Experimental Evaluation of Biogas Production by using HPTC-CSTR for Complex Organic Substrates

Ramdayal Kumawat[1] Vijayendra Singh Sankhla[2] Indrajeet Jat[3] Udai Singh Chouhan[4]
[1,2,4]Assistant Professor [3]PG Students
[1,2,4]Department of Mechanical Engineering [3]Department of Renewable Energy Technology
[1,2,3,4]GITS,Udaipur

Abstract— In today's world of dwindling fossil fuel reserves, latest developments in biogas technologies have become a ray of hope for solving energy supply and waste management problems in rural as well as urban area in a sustainable manner. In this study we intended to increase biogas production and reduce the hydraulic retention time (HRT) for that partheniume hystrophorus and cow dung selected as biomass substrate and carried out physiochemical analysis of the sample. Production of biogas involves complex physiochemical and biological processes depending upon different factors like the type of substrates, temperature, pH etc. A batch process was carried out in HPTC-CSTR (High performance temperature control-continuous stirred tank reactor) of 20 L capacity with 12L load of organic substrates for HRT 20 days .The experiment carried out the thermophiles consortium above 40°C (±2°C/h). To optimize the degradation of organic matter, we followed the evolution of the degradation of organic matter by measuring the COD, BOD, VS, TS, C: N the volume of biogas formed during the digestion, the temperature and the pH of the process. The pH maximum level of 7.2& at the end of the digestion period pH (acid production) was decreased. The end of study gave the cumulative yield of 9920 ml biogas production. Involving technology can make the biogas production even more sustainable and economically viable.

Key words: biogas yield, biomass substrate, HPTC-CSTR, Partheniume, Thermophiles Consortium, pH

I. INTRODUCTION

In today's word energy security and environment have become matter of great concern. Waste management, energy generation and safe disposal of biodegradable are being explored across the world to reduce the environment pollution and to provide energy security in the present era of the climate change. Biogas production from the biodegradable wastes offers safe disposal method through anaerobic digestion process. Anaerobic digestion process has been recognized as one of the most optimal options for treating biodegradable wastes stream since it result in two valuable final product, biogas and compost that may be utilized as organic fertilizer.

Biogas production for utilization in cooking, lighting andpower generation as well as most important to substitute petrol and diesel by compressed biogas for vehicle, but till large scale installation of biogas plants across the country has not achieved substantial progress in comparison with progress of the other know matured renewable energy technologies.There is large potential of the resources for biogas production in small, medium and large scale categories by means of advance technology. The main objective of this study is to determine the biomass potential of some complex substrate asP.hysterophorus that is declared invasive weed, and obnoxious flowering plant which is a big challenge to all attempts of control. Although several eradication measures have been undertaken in this regard for many years, not a single method is yet an option for the total eradication of Parthenium. Thus the status of Partheniume management is visualized with respect to large-scale utilization. Therefore, in the present work, Parthenium is chosen to comparatively analyse and its efficiency as a potential feed stock.

The CH_4 is the component chiefly available for its general calorific value of 21-24MJ/M^3[2].The biogas technologies mostly apply natural anaerobic bacteria for microbes. Biogas as a fuel in any country for used in cooking, heating purposeand purified biogas used in a gas engine to covert the electricity[4].The gases methane, and hydrogen produced, can be combusted from raw biogas[5].These study of biogas production system having main advantages of eliminating greenhouse gas, betterment of fertilizer and production of power and heat [6].Generally bio digester can be operated on their temperatures ranges (a)psychrophiles below 28˚c (b)mesosphilic medium temperature at 29 to 40˚c (c)thermophile at 40 ˚c to 55˚c[7].The methanogenesis and microorganisms growth is mainly depend on various parameters like pH, temperature, C/N ratio, organic loading rate, reactor design, inoculums and HRT [8].

This paper will focus on the factors (such as temperature, mechanical stirring and type substrates affecting biogas yield in a biogas digester and finding the biogas potential of invasive weed partheniume and mixing of it with cattle manure which is co-substrates.

II. MATERIALS AND METHODS

A. Processing of Partheniume and Cow Manure for Experiment:

Sample of substrate for physiochemical test was chosen Partheniume hysterophorus weed, used in this study was collected from roadsides. The plant when collected was in the flowering stage. The entire plant was carefully uprooted and was thoroughly washed under running tap water. Later the long stems and leaves along with other parts of the plant were cut into small pieces of 1-2inches in length. This was later subjected for physiochemical and biological test. For chemical test the

sampleof 100ml were prepared by grinding the small pieces in juicer (Bajaj majestic JX4) and fresh cattle manure were collected from nearby cow house and subjected for the same test. The result of the physiochemical and biological tests are shown in the below table 2. In this study three kind of feedstock were prepared firstis fresh cow manure and water in 1:1, second is partheniume hysterophorus 1:0.5 and third one was cow manure and partheniume with water in 4:5:5 on the basis of weight-to-volume ratio and subjected to three different digester of same specification .

