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Summary

Cattle diet can impact manure quality and quantity but has minimal impacts on methane production from anaerobic digestion of manure. Quality of manure, measured as OM, does affect methane production and is largely impacted by the environment cattle are housed in and methods used to collect manure. As the amount of ash contamination of manure was increased, or OM content of the manure was decreased, organic matter degradation and methane production were decreased. With adequate daily cleanout of ash from digesters, open-lot beef cattle manure can be used for anaerobic digestion.

Introduction

Anaerobic digestion of manure is more common in the dairy and swine industries compared to beef. Utilizing feedlot manure for anaerobic digestion is more challenging due to ash contamination from soil-based pens. Within Nebraska, the feedlot industry produces significant amounts of manure each year. Transforming the energy within this manure into methane and using that energy has significant economic and environmental implications. This research studied the effects of adding anaerobic digestion of manure to a cattle, crop, and ethanol system, similar to facilities in place within Nebraska. Currently, distillers grains are commonly fed to feedlot cattle that are located in close proximity to ethanol plants. Methane production from manure resulting from cattle fed distillers grains was compared to manure from cattle fed a corn-based diet. Varying levels of ash contamination were also evaluated to identify if ash contamination of manure can be overcome in order for open lot feedlot manure to be used as anaerobic digestion feedstock.

Procedure

Nine, 12-gallon anaerobic digesters were utilized to study biogas generation from feedlot cattle manure. Prior to the start of Experiment 1, digesters were inoculated and maintained for two months to ensure steady-state. In Experiment 1, varying concentrations of ash were added to manure to equal 65, 40, or 15% OM manure fed to digesters. In Experiment 2, treatments were cattle diet that consisted of either a corn-based control diet (CONT) or a diet with modified distillers grains plus solubles (MDGS) replacing 40% of the corn. For both trials, digesters were allowed to stabilize for 41 days after which measurements were collected on five consecutive days. During both trials, digesters were stirred for two minutes every four hours and temperature was maintained at 99°F. Digesters were designed for effluent removal through a 2-inch ball valve located at the bottom of a cone-shaped tank. Intermittent mixing and the cone bottom on the tank allowed for inorganic particles to settle out and be removed in the effluent. Manure slurry was fed to the digesters each day through a tube at the top of the digester. Measurements of OM degradation and methane production were collected for five days at the end of each 41-day period. Weight, DM, and OM of manure fed to digesters and effluent removed from digesters were measured on these days. Concentration of methane within a known flow of N_2 gas was measured twice daily, prior to mixing. Each day, approximately 0.6 gallons (5% of total volume) of effluent was removed from each digester and 0.6 gallons of manure slurry was added to each digester to maintain a constant volume of material.

Manure for Experiment 1 was collected from the settling basin of the individually fed cattle barn at the research feedlot at the ARDC near Mead, Neb. This barn has a sloped floor and water flush system, with minimal soil contamination. Manure averaged 18% DM and 65% OM. Soil (90% DM, 97% ash) was also collected and added to digesters to have three treatments: 65, 40, and 15% OM manure fed to digesters. Water was added to the manure-soil mixture to equal 9% DM when fed into the digesters. All digesters received the same amount of OM each day (i.e., varying amount of soil and constant amount of manure).

In Experiment 2, the 65% OM manure collected for Experiment 1 was compared to manure collected from cattle fed two different diets. Manure for Experiment 2 was collected over an eight-day period with three steers per dietary treatment. Cattle diets included a corn-based control (CONT) and a 40% modified distillers grains plus solubles diet (MDGS; Table 1). Cattle were housed indoors and tied in stanchions with complete manure (urine and feces) collection in a cement pit behind the cattle. Manure was collected, mixed, and subsampled for DM, OM, and mineral analysis. Manure that was collected averaged 11% DM and 85% OM, water was added to the manure to lower percent DM of manure slurry fed to the digesters to 9%.

In both experiments there were three treatments with three digesters per treatment. Experiment 1 was a switchback design with three periods; each digester was evaluated on each treatment. Three measurement periods were made with 40 days of acclimation followed by five days of measurements. Experiment 2 consisted of a 41 day acclimation period followed by one five day measurement period. Data were analyzed as a repeated measure using a compound symmetry covariance pattern with day repeated in both Experiment 1 and 2. Measures of OM degradation were taken on five consecutive days and methane concentration was measured twice per day for five days in both Experiment 1 and 2.

Results

Experiment 1—Ash Contamination

Increased ash contamination of manure decreased organic matter degradation (OMD) from 63.2 to

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54.1% for the 65 and 15% OM treatments (respectively; $P = 0.02$; Table 2). The 40% OM treatment was intermediate and not statistically different from 65 or 15% OM treatments ($P > 0.06$; linear $P = 0.02$).

The high level of ash contamination also decreased daily methane production from 0.589 to 0.425 L CH_4 per L digester volume per day for the 65 and 15% OM treatments, respectively (linear $P < 0.01$). This is equal to 0.187 and 0.139 L CH_4 per g of OM fed (linear $P = 0.02$) for the 65 and 15% OM treatments respectively. The 40% OM treatment was intermediate for both L CH_4 per L digester volume daily and L CH_4 per g of OM fed.

