A Comparison of Gaseous Emissions from Swine Finisher Facilities Fed Traditional vs. A DDGS-Based Diet

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Abstract
Expansion of the corn grain ethanol industry has led to increased availability of dried distillers grains with solubles (DDGS), and feeding DDGS to swine is becoming more common in pork production. Because feed is the primary cost in pork production and interest in air emissions from animal feeding operations is increasing, it is important to understand the impacts of non-traditional dietary formulations on aerial emissions. The purpose of this study was to identify and quantify the impacts of feeding DDGS on gaseous emissions from deep-pit swine finisher operations. To complete the study, two full-scale, commercial, co-located swine barns were monitored; one of the barns received a traditional diet, and the other received a diet that included DDGS. The constituents measured during this project were ammonia (NH3), hydrogen sulfide (H2S), and greenhouse gases (GHG) (carbon dioxide – CO2, nitrous oxide – N2O, and methane – CH4). At the time of this writing, results from this study indicated feeding 22% DDGS increased aerial NH3 emission from 3.1 g/pig-d to 4.6 g/pig-d and H2S emissions from 0.10 g/pig-d to 0.19 g/pig-d, but had no effect on GHG.

Keywords
DDGS, aerial emissions, gas concentrations, swine

Disciplines
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A COMPARISON OF GASEOUS EMISSIONS FROM SWINE FINISHER FACILITIES FED TRADITIONAL VS. A DDGS-BASED DIET

L. M. Pepple¹, R. T. Burns¹, H. Xin¹,², H. Li¹, J. F. Patience²

ABSTRACT

Expansion of the corn grain ethanol industry has led to increased availability of dried distillers grains with solubles (DDGS), and feeding DDGS to swine is becoming more common in pork production. Because feed is the primary cost in pork production and interest in air emissions from animal feeding operations is increasing, it is important to understand the impacts of non-traditional dietary formulations on aerial emissions. The purpose of this study was to identify and quantify the impacts of feeding DDGS on gaseous emissions from deep-pit swine finisher operations. To complete the study, two full-scale, commercial, co-located swine barns were monitored; one of the barns received a traditional diet, and the other received a diet that included DDGS. The constituents measured during this project were ammonia (NH₃), hydrogen sulfide (H₂S), and greenhouse gases (GHG) (carbon dioxide – CO₂, nitrous oxide – N₂O, and methane – CH₄). At the time of this writing, results from this study indicated feeding 22% DDGS increased aerial NH₃ emission from 3.1 g/pig-d to 4.6 g/pig-d and H₂S emissions from 0.10 g/pig-d to 0.19 g/pig-d, but had no effect on GHG.

KEYWORDS. DDGS, aerial emissions, gas concentrations, swine

INTRODUCTION

Iowa leads the nation in corn and ethanol production. For corn-based ethanol plants, a primary co-product of the process is distillers dried grains with solubles (DDGS). DDGS have been reported to contain high levels of digestible energy and metabolizable energy, digestible amino acids, and available phosphorus (Shurson et al., 2003; Honeyman et al., 2007). Generally, DDGS have been found to contain 2 to 3.5 times more amino acids, fat, and minerals than corn (Honeyman et al., 2007). Animal nutritionists have suggested including up to 20% DDGS in nursery, grow-finish, and lactating sow diets and up to 40% in gestating sows and boars (Honeyman et al., 2007). However, the decision to feed DDGS is generally based on economics. At the current DDGS and corn prices the inclusion of DDGS in swine diets has provided a cost savings over traditional non-DDGS diets.

It has been hypothesized that sulfur levels in DDGS could result in increased hydrogen sulfide (H₂S) emissions from stored swine manure when pigs were fed rations containing DDGS. However, comparative data from full-scale swine production systems is needed to confirm any impacts on air emissions from feeding DDGS. The increased usage of DDGS at swine facilities has led several researchers to examine the effect of DDGS on emissions, odors, and manure composition, but these studies have been at lab or at non-commercial scales and the data from these studies have not produced consistent data.

