International Journal of Scientific Engineering and Technology ISSN : 2277-1581
Volume No. 6, Issue No. 7, PP : 224-227 1 July 2017

Production of Biogas from Treated Sugarcane Bagasse

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Abstract - ***Sugarcane bagasse is available in plenty in and around communities of almost all major and minor places of India. Among all the potential lignocellulosic sources of biogas production sugarcane bagasse was selected for this study related to enhancement of biogas production and minimization of retention time. It was clearly observed that biogas generation response from sugarcane bagasse treated mechanically (A) was maximum both in terms of production rate and ultimate yield of biogas. Alkaline (B) and acid (C) treatment also led to biogas production but their corrosive effect on the sample might have been the possible reason for being less effective in enhancement of biogas yield as compared to that of mechanical treatment. The maximum ultimate yield of biogas was 308.7 ml/gVS (A) followed by 272.6 ml/gVS and 240.2 ml/gVS respectively.***

Keywords - sugarcane bagasse, mechanical, alkaline, acid, anaerobic digestion, biogas, pretreatment.

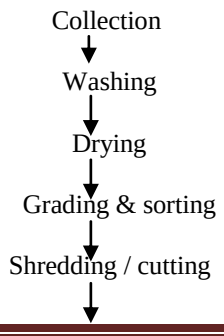
I. Introduction

India is a land of many and ranks amongst the developed first, second and third world countries in terms of agricultural produce. Naturally wastes associated with agriculture is available in abundance in the nation extending from north to south and east to west and all across the other geographical locations including the coastal areas. Agricultural wastes are normally associated with very less or no procurement cost. Hence, the source of wastes is always decided at a distance of minimum expenditure for carrying them to the work place. Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is dry pulpy residue left after the extraction of juice from sugarcane. Bagasse is used as a bio-fuel and in the manufacture of pulp and building materials. Bagasse is a heterogeneous material containing around 30-40 % pith fibre which is derived from the core of the plant and is mainly parenchyma material and bast, rind or stem fibre which makes up the balance and is largely derived from sclerenchyma material. These properties make bagasse particularly problematic for paper manufacture and have been the subject of a large body of literature. Many research efforts have explored using bagasse as a renewable power generation source and for the production of bio-based materials. Moreover Bagasse is a good source for CHP generation. Bagasse is often used as a primary fuel source for sugar mills. It produces sufficient heat energy to supply all the needs of a typical sugar mill with energy to spare. The resulting CO_2 emissions are less than the amount of CO_2 that the sugarcane plant absorbed from the atmosphere during its growing phase which makes the process of cogeneration of greenhouse gas neutral. Anaerobic digestion is a 4-step biochemical process involving different microbial populations for each step. The first step begins with hydrolysis of the complex organic wastes resulting into generation of simpler components or compounds and formation of organic acids. The second and third step is collectively called acid phase involving acetogenesis and acidogenesis. The fourth step is methane phase involving methanogenesis. Solids retention time for batch digesters is high. The retention time depends on the biodegradability of the material. The more the biodegradability of the material the lesser the retention time of solids in the digester. As bagasse wastes are lignocellulosic in nature hence digestion of these waste take longer time to complete and as a result of which the retention time increases. This very retention time can be reduced and biodegradability can be increased by some pre-treatment methods which have been discussed later in subsections of this paper. In this study anaerobic digestion was carried out under similar operating conditions. Anaerobic digestion processes were designated as A, B and C for samples obtained after suitable pre-treatment methods such that process A (mechanical), B (alkaline) and C (acid). The aim of this study is to work upon enhancement of biogas yield after suitable pre-treatment of sugar bagasse. The extensive work was carried out in the Energy Engineering laboratory, Department of Chemical Engineering, Jadavpur University.

