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RESEARCH ARTICLE

ANAEROBIC BIOGAS GENERATION FROM COW DUNG AND WATER HYACINTH: A COMPARATIVE STUDY WITH REFERENCE TO QUALITY OF GAS AND RETENTION TIME

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ABSTRACT

The aim of this work was to study the potential use of biological solid materials aquatic weeds as alternative sources for the production of biogas. In this study six different slurry samples were used for the production of biogas. Aquatic vegetation is an essential component of the aquatic ecosystem with both positive and negative implications on the water body. In This study the aquatic weed was analyzed for total solids, volatile solids, total dissolved solids and pH content. The pH value of the digesters was taken before and after the production of biogas in anaerobic condition. Biogas production was carried out from 6 digesters containing varying cow dung and others. This was studying was carried out for a period of 63 days at ambient temperature. It is essential to replace conventional energy source with the renewable energy source to save our natural resources and environment. The anaerobic digestion of cow dung with water weeds is feasible and could serve the dual roles of producing biogas, a clean renewable energy source and reducing the cost of weeds control. Two species of water weeds *Typha latifolia* and Water hyacinth were evaluated as substrates for biogas production. Water hyacinth (*Eichhornia crassipes*) is one of the fastest growing aquatic weed known to man. It is a free-floating perennial aquatic plant with broad, thick, glossy, ovate leaves with long, spongy and bulbous stalks. The results also show that digesters with dried water hyacinth (DWH) produced slightly more biogas in comparison to digesters with cow manure (CM). This indicated the fact that substrates for methanogenic bacteria were readily available in water hyacinth.

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INTRODUCTION

Recently biogas generation from microbial conversion of biogenic organic wastes under anaerobic condition has become globally fascinating because of its importance as a method of waste treatment and resource recovery. Worldwide energy crisis and the environmental problems that the world is facing today diverted the attention of researchers to the alternative sources of energy instead of underground fossil fuel. In this regard, renewable energy resources appear to be the most efficient and effective solutions (Kaygusuz *et al*., 2002). Among different types of alternative energy resources bio-gas from the bacterial biodegradation process of organic waste water or solid waste under anaerobic condition proves to be one of the most promising options. Biogas, a clean and renewable form of energy can well substitute (especially in rural sector) conventional sources of energy viz. fossil fuels which at one end causing ecological environmental problems while on the other end depleting at a faster rate (Yadvika *et al*., 2004). Renewable energy plays an important role in reducing the greenhouse gases particularly energy from biomass as it is a ''carbon neutral" fuel (Fantozzi *et al*., 2009). Biogas production from manures, from sewage sludges and agricultural wastes has been well studied (Sridhar *et al*., 2013; Sridhar *et al*., 2009). It has been used as a source of fuel in several countries such as some parts of India, China, Sweden, Bangladesh etc., for lighting and cooking purposes. Bio-energy is now accepted as having the potential to provide a major part of the projected renewable energy provisions of the future (Kaygusuz, 2009; Schuck, 2006). Thus keeping results of previous studies in view present study has been initiated with specific objectives of comparision of the rate of biogas generation from the anaerobic co-digestion of water hyacinth and/or *Typha Latifolia* with cow-dung, optimizing the biogas evolution with co-substrates under ambient temperature conditions determining parameters, such as Total or dry solids (TS), pH dynamics, Chemical oxygen demand (COD) dynamics and Microbial population dynamics (MPD) for the stability of anaerobic digestion systems. Numerous studies (Igoni *et al*., 2008; Ojolo *et al*., 2008; Patil *et al*., 2011;

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Ofoefule *et al*., 2010; Yusuf *et al*., 2011) has been carried out by several researchers. A survey of literature reveals that in order to optimize biogas yield in anaerobic digestion researchers worked on biogas production from different co-substrates (Nnabuchi *et al*., 2012; Nordberg *et al*., 2005; Yadvika *et al*., 2004). Few of the previous studies on anaerobic digestion of water hyacinth decline higher retention times with lower methane yields (Wadamwar *et al*., 1990). However others reported optimizing anaerobic digestion of water hyacinth a maximum methane yield can be achieved (Almoustapha *et al*. 2009). Developed a regression model (Singh *et al*., 1984) that estimates methane yield from the composition of water hyacinth and bio-dung. In the present study an attempt has been made to find out the rate of biogas production in Sintex Biogas Plants.

