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Original Research Paper

Studies on Biomethanation Potential of Liquid Composite Waste from Corn Glucose Factory

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ABSTRACT

The present work was undertaken to study the biomethanation potential of liquid composite waste from a corn glucose factory. One litre capacity biogas digesters were used for testing of biomethanation potential of the waste. It was found from the results that satisfactory amount of biogas is produced at optimum retention time of 25 days, at pH 7.5 and at 38°C ambient temperature. Scale-up studies on biomethanation of the waste in 5 L, 25 L and 125 L biogas digesters showed that the percent methane content of the biogas gradually increases. The biomethanation of liquid composite waste of glucose factory was found to be effective and capable to reduce organic load of the waste effectively than aerobic treatment process currently existing at the factory site.

INTRODUCTION

In the wake of technological growth, waste accumulation and its disposal has assumed serious dimensions not only in the western world but also in the third world countries. Today, it is necessary to emphasize that the 'waste is a resource' and, therefore, its management and utilization is a must. The utilization approach rather than mere disposal needs to be adopted for conservation of resources through biotechnological methods to utilize them fully.

In western Maharashtra, large number of agro-industries are located, which generate various organic wastes. Most of these these industries have applied conventional processes for treatment of their wastes, but such processes are incomplete for reduction of pollution load. The new biotechnological methods are advantageous for such industries and for protection of the environment. The industries have realized now the need of generation of biogas as an alternative source of energy from organic wastes. Biogas production from agro-industrial wastes is quite cost effective at high loading of organic matter at 4,000 to 50,000 mg/L COD (Cheremisinoff & Ovellettee 1985). The process offers an attractive alternative of handling organic wastes since most of the carbon in the waste is converted to biogas and the nutrients from the waste remain in the digested residue. Production of biogas from organic matter will not only cater to the needs of energy but may also serve as means of pollution control and maintaining environmental balance. A large number of industrial wastes with high organic contents can be converted into biogas by use of anaerobic digestion process, which can be used as a means of wastewater treatment, where biogas can be obtained as a fuel gas and digested effluents, rich in nutrients, could be used as supplementary fertilizer.

The production of biogas can also serve as a means of recycling of organic matter. The organic matter is converted into energy and nutrients (manure), where the latter goes back to plants and energy can be used for various purposes (Quian et al. 2007). Keeping this in view, the present study aims to evaluate biomethanation potential of liquid composite waste from a corn glucose factory.

MATERIALS AND METHODS

Collection and storage of liquid composite waste from the factory: The waste was collected as fresh composite sample in disinfected plastic carboys of 5-50 L capacity and stored under refrigeration till further use.

Biogas digesters: Primary biomethanation potential and optimization of parameters of waste for biomethanation studies were carried out in 1 L capacity biogas digesters (Fig. 1). Scale-up studies were performed using 5 L, 25 L and 125 L capacities biogas digesters. Floating dome biogas plant (Khadi and Village Industries Commission) design were used for fabrication of biogas digesters. The gas collection system used for all the digesters was consisted of an assembly of water displacement method (APHA 1985). Analysis of gas was made at Nikhil Analytical Laboratory, Sangli by gas chromatography using H_2 as a carrier gas (Fig. 2).

Primary biomethanation potential studies of liquid composite waste: In five 1 L capacity digesters 600 mL gobar gas dung slurry was added as initial seeding material. The gradual and stepwise removal of dung slurry from these tanks and replacement with increasing amount of waste (30 days retention time) was carried out. The details of daily loading are given in Table 1.

Optimization of parameters for biomethanation of waste: Optimization studies were performed on the basis of average daily volume of biogas produced and its percent methane content. The optimization studies were performed by using 1 L capacity biogas digesters.

