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EFFECT OF MIXING SPEED ON ANAEROBIC DIGESTION OF SUGARCANE TRASH INTO BIOGAS IN A BATCH-FED DIGESTER

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ABSTRACT

A massive measure of waste gets produced following the harvest of sugarcane which is one of the foremost crops cultivated in the subtropical regions all over the world. Degradation of these lignocelluloses wastes takes a long time naturally and hence disposed of through open burning that in turn consequences atmospheric pollution. These tribulations could be detached on practicing the rapid degradation method called anaerobic digestion method. The present study assesses the effect of mixing speed on biogas production through anaerobic digestion of sugarcane trash. The study was intended to get the effect of mixing speed on the degradation of lignocelluloses and in biogas production from sugarcane trash substrate inoculated with dairy manure. In this study, the anaerobic digestion process was kept under mesophilic conditions of 32^0C for 30 days in a batch feed anaerobic digester at differential mixing speeds of 0 rpm, 50 rpm, 100 rpm and 150 rpm. Results showed that better degradation of lignocelluloses and high production of biogas (109.55 mL gVS^{-1}) was observed in the reactor R3 (100 rpm) and the value was at the least in the reactor R1 where mixing was not provided. Hence, it was observed that the mixing speed greatly affect biogas properties of sugarcane trash that undergo batch fed anaerobic digestion process.

Keywords: inoculum, manure, lignocellulose, methane, agro-residue, degradation.

INTRODUCTION

India is now the second biggest cultivator of sugarcane after Brazil producing 32.25 million tons of sugar every year. It has pinched global interest as an efficient raw material source for energy production due to its high positive energy and greenhouse balance (de Oliveira Bordonal *et al.*, 2015). Based on the recent satellite images, sugarcane acreage in the country was estimated to be 5.43 million hectares. It is estimated that about 80% of sugarcane trash is left in the field after harvest, which in turn benefits agriculture by preventing soil erosion, restraining soil temperature variations, rising biological action, enhancing soil carbon (Sousa Junior *et al.*, 2018), intensifying weed control (Araldi *et al.*, 2015), better infiltration of water and nutrient cycling. These trash in excess on the field also cause few detrimental effects such as reduction of ratoon sprout (Begum and Bordoloi, 2016), increased fire outbreak, a larger incidence of sugarcane pests (Goebel and Nikpay, 2017) and intricacy in mechanized cultivation. This signifies anaerobic digestion of sugarcane trash as an optimistic process to deteriorate those problems as the cellulose, hemicelluloses and lignin components which comprise the foremost part of sugarcane trash when on exposure under controlled anaerobic environment results into renewable energy sources such as ethanol & biogas (Achinas, 2017) and the digestive resulting in the course gives out mineral fertilizers for sugarcane fields and the biogas produced could get advanced to energy-rich methane.

For cane trash that encompasses complex lignocellulose composite, natural degradation would be extremely obscure (Janke *et al.*, 2015). Henceforth, microbial inoculums source is predominantly significant (Liu *et al.*, 2017) to set up a biogas reactor as the degradation rate and production of biogas could be bettered with the reduction of reactor preparatory time and the process of digestion get stabilized with resituated microbial growth (Mehta, 2018). The application of rumen fluid enhances the digestion of lignocelluloses biomass under anaerobic conditions (Ozbayram *et al.*, 2018). The rumen fluid could not be obtained readily as like ruminant animal manure. Therefore on a practical level, usage of rumen biota as inoculum for digestion would be difficult. Hence, usage of dairy manure which is rich in rumen biota as inoculums for anaerobic digestion of lignocellulose biomass could be ideal as they are available in abundance all throughout the nation.

The methanogenic digesters used nowadays facilitate substrate agitation which facilitates the formation of biogas (Lemmer *et al.*, 2013). The provision of agitation enhances anaerobes, for a level contact and distribution of the substrate thereby preventing solids flotation and deposition, assurance of unvarying temperature and pH. This study was intended to assess the anaerobic digestion process of sugarcane trash on effect with differential mixing speeds (0rpm, 50rpm, 100rpm and 150rpm) in a batch-fed digester. The degradation of lignocelluloses and production of biogas on influence with different mixing speeds were the key indicators of this study.

