthermore, the range of possible fermentation products will have differing volatilities, odor thresholds, and odor offensiveness, which all impact perceived odor.

The accumulation of acid end-products, particularly lactate, can limit the further production of VFA in manure slurries (Miller and Varel, 2002) and enhance the volatility of acidic fermentation products. In a previous study with cattle manure (Miller and Varel, 2001), lactate was a major fermentation product (concentrations reached 50 mM), which led to very low pH (<4.5) and VFA toxicity to the fermentative microorganisms (Switzenbaum et al., 1990). Lactate accumulated ($P < 0.001$) in the various swine manure treatments (Figure 2A), but the concentration of lactate was relatively low compared to total VFA accumulation. All substrate additions accumulated more lactate ($P \leq 0.002$) than the no-addition treatment. The protein addition, however, had greater lactate accumulation than any other treatment ($P < 0.001$). The pH of the swine slurries was relatively unaffected by lactate concentration (Figure 2B). The decrease in the pH swine manure slurry was very small (0.3 to 0.6), and the pH never approached the pH 4.75 threshold for VFA toxicity (Switzenbaum et al., 1990; Miller and Varel, 2001). The relative stability of swine manure slurry pH can be attributed to low lactate concentrations in all treatments and to the buffering capacity of ammonia nitrogen normally found in swine manure.

**Origins of Swine Odor Compounds**

The accumulation of branched-chain VFA and aromatic compounds, which are products of protein fermentation (Mackie et al., 1998), provided indirect evidence for protein fermentation in all treatments and in the no-addition treatment. An estimate of the proportion of protein fermentation relative to starch was made by examining the proportion of branched-chain VFA to total VFA produced exclusively during the incubation. Of the total VFA accumulated during the incubation in the no-addition treatment, 11.7% was branched-chain VFA. The starch and cellulose amendments also accumulated similar percentages (9.4 and 10.5%, respectively) of branched-chain VFA, but did not differ from the no-addition treatment ($P \geq 0.21$). The protein treatment accumulated more ($P \leq 0.025$) branched-chain VFA as a percentage of total VFA than all other treatments, averaging 17.3%. Mixed culture microbial fermentations of human colonic bacteria utilizing only protein as a substrate typically produce 7 to 17% of total

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**Table 1. Initial and final composition of important volatile fatty acid fermentation products in swine manure slurries**

<table>
<thead>
<tr>
<th>Fermentation product</th>
<th>Initial composition, mol/100 mol</th>
<th>Final composition for each treatment after 37 d of incubation, mol/100 mol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All treatments</td>
<td>No addition</td>
</tr>
<tr>
<td>SSC VFA&lt;sup&gt;b&lt;/sup&gt;</td>
<td>91.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>79.4&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Acetate</td>
<td>50.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>40.2&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Propionate</td>
<td>24.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>22.4&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>Butyrate</td>
<td>16.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>16.8&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Valerate</td>
<td>1.9&lt;sup&gt;d&lt;/sup&gt;</td>
<td>7.1&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>BC VFA&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.9&lt;sup&gt;d&lt;/sup&gt;</td>
<td>9.6&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>The SE of the least squares means of initial composition ($n = 20$) for SSC VFA, acetate, propionate, butyrate, valerate, and BC VFA = 0.6, 1.4, 0.9, 1.1, 0.2, and 0.3, respectively. The SE of the final composition ($n = 5$) for each constituent is identified in the final column. All ANOVA for incubation condition (initial composition for all treatments and final composition for each treatment) were significant ($P \leq 0.005$), with the exception of butyrate ($P = 0.686$).

<sup>b</sup>Short straight-chain VFA is the sum of acetate, propionate, and butyrate.

<sup>c</sup>Branched-chain VFA is the sum of isobutyrate, isovalerate, and isocaproate.

<sup>d,e,f</sup>Least squares means of initial and final composition within a row without a common superscript letter differ ($P \leq 0.005$).
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Figure 2. Concentrations of L-lactate and slurry pH during the incubation of swine manure slurries. The SE of the least squares means (n = 5) for L-lactate = 0.03 and for pH = 0.006. All ANOVA for treatment × incubation time differed at P < 0.001.