Optimization of retention time: For optimization of retention time 15, 20, 25, 30 and 35 days retention periods were used at pH 7 and ambient temperature of 35°C. (Table 2). The five biogas digesters of 1 L capacity were initially loaded with 600 mL slurry from ongoing cattle dung based biogas plant as initial seeding material. The amounts of daily loadings were 40, 30, 24, 20 and 18 mL for 15, 20, 25, 30 and 35 days retention times respectively. The cattle dung slurry was gradually replaced from daily loading by decreasing the quantity of cattle dung slurry and increasing the amount of glucose factory waste till daily loading material consists of only glucose factory waste. Dung slurry is completely replaced by liquid composite waste at the end of first cycle. The seed culture gets acclimatized with liquid composite waste in second cycle. The biogas volume was measured daily and combustibility was tested by burning test for each digester. Percent methane contents were recorded on last day of retention time. The digester and its retention time, which showed maximum biomethanation with respect to average daily volume of biogas produced and percent methane content, was taken as optimum retention time.

Optimization of pH: The pH values of glucose factory waste were adjusted to 6, 6.5, 7, 7.5 and 8. These wastes were used for daily loading (24 mL) of 1 L capacity digesters with 25 days retention time found optimum in the earlier experiment. The initial seeding material in all the five digesters was exclusively the glucose factory waste, which was obtained from earlier retention time optimization studies. The experiment was performed at 35°C ambient temperature. The volumes of biogas were recorded and combustibility was tested daily. The average percent methane contents were determined twice a week. The digester showing maximum average volume of biogas and percent meth-

Fig. 1: 1 L capacity biogas digesters in row used for optimization studies.

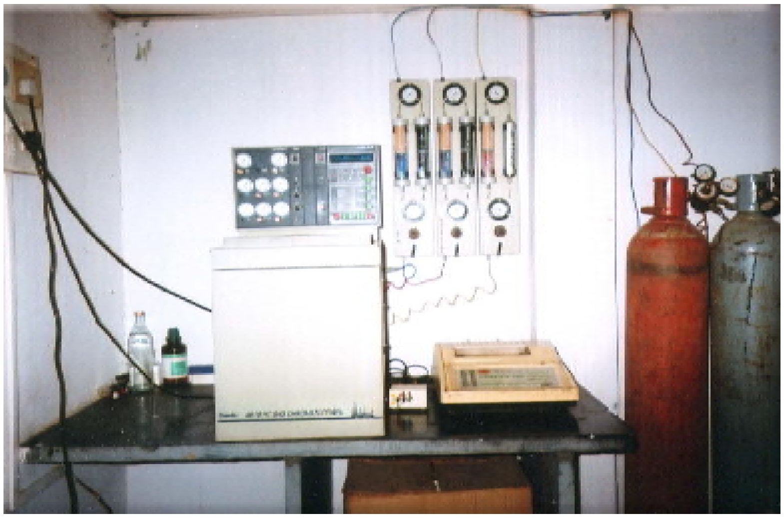

Fig. 2: Gas chromatography equipment (Chemito 8610 HT).

ane content was taken as indication of maximum biomethanation and pH of the slurry in that digester was considered as optimum pH.

Optimization of temperature : The ambient temperatures in the study were 30-32, 33-34, 35-36 and 38°C (total 30 days) during the experiment at pH 7.5 and retention time of 25 days (optimized earlier). The experiment was done during the summer season for getting temperature variations. During the studies the volumes of biogas were recorded daily and combustibility was tested, while percent methane contents were recorded twice a week. The temperature range which showed maximum average daily biogas volume and percent methane content was taken as the optimum temperature range for biomethanation of the waste.

Table 1: Admixture pattern of waste with cattle dung slurry in five 1 L capacity biogas digesters.

Stages	Retention time (days)	Amount of daily loading	
		Waste (mL)	Dung Slurry (mL)
Stage I	1 – 10	5	15
Stage II	11 – 20	10	10
Stage III	21 – 30	15	5
Stage IV	31 – 40	20	0

Table 2: Charge pattern of waste admixed with cattle dung slurry in the biogas digesters (1 L capacity) at various stages of experiment for optimization of retention time.