Effluent removal from the cone bottom of the digesters aided in separating organic and inorganic particles within the digesters. Of ash added to digesters, 9.5, 18.3, and 20.5% was not removed from the 15, 40, and 65% OM treatments, respectively ($P = 0.11$). This resulted in ash buildup (mineral or inorganic material that was added to the digester, but not removed in the effluent and not degraded within the digester) of 64.7, 45.5, and 17.0 g/day, respectively, as % OM in the manure increased (linear $P < 0.01$). A majority of the ash was removed; however, eventually digesters are expected to fill up with ash and have to be shut down and cleaned out. The better ash removal is, the less often shut down will need to occur.

Feedlot manure has greater ash contamination and lower OM content than manure that has traditionally been used for anaerobic digestion. With adequate daily cleanout of ash from digesters, open-lot beef cattle manure can be used for anaerobic digestion, although small decreases in methane production are to be expected. Increasing the amount of effluent removed from digesters each day results in less ash buildup within digesters. However, reducing retention time of manure within digesters also limits degradation and methane production per g of OM fed. The 20 day retention time used in the current study attempts to balance between ash buildup and methane production. The OM content of feedlot manure varies depending on frequency of pen cleaning, time of year, and area of the pen the manure is removed from; however, open lot manure is generally 25% OM.

Table 1. Composition of diets fed to cattle for manure collection and digester feeding in Experiment 2.

Ingredient, % of DM	CONT[1]	MDGS[2]
Dry-rolled corn	80	40
Corn silage	15	15
MDGS[2]	—	40
Supplement	5	5
Urea	1.66	—
Monensin, g/ton	30	30
Tylosin, g/ton	8	8

[1]Treatments were due to cattle diet, CONT, and MDGS.
[2]MDGS = modified distillers grains plus solubles.

Table 2. Degradation of manure and methane production within anaerobic digesters fed cattle manure[1].

Experiment 1	15% OM	40% OM	65% OM	SEM	*P*-value	Linear	Quad
DM fed, g/day	824	388	223	—	—	—	—
OM fed, g/day	140	140	140	—	—	—	—
Ash buildup, g/day	64.7[b]	45.5[ab]	17.0[a]	17.1	0.02	< 0.01	0.74
Ash buildup, % of ash fed	9.46	18.3	20.5	5.94	0.11	0.12	0.16
OMD[2], %	54.1[a]	56.5[ab]	63.2[b]	3.8	0.05	0.02	0.45
Methane, L/L digester volume daily	0.425[a]	0.501[ab]	0.589[b]	0.051	< 0.01	< 0.01	0.86
Methane, L/g OM fed	0.139[a]	0.167[b]	0.187[b]	0.017	0.02	< 0.01	0.71
Experiment 2	**CONT**	**MDGS**	**65% OM**	**SEM**	***P*-value**		
DM fed, g/day	228	216	220	—	—		
OM fed, g/day	205	183	132	—	—		
Ash buildup, g/day	1.37[a]	2.16[a]	16.3[b]	2.24	< 0.01		
Ash buildup, % of ash fed	5.96[a]	6.55[a]	18.5[b]	1.10	< 0.01		
OMD[2], %	61.7[b]	65.9[b]	45.0[a]	5.9	< 0.01		
Methane, L/L digester volume daily	0.506	0.491	0.462	0.11	0.92		
Methane, L/g OM fed	0.112	0.123	0.158	0.033	0.37		

[1]In Experiment 1, manure was collected from a sloped floor cattle barn with a water flush system and averaged 65% OM. Soil was added to this manure to create the 40 and 15% OM treatments. Treatments in Experiment 2 were due to cattle diet, a corn- based control diet (CONT), a 40% modified distillers grains plus solubles diet (MDGS), or a mixture of diets collected from a sloped floor barn (similar to 65% OM treatment in Experiment 1).
[2]OMD = organic matter degradation.
[a,b]Within a row, means without a common superscript differ ($P < 0.05$).

Experiment 2 — Diet Impact

Ash buildup was greater and OMD was lower for the 65% OM manure compared to the CONT and MDGS manure, which averaged 85% OM. Organic matter degradation averaged 63.8% for CONT and MDGS ($P = 0.48$). The 65% OM manure had 45.0% OMD. Ash buildup, as a percent of total ash fed into the digester was 18.5% for the 65% OM treatment. The CONT and MDGS treatments had less ash buildup ($P < 0.01$) and averaged 6.3%. Even with small amounts of ash buildup, eventually digesters will likely need to be shut down and cleaned out.

There were no statistical differences in methane production, measured as daily production per L of digester volume ($P = 0.92$) or daily production per g of OM fed ($P = 0.37$). For all three treatments, daily methane production averaged 0.486 L/L of digester volume or 0.131 L/g of OM fed.

Cattle diet can impact manure quality and quantity but has minimal impacts on methane production from anaerobic digestion of manure. Quality of manure, measured as OM, has a larger impact on methane production and is largely impacted by the environment the cattle are housed in and methods used to collect the manure (i.e., ash contamination).

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