II. Material and Methodology

A. Collection and preparation of sample

Sugarcane bagasse was obtained in bulk quantity for no procurement and transportation cost from a sugarcane juice seller dwelling outside the campus locality. They were carried safely to the work place in polythene bags and washed with water to get rid of sticky cane sugar juice. Later they were spread on roof over tin plates for better heat and light exposure. After 8 hours they were found to be sufficiently dry and further graded and sorted to separate out any possible contaminants. The fibrous matter was shredded using sharp and fine scissors followed by particle size reduction using a Wiley mill. The finely ground sample was stored in air tight containers till further use.



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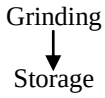

Fig 1 Schematic of feedstock processing

B. Characterization of sample

The proximate properties of the cane sugar bagasse sample were determined according to the standard procedure and specifications of Fuel Research Board and British Standard Institutions. Dried and finely ground sugarcane bagasse was charged at 105^0C in a hot air oven for 1h and gradually checked for loss of weight after every hour till negligible loss in weight was attained. Similarly, the sample was charged at 450^0C for 30mins in a muffle furnace followed by heating in a separate muffle furnace at 775^0C for determination of ash content.

The sample was characterized and the results have been tabulated as follows:

Table 1. Proximate properties

Parameters	Results
Moisture (M), %	9.20±0.60
Total solids (TS), %	90.8±0.60
Volatile solids (VS),%	80.48±0.78
Ash, %	4.85±0.00
Fixed Carbon (FC), %	5.47±0.60

C. Methods

C.1 Pre-treatment of sample

About 90% of all plant matter is composed of four major components like lignin, cellulose, hemicellulose and pectin. Lignin is a cross-linking polymer that binds cellulose and hemicellulose together. Practically lignin is recalcitrant in nature and not easily degradable which makes lignocellulosic matter difficult to digest for anaerobic digestion process. Hence, few pre-treatment methods are always applicable to make the sample degradable by breaking the cross-linkages of lignin with cellulose and hemicellulose and make the cellulose available for conversion to biogas [iii, v]. Certain goals of pre-treatment process are breakage of lignin, disruption of cellulose crystallinity and increase porosity of lignocellulosic materials. Pre-treatment also meets some essential requirements like: (1) improve the formation of sugars or ability to form sugar by hydrolysis, (2) avoid degradation or loss of carbohydrates, (3) avoid formation of inhibitory by-products of hydrolysis and fermentation processes, (4) be cost-effective. Some suitable and selected pre-treatment processes were taken onto consideration for this study and discussed below.

C.1.1 Alkaline pre-treatment of sample

Alkaline pre-treatment is a popular chemical pre-treatment for delignification. Different chemical agents namely NaOH (sodium hydroxide), $Ca(OH)_2$ (calcium hydroxide) and aqueous ammonia (NH_3) are normally used to chemically treat the material [i]. Here NaOH was used to treat the sugarcane bagasse. The collected material was sun dried and cut into small pieces. Further they were treated with 0.2g NaOH / g dry solids and thereafter washed rigorously with warm water and subjected to drying and was stored in air tight containers till further use. Advantage of this method is it can break down lignin and carbohydrate cross-linkages, increase crystallinity that affects the rate of hydrolysis but there happens no loss is ultimate yield of biogas.

C.1.2 Acid pre-treatment of sample

Acid pre-treatment is another type of chemical treatment of importance. Hydrochloric acid (HCl), Sulphuric acid (H_2SO_4), Nitric acid (HNO_3), Phosphoric acid (H_3PO_4), Acetic acid (CH_3COOH) etc., are the major acids used for this treatment. Here H_2SO_4 was used to treat sugarcane bagasse. Acid pre-treatment can be performed under two conditions, one is dilute acid (1%v/v) at high temperature (230^0C), another concentrated acid (approximately 70%v/v) at low temperature (50^0C) [i]. 1%v/v H_2SO_4 treatment is very effective for biogas production. So, here we have used dilute H_2SO_4 (1%v/v) and high temperature (150^0C) to remove lignin. Advantage of using dilute acid is it can disrupt the major amount of structure of hemicellulose and then hemicellulose easily converts to sugars. Another advantage is it can improve microbial degradation and enzyme hydrolysis. Small pieces of bagasse were dried in hot air oven. Dried sample was mixed with distilled water and 1%v/v H_2SO_4 by stirrer for 3 hours. After complete mixing the sample was washed by distilled and dried in hot air oven for 2 days at 50^0C.