MATERIALS AND METHODS

For the purpose instruments/equipments used were weighing balance, gas chromatograph, pH meter, a mercury glass thermometer (range 0^0C to 100^0C), borosilicate desiccators, silica glass crucibles, oven, grinding mill, temperature controlled water bath, water troughs, graduated transparent glass gas collectors, tap water, rubber corks, connecting tubes and biogas burner fabricated locally for checking gas flammability. AR grade sodium hydroxide and acetic acid were used without any further purification. Water hyacinth, typha and cow dung for the study were collected from Kota District, Rajasthan, India. Fresh cow dung was collected from dairy farm while water hyacinth & typha were collected from different locations of Kota City. Fresh water hyacinth (leaves, stem and root) and typha after collection were chopped separetely to small sizes of about 2 cm, allowed to dry up under the sun for a period of 7 days, after it these were dried in an oven at 60^0C for 6 hours. These oven-dried water hyacinth and typha were further ground to finer pieces using a grinding mill. Different series (A-F) were prepared to study the anaerobic digestion of a material and mixture of materials. Series-A was prepared to study the anaerobic digestion of cow dung. Series-B was prepared to study the anaerobic co-digestion of water hyacinth with cow dung. Series-C was prepared. to study the anaerobic co-digestion of typha with cow dung. Series-D was prepared to study the anaerobic digestion of typha. Series-E was prepared to study the anaerobic co-digestion of water hyacinth, typha with cow dung. Series-F was prepared to study the anaerobic digestion of water hyacinth.

Biomethanation unit

It consists of a temperature controlled thermo bath which was maintained at 35^0C. It can accommodate 6 bio digesters. Each bio digester is connected to a graduated gas collector by means of a connecting tube. In a 2.5 L six glass bottle digesters with different concentrations of slurry were used for the production of biogas. The bottle was maintained at 35^0C and was fitted with a rubber cork having one hole [Figure 1]. A glass tube was inserted in the hole which remained above the layer of the slurry. The other end was connected with Teflon tubing, the outlet of which was dipped in a gas wash bottle filled with basic nature water with universal indicator. The gas produced during the incubation period could bubble through the water but no air. Then rubber balloon attached to the out let of gas wash bottle for gas collection. Analysis of the gas was done with the help of gas chromatograph (Table 3). Table 1 gives the results of bio gas production from all digesters. Biomethanation of these digesters were carried out in duplication with a retention time 63 days in the mesophilic range (30-40^{o}C). Cumulative biogas production, slurry temperatures were monitored throughout the period of the study.

Figure 1. Single Biomethantion unit (Digester)

Total Solids: Total solid (TS) and volatile solid (VS) were analyzed for water hyacinth, typha and cow dung according to standard methods (APHA, AWWA and WPCF, "Standard methods for the examination of water and waste water", 19, Washington, D.C., 1995”). Total solids (TS) are the sum of suspended solids and dissolved solids. TS analysis is important for assessing anaerobic digestion efficiencies. Total solids can be of two types, volatile solids (VS) and fixed solids. Volatile solids are organic portion of total solids that biodegrade anaerobically. Total solids and volatile solids are calculated using the equations 1 and 2:

$$TS\ \% = \frac{(A-B)}{(D-B)} \times 100 \quad ....1$$

$$\text{and } VS\% = \frac{(A-C)}{(A-B)} \times 100 \quad ………………2$$

A= Weight of dish + dried sample at 103^0C to 105^0C (in gram)
B =Weight of dish (in gram)
C =Weight of dish + sample after ignition at 550^0C (in gram)
D =Weight of dish + wet sample (in gram)

pH analysis

pH was measured by pH meter which consists of a potentiometer, a glass electrode, a reference electrode and a temperature compensating device. Electrodes were connected to the pH meter and were calibrated using buffer solutions before pH analysis.

Gas analyser

Gas chromatograph (Chemito 1000) equipped with a thermal conductivity detector was used to analyze the biogas sample. Hydrogen was used as carrier gas (25 ml/min) with Porapak Q column. Standard calibration gas mixture was used for calibration. Biogas samples were collected in rubber bladders; the sample and standard were injected using a gas tight syringe into the gas chromatograph. The parameters were set at oven temperature of 40^0C, detection temperature of 80^0C and the detector current of 180 mA. The concentrations of different components were calculated using.

RESULTS AND DISCUSSION

In the present study, the water weeds were used for the production of biogas. The weeds were converted into small pieces, dried and macerated with distilled water. The cow dung slurry was used as inoculums. In this study six digesters with different concentrations of slurry were used for the production of biogas Table 2. In digester A 100 percent cow dung slurry was used. In digester B cow dung and water hyacinth plant crushed slurry were used in equal proportion i.e. 50 percent each. In digester C cow dung and Typha crushed slurry were used in equal proportion i.e. 50 percent each. In digester D 100 per cent Typha crushed slurry was used. In digester E cow dung, water hyacinth crushed slurry and Typha crushed slurry were used in the ratio 50:25:25. In digester F 100 percent water hyacinth crushed slurry was used. The experiment was done in saline bottles, which were made airtight using rubber cork to ensure anaerobic condition. The whole experimental work was done for 63 days. The observation are summarized and analyzed in Table 2 & 3.

