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Research Article

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Study on biomethanation of water hyacinth using primary sludge as inoculum

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ABSTRACT

Water hyacinth (Eichhornia crassipes) is a noxious weed that has attracted worldwide attention due to its fast spread and congested growth, leading to serious problems in fishing, evapotranspiration, navigation, irrigation, power generation, and reduction in biodiversity. However it is a potential source of biomass to produce ecofriendly biogas. In this study, primary sludge from sewage treatment plant was used as inoculum to increase biogas production from biomethanation of water hyacinth at mesophilic condition. Series of laboratory experiments using 250 ml biodigesters were performed in batch operation mode. 4 grams of completely dried and ground water hyacinth were fed to each biodigester and mixed with primary sludge inoculums (PSI) and water in different combinations resulting in five different fermentation slurries (PSI-0, PSI-25, PSI-50, PSI-75 and PSI-100) with different total solids of 3.8, 5.5, 7.2, 8.9 and 10.6% respectively. The results showed that the PSI inoculated to biodigester improved biogas yield significantly and was almost two times, compared to Water Hyacinth substrate without PSI. The best performance for biogas production was from the digester PSI-75 followed by PSI-50 and PSI-100 whose TS contents are 8.9, 7.2 and 10.6% respectively. These results suggest that, TS content affects the biogas yield and optimum total solids content for biogas production is between 7 and 9 %.

Key words: Water hyacinth, Biomethanation, Primary Sludge Inoculums, Biogas, Mesophilic.

INTRODUCTION

Global depletion of energy supply due to the continuing over-utilization is being a major problem of the present and future world community. It is estimated that the fossil fuels will be running out by the next few decades [1] [2], therefore, Governments and industries are constantly on the lookout for technologies that will allow for more efficient and cost-effective waste treatment [3]. One technology that can successfully treat the organic fraction of wastes is anaerobic digestion [4]. Biomethanation is a complex process consisting of a series of microbial reactions catalyzed by consortia of different bacteria [5]. The process is one of the most promising for biomass wastes as it provides a source of energy while simultaneously resolving ecological and agrochemical issues [6].

Water hyacinth (Eichhornia crassipes) is a perennial aquatic plant weed which belongs to pickerel weed family (Pontederiaceae). It is a noxious weed that has attracted worldwide attention due to its fast spread and congested growth, which lead to serious problems in fishing, evapotranspiration, navigation, irrigation, and power generation, reduction in dissolved oxygen and reduction in biodiversity [7]. Attempts to control the weed have caused high costs and labor requirements, leading to nothing but temporary removal of the water hyacinths [8]. In developing country like India the most favorable conditions for the growth of the water hyacinth often are found, very limited resources have been put into curbing them. Fighting the water hyacinth generates neither food nor income. Fast growth is a feature of water hyacinth, this would therefore have a great potential, if seen as raw material for biogas production as it is rich in nitrogen, essential nutrients and has a high content of fermentable matter [9]. Apart from biogas, the sludge from the biogas process contains almost all of the nutrients and can be used as a good fertilizer with no detrimental effects on the environment [10].

Numerous studies have been conducted by several researchers in order to increase biogas yield from biomethanation of water hyacinth. An effort to improve biomass conversion efficiency and biogas yield conducted by several researchers i.e. by using different pretreatment methods [11]; improving substrate composition by co-digesting with other substrates [12] [13]; optimization of dilution on biomethanation fresh water hyacinth [14]; and effects of particle size, plant nitrogen content and inoculum volume [15]. Different with other researchers mentioned earlier, an effort to improve biogas yield was carried out by using primary sludge inoculums. Primary sludge is rich in anaerobic bacteria and is abundantly available near by; hence this study focuses on the use of primary sludge inoculums in biomethanation of water hyacinth as there is very limited academic literature available on using primary sludge inoculums in biomethanation of water hyacinth.

Fig. 2: Biomethanation unit

EXPERIMENTAL SECTION

2.1 Sample collection

Water hyacinth used for the study was obtained from silver lake at HBR layout (Bangalore, Karnataka,India).Thickened primary sludge was collected from primary clarifier from Vrishabhavathi sewage treatment plant at Vrishabhavathi valley, Nayandanahalli (Bangalore, Karnataka, India).

2.2 Biomethanation unit
Biomethanation unit consists of a temperature controlled thermo bath which is maintained at 35^0C and has a battery of biodigesters. Each biodigester is connected to a graduated gas collector by means of a connecting tube. A stand holds all the gas collectors. Biogas evolved is collected by downward water displacement.

2.3 Sample analysis
Water hyacinth and primary sludge were analyzed for the following parameters
1. pH measurement: pH measurement was monitored using a glass electrode pH meter (Systronics)
2. Total solids (TS) and total volatile solids (VS) [16]: TS were determined at 104 ^{0}C to constant weight (Standard method part 2540 B) and VS were measured by the loss on ignition of the dried sample at 550 ^{0}C. (Standard method part 2540 E)
3. Biogas collection and composition: Biogas produced by anaerobic digestion was collected by water displacement method. The composition of the gas was measured using a gas chromatograph (CHEMITO)

2.4 Inoculum preparation
In a 2.5L glass bottle, 933 gm of primary sludge was mixed with 1067 gm of water to obtain a slurry of 7% TS. The bottle was maintained at 35^0C and was fitted with a rubber cork having one hole. 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 container filled with water. The gas produced during the incubation period could bubble through the