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Impact of fiber source and feed particle size on swine manure properties related to spontaneous foam formation during anaerobic decomposition

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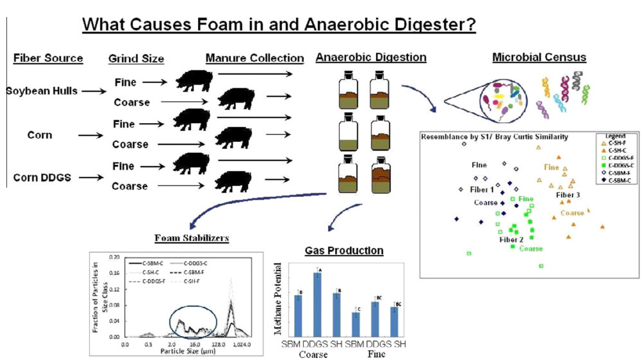
HIGHLIGHTS

- Finer grinding of feed results in reduced methane production potential.
- Grind size and fiber source influenced the microbial community.
- Feeding DDGS increased biogas production potential of swine manure.
- Fine particles are important in foam stabilization.
- Less digestible fiber resulted in more fine particles in manure.

GRAPHICAL ABSTRACT



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ABSTRACT

Foam accumulation in deep-pit manure storage facilities is of concern for swine producers because of the logistical and safety-related problems it creates. A feeding trial was performed to evaluate the impact of feed grind size, fiber source, and manure inoculation on foaming characteristics. Animals were fed: (1) C–SBM (corn–soybean meal): (2) C–DDGS (corn–dried distiller grains with solubles); and (3) C–Soybean Hull (corn–soybean meal with soybean hulls) with each diet ground to either fine (374 μm) or coarse (631 μm) particle size. Two sets of 24 pigs were fed and their manure collected. Factors that decreased feed digestibility (larger grind size and increased fiber content) resulted in increased solids loading to the manure, greater foaming characteristics, more particles in the critical particle size range (2–25 μm), and a greater biological activity/potential.

1. Introduction

The Midwestern United States is responsible for more than 50% of pork produced in the U.S. Finishing swine operations in this region typically utilize deep-pits to store manure produced until land application can occur. Deep-pit manure storages are located within the swine production building, beneath a slatted floor on which the pigs are raised. This allows the manure to fall through slatted floors into the storage below, where it is held for up to a year before being utilized as crop nutrients. These manure storage systems were adopted by producers in the late 1970s and today represent more than 50% of swine finishing operations in the U.S. (Key et al., 2011). Even though these systems improve nutrient content and manageability of the stored manure, there are concerns that have than arisen since their implementation.

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In 2009, swine producers began observing a brown, viscous foam forming on the manure surface in their deep-pit storages. Foam production in deep-pit manure storages has significant implications on facility management and safety and is a serious concern for Midwestern U.S. pork producers. The accumulation of foam can significantly reduce the volume of the manure storage, causing producers to seek alternative acres for application during untimely seasonal windows to prevent the overflow of storages. As deep-pit storages are anaerobic environments the breakdown of organic matter in swine manure will occur. This decomposition produces biogas (i.e., methane, carbon dioxide, and hydrogen sulfide). When foam is present, it traps these gases, storing hydrogen sulfide and methane; a major safety concern for animals and farm employees (Moody et al., 2009). This has resulted in increased occurrences of poisoned swine and flash fires at facilities where foam is present, disturbed, and then a spark occurs. Thus, determining the root cause of manure foam in these systems is necessary to develop mitigation options.

Similarly, foaming has been reported to be a serious problem in many biogas plants (Kougias et al., 2013; Ross and Ellis, 1992). As reported by Oether et al. (2001) this is often a deep brown, extremely viscous layer with higher solids content, making it very similar in description to the foam forming on deep-pit manure storage. These foams can result in poor gas recovery, creation of dead zones in the digester, and blockages of gas meters (Ganidi et al., 2009). In some cases, foaming has been reported due to the feedstock composition, with Kougias et al. (2014) showing that feedstock composition could alter the microbial ecology. This has made determining the cause and developing potential mitigation approaches a topic of major interest to the anaerobic digestion industry (Pagilla et al., 1997).

The inputs to deep pit manure storages consists of animal feces and urine, wasted feed and water, and wash waters generated from cleaning between groups of animals. This creates a well-established link between feed composition and the physical and chemical characteristics of the manure (Kerr et al., 2006; Jarret et al., 2011; Trabue and Kerr, 2014). Van Weelden (Unpublished Results) found that this was also true for properties of manures thought to be related to foam formation, where they reported that manures from pigs fed varying sources and levels of carbohydrate or proteins resulted in manure with different microbial community structures, different methane production characteristics, and different capacities to form and stabilize foam.