VFA as branched-chain VFA, with large increases in aromatic compound concentrations (Smith and Macfarlane, 1996; 1998). Based on the percentage of branched-chain VFA in the total VFA pool and the large accumulation of aromatic compounds in our swine manure incubations, we estimate that protein fermentation pathways produced at least half, and maybe substantially more, of the VFA that accumulated during the swine manure incubation. In the protein treatment, protein fermentation may supply essentially all the VFA accumulated during the incubation.

Starch, NAN, and NSP substrate concentrations during the incubation provide a more direct approach to determining the relative contribution of the various substrates to odor compound accumulation during swine manure fermentation. The accumulation of fermentation products, including VFA, alcohols, and lactate, was related to the disappearance of starch and NAN (Figure 3). Correlations were strongest between the accumulation of fermentation products and starch disappearance (r = 0.940, P < 0.001) and NAN disappearance (r = 0.761, P < 0.001) for all data. The correlation between the accumulation of fermentation products and NSP was much weaker (r = 0.280, P = 0.066). All treatments produced similar amounts (P ≥ 0.253) of total fermentation product, ranging from 2.8 to 3.4 g/L (± 0.3, n = 20) for the no-addition and starch treatments, respectively. Starch and NAN in all treatments decreased (P < 0.001) during the incubation (Figure 3B, C). Decreases in starch for all treatments ranged from 2.5 to 3.2 g/L (± 0.2, n = 20); the no-addition treatment had the smallest decrease but did not differ from the protein or cellulose treatments (P > 0.162), whereas the starch treatment had a greater decrease compared to the no-addition control (P = 0.006). Decreases in NAN ranged from 0.59 to 1.31 g/L (± 0.08, n = 20); the cellulose treatment had the smallest decrease but did not differ from the no-addition or starch treatments (P > 0.548), whereas the protein treatment had the largest decrease and differed from all the other treatments (P < 0.001). When NAN loss was expressed as CP (NAN × 6.25) loss, CP losses ranged from 3.7 to 8.2 g/L, which equaled or exceeded starch losses. When either starch or protein was added to the slurries, the amount of that particular substrate consumed was greater (P < 0.01) than the consumption in the no-addition treatment. In other words, the greatest losses of a particular substrate were associated with treatments where the substrate was supplied in a highly available form, such as soluble starch or casein. The cellulose treatment was an exception to this trend as NSP consumption only tended to differ (P = 0.075) from NSP consumption in the no-addition control treatment. Although NSP was consumed in the starch, protein, and cellulose treatments (P < 0.03), no NSP was consumed in the no-addition control treatment, thus the contribution of NSP to odor compound formation is more difficult to assess.

An estimate of the relative contribution of protein or starch fermentation to odor compound production can be made based on the amount of NAN (as CP) and starch consumed. If one assumes that NSP does not contribute to odor compound formation, then the conversion of substrate (starch and NAN as CP) to fermentation product averaged 42.0% (± 2.9; n = 20). No differences were detected between treatments for percentage conversion of substrate into fermentation product (P = 0.093). Crude protein (NAN × 6.25) loss, as a percentage of the sum of CP and starch losses, differed (P < 0.001) within treatment and accounted for 61.4, 75.4, 56.3, and 55.7% (SE = 2.9%; n = 20) of the substrate loss in the
Figure 3. Relationships between fermentation product (sum of ethanol, propanol, isobutanol, butanol, total VFA, and L-lactate) accumulation and starch, nonammonia nitrogen (NAN), and nonstarch polysaccharide (NSP) content in the swine manure slurries during incubation. The SE of the least squares means (n = 5) for fermentation products = 0.23, for starch = 0.10, for NAN = 0.06, and for NSP = 1.8. All ANOVA for treatment × incubation time differed at P < 0.02 with the exception of starch (P = 0.067) and fermentation product accumulation (P = 0.229), which differed by treatment (P < 0.01).

Odor Formation Processes Differ Between Cattle Feedlot and Swine Manure

A generally held belief is that odors from swine production are more objectionable than odors from cattle production. Manure storage, handling, and treatment practices are very different between (and within) swine production and cattle feedlot systems and are likely to account for some of the differences in perceived odor. However, odor compounds originating from both systems share a common microbial origin (i.e., microbial fermentation of undigested substrates in manures). A portion of the perceived odor difference between feedlot cattle and swine may be attributable to differences in odor-producing fermentation pathways, which are influenced by differences in substrate availability and/or content in swine and cattle feedlot manures.