C.1.3 Mechanical pre-treatment of sample

Mechanical pre-treatment is a kind of physical treatment. Size reduction from larger to smaller particles was achieved by grinding [i]. Procured sugarcane bagasse was subjected to water washing followed by drying till removal of superficial moisture that rendered the material sufficiently dry for grinding. The larger particles were crushed in a Wiley mill to form smaller particles of uniform size. The aim of this treatment was to rupture the cross linkages of lignin with cellulose and hemicellulose and also to reduce the percentage of crystallinity of the material.

C.2 Preparation of starter culture

Bovine rumen was selected as the source of mixed consortia of microorganisms due to the easy availability of this material and the fact that the microbial ecology of the rumen is indicative of cellulolytic bacterial activity in enteric system. Rumen was procured from an instantaneously slaughtered animal from Central meat shop at C.I.T market, Jadavpur, Kolkata, India. Sample was brought to the laboratory in a sterile and sealed Scott Duran glass bottle and immediately processed in a dilution series for inoculating plates. For serial dilution technique, 1ml of rumen slurry was added to 9ml of sterile distilled water in a 20ml test tube using a sterile 5ml borosilicate glass pipette and shaken vigorously at least for 1 minute. This dilution was marked as stock and was then allowed to sediment for a short period. These were further diluted starting from 10^{-1} to 10^{-5} sequentially. 200 ml of nutrient agar media was prepared according to the manufacturer (Hi media, Mumbai, India) specifications. From

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Volume No. 6, Issue No. 7, PP : 224-227
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each of the five dilution tubes (10^{-1} to 10^{-5}) dilution fluid was transferred to the agar plates and inoculated by spread plating technique using a borosilicate glass spreader. Each inoculation was duplicated and 10 agar plates were obtained, which were incubated at 37^0C for 24 hours. To achieve aseptic conditions and contamination free cell growth flame sterilisation of the petri dishes were performed and the lids of the agar plates were moved over the flame of the ethanol spirit lamp before closing and sealing of the agar plates. After successful growth of bacteria in nutrient agar plates, pure culture with the greatest microbial cell growth was sub cultured in a 1L Scott Duran thermo resistant autoclavable glass bottle containing nutrient broth media. The culture was hermetically sealed and incubated at 37^0C to achieve vigorous growth of bacteria isolated from rumen mix consortia of organism. The whole process was aseptically carried out in laminar air flow table.

C.3 Anaerobic digestion

Anaerobic assimilation is a utilization of organic methanogenesis which is an anaerobic procedure responsible for degradation of a great part of the carbonaceous matter in indigenous environments where organic accumulation brings about consumption of oxygen for aerobic digestion [iv]. All experiments were conducted using table top digesters essentially made of hard glass and 500ml capacity. The effective / working volume of the digester was maintained at 375ml excluding 25% of the total digester volume as the space allowance for gas hold up. Rubber cork was tightly fitted to the opening of each digester to maintain the anaerobic environment properly. The rubber cork was subjected to appropriate mechanical boring prior fitting to digester and thereafter three glass tubes of similar diameter was inserted into the digester through the bores of the rubber cork and it was ensured that the tubes fit firmly to the cork. Among the three tubes, one of them was facilitated for gas delivery and other two were kept dipped in slurry for time to time determination of pH, total solids and volatile solids. The process was operated at mesophilic conditions (37^0C) and total solids concentration was maintained at 9% of the effective / working volume, so as to maintain the C/N ratio of the feed in the range of 25-30. Biogas was measured by the method of downward displacement of water. A cylindrical jar with glass knob at both ends, essentially made of borosilicate glass of 500ml capacity was connected to an aspirator bottle of 500ml capacity by means of rubber tube at one end. The other end of the jar was connected to gas delivery tube of the digester. Upon commencement of biogas production, the gas was ideally held in the headspace provided for gas hold up during digester set up. Practically some volume of gas also gets dissolved into the fermentation slurry. Hence, while measurement of gas at regular interval, the digester was subjected to proper shaking and swirling prior observation of water displacement into the aspirator bottle from the glass jar. The volume of water displaced from the jar to the aspirator bottle, was considered as the amount of gas produced. All gas volumes were reported as correct to STP of 0^0C and 101.325 k Pa.