Digesters (1 L capacity)	Retention Time (days)	Amount of daily loading (mL)	Proportion of dung slurry admixed with waste (mL)							
			Stage I 1-10 days		Stage II 21-20 days		Stage III 21-30 days		Stage IV 31-40 days	
			Waste	Dung Slurry	Waste	Dung Slurry	Waste	Dung Slurry	Waste	Dung Slurry
A	15	40	10	30	20	20	30	10	40	0
B	20	30	7.5	22.5	15	15	22.5	7.5	30	0
C	25	24	6	18	12	12	18	6	24	0
D	30	20	5	15	10	10	15	5	20	0
E	35	18	4.5	13.5	9	9	13.5	4.5	18	0

Scale-up studies on biomethanation of the waste: The scale-up studies were performed with 5, 25 and 125 L capacity biogas digesters using the parameters optimized in earlier studies. The waste with pH 7.5 was added in daily amounts of 200, 1000 and 5000 mL for 5, 25 and 125 L capacity digesters respectively. The initial seeding material was obtained from 1 L digesters, which contained exclusive fermenting waste. It was used for 5 L digester. The fermenting waste of 5 L digester was used as initial seeding for 25 L digester. Ultimately, the fermenting slurry from 25 L digester was used as initial seeding for 125 L digester. The biogas volumes were recorded daily for 5 L, 25 L and 125 L digesters, while percent methane contents were estimated twice a week.

RESULTS

The liquid composite waste from corn glucose factory was acidic with the pH ranging from 6.8 to 7. The waste contained significant amount of organic matter. The waste has 14,000 mg/L BOD, 22,000 mg/L COD, 12,700 mg/L of total organic carbon and 17,000 mg/L of total volatile substances.

Primary biomethanation potential studies on liquid composite waste of glucose factory: When liquid composite waste along with cattle dung biogas plant slurry was subjected to biomethanation in 1 L level biogas digesters at 25 days retention time, it was observed that volume of biogas produced was satisfactory and in sufficient amount (Table 3).

Studies on optimization of parameters for biomethanation of liquid composite waste of glucose factory: It is evident from Table 4 that when five retention periods were selected for the biomethanation studies viz. 15, 20, 25, 30 and 35 days at 35°C and 7 pH of digester slurry, the range of biogas produced per day was 210-300 mL. The minimum biogas production was found at 35 days retention time, i. e., average 210 mL/day, while maximum biogas volume was obtained at retention time of 25 days, with an average of 300 mL/day of biogas.

It was found from Table 5 that, when biomethanation of the waste was carried out at five different pH, the daily amount of biogas produced ranged from 200-310 mL. The minimum amount of biogas 200 mL/day was found at pH 6, while maximum 310 mL/day was found at pH of 7.5.

The influence of temperature on biomethanation process at the retention time of 25 days and influent pH 7.5 was studied. Table 6 indicates that the ambient temperature of digesters ranged from 30-38°C due to seasonal variations. It was found that minimum of average 230 mL/day biogas was produced during the studies, when the ambient temperature was in the range of 30-32°C, while significant increase in amount of biogas was observed when there was gradual increase in the ambient temperature from 30 to 38°C with the increase in average amount of biogas from 230 to 300 mL/day. The volume of biogas obtained at temperatures 37°C to 38°C was 290 and 300 mL/day respectively.

Scale-up studies on biomethanation of waste: The optimized conditions of biomethanation viz., 25 days retention time, 7.5 pH of fermenting slurry and 37-38°C ambient temperature of digester at 1 L level studies were thoroughly transformed at scale-up levels of 5, 25 and 125 L digesters. At 5 L digester, the volume of biogas ranged from 1.6 to 2.4 L/day with an average of 1.9 L/day. When it was further scaled up to 25 L digester level, the volume of biogas was comparatively higher and ranged from 11.10-12.50 L/day with an average of 12.11 L/day. In the further scale-up of 125 L digester level, the efficiency of biomethanation was found to be increased further and volume of biogas ranged from 70 to 71.40 L/day with an average of 70.71 L/day (Table 7). The percent methane content in the scale-up studies was also increased with increase in size of digester. In the 125 L scale-up studies, the biomethanation efficiency was good. The composition of biogas from 125 L digester was 64.20% methane, 30.00% CO_2, 2.16% H_2S and 3.64% moisture. The pH of influent was 7.5 and COD and BOD were 22,000 mg/L and 14,000 mg/L respectively, while effluent has 7.2 pH and COD and BOD values of 4900 mg/L and 2100 mg/L respectively.