The initial substrate composition of fresh swine manure in the control (no-addition) treatment was compared to the substrate composition of fresh cattle feedlot manure in an earlier study (Table 2). The NSP comprised the largest fraction of potential substrate in the swine manure when compared to other substrates on a DM basis, whereas starch was the major substrate in fresh cattle feedlot manure. Starch content in the cattle feedlot manure was nearly sixfold greater than the starch content of swine manure. For NAN (our marker of CP), the situation was reversed, with NAN content in the swine manure twice as high as NAN in the cattle feedlot manure. Our earlier work with cattle feedlot manure indicated that starch fermentation in fresh cattle manures was the dominant route for odor compound formation (Miller and Varel, 2001; 2002). Furthermore, adding starch to aged, starch-depleted cattle manures temporarily circumvented a low rate of protein fermentation. Results from these swine manure incubations indicate that very different odor formation processes are responsible for the accumulation of odor compounds. In fresh swine manure, protein fermentation was responsible for roughly half of the substrate loss and odor compound production, whereas there was no evidence for protein fermentation in the fresh cattle feedlot manure. Our interpretation of these cattle feedlot and swine manure studies is that starch was the primary (and preferred) substrate for microbial fermen-
Implications

Starch and protein are primary substrates for odor compounds produced during swine manure fermentation. The contribution of starch or protein to odor production differs between animal manures and determines the composition of malodorous compounds. Starch fermentation dominates in cattle manure fer-

Table 2. Initial manure and final fermentation product composition in fresh swine and cattle manure

<table>
<thead>
<tr>
<th>Item</th>
<th>Swine manure</th>
<th>Cattle manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial manure composition, % of DM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starch</td>
<td>4.8 ± 0.3</td>
<td>28.0 ± 0.5</td>
</tr>
<tr>
<td>Nonammonia nitrogen</td>
<td>3.3 ± 0.1</td>
<td>1.6 ± 0.1</td>
</tr>
<tr>
<td>Nonstarch polysaccharide</td>
<td>37.3 ± 3.8</td>
<td>19.7 ± 1.2</td>
</tr>
<tr>
<td>Final fermentation products, µmol/g DM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactate</td>
<td>23 ± 2</td>
<td>524 ± 141</td>
</tr>
<tr>
<td>Total alcohols</td>
<td>29 ± 11</td>
<td>221 ± 46</td>
</tr>
<tr>
<td>Total VFA</td>
<td>1018 ± 65</td>
<td>1800 ± 194</td>
</tr>
<tr>
<td>Acetate</td>
<td>412 ± 39</td>
<td>470 ± 89</td>
</tr>
<tr>
<td>Propionate</td>
<td>227 ± 11</td>
<td>317 ± 13</td>
</tr>
<tr>
<td>Butyrate</td>
<td>169 ± 7</td>
<td>1001 ± 259</td>
</tr>
<tr>
<td>Total branched-chain VFA</td>
<td>97.1 ± 8.5</td>
<td>5.5 ± 0.4</td>
</tr>
<tr>
<td>Total aromatics</td>
<td>33.3 ± 1.8</td>
<td>20.3 ± 1.3</td>
</tr>
</tbody>
</table>

*Fermentation product composition from the final collection time determined from samples collected on d 36 in fresh cattle manure slurries (Miller and Varel, 2001) and d 37 in fresh swine manure slurries. Reported values are the average of five samples ± 1 SE. Incubation, sampling, and analytical methods used in Miller and Varel (2001) are identical to those described herein.

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mentation, whereas both protein and starch fermentation occurs in swine manure. Protein fermentation tends to produce more offensive compounds (branched-chain volatile fatty acids and aromatic ring compounds) that have low detection thresholds. This research emphasizes the strong ties between diet, manure composition, microbial fermentation, and odor production. Limiting starch excretion in cattle and both protein and starch excretion in swine through dietary changes should help control the production of odors during manure storage. Manipulating swine and cattle diets to better manage odors originating from confined animal feeding operations will be a critical issue for animal production in the future.

Literature Cited