D. Limitations

As all experiments were carried out in batch mode, it was not possible to determine the kinetic parameters. Requisite bacterial consortium was isolated from rumen slurry but they were not identified as a result of which growth and death parameters were not studied. Substrate concentration was known at the time of digester set up but it was not measured during digester run for anaerobic digestion. Here the anaerobic digestion study was carried out for 30 days only and therefore it believed that ultimate biogas yield reported in this study may be less than the actual what would have been possible if the study would have been conducted till complete decomposition of the feed.

III. Results and Tables

Experimental data obtained from measure of yield of biogas at regular interval was plotted against retention time as shown in fig 2. From fig 2 we can see the production of biogas follows a typical pattern for all the three processes A, B and C. The fig 2 we can get the idea of biogas production of a particular day or any instant of time. Hence, this is the biogas production rate that shows production of biogas increases with increase in number of days and reaches a peak value, thereafter decreases with increasing number of days.

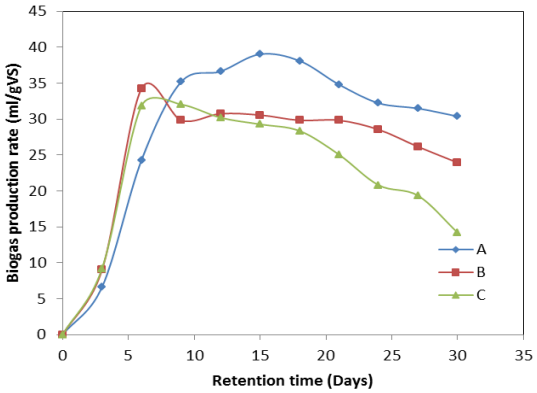

Fig 2 Biogas production rate

For process A peak value of biogas yield was obtained on day 15. In the same process previous peak was observed on day 8 but a fall in slope was observed which was believed to be due to fall in pH of the process and was adjusted using few drops of 6N NaOH solution into the system. For process B clear peak was observed on day 6/7, thereafter the slope was observed to decrease gradually. Similarly for process C, the peak was observed on day 7 and gradually the slope was found to decrease. All the three processes followed same pattern or profile of biogas production but they were found to be different in terms of biogas production rate.

Fig 3 represents cumulative yield of biogas over the same retention time of 30 days study. At any instant of time it is possible to get the total yield of biogas from the beginning or commencement of biogas production. It is clearly evident from fig 3 that the slope of the processes A, B and C varies adversely after a common intersection point of the three lines in the graph. The slope of process A increases gradually whereas the slope of processes B and C gradually decreases. The point of intersection or inflection

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in the graph for all the processes was obtained on day 12 or 13 approximately. The ultimate yield of biogas was maximum for process A and then process B & C gradually.