MATERIALS AND METHODS

Feed

The feed used in this study comprises of the mixture of sugarcane trash collected randomly in a sugarcane field and dairy manure collected from a dairy farm in Thanjavur. After collection, the sugarcane trash

was sliced using (Sri Escorts, PTO- 500) a cane trash cutter and reduced even further to finer particles using Prestige, PDMG-01 and was stocked in vacuum bags after air drying at 35^0C. The dairy manure sources were subjected to anaerobic conditions for 30 days in a digestive unit. These manures after a month of anaerobic exposure were stored at 4^0C and were reactivated at 37^0C before their usage as inoculums in the study. Apart from the substrate size reduction, any other extra pretreatment methods were not applied over the feed in this study.

Experimental system

The lab-scale experimental system consists of a batch digester of volume 2 L with a working capacity of 1.6 L and the remaining 0.4 L constitutes the head volume. An electrical stirrer was provided for feed agitation whose speed of revolution was controlled by a regulator. Required temperature conditions were offered for the feed in the reactor kept inside a water bath with (RS-300W) an automatic thermostatic water heater. A water-filled reagent bottle of 1 L capacity and a calibrated cylinder of volume 1L were coupled together with the reactor. Thus the reactor which was kept inside the water bath, the water compartment & the calibrated cylinder linked in sequence forms the experimental setup (Figure-1). The closures were sealed up with (Metroark 211 compound) silicon grease and the openings were closed with glass stoppers.

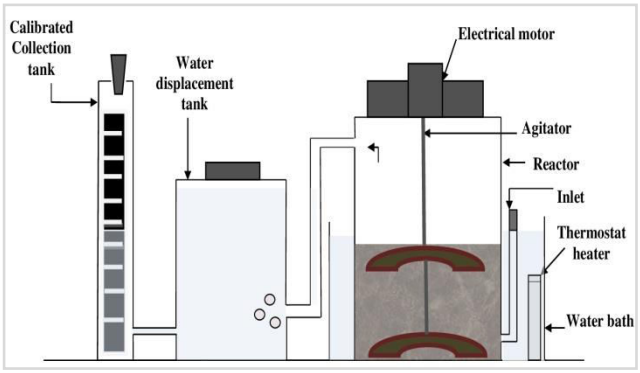

Figure-1. Experimental setup.

Operational conditions

The pre-digested manure inoculums and the substrate sugarcane trash blended together at an inoculum substrate ratio (ISR) of 0.5 (VS based) comprise the feed in the reactors. The total solids (TS) value of 5% and a mesophilic temperature range of 32^0C were reserved for the digesters. In order to ensure the anaerobic environment, the digesters were kept bunged for a 30 days trial and daily recordings on biogas productions were made. Further addition of acids, bases, nutrients, etc in the feed was not carried out during the study. The reactors which were subjected with differential mixing speeds of (0 rpm, 50 rpm, 100 rpm and 150 rpm) were named as R1, R2, R3 and R4 respectively.

Instrumentation Analysis

The measurement of moisture, ash and volatile contents of the sugarcane trash samples were recorded using (Perkin Elmer/ TGA4000N5200111) a thermogravimetric analyzer within 1 hour and 30 minutes. The carbon, hydrogen and nitrogen concentrations of the sugarcane trash were measured by (Perkin Elmer/ TEAN5340015) a CHNSO analyzer. Fourier transform infrared spectroscopy (Perkin Elmer/ Spectrum Two) was used to quantify the composition of celluloses, hemicelluloses and lignin contents of the biomass sugarcane trash. Liquid displacement method was adapted to evaluate the sum of the produced biogas. A gas-chromatograph (Scientific, STS 9001) was used to determine the methane content of the biogas and the specific methane concentration was calculated by multiplying the amount of produced biogas with that of methane content. Standard experimental methods (APHA, 2005) were practiced to determine pH and alkalinity.

RESULTS AND DISCUSSIONS

Characterization of Feed

Table-1 shows that the substrate sugarcane trash constitutes cellulose of 43.2%, 31.0% of hemicellulose & lignin concentration of about 21.3% with the TS value of 98.2%. The C/N ratio of the substrate was recorded to be 57.6% much greater than the optimal value of 30% (Dioha *et al*., 2013).

Table-1. Inoculum and substrate characteristics[a].

