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Optimization of Physico-Chemical parameters for Biomethanation of Bagasse and Press mud Admixture

Ganesh Bartakke and Hanamantrao Deshmukh
Dept of Microbiology, Yashavantrao Chavan Institute of Science, Satara- 415001, INDIA

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Abstract

Energy is considered as one of the important factor contributing in the economic and social development of the country. Non renewable energy sources are limited and now there is no alternative to use renewable energy sources rather than non renewable one. In the developing country like India bagasse and press mud wastes are available in plenty, these wastes can be used for generation of biogas. As most of the wastes alone cannot be used directly for Biomethanation some combinations of waste were tested. The Biomethanation process is carried out by microorganisms and various environmental factors affect the Biomethanation process. In the present study different physicochemical parameters of Biomethanation optimized at 4 L level digesters, mainly hydraulic retention time (HRT), Organic loading rate (OLR), temperature, pH affecting Biomethanation process were studied. It was found that hydraulic retention time of 20 days, Organic loading rate of VS 6.1gm/day, pH of 7, and a temperature range of 38-40^{0}C were optimum for biogas production.

Keywords: Renewable energy, biogas, biomethanation, HRT, OLR.

Introduction

Man has been dependent on energy since down of civilization[1]. Most of the energy is utilized from fossil oil, gas and coal; many developing countries are finding the alternative energy sources. These sources may be biomass, solar energy, geothermal, hydropower, and wind power and ocean energy. These energy sources reduce global warming[2]. In India 579 sugar industries with daily crushing capacity varying from 800- 10000 tons per day, produces 19 million tones white sugar and also discharge a large amount by products waste material. Around 7 million tones of press mud and 44 million tons of bagasse are produced as waste[3]. Routinely used methods for disposal of these wastes are energy consuming and expensive.

Very few types of pollutants are produced by renewable technologies, therefore are considered as clean and green energy sources. Emission of green house gases from burning fossil fuel has adverse effect on the nature. To decrease the green house gases renewable sources of energy such as biogas are much useful.[4] Biomethanation is economically proven and promising technology as it provides methane which is energy efficient and environmentally sustainable vehicle fuel and Effluent of digester can be used as a fertilizer for crop production[5].

Biogas production has four key parameters as feed stock, microorganisms, environmental control for anaerobic digestion and reactor configuration[2]. Biogas production is a microbial process that may be affected by various conditions associated with digesters like pH, temperature and retention time of the substrate[6]. PH is an important parameter for biogas production. Change in pH values during biomethanation process considered as effective as it facilitates two stage processes – hydrolysis / acidogenesis and acidogenesis / methanogenesis separately[7].

Most anaerobic systems are designed to retain the waste for a fixed number of days in the digester tank is called hydraulic retention time (HRT) [8]. HRT values in tropical countries ranges from 30-50 days depending on the weather conditions[9]. HRT also establishes the correlation between time available for bacterial growth and subsequent conversion of the organic material to the biogas. Organic loading rate (OLR) in terms of volatile solids gm per day or VS/L of influent also considered as rate limiting factor for biogas generation. High OLR reduces the HRT and capital cost generated by size of digesters. Temperature range required for biogas production is also considered as prime factor. Small variation in temperature of digester changes and affects activity of bacteria associated with anaerobic digestion for biogas generation. VS degradation decreases with temperature in that psychrophilic bacteria produces gas at very low rate.

Present study was basically performed to check the feasibility of use of an abundantly available wastes for biogas generation and optimization of conditions best suited for maximum biogas production from sugar industry wastes mainly bagasse and press mud.

Material and Methods

Materials: Sugar industry wastes: Bagasse- Collected from Kisan veer Satara Sahakari Sakhar Karkhana Ltd Bhuinj, Press mud- Collected from Kisan Veer Satara Sahakari Sakhar Karkhana Ltd Bhuinj.

Cow dung: Collected from cow shed located at Degaon, M.I.D.C. region Satara.

Slurry of cattle dung based biogas plant: Cattle dung based biogas plant slurry was collected from a biogas plant situated at Degaon, M.I.D.C. region Satara,

Biogas digesters: 4-L capacity metal digesters.

Methods: Collection and storage of sugar industry waste: Sugarcane bagasse and press mud, were collected from sites in sterile plastic bags using sterile hand gloves. Then it was carried to laboratory, and stored in room temperature for further use.

Preparation of Inoculums: Bagasse and press mud were mixed in 1:1 proportion and slurry was prepared. For whole experiment i.e. optimization of HRT, OLR, and pH as well as to study the effect of temperature on biomethanation the same admixture of bagasse and press mud was used.