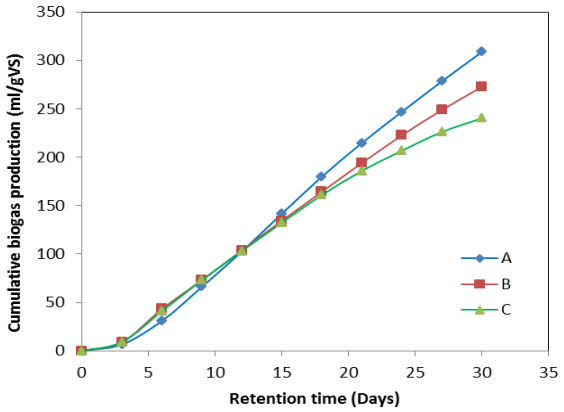

Fig 3 Cumulative biogas production

Yield of biogas from anaerobic digestion of pre-treated samples for lignin extraction is clearly depicted in fig 4. It was observed that mechanical treatment was most effective in rupture of cross linkages of lignin which allowed better penetration of microbial enzymes to access the cellulose inside sample while anaerobic digestion which in turn led to contribution of maximum biogas production as compared to all the three processes. Possible reason for lower yield of biogas gradually for process B (alkaline) and C (acid) is possible removal of cellulose from microfibrils of sample while hydrolysis of hemicellulose for alkaline process and corrosive action and possible damage of cellulose for acid treatment.

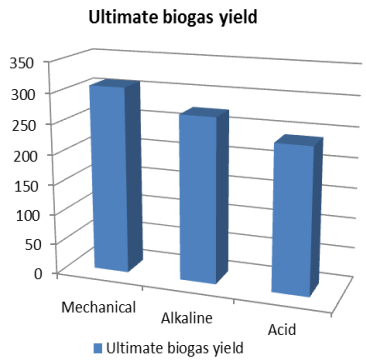

Fig 4 Yield of biogas

IV. Conclusion

Enhancement of biogas production from sugarcane bagasse was achieved using selective pretreatment methods. Biogas production rate and ultimate biogas production was maximum for process A (mechanical) as compared to that of process B (alkaline) & C (acid). Pretreatment was considered as the most cost effective stage for this study. Mechanical treatment was found to be most economic and suitable, both in terms of investment and outcome such that anaerobic digestion of mechanically treated sample led to maximum yield of biogas (308.7 ml/gVS) followed by 272.6ml/gVS and 240.2 ml/gVS for alkaline and acid treated processes respectively. Therefore sugarcane bagasse can be considered as a potential source of biogas production after selective pretreatment.

Acknowledgement

We extend our deep sense of gratitude and thank the Department of Chemical Engineering, Jadavpur University for providing extensive cooperation, help and guidance for successful completion of experimental work within stipulated time followed by development of this research paper.

References

i. *i. Zheng, Y., Zhao, J., Xu, F. and Li, Y., 2014. Pretreatment of lignocellulosic biomass for enhanced biogas production. Progress in Energy and Combustion Science, 42, pp.35-53.*

ii. *Teghammar, A., 2013. Biogas Production from Lignocelluloses: Pretreatment, Substrate Characterization, Co-Digestion and Economic Evaluation. Chalmers Tekniska Högskola.*

iii. *Mosier, N., Wyman, C., Dale, B., Elander, R., Lee, Y.Y., Holtzapple, M. and Ladisch, M., 2005. Features of promising technologies for pretreatment of lignocellulosic biomass. Bioresource technology, 96(6), pp.673-686.*

iv. *Chynoweth, D.P., Owens, J.M. and Legrand, R., 2001. Renewable methane from anaerobic digestion of biomass. Renewable energy, 22(1), pp.1-8.*

v. *Anwar, Z., Gulfraz, M. and Irshad, M., 2014. Agro-industrial lignocellulosic biomass a key to unlock the future bio-energy: a brief review. Journal of radiation research and applied sciences, 7(2), pp.163-173.*

vi. *Amin, F.R., Khalid, H., Zhang, H., u Rahman, S., Zhang, R., Liu, G. and Chen, C., 2017. Pretreatment methods of lignocellulosic biomass for anaerobic digestion. AMB Express, 7(1), p.72.*

vii. *Kim, J.S., Lee, Y.Y. and Kim, T.H., 2016. A review on alkaline pretreatment technology for bioconversion of lignocellulosic biomass. Bioresource technology, 199, pp.42-48.*

viii. *Kamarludin, C., Norsyarahah, S., Jainal, M.S., Azizan, A., Safaai, N.S.M., Daud, M. and Rafizan, A., 2014. Mechanical Pretreatment of Lignocellulosic Biomass for Biofuel Production. In Applied Mechanics and Materials (Vol. 625, pp. 838-841). Trans Tech Publications.*