Parameter	Sugarcane Trash	Dairy Manure
Proximate Analysis		
TS (%)	98.2 ± 0.2	15.8 ± 0.2
VS (%)	86.4± 0.3	12.2 ± 0.1
VS/TS (%)	87.9	77.2
Ash (%)[b]	12.1 ± 0.5	22.8± 0.1
Ultimate Analysis		
H (%)[b]	5.8 ± 0.1	4.6 ± 1.4
C (%)[b]	40.9 ± 1.3	38.8 ± 1.6
N (%)[b]	0.71 ± 0.2	1.3 ± 0.2
C/N (%)[b]	57.6	29.8
Composition Analysis		
Cellulose (%)[b]	43	
Hemicellulose (%)[b]	31	
Lignin (%)[b]	21	

[a] Data is expressed as means ± SD ($n \geq 3$)
[b] Data is based on TS

Effects on Biogas Production

Biogas production was minimum (Figure-2) during the initial days reasoned owing to the lag in the

microbial growth phase (Abubakar and Nasir Ismail, 2012). In reactors R3 (100 RPM) & R4 (150 RPM) the biogas values were peaked in the 14th day by 9.15 mL gVS^{-1} & on the 17th day by 8.95 mL gVS^{-1} whereas on reactors R1 (0 RPM) & R2 (50 RPM) peak values of 7.05 mL gVS^{-1} on 19th day & 7.95 mL gVS^{-1} on 16th day were recorded. The biogas production in the reactor R3 maintained under the mixing speed of 100 RPM was 109.55 mL gVS^{-1} recording the highest (Figure-3) followed by the reactors R2 (106.1 mL gVS^{-1}), R4 (96.25 mL gVS^{-1}) & R1 (92 mL gVS^{-1}). Although the reactor R3 experienced high production of biogas, its daily biogas yield experienced heavy fluctuations whereas the daily biogas production from the reactor R2 and R1 were steady and were devoid of much flux. The reactor R4 maintained under the mixing speed of 150 RPM recorded the least biogas yield together with the highest instability in daily biogas production. The start time for biogas production in the reactors could get quicken and be enhanced by pretreatment methods (Gu *et al*., 2014).

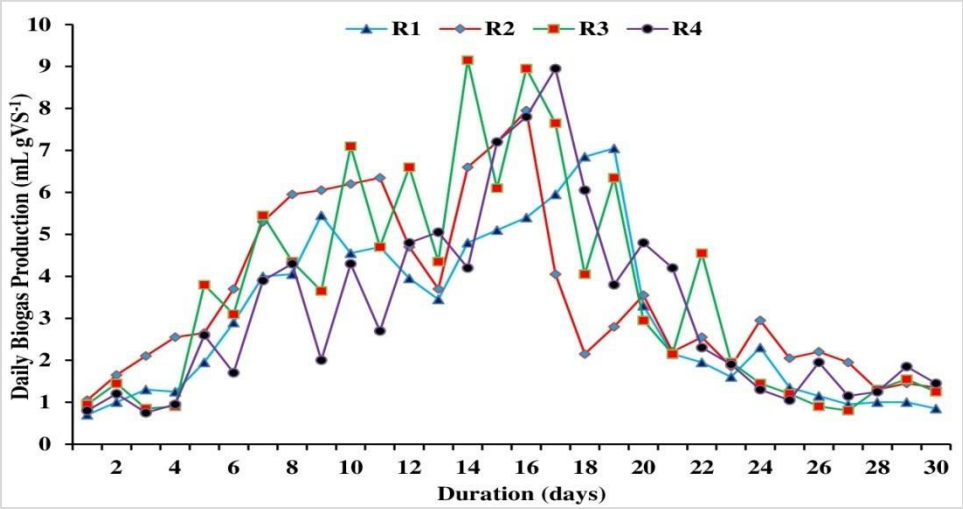

Figure-2. Daily biogas production (mL gVS^{-1}).