The results from those diet trials, along with results from their analysis of manures from foaming and non-foaming commercial production facilities (Van Weelden et al., 2015) helped provide direction for the experiments discussed in this manuscript. In brief, they showed: (a) foaming manures make methane at faster rates than their non-foaming counterparts, (b) foam stability was drastically different between foaming and non-foaming manures with fine particles appearing to be important in the stabilization of the foam bubble structure, and (c) foaming barns have lower concentrations of volatile fatty acids and higher surface tension. Taken together, these results indicated that the microbial community in foaming manures appears to be more active than non-foaming manures as a greater amount of the manure substrates have been converted to methane, which then appears to be adjusting physical properties of surface tension and the amount of fine particles.

Based on these results, along with changes in the swine feeding industry where finer particle size grinds and diet formulations with a greater amount of high fiber ingredient inclusion have become common, further study focused on the impact of diet physical properties (grind size) as well as fiber source/content were justified. Consequently, the purpose of this study was to develop a greater understanding of the role of dietary inputs and feed formulations on manure properties and the microbial community. This study was designed to understand the role of fiber content, manure inoculation, and diet grind size has on manure properties associated with foaming.

2. Methods

2.1. Animal management and manure storage

A feeding trial was conducted at the Iowa State University Swine Nutrition Farm (Ames, IA) utilizing two groups of 24 growing gilts; average individual weight initially 1195.5 kg 119.5 (SD = 8.9 kg). Pig were fed one of three diets: (1) corn–soybean meal (C–SBM); (2) corn–dried distillers grains with solubles (C–DDGS); or (3) corn–soybean meal with soybean hulls (C–SH) and each diet was ground to a particle size of either 374 (fine) or 631 μm (coarse) (see Tables 1 and 2 for ingredient and nutrient content of the animal diets). Within each group of 24 pigs, 8 received diets of each fiber source, 4 received fine grind and 4 received coarse ground. The entire trial was then replicated with an additional 24 pigs, so that the impact of inoculating the manure could be evaluated. That is, trial 1 represented un-inoculated manure and trial 2 inoculated manure (manure in trial 2 was inoculated with manure from the same diet/grind and was intended to provide a starter culture of bacteria).

All diets were balanced for metabolizable energy, digestible lysine per unit of energy, calcium, and phosphorus, but differed in their lipid and fiber contents. In particular, the C–SH diet had roughly 3 times the neutral detergent fiber content of the C–SBM diet, while the C–DDGS diet had twice the neutral detergent fiber level of C–SBM diet. Similarly, both the C–DDGS and C–SH diets had approximately 50% higher lipid content than the C–SBM diet to balance the diets to a similar metabolizable energy level. Soybean hulls were utilized as they represents a fiber from legumes and contain proportionally more cellulose than hemicellulose, while DDGS represents a fiber from a cereal grain contains proportionally more hemicellulose than cellulose; both fibers being prevalent in diets fed to pigs throughout the U.S.

Pigs were randomly allotted to individual metabolism crates (1.2 × 2.4 m) that allowed for total collection of feces and urine. Crates were equipped with a stainless steel feeder and a nipple waterer to which the pigs had ad libitum access. Ambient temperature in the metabolism room was maintained at approximately 18.4 °C, and lighting was provided continuously. Diets were typical for pigs of this body weight and were formulated to be adequate in all nutrients (NRC, 2012). Pigs were fed twice daily (0700 and

Table 1
Ingredient concentration of diets.

Ingredient	Diets		
	C–SBM[a]	C–DDGS[b]	C–SH[c]
Ingredient, as-fed basis, %			
Corn	79.72	62.50	57.34
Soybean hulls	0.00	0.00	20.75
Soybean meal	18.00	0.00	16.80
Soybean oil	0.30	0.00	3.32
Distiller's dried grains with solubles	0.00	35.10	0.00
Limestone	0.87	1.15	0.60
Monocalcium phosphate (21% P, 17% Ca)	0.41	0.10	0.49
Sodium chloride	0.35	0.35	0.35
Vitamin mix	0.20	0.20	0.20
Trace mineral mix	0.15	0.15	0.15
L-Lys-HCl	0.00	0.39	0.00
L-Trp	0.00	0.03	0.00
L-Thr	0.00	0.03	0.00

[a] C–SBM = corn–soybean meal.
[b] C–DDGS = corn–distiller's dried grains with solubles.
[c] C–SH = corn–soybean meal–soybean hulls.