Experimental design for optimization studies: In the earlier studies it was found that, bagasse and press mud admixture was the most promising combination amongst the lot initially tested as determined on the basis of average daily volume of biogas produced and its methane content. Therefore admixture of bagasse and press mud was used for this study. The optimization studies were performed by using 4 L capacity biogas digesters. The biogas volume was measured daily. Percent methane was also recorded at the end of the experiment. The maximum biomethanation with respect to average daily volume of biogas produced and % methane content was taken as optimum.

Optimization of retention time: Five retention periods i.e. 15, 20, 25, 30 and 35 days were taken for the optimization studies of retention time for the admixture of bagasse and press mud at pH 7 and ambient temperature of 35^0C. The five biogas digesters were initially loaded each with slurry from ongoing cattle dung based biogas plant as seeding material. Table – 1 shows the amount of daily loading of substrate was 267, 200, 160, 133 and 114 gm for 15, 20, 25, 30, 35 days retention time respectively. The cattle dung slurry was gradually replaced with bagasse – press mud admixture by decreasing daily loading of cattle dung slurry and increasing the amount of bagasse – press mud admixture till daily loading material consisted only of the latter resulting in the total replacements of digester contents with bagasse – press mud admixture.

Optimization of OLR: Organic loading rates in terms of VS gm/day added in different digester used for this experiment were 3.4, 4.0, 4.8, 6.1 and 8.1 VS gm/day for optimization of organic loading rate for admixture of bagasse and press mud at pH 7 and ambient temperature 35^0C. The five biogas digesters were initially loaded each with 4L of slurry from ongoing cattle dung based biogas plant as seeding material. The amount of admixture added in the form of liquid material. Organic material in the influent was then calculated in the form of VS in gm.

Optimization of pH: The pH values of admixture of bagasse and press mud were adjusted to 6, 6.5, 7, 7.5 and 8. The 200 gm of slurries of each were used for daily loading of digesters at 20 days retention time found optimum in the previous experiment. The initial seeding material in all the five digesters was exclusively the admixture of bagasse and press mud which was obtained from the retention time optimized studies. The experiment was performed at 35^0C of ambient temperature with two cycles of 20 days retention period. The volumes of biogas were recorded and combustibility tested daily in the second cycle of retention time. The average percentage methane content was determined at final cycle of retention time.

Table-1
Daily loading pattern of admixture of bagasse and press mud for optimization of retention time

Digesters	Retention time days	Amount of loading (gm)	Preparation of dung slurry admixed with bagasse and press mud at various stage of experiment(gm)			
			Stage I 1 -8 days 25%(bagasse + press mud) + 75% cow dung	Stage II 9-16 days 50%(bagasse + press mud) + 50% cow dung	Stage III 17 -24 days 75%(bagasse + press mud) + 25% cow dung	Stage IV 25-32 days 100%(bagasse + press mud)
A	15	267	66.75+200.00	133.5+133.5	200.25+66.75	267+0
B	20	200	50+150	100+100	150+50	200+0
C	25	160	40+120	80+80	120+40	160+0
D	30	133	33.25+99.75	66.5+66.5	99.75+33.5	133+0
E	35	114	28.5+85.5	57+57	85.5+28.5	114+0

Effect of temperature: The ambient temperatures during the study period were in the range of 30-32, 32-34, 34-6, 36-38 and 38-40^{0}C (total 32 days) especially in summer season. As it was not feasible to maintain the temperature artificially, so natural temperature ranges were taken for study. The experiment was performed by using admixture of bagasse and press mud at pH 7 at 20 days retention time which was optimized in the previous experiment.

Analytical methods for biogas: Biogas samples were collected in 20 mL capacity glass bottles, sealed properly and analysis of biogas was carried on Michro 9100 Gas chromatograph by using TCD and nitrogen as carrier gas at Nikhil scientific and analytical laboratory.

Results and Discussion

Optimization of Hydraulic Retention Time (HRT) and Organic Loading Rate (OLR): Biogas production from admixture of bagasse and press mud was observed at hydraulic retention time (HRT) 15,20,25,30 and 35 days. Hydraulic retention time affects the biogas production Table-2 shows amount of biogas at different HRT. Biogas production at 15 day HRT was 151.96 mL/ gm of VS and at 35days HRT it was 114.4 mL/ gm of VS. The optimum biogas yield was reported at 20 days HRT i.e. 118.39 mL/ gm of VS. There was increasing trend from 15 to 20 days but decreased thereafter till the end of the experiment at 35days. It is known the retention time for Biomethanation of distillery waste alone varies from 30-50 days but with bagasse and press mud it has decreased to 20 days. Some worker has also reported lower retention time by using selective Biomethanation inoculums, but in case of dung slurry Biomethanation, about 30 days retention time is commonly used. The 20 days optimal retention time obtained in the present study could be because of desired C:N and BOD:N:PRATIOS and improved VS content. It was reported that HRT values in tropical countries like India ranges from 30-50 days depending on the weather conditions[9].