Digestion of cow dung

The trend of cumulative biogas production with time for the digesters of series-A are given in Table 2. As shown in Graph 1 biogas production commenced in the digesters on 12^{th} day. The digesters produced flammable biogas on 15^{th} day. The maximum biogas produced was 0.39 l/g vs on 42^{nd} day and least biogas produced 0.01 l/g vs on 12^{th} day.

Co-digestion of water hyacinth with cow dung

The trend of cumulative biogas production with time for all the digesters of series-B is given in Table 2. As shown in Graph 1, Digesters commenced biogas production from 15th day. Digesters produced flammable biogas on 21^{st} day. The maximum biogas produced 0.19 l/g vs on 24^{th} and same amount on 36^{th} day, While Digesters produced least amount of biogas 0.01 l/g vs on 63^{rd} day.

Table 1. Solid analysis and pH data

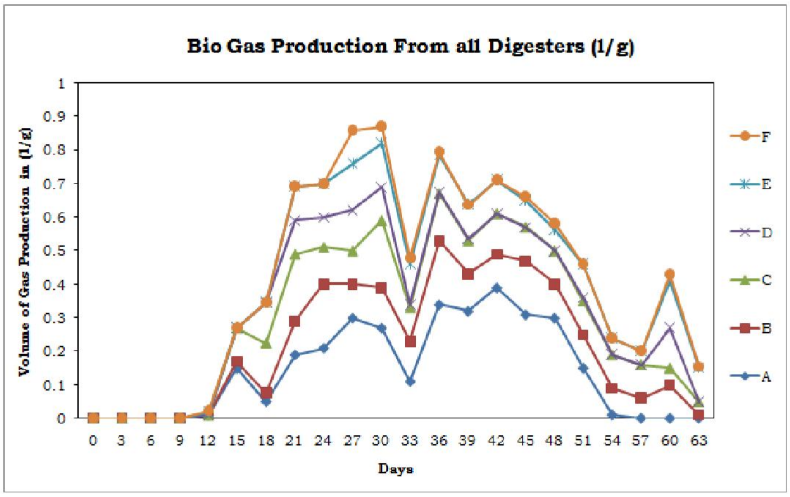
Solid Analysis And Ph Data				
Digester	Material	%Ts	%Vs	Ph
A	Cow Dung Pure	86	76.74	6.5
B	Cow Dung Pure + W. Hyacinth Crushed	88	80.68	6.4
C	Cow Dung Pure + Typha Crushed	94	75.53	6.8
D	Typha Crushed	84	61.90	6.2
E	Cow Dung Pure + W. Hyac. Crushed + Typha Crushed	95	56.34	7.1
F	Water Hyacinth Crushed	78	73.08	6.5

Table 2. Bio gas production from all digesters in l/g

Bio gas production from all Disgesters (l/g)						
Digesters Days	A	B	C	D	E	F
0	0	0	0	0	0	0
3	0	0	0	0	0	0
6	0	0	0	0	0	0
9	0	0	0	0	0	0
12	0.01	0	0	0	0.01	0.002
15	0.15	0.02	0.10	0	0	0
18	0.05	0.025	0.15	0.12	0	0
21	0.19	0.10	0.20	0.10	0.10	0
24	0.21	0.19	0.11	0.09	0.10	0
27	0.30	0.10	0.10	0.12	0.14	0.10
30	0.27	0.12	0.20	0.10	0.13	0.05
33	0.11	0.12	0.10	0.01	0.12	0.02
36	0.34	0.19	0.14	0.005	0.11	0.01
39	0.32	0.11	0.10	0.006	0.10	0
42	0.39	0.10	0.12	0	0.10	0
45	0.31	0.16	0.10	0	0.08	0.01
48	0.30	0.10	0.10	0	0.06	0.02
51	0.15	0.10	0.10	0.01	0.10	0
54	0.01	0.08	0.10	0	0.05	0
57	0	0.06	0.10	0	0.04	0
60	0	0.10	0.05	0.12	0.14	0.02
63	0	0.01	0.04	0	0.10	0.004