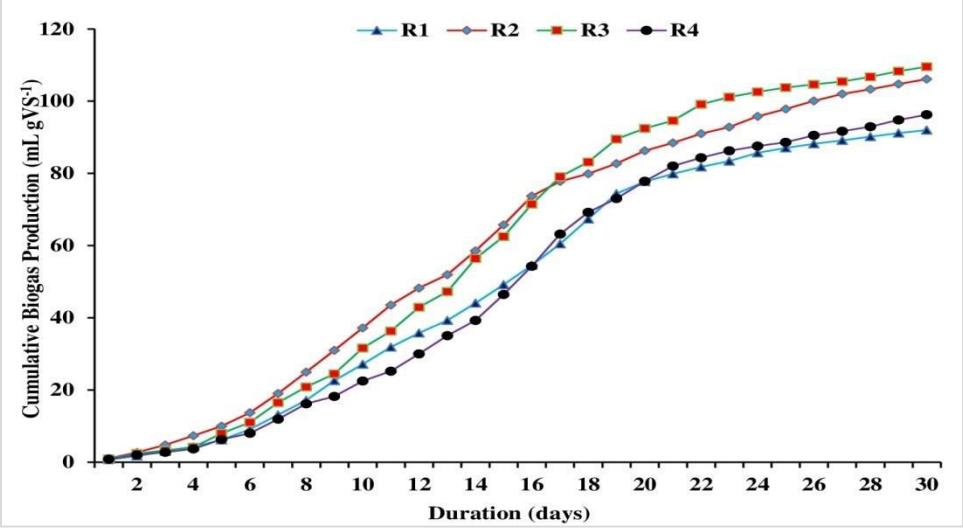

Figure-3. Cummulative biogas production (mL gVS^{-1}).

Effects on pH & Alkalinity

The initial pH value of the feed was recorded to be 7.9 (Figure-4) satisfying the optimal pH of 7 to 8 for better production of biogas (Simon Jayaraj *et al*., 2014). The pH values on the final day i.e. after 30 days of digestion in the reactors R1, R2, R3 & R4 with mixing speeds of 0 RPM, 50 RPM, 100 RPM & 150 RPM was found to be 8.1, 8.2, 8.3 & 8.1. It was observed from the initial and final pH values of the reactors that a healthy pH range (Chandra *et al*., 2012) for microorganisms to produce biogas prevailed throughout the study.

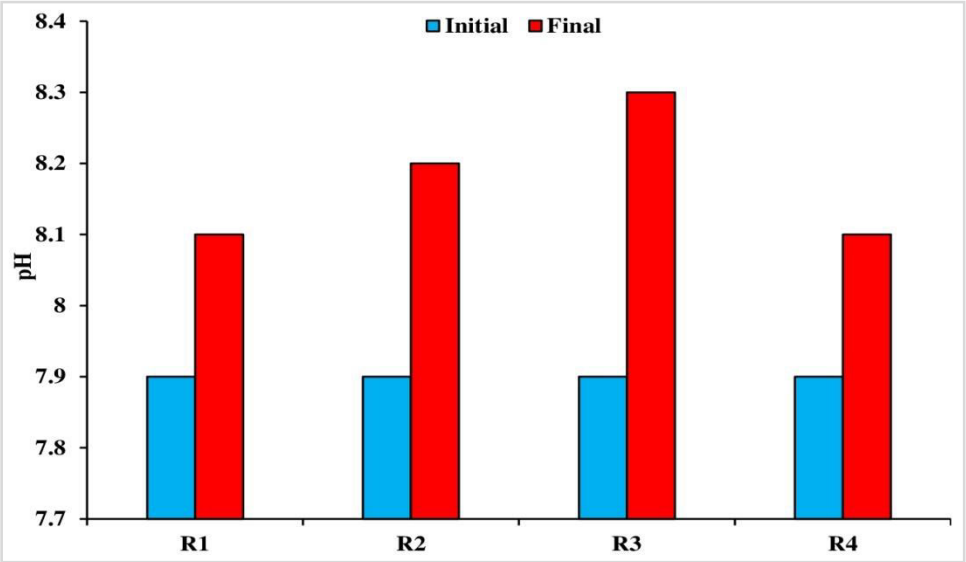

Figure-4. Initial and final pH for reactors

The feed in the reactors had an initial alkalinity (Figure-5) of 8.9 g $CaCO_3$/L and the alkalinity values after 30 days of digestion in the reactors R1 (0 RPM), R2 (50 RPM), R3 (100 RPM) & R4 (150 RPM) were 9.7 g $CaCO_3$/L, 9.8 g $CaCO_3$/L, 9.8 g $CaCO_3$/L & 9.6 g $CaCO_3$/L. Chemical bases were not added further in the reactors and the inoculums alkalinity itself prevented the acidification.