Substrate	Mass of substrate in Kg	Mass of water in litre	Mixing ratio
Partheniume hysterophorus	6	3	1:0.5
Cow manure	6	6	1:1
Partheniume h. and CM	3+3=6	3	1:0.5

Table 1: Mix masses of charge substrate with water

B. Physiochemical analysis of the sample:

The physiochemical analysis of the sample includes the finding of TS, VS, COD, and C: N and BOD of the sample. For finding the TS, VS and OM a 100gram sample of the substrate taken and kept it in muffle furnace for 24hrs.at105^0C for removing the moisture content from the sample, further cooled down the sample inside the furnace and it is weighted. Again the sample placed inside the furnace for3 hrs.at550^0C for various observation and calculation. All the parameter were analysed according standard analysis method of APHA [3].This same procedure is followed for three samples of partheniume, cattle manure and mixture of both respectively. MC and TS calculated by the following formulas

$$MC\ (\%) = Wi\text{-}Wf\ /\ Wi \times 100 \quad (1)$$

$$TS\ (\%) = 100\text{-}MC\ (\%) \quad (2)$$

C. Chemical analyses:

A representative sample of the substrate is taken each time to perform chemical analysis. The physicochemical analyses used are:

1) Measurement of the pH: The measurement of pH is done directly by reading on a pH-meter to combined electrode.
2) Dry Matter (%): The measure must be determined as quickly as possible, to limit the losses through evaporation. The standardized method Afnor NF U 44-171, consists of a levy of a maximum quantity of sample, preferably a mass greater than 100 ±0.1 g, placing in the oven at 105 ± 2 °C until constant weight, approximately 24 hours. The dry matter (MS %) is the supplementary rate degree of humidity.
3) Dry volatile Matter (%) A mass around 50 ±0.1 g is placed at 550 °C, for 2 hours in a muffle furnace TEMR (NF U 44-160)220/230V ac supply.
4) Determination of the chemical oxygen demand (COD) used titration method [6].
5) Measurement of the NTK (Nitrogen Kjeldahl) 5 ml of the sample is place in the flask of Kjeldhal. Add 7, 5 g of catalyst ($CuSO_4 + K_2SO_4$). Add 10 ml of H_2SO_4.
6) Measurement of the biochemical oxygen demand (BOD) is measurement of the oxygen consumed in five days by a sample diluted with saturated water into oxygen, sown with the seeds, and then placed in a thermostatic chamber at 20°C.

D. Reactor& Experimental set up:

The semi-pilot scale study on effective fermentation of substrates was conducted at the Mechanical Engineering workshop of Mewar University. Experimental reactor for high performance temperature controlled made by the mild steel and coated outside by the corrosion resistant. On the reactor top surface a suitable provision was made for continuous stirring ofthe substrate inside the reactor. The stirrer was operated by usingelectric motor connected through the speed controller, which maintained the speed of the rotation as 30 rpm in CSTR. Thermophilic temperatures were obtained by keeping the digester in enclosed tank with bulbs turned on to maintain the required temperature. The experiments of anaerobic digestion of two organic substrates are carried out using awell-designed high performance temperature controlled continuous stirred tank reactor as an experimental device as shown in Fig. 1 consists of:

1) Digester with a capacity of 20 L equipped with a sampling loaded by approximate 60% volume.
2) Half-closed water container set to the temperature at 38° C and temperature inside the digester recorded 40^0.
3) Thermostat temperature controlled (Bajaj durable immersion rod 1500 watt) having temperature range 10^0C to 70^0C.
4) Electric motor operated mechanical stirrer.
5) System for measuring the volume of gas produced (volume measurement by the method of the liquid displacement)
6) Long length thermometer