Spiels et al. (2000) performed a 10-week trial on 20 barrows receiving either a DDGS (at a 20% inclusion rate) or non-DDGS ration. The pigs were housed, based on diet, in two

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fully-slatted pens within the grow-finish room of a swine research facility. The non-DDGS diet was a typical corn-soybean meal; total phosphorus and total lysine were held constant in both diets within each phase of feeding. The study was conducted to evaluate differences in odor, H$_2$S, and Ammonia (NH$_3$) from stored manure as a result of the pig’s diet. The stored manure that was evaluated for emissions was maintained in a container to simulate deep pit storage. Air samples were collected from the headspace of storage containers. Over the 10-week period, this study reported that DDGS (at a 20% inclusion level) did not affect odor, H$_2$S, or NH$_3$ emissions in the stored manure.

Conversely, Powers et al. (2008 & 2006) completed a study in 2006 that included 48 barrows in 8 chambers at Iowa State University. In the study, the animals received increasing amounts of DDGS in their ration (from 0 – 30%) as they progressed through their feeding phases; corn based control diets were also included. The diets were formulated to contain similar amounts of lysine and energy. Manure collection pans were placed under the animal pens and were partially cleaned twice weekly to remove manure and prevent overflow. Air samples were collected from within the animal chambers. The reported results indicated that the NH$_3$ and H$_2$S emission rates from the chamber were higher as a result of the DDGS ration, but methane emissions were reduced.

The results of these studies cannot be directly compared because of differences in rations, animal housing, manure storage, and analytical methods. However, in general, the studies provide conflicting results. Besides differences in the experimental design of the two studies, the conflicting results may also be affected by scaling issues. The objective of this paper was to quantify the impact on gaseous emissions of feeding DDGS to finishing pigs in two commercial deep-pit swine facilities. To meet this objective NH$_3$, greenhouse gases (GHG) (carbon dioxide – CO$_2$, nitrous oxide – N$_2$O, and methane – CH$_4$), and H$_2$S concentrations were measured and emission data were collected using a mobile air emissions monitoring unit (MAEMU).

**METHODS AND MATERIALS**

**Site and Instrumentation Description**

Two 12.5 x 57 m (50 x 190 ft) co-located wean-to-finish deep pit swine barns, designated as barn 1 and barn 2, located in central Iowa were monitored in this study. Pigs started in the barns at 5.5 kg (12 lbs) and were marketed at 118 kg (260 lbs) with two turns completed a year. The barns have a rated capacity of 1,300 marketed head. Both barns were doubled stocked initially, meaning during the wean to grow phase both barns held 2600 pigs, roughly. When the pigs weighed 27 kg (60 lbs), approximately half the pigs were moved off site to another facility. Each barn had four 0.6 m (24 in.) pit fans, two 0.6 m (24 in.) endwall fans and sidewall curtains on both sides to provide natural ventilation when needed. The barns were equipped with three space heaters 66 kW (225,000 BTU/h) each, 20 brooder heaters 5 kW (17,000 BTU/h) each and 20 bi-flow ceiling inlets. Both barns were managed identically with the exception of feed rations. Barn 1 received a traditional corn based diet (non-DDGS) while Barn 2 received a DDGS (22%) ration. The producer provided weekly pig performance data, including mortality and average body weight for the duration of this project.

A MAEMU was used to continuously collect emissions data from two deep pit wean-to-finish swine barns. The instruments and data acquisition system were housed in the MAEMU. A detailed description of the MAEMU and operation can be found in Moody et al. (2008). To date this study has monitored NH$_3$, CO$_2$, N$_2$O, CH$_4$, and H$_2$S aerial emissions for three months. A photoacoustic multi-gas analyzer (INNOVA Model 1412, INNOVA AirTech Instruments A/S, Ballerup Denmark) was used to measure NH$_3$, CO$_2$, N$_2$O, and CH$_4$ concentrations. H$_2$S concentrations were measured using an Ultraviolet Fluorescence H$_2$S analyzer (Model 101E, Teledyne API, San Diego, CA). Instruments were challenged weekly with calibration gases and recalibrated as needed. All calibration gases were certified grade with ± 2% accuracy.
Air samples were collected in 30-s cycles for four cycle periods (120 s) at each location. The fourth reading from each sampling cycle was used as the measured pollutant concentration. Use of the fourth reading was due to the fact that the Innova and API had T98 and T95 response time of 120 s and 100 s, respectively. Air samples were drawn from three composite locations (north pit fans, south pit fans, and endwall fans) in each barn and an outside location to provide ambient background data (Figure 1). Each composite sampling location was chosen to match the fan stages used at this facility. Pit fan sampling points were located below the slats directly below each fan. Endwall sample ports were placed approximately 1.0 m (3.28 ft) in front of each endwall fan. Sample locations and placement of sampling ports were chosen to ensure representativeness of the air leaving the barns. Each sampling point had three consecutive dust filters (60, 20, 5 µm) to keep large particulate matter from plugging or contaminating the sample lines, the servo valves, or the delicate instruments.