The table-2 shows organic loading rate at 15, 20, 25, 30 and 35 HRT were 8.14, 6.10, 4.88, 4.05 and 3.47 VS gm/day the biogas yield was within range of 114.40 -157.70 mL/gm of VS. The optimum yield was at OLR 6.10 VS gm/day.

Optimization of pH: The admixture of bagasse and press mud was used for biomethanation at different pH values as 6, 6.5, 7, 7.5 and 8. Experiments were carried at 35^{0}C with 20 days retention time, the average amount of biogas produced ranged from 500 to 1662.50 mL Optimum amount of biogas production was observed at pH 7. Table-3 shows amount of biogas production at different pH range. The optimum pH ranges previously reported for Biomethanation by different workers are 6.9-7.2. Methanogenic activity decreases drastically at acidic pH or highly alkaline pH. There are reports that optimal biogas production is obtained around pH 7.3 - 7.4 from distillery waste as well as dung slurry .Maximum biogas generation from press mud in the pH range 7 to 7.5[9]. Relatively narrow pH range i.e. 6.5 to 8.5 is observed for biomethanation process[7]. Optimum pH of hydrolysis and acidogenesis has been reported as between 5.5 to 6.5 while, optimum pH of biomethanation is around 7[10].

Effect of temperature: It was reported that Biomethanation efficiency increases at higher temperature like 36^0 and above, while decreases at lower temperature. In fact better biogas production was reported at thermophilic range, Table – 4 shows effect of temperature on biogas yield. The temperature range used was from 30^{0}C- 40^{0}C. The optimum yield average 912.50 mL of biogas production was found at temperature range 38-40^{0}C. The average biogas production was relatively lower (100 mL) at temperature range 30-32^{0}C as it is not favorable for growth of mesophilic bacteria. It was previously reported that Optimized conditions for biogas production are thermophilic 50-60, mesophilic 32-35 and psychrophilic up to 20^{0}C [11].

Optimized parameters: The bagasse and press mud was found to be a best substrate for biogas production as it produces appreciable amount of biogas with 52.00 % methane containt. Table – 5 shows optimized parameters for biogas production

Table–2
Optimization of hydraulic retention time (HRT) and Organic loading rate (OLR)

HRT (days)	Daily loading (ml)	Organic loading rate VS gm/day (OLR)	Average biogas mL/day	Biogas yield mL/gm of VS
15	267	8.14	1237.5	151.96
20	200	6.10	962.5	157.7
25	160	4.88	725	148.5
30	133	4.05	487.5	118.39
35	114	3.47	387.5	114.4

Table-3
Optimization of pH for biogas production

Sr No	Digester	pH of influent	(HRT days)	daily loading	Total gas produced	Average gas produced
1	A	6	20	200	289	500
2	B	6.5			8.5	737.50
3	C	7			10	1662.50
4	D	7.5			11.5	687.50
5	E	8			13	587.50

Table-4
Effect of temperature on biogas production

Temperature range	HRT (days)	Amount of biogas generated in ml								Total biogas generated (ml)	Average biogas generated (ml)
30-32	20 days	1	2	3	4	5	6	7	8	800	100
32-34		100	100	100	100	100	100	100	100	2100	262.5
34-36		300	200	300	200	200	300	300	300	3000	375
36-38		400	400	400	300	400	300	400	400	5100	637.5
38-40		600	600	600	700	600	700	600	700	7300	912.5

Table-6
Optimized parameters for biomethanation of bagasse and press mud admixture

Parameter optimized	Value
Hydraulic Retention time	20 days
Organic loading rate of influent, VS(gm)/day	6.1
pH of influent	7
Temperature of digesters (ambient)	38-40C

Conclusion

The untreated bagasse and press mud were used as a substrate for Biomethanation. By using 4 L level digesters different parameters for biomethanation were optimized. Present study shows optimum Hydraulic Retention time (HRT) 20 days, organic loading rate (OLR) 6.1 gm of VS/day, pH 7 and optimum temperature range 38 - 40^0 C. The project helps to remove bagasse and press mud from the area. It also helps to achieve the goal of the energy generation with zero pollution.

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