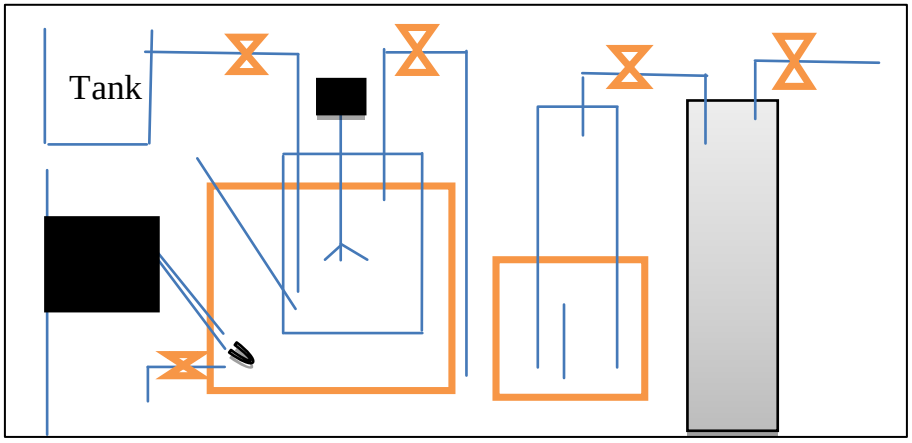


Fig. 1: Experimental Reactor Set up of Anaerobic Digestion process

The parameters monitored during the anaerobic digestion of substrates are pH, temperature, the volume of biogas produced and the chemical oxygen demand COD. The volume of biogas produced is measured by connecting the graduated cylinder meter having capacity of 1000ml connected to a digester and it immerse half into the water bath as the gas accumulated the water in cylinder meter moves to the water bath. The anaerobic conditions must be controlled very strictly in the digester before the start of the digestion reaction. The experiments are conducted for HRT of 20 to 25 days.

E. Analytical tool and method:

The measurement of daily gas production, substrate temperature and pH of the slurry were collected from the each reactor after every five day period and analysed for proximate parameters. Measurement of biogas production was done by volumetric displacement method, temperature was observed by long neck thermometer inserted into the digester and pH was measured by digital electrode pH meter.

III. RESULT AND DISCUSSION

The performance of all three types of substrates subjected to CSTR reactor was analysed for daily biogas production yield, substrate temperature, substrates pH. It has been reported that the biogas process is greatly affected by the reactor type and operating conditions.

Daily biogas production from various reactor having different substrates are shown in fig.1 further volumetric biogas production shown in fig.2

A. Physiochemical properties:

Sr.no	Parameter	Partheniume hystrophorus	Fresh cattle manure	Co-substrates (partheniume and CM)
1	Total solid (%)	10.5	21	4.3
2	Volatile solid (%)	23.5	14.8	94
3	Moisture content (%)	88.5	68	91.6
4	C:N	14.9	24	16.6
5	COD (mg/L)	500	1200	800
6	BOD(mg/L)	72	400	370
7	NTK(mg/g)	4.5	3.1	3.9

Table 2:

B. Temperature variation:

The experiment were carried out at thermophilic temperature range so inside temperature of the digester keep static&outside temperature varied greatly because experiment was performed in month of November and December. The outside temperature was varied between15-22^{0}C. although this temperature didn't influence the process.

C. pH variation:

Sr.no.	substrates	pH	Digestrate pH
1	Partheniume hystrophorus	6.7	3.9
2	Fresh cow dung	7.2	5.9
3	Co-substrates (partheniume and CM)	5.5	4.7

Table 3:

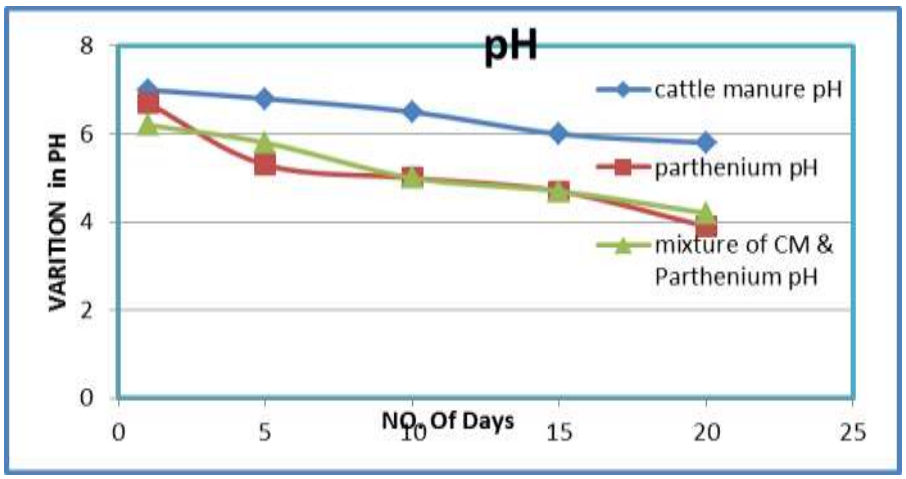


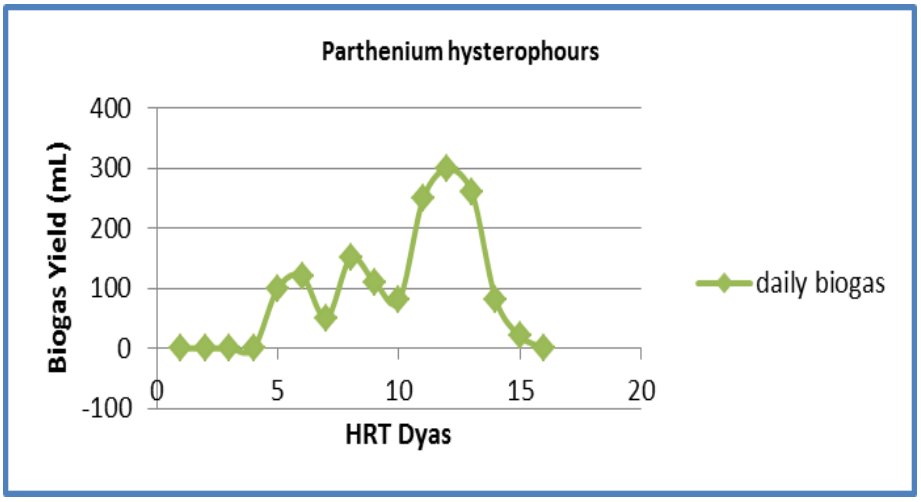
Fig. 2: Variation of pH. Over HRT

D. Biogas production yield:

The experiment showed the following results for biogas production, temperature and pH.

CSTR Reactor	Substrates	Total biogas yield(mL)	Mean outside temperature	Mean inside temperature	Mean pH
First	Parthenium hysterophorus	1520	20^0 C	40^0 C	5.2
Second	Cattle manure	5920	20^0 C	40^0 C	6.5
Third	Co-substrates	2480	20^0 C	40^0 C	5.6

Table 4:



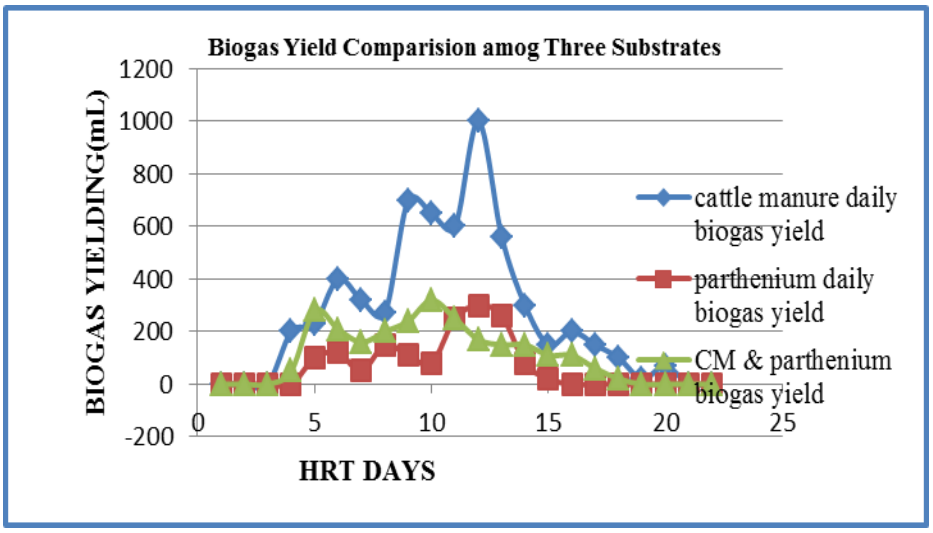


Fig. 5: Comparatively Biogas Yield

IV. CONCLUSIONS & RECOMMENDATIONS

Harnessing bio-wastes from all sources is undoubtedly necessary to address sustainable wastes management and also a strategic approach to decrease dependence on expensive fossils fuels. Bio wastes are projected to increase steadily worldwide. Therefore, deploying biogas production facilities is a win-win economic endeavour, in this study the conclusion is the laboratory scale evaluation on partheniume hysterophorus, cattle manure and Co-digested substrate with cattle manure in semi-continuous reactor revealed that cattle manure reactor is a highly feasible and economical way of biogas production through anaerobic digestion process and followed the co-digested rector yield the biogas and very low biogas yield by partheniume reactor. Parthenium hysterophorus a noxious weed has been a challenge for various prevention and eradication procedures, calling for an effective management method. Therefore this weed can also be used for biogas production in medium and large scale plant.

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