A positive-pressure gas sampling system (P-P GSS) was used in the MAEMU to minimize introduction of unwanted air into the sampling line. The P-P GSS consecutively pumped sample air from each sampling location using individual designated pumps. Air samples from each location were collected sequentially over a 2-min period via the controlled operation of servo valves of the PP-GSS. Each barn sampling location was sampled continuously every 14 min. A background ambient air sample was collected every two hours for 8 minutes. All pumps and the gas sampling system were leak checked weekly to ensure no contamination was occurring.

Pit fans at this facility had variable speeds, while the endwall fans had a single speed. All fans were calibrated in situ at multiple operation points to develop a performance or airflow curve for each fan. The in situ calibration of the exhaust fans was conducted with a fan assessment numeration system (FANS) (Gates et al. 2004). For single-speed fans (endwall), their airflow was a function of static pressure, whereas for variable-speed fans the airflow was a function of static pressure.
Gaseous Emission Rate Determination

Constituent emission rates were calculated as the mass of the gas emitted from the barn per unit time and expressed in the following form:

\[
ER_{\text{g}} = \sum Q_i \left( \frac{P_{\text{eq}}}{\rho_i} \left[ G \right]_i - \frac{P_{\text{eq}}}{\rho_e} \left[ G \right]_e \right) 10^{-6} \frac{T_{\text{std}}}{T_a} \frac{P_{\text{eq}}}{P_{\text{std}}} \frac{w}{V}
\]

Where
- \( ER_{\text{g}} \) = Gas emission rate for the house, g hr\(^{-1}\) house\(^{-1}\)
- \( Q_i, Q_e \) = Incoming and exhaust ventilation rate of the house at field temperature and barometric pressure, respectively, m\(^3\) hr\(^{-1}\) house\(^{-1}\)
- \( \left[ G \right]_i, \left[ G \right]_e \) = Gas concentration of incoming and exhaust ventilation air, respectively, ppmv
- \( w_m \) = molar weight of the gas, g mole\(^{-1}\) (e.g., 17.031 for NH\(_3\))
- \( V_m \) = molar volume of gas at standard temperature (0\(^\circ\)C) and pressure (101.325 kPa) or STP, 0.022414 m\(^3\) mole\(^{-1}\)
- \( T_{\text{std}} \) = standard temperature, 273.15 K
- \( T_a \) = ambient air temperature
- \( \rho_i, \rho_e \) = density of incoming and exhaust air, respectively, g/cm\(^3\)
- \( P_{\text{std}} \) = standard barometric pressure, 101.325 kPa
- \( P_{\text{a}} \) = atmospheric barometric pressure at the monitoring site, kPa

Data presented in this paper cover the period of November 22, 2009 to March 11, 2010. Statistical analysis was performed using SAS 9.2. Data were analyzed using single factor ANOVA and considering each day as a repeated measure during the period. The dietary effect was considered significant at \( P\)-value \( \leq 0.05 \).

RESULTS AND DISCUSSION

The diets used during this study were formulated to meet the pigs’ requirements as they grew towards market weight (NRC, 1998); the only difference between the control diet and the treatment diet was the inclusion of 22% DDGS. Including DDGS resulted in higher levels of crude protein, crude fiber, acid detergent fiber and sulfur compared to the traditional diet. The results to date are for nursery, starter and two finish phase diets. The nursery phase diets for either barn did not include DDGS.

The number of pigs in each barn was different, but the weight and age of the pigs were similar (Table 1). The average ventilation rate for barn 1 (Non DDGS) was 17966 m\(^3\)/hr and 16679 m\(^3\)/hr for barn 2 (DDGS). The ventilation rates for the two barns were not significantly different (\( P\)-value =0.0665). The average daily ventilation rate for each barn and the corresponding outside temperature are shown in Figure 2a.