Table 3. Analysis of components of flammable biogas for the digesters

Bio Gas Production From All Digesters								
DAYS	Substrates	C	N	O	CH_4	CO	CO_2	IT
15	Cow Dung Pure	17	61	21	11.7	26.4	10.2	1
	Cow Dung Pure + W. Hyanc. Crushed	-	-	-	-	-	-	-
	Cow Dung Pure + Typha Crushed	-	-	-	-	-	-	-
	Typha Crushed	-	-	-	-	-	-	-
	Cow Dung Pure + W. Hyanc. Crushed + Typha Crushed	-	-	-	-	-	-	-
	Water Hycinth Crushed	-	-	-	-	-	-	-
30	Cow Dung Pure	18	48	22	26.4	2.6	20.4	7
	Cow Dung Pure + W. Hyanc. Crushed	-	-	-	21.2	2.9	19.4	4
	Cow Dung Pure + Typha Crushed	13	56	17	16	2.7	16.4	3
	Typha Crushed	-	59	-	10	1.8	9.4	2
	Cow Dung Pure + W. Hyanc. Crushed + Typha Crushed	17	47	21	24.4	2.1	21.4	4
	Water Hycinth Crushed	-	-	-	4	2.1	24.2	1
45	Cow Dung Pure	24	34	29	40.1	2.4	24.1	10
	Cow Dung Pure + W. Hyanc. Crushed	18	46	22	24.5	2.4	21.4	6
	Cow Dung Pure + Typha Crushed	-	-	-	21.4	2	15.8	5
	Typha Crushed	-	-	-	-	-	-	-
	Cow Dung Pure + W. Hyanc. Crushed + Typha Crushed	-	-	-	26.4	2.4	22.1	6
	Water Hycinth Crushed	-	-	-	-	-	-	-
60	Cow Dung Pure	17	56	21	10.2	29.1	9.1	2
	Cow Dung Pure + W. Hyanc. Crushed	-	-	-	-	-	-	-
	Cow Dung Pure + Typha Crushed	-	-	-	-	-	-	-
	Typha Crushed	-	-	-	-	-	-	
	Cow Dung Pure + W. Hyanc. Crushed + Typha Crushed	-	-	-	10.4	2.1	1.2	2
	Water Hycinth Crushed	-	-	-	-	-	-	-



Graph.1 Biogas Production of all Series Digesters in (l/g) Digesters - A, B, C, D, E, F

The time period for attaining the maximum production rate was longer for water hyacinth as compared to cow dung. Comparison show that anaerobic co-digestion of water hyacinth with cow dung produced better results Table 3.

Co-digestion of typha with cowdurg

The trend of cumulative biogas production with time for all the digesters of series-C is given in Table 2. As shown in Graph 1, Digesters commenced biogas production from 15th day. Digesters produced flammable biogas on 15th day. The maximum biogas produced 0.2 l/g vs on 21st day and same amount on 30th day, While Digesters produced least amount of biogas 0.04 l/g vs on 63rd day.

Digestion of typha

The trend of cumulative biogas production with time for all the digesters of series-D is given in Table 2.

As shown in Graph 1, Digesters commenced biogas production from 18th day. Digesters produced flammable biogas on 18th day. The maximum biogas produced 0.12 l/g vs on 18th and same amount on 27th & 60th day, While Digesters produced least amount of biogas 0.005 l/g vs on 36th day.

Co-digestion of water hyacinth, cow dung and typha

The trend of cumulative biogas production with time for all the digesters of series-E is given in Table 2. As shown in Graph 1, Digesters commenced biogas production from 12th day. Digesters produced flammable biogas on 21st day. The maximum biogas produced 0.14 l/g vs on 27th and same amount on 60th day, While Digesters produced least amount of biogas 0.01 l/g vs on 12th day.

Digestion of water hyacinth

The trend of cumulative biogas production with time for all the digesters of series-F is given in Table 2. As shown in Graph 1, Digesters commenced biogas production from 12th day. Digesters produced flammable biogas on 27th day. The maximum biogas produced 0.1 l/g vs on 27th day, While Digesters produced least amount of biogas 0.002 l/g vs on 12th day. Digesters of series - A produced better results for biogas production.

Conclusion

Conclusively digesters of series A produced better results for biogas production. This could be because of cow dung has high nitrogen concentration and favourable pH of 7.01 as compared to fermentation of other series digesters. It also contains adequate amount of carbon, oxygen, hydrogen, sulphur, phosphorous, potassium, calcium, magnesium and a number of trace elements helpful for bio-digestion. The results also show that digesters with dried water hyacinth (DWH) produced slightly less biogas in comparison to digesters with cow manure (CM). This indicated the fact that substrates for methanogenic bacteria were readily available in the media. However, the time period for attaining the maximum production rate was longer (about 27 - 48 days) in comparison to cow manure (21 - 42 days). It can be explained as in case of water hyacinth bacteria needed a longer time period to grow for biogas production whereas in case of ruminants waste such as cow manure pathogens were already present and bacterial growth takes comparatively in lesser time for biogas production.

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