BIOGAS PRODUCTION FROM DAIRY MANURE AND ITS FILTRATE

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The effect of liquid-solid separation pretreatment on methane production from the anaerobic digestion of cattle manure was investigated in the laboratory. Screening out the coarse solid fraction from the waste before digestion had a minimal effect on the rate of biogas production for equal volatile solids loading rates at a 16-day hydraulic retention time. For a 12-day hydraulic retention time, a significant increase was found in the biogas production rate per litre of digester or per gram volatile solids added for the screened manure over the unscreened manure. The results support the concept that a liquid-solid separation pretreatment step could significantly reduce the volume of digester required for a farm with no decrease in biogas production.

INTRODUCTION

In recent years, biogas production through anaerobic digestion of animal manures has received renewed interest. The present state of the art has been reviewed by several researchers (Hashimoto et al. 1980; Smith 1980). Most of the existing on-farm anaerobic digester feed materials are in the range of 8–12% total solids (TS). At these levels, many are having material-handling problems typified by difficulties in manure slurry pumping and solids settling out in the digesters due to inadequate mixing (Abeles et al. 1978). Additional water is sometimes added in an attempt to solve these problems, resulting in an increase in digester volume requirements and hence a higher capital cost.

In the conventional anaerobic digestion process, the volatile solids (VS) breakdown is usually in the range of 15–30% (Hills 1980; National Academy of Sciences-National Research Council 1977). It is logical to assume that the principal organic fraction being metabolized consists of the organic molecules which are already in solution and the very fine particles having a high surface to volume ratio which are readily attacked by bacterial enzymes. If it is hypothesized that a very high percentage of the VS fraction which is destroyed in most digesters is contained in this liquid fraction, then a liquid-solid separation pretreatment of the waste should produce a filtrate which on digestion will still yield a high volume of biogas but which will not have the same material-handling problems. It would also be expected that the size of digester needed to treat the waste from a given number of animals would be smaller with only a small decrease in total biogas production.

The objective of this project was to determine the feasibility of reducing the digester volume per animal unit or per litre of biogas produced by removing a portion of the VS in the waste via screening.

METHODS AND ANALYSIS

Feed Material

Manure from a confined Holstein dairy herd in Aldergrove, B.C. (Blair Farms 7851 184th St., Aldergrove, B.C.), was used for this study. Manure from the free-stall dairy barn is scraped twice daily to the end of the alley. Samples of this manure were collected in plastic pails and stored in the University of British Columbia Bio-Resource Engineering cold storage room at 4°C. The dairy herd was fed with dairy concentrate (16% protein), alfalfa hay, grass and/or corn silage, salt and minerals. No antibiotics were incorporated in the animal feed.

In order to ensure a constant supply and stable feed material, enough dairy manure was taken from the dairy farm to last for the 6-mo duration of the experiment. Before being placed in the cold room, the fresh manure (15% TS wet weight basis) was mixed with an equal volume of water to give a final feed material of 7.5% TS, a level typical of those being recommended in the literature for anaerobic digesters (Lapp et al. 1978). This unscreened manure had a 6% volatile solids (VS) content and was used as feed material (feed D) for digester D. Portions of the thoroughly mixed unscreened manure were then passed through either a No. 10 (2.0-mm) or No. 8 (2.4-mm) vibrating screen to obtain feed materials for digesters A and B, respectively. The No. 8 mesh screen was chosen to match the screen opening of a commercially available rotating-screen liquid-solid separator (Rotostrainer, Hycor Corporation, Lake Bluff, Ill. 60044). The No. 10 mesh was selected based on our preliminary investigation of obtaining an adequate VS level for feed materials. The TS and VS for feed materials A and B were 4.3% TS and 3.3% VS, and 4.7% TS and 3.7% VS, respectively. A portion of the feed material D was further diluted to obtain feed C with a VS content (3.6% VS) similar to that of feed B. The feed materials A, B and C were prepared weekly.

Anaerobic Digesters

Four laboratory scale completely mixed 4-L digesters (Fig. 1) were fabricated. For each digester, mixing was accomplished using an impeller driven by a DC motor for 15 min every hour. The digester temperature was maintained at 30°C using a thermostatically controlled electric heater. Gas produced was held in a collector filled with saline water which was connected to a reservoir. The gas volume was measured by reading the liquid level in the collector when the gas reached equilibrium with the atmospheric pressure as indicated by a mercury manometer.

The feed material preparation and characteristics (TS, VS, total Kjeldal nitrogen (TKN), ammonia nitrogen (NH_3-N)), and the loading rate and hydraulic retention time (HRT) for the digesters are presented in Table I. Digester D, using the unscreened manure, was set up as a control. Digesters A and B were fed with liquid filtrates (feeds A and B) to compare the effect of screen size on filtrate VS content and subsequent biogas production rate. Digester C was fed with diluted feed material D to compare directly with digester B. While the VS loading rates in both digesters C and B were about the same, a portion of the VS in feed C was made up of a coarse solid fraction which had been removed from B by the screen.