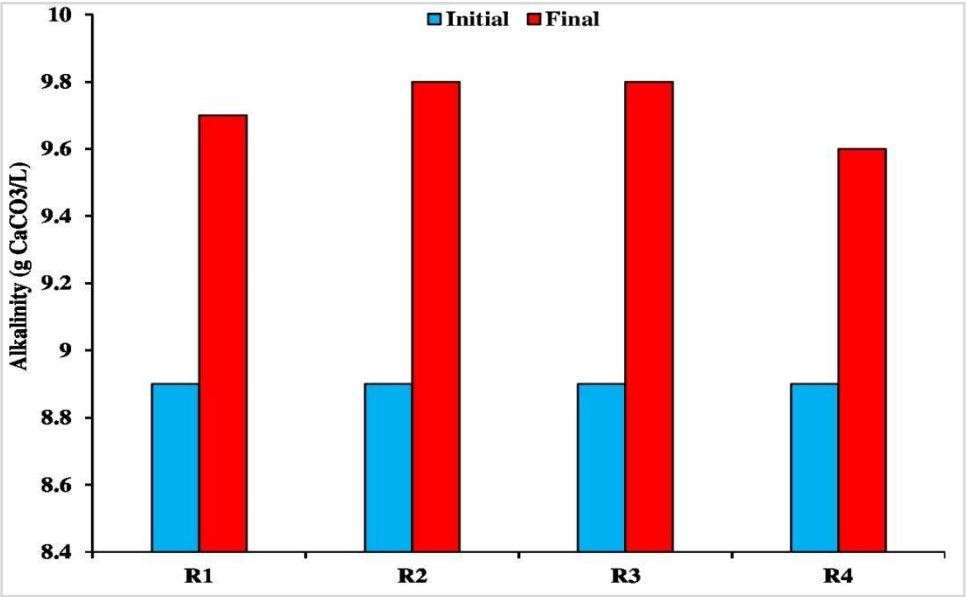

Figure-5. Alkalinity for reactors.

Effects on Lignocellulose degradation

During the anaerobic digestion process, the core component of the lignocelluloses biomass such as the celluloses and hemicelluloses endures reduction resulting in biogas production (Gu *et al*., 2014). The degradation rate of cellulose (53.7%) was highest in the reactor R3 (Figure-6) kept under mixing speed of 100 RPM whereas highest hemicelluloses degradation rate (43.6 %) was observed in the reactor R2 with mixing speed of 50 RPM. The degradation rates of celluloses and hemicelluloses were at least in the reactor R4 (150 RPM) and thus resulting in less production of biogas. Clear evidence for lignin degradation was not observed during the study.

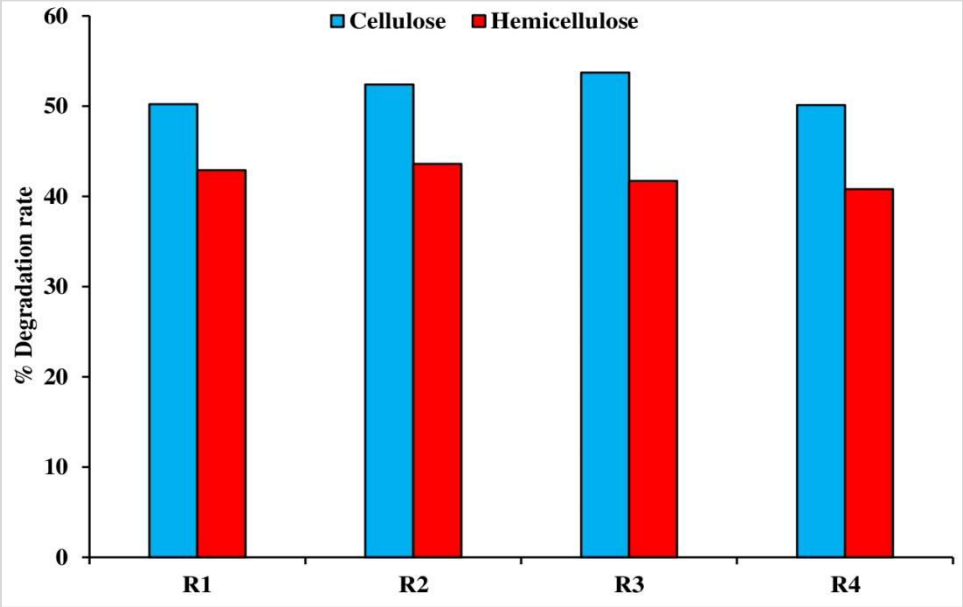

Figure-6. Degradation rate of lignocellulosic biomass in reactors.

CONCLUSIONS

This study observed variations in the rate of production of biogas in the reactors with the change in feed mixing speed conditions. The degradation rate of lignocelluloses and biogas production was found better in reactors operated at moderate mixing speed of 50 RPM & 100 RPM as seen in the reactors R2 & R3 whereas in reactors with no mixing as seen in reactor R1 and in the reactor R4 with maximum mixing speed of 150 RPM it was found to be at least. The best degradation of organic substances and biogas production were achieved at 100 rpm. The result showed that the pH and alkalinity were still in the range of methanogenesis process.

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