The average in-house gas concentrations measured to date are shown in Table 1. Average NH\(_3\), CO\(_2\), H\(_2\)S, N\(_2\)O, and CH\(_4\) concentrations were 18 ppm, 3901 ppm, 337 ppb, 0.17 ppm and 140 ppm, respectively, for barn 1. For barn 2, the average concentrations for NH\(_3\), CO\(_2\), H\(_2\)S, N\(_2\)O, and CH\(_4\) were 24 ppm, 3719 ppm, 575 ppb, 0.2 ppm and 121 ppm, respectively. There was no
significant difference in CO₂ or N₂O concentrations between the barns. However, NH₃, H₂S, and CH₄ concentrations were significantly different (P-values: NH₃ & H₂S = 0.0001, CH₄=0.0393).

**Figure 2:** Ventilation rate for each barn and ambient temperature for monitored period

**Table 1:** Average number of pigs, ventilation rate, and in-house gas concentration values for wean-finish swine barns fed traditional (non-DDGS) or DDGS diet.

<table>
<thead>
<tr>
<th>Barn Description</th>
<th># Pigs*</th>
<th>VR (m³/hr)</th>
<th>NH₃* (ppm)</th>
<th>CO₂ (ppm)</th>
<th>H₂S* (ppb)</th>
<th>N₂O (ppm)</th>
<th>CH₄* (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barn 1 (Non-DDGS)</td>
<td>1858</td>
<td>17966</td>
<td>17.6</td>
<td>3901</td>
<td>337</td>
<td>0.172</td>
<td>139.6</td>
</tr>
<tr>
<td>SEM</td>
<td>58</td>
<td>537</td>
<td>0.6</td>
<td>84</td>
<td>25</td>
<td>0.012</td>
<td>7.4</td>
</tr>
<tr>
<td>Barn 2 (DDGS)</td>
<td>1662</td>
<td>16679</td>
<td>24.2</td>
<td>3719</td>
<td>575</td>
<td>0.198</td>
<td>121</td>
</tr>
<tr>
<td>SEM</td>
<td>48</td>
<td>440</td>
<td>0.4</td>
<td>54</td>
<td>27</td>
<td>0.011</td>
<td>4.9</td>
</tr>
</tbody>
</table>

* Barn 1 was significantly different from Barn 2 at α=0.05 level
** SEM = Standard Error of the Mean

Ventilation rate for each barn and ambient temperature for monitored period

**Table 1:** Average number of pigs, ventilation rate, and in-house gas concentration values for wean-finish swine barns fed traditional (non-DDGS) or DDGS diet.

**Emission Rates**

Emission rates were expressed in kg/barn-d and g/pig-d. A statistical analysis was completed to determine if difference in emission rates between the two barns was significant.

The average emission rates for NH₃, CO₂, H₂S, N₂O, and CH₄ in kg/barn-d are shown in Table 2. NH₃, CO₂, H₂S, and CH₄ were all significantly different with P-values less than 0.05. Although CO₂ and CH₄ emissions were significantly different between the two barns in terms of kg/barn-d, they were not significantly different in terms of g/pig-d (i.e., when the number of animals in the two barns was accounted for). N₂O was not significantly different between the barns. Emission rates for NH₃, CO₂, H₂S, N₂O, and CH₄ expressed in g/pig-d are presented in Table 3.

**Table 2:** Average gaseous emission rates (kg/barn-d) of the monitored W-F swine barns fed non-DDGS or DDGS diet
NH₃ and H₂S emission rates were significantly different between the two barns after the number of pigs was considered. This was likely caused by the higher in-house gas concentrations found in barn 2 (DDGS) for NH₃ and H₂S. Figure 3a and 3c show the average daily emissions for NH₃ and H₂S for the reported period. These results were comparable to similar studies investigating the effects of feeding dried distillers grains with solubles (Powers et al. 2008 & 2006). The increase in H₂S concentrations could be attributed to the addition of sulfur contained in the DDGS diet, especially since the two barns shared the same water source. More investigation is needed to determine if sulfur from feedstuffs is the only influencing factor. Higher ammonia concentrations in barn 2 (DDGS) could be caused by the increase of ammoniacal nitrogen excreted when pigs are fed more dietary protein (Kerr et al. 2006), as is the case when feeding DDGS.

According to Pedersen and Sallvik (2002), manure accounts for only 4% of CO₂ produced in livestock facilities. Therefore, the inclusion of DDGS was not expected to affect the CO₂ emissions from barn 2 (DDGS). The significant difference in CO₂ emissions per barn was no longer significant when the emissions were expressed on a per-pig basis (P-value=0.1391). The difference was likely caused by the higher animal numbers in barn 1 (Non DDGS) and increased respiration. CH₄ emissions reported as kg/barn-d were significantly different between the two dietary regimens. This difference was likely caused by the increased amount of manure excreted in barn 1, which became non-significant when the number of pigs in each barn was considered. Both CO₂ and CH₄ emissions increased with pig weight, as shown in Figure 3b and 3e, caused by increased metabolic rate (thus respiratory CO₂ production) and manure excretion as pigs grow.

Table 3: Average gaseous emission rates (g/pig-d) of the monitored W-F swine barns fed non-DDGS or DDGS diet

<table>
<thead>
<tr>
<th>Barn Description</th>
<th># of Days Monitored</th>
<th># Pigs</th>
<th>Avg Wt. (kg)</th>
<th>VR (m³/hr)</th>
<th>NH₃*</th>
<th>CO₂*</th>
<th>H₂S*</th>
<th>N₂O</th>
<th>CH₄*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barn 1 (Non-DDGS)</td>
<td>103</td>
<td>1858</td>
<td>37.1</td>
<td>17966</td>
<td>3.1</td>
<td>1592</td>
<td>0.102</td>
<td>0.06</td>
<td>25.0</td>
</tr>
<tr>
<td>SEM</td>
<td>58</td>
<td>2.2</td>
<td>537</td>
<td>0.16</td>
<td>78</td>
<td>0.005</td>
<td>0.006</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>Barn 2 (DDGS)</td>
<td>103</td>
<td>1662</td>
<td>34.0</td>
<td>16679</td>
<td>4.6</td>
<td>1450</td>
<td>0.187</td>
<td>0.079</td>
<td>23.4</td>
</tr>
<tr>
<td>SEM</td>
<td>48</td>
<td>1.8</td>
<td>445</td>
<td>0.23</td>
<td>55</td>
<td>0.008</td>
<td>0.008</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>

* Barn 1 was significantly different from Barn 2 at α=0.05 level
Nitrous oxide was not significantly different between the barns. As shown in Figure 3d, the N$_2$O emission rates ranged from -0.02 to 0.01 g/pig-d. The detection limit of the instrument for N$_2$O measurement was 0.5 ppm. Since the concentrations measured inside the barns and outside were lower than the detection limit of the instrument (Table 1), it is likely that the range of N$_2$O emissions stemmed from the instrument noise.

**CONCLUSIONS**

The results from this study indicated feeding DDGS increased aerial ammonia emission from 3.1 g/pig-d to 4.6 g/pig-d and hydrogen sulfide emissions from 0.10 g/pig-d to 0.19 g/pig-d, but had no effect on greenhouse gases (GHG) emissions. These results are comparable to Powers et al. 2006 & 2008. CO$_2$ emissions were not different between barns, and when reported as g/pig-d, there was no difference between the diets (P-value = 0.1391). The amount of nitrous oxide emitted from the barns and present in the atmosphere was below the detection limit of the instrument used and therefore any variation was attributed to instrument noise. There was no significant difference found for methane emissions between barns in terms of g/pig-d. However, there was a significant difference in methane concentrations between barn 1 and barn 2 with a P-value of 0.0393. By feeding DDGS, the methane concentrations were lower in barn 2 than barn 1. This is comparable to a study by Powers et al. (2006) which reported DDGS diets produced lower methane concentrations than traditional corn diets.

This is an ongoing study that will provide more data to determine if the findings in this paper are representative of aerial emissions year round or if there is seasonal variation for emissions from swine facilities feeding DDGS. There also needs to be more investigation into other causes of higher hydrogen sulfide and ammonia in-house concentration levels.

Figure 3: Aerial emissions in g/pig-d for a. Ammonia, b. Carbon Dioxide, c. Hydrogen Sulfide, d. Nitrous Oxide, e. Methane. Gaps represent time periods of power or instrument failure.
Acknowledgements

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REFERENCES