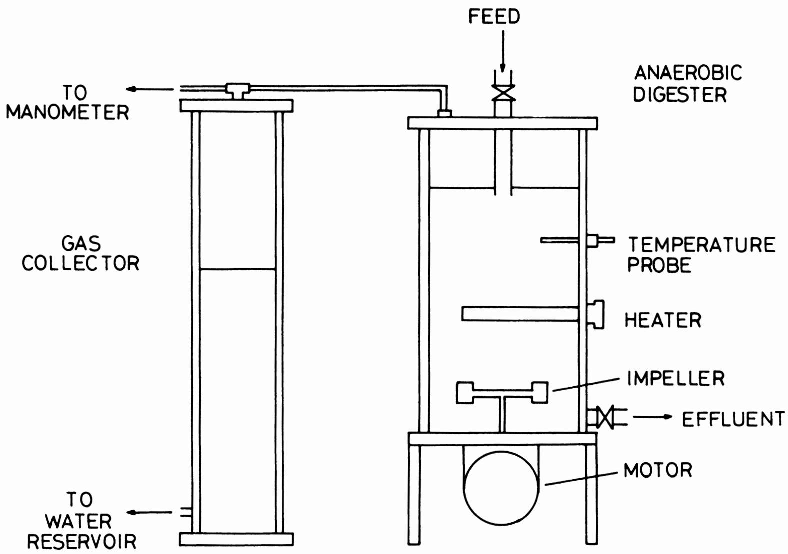

Figure 1. Schematic of experimental digests.

a period of four HRTs and then changed to 12 days for a period of four HRTs.

Chemical Analysis

Chemical analyses were performed weekly for the feeds and the effluents of all digesters. Analyses for TS, VS, and pH were carried out according to standard methods (American Public Health Association 1971). Total Kjeldahl nitrogen (TKN) and ammonia-N were determined using a block digester and a Technicon AutoAnalyser II according to the method of Schumann et al. (1973). The biogas production was monitored daily and the methane content was analyzed every 2 wk with a Fisher-Hamilton (model 29) gas partitioner. All gas measurements were expressed at 0°C and standard pressure 760 mm of Hg).

At start up, 2L of the thoroughly mixed effluents from the anaerobic digesters from our preliminary studies and 2L of the prepared feed materials were added to each digester. After a 1-wk period, daily feeding began and the loading rates were gradually increased to the desired level within a 4-wk period. Prior to daily feeding, each digester was thoroughly mixed for 15 min. A fixed volume of effluent was then withdrawn and the prepared feed material of equal volume added. The study was carried out from July to December 1981. The HRT was set at 16 days for

RESULTS AND DISCUSSION

The composition of the dairy manure remained very stable during the 6-mo storage period at 4°C. The averaged values and the ranges of the chemical compositions of the feed materials are presented in Table I.

TABLE I. FEED AND OPERATING CHARACTERISTICS OF ANAEROBIC DIGESTERS

Digester	Dilution (manure: water)	Screen mesh no. (mm)	HRT (days)	TS (%) In	TS (%) Out	VS (%) In	VS (%) Out	Loading rate (g VS/ L·day)	TKN (mg/L) In	TKN (mg/L) Out	NH_2-N (mg/L) In	NH_2-N (mg/L) Out	Methane production ($L·CH_4$/ L·day)	Methane production ($L·CH_4$/ g·VS added)
A	1:1	No. 10 (2.0)	16	4.3 (4.2–4.5)†	3.7 (3.6–3.8)	3.3 (3.2–3.4)	2.8 (2.8–2.9)	2.1	2790 (2215–3100)	2805 (1962–3200)	281 (270–293)	618 (600–651)	0.17	0.08
			12	4.4 (4.2–4.5)	3.7 (3.5–3.8)	3.4 (3.3–3.5)	2.7 (2.7–2.8)	2.8	3182 (3049–3461)	2980 (2544–3412)	432 (375–513	824 (725–888)	0.35	0.13
8	1:1	No. 8 (2.4)	16	4.6 (4.5–4.8)	4.4 (4.2–4.5)	3.7 (3.6–3.8	3.2 (3.2–3.4)	2.3	2890 (2452–3720)	2487 (2215–3162	254 (242–273)	649 (594–660)	0.18	0.08
			12	4.7 (4.4–5.0	4.0 (3.8–4.2)	3.7 (3.7–3.8)	3.1 (2.9–3.2	3.1	2820 (2527–2961)	3081 (2941–3558)	432 (375–513	866 (802–915)	0.39	9.13
C	1:2.3	NA‡	16	4.6 (4.4–4.8)	3.9 (3.6–4.4)	3.7 (3.7–3.8)	3.3 (3.1–3.4)	2.3	1860 (1725–1932)	1914 (1736–3200)	146 (144–148)	525 (512–575)	0.18	0.08
			12	4.8 (4.5–5.1)	4.1 (3.8–4.3)	3.6 (3.4–3.8)	3.1 (2.8–3.4)	3.0	2355 (2213–2563)	2314 (1843–2660)	261 (250–272)	567 (523–588)	0.21	0.07
D	1:1	NA	16	7.5 (7.3–7.5)	6.3 (5.8–6.9)	6.0 (5.8–6.3)	5.3 (5.0–5.7	3.8	2961 (2468–3109)	2816 (2215–3702)	273 (251–287)	621 (604–653)	0.24	0.06
			12	7.4 (7.3–7.4)	6.5 (6.2–6.8)	5.7 (5.3–6.0)	5.1 (4.8–5.3	5.0	3355 (2913–3576)	3129 (2679–3529)	460 (433–550)	837 (767–915)	0.20	0.04

‡Numbers in parentheses indicate the range obtained.
‡NA = not applicable.