DISCUSSION

Corn glucose factory liquid composite waste was used in the present studies to tap its biomethanation potential. Utilization of such organic waste for generation of biogas is useful for industry itself. The liquid composite waste included liquid wastes of various processing units. The C:N and BOD:N:P ratios are critical for biomethanation and they should be in the range of 20-30 and 120:5:1 respectively (Hobson et al. 1981, Hills & Roberts 1979, Ghosh 1978). Chemical analysis of liquid composite waste showed that its C:N ratio was 14.46, and BOD:N:P ratio 120:7.6:0.64. It was found that BOD:N:P ratio of liquid composite waste of glucose factory was comparatively closer to the expected ratio of 120:5:1.

There are reports of an efficient digestion of various agro-based industrial wastes admixed with cattle dung (Unni 2004, Cheremisinoff & Ovellettee 1985). Petrochemical crude waste admixed with agro-cellulolytic and municipal wastes has been reported for biomethanation (Brahma 2001). Abhishek et al. (2000) studied anaerobic treatment of distillery effluent and found that there was good potential of distillery waste for production of biogas. Studies on biomethanation potential of the waste showed that biogas produced was fairly good, which indicated that organic material from waste was available for biomethanation.

During optimization of retention time, 25 days period seems to be optimum. Studies showed that at 25 days of retention time there was peak in biogas production and at 30 and 35 days there was decline in biogas production. Therefore, 25 days retention time was taken as optimal retention time.

Table 3: Primary biomethanation potential studies on waste in five 1 L capacity biogas digesters.

Parameters	Values
Average amount of biogas produced (Average of 30 days mL/day)	229
Average content of methane, %	54.40
Ambient temperature, °C	30 to 35°C

Table 4: Optimization of retention time for biomethanation of waste in 1 L capacity digesters at pH of waste = 7.0 and temperature = 35°C.

Sr. No.	Retention time (day)	Average of daily amount of biogas produced (mL)	Average % methane
1	15	230	52.0
2	20	240	50.0
3	25	300	53.2
4	30	280	53.0
5	35	210	52.5

Table 5: Optimization of pH for biomethanation of waste in 1 L capacity digesters at retention time = 25 days and temperature = 35°C.

Sr. No.	pH of waste	Average of daily amount of biogas produced (mL)	Average % methane
1	6.0	200	51.8
2	6.5	260	50.5
3	7.0	300	54.0
4	7.5	310	56.1
5	8.0	270	55.0

Table 6: Effect of temperature on biomethanation of waste in 1 L capacity digesters at retention time = 25 days and pH of waste = 7.5.

Temperature range(°C)	No. of days available at particular temperature range	Average of daily amount of biogas produced (mL)
30-32	3	230
33-34	4	260
35-36	7	270
37-38	7	290
38	4	300

Table 7: Amount of biogas produced at scale-up studies in 125 L biogas digesters.

Parameters	Capacities of digesters		
	5 L digester	25 L digester	125 L digester
Average amount of biogas produced (Average of 50 days, mL/day)	1.9	12.11	70.71
Percent methane content	58.20	60.10	64.20
Ambient temperature (°C)	33	34	37

Biomethanation of waste at different pH values shows that there was gradual increase in volume of biogas from pH values 6.5 to 7.5. However, the biogas volume was decreased drastically at pH 8. The peak of biogas volumes was obtained at pH 7.5, hence this pH has been taken as optimum. The optimum pH ranges previously reported for biomethanation was 6.9-7.2 (Cheremisinoff & Moresi 1976).

At 37 to 38°C maximum amount of biogas was produced and it seems possible that beyond 38°C temperature one could obtain further increase in the biogas volume, but the trend showed that ambient temperature around 38°C could be the temperature nearly optimum for biomethanation of waste. It is evident from the study that biomethanation efficiency increases at higher temperatures like 35°C and above, while it decreases as temperature decreases.

In 5 L, 25 L and 125 L scale-up biomethanation studies, there was gradual increased efficiency of biomethanation due to better acclimatization of methanogens and uniform higher ambient temperature. It was reported that biogas from the agricultural wastes usually contains 60 to 70% methane and 30 to 40% CO_2 (Cowley & Wase 1981), but yields of methane may be lower or higher with different feed stocks and technologies (Silverio et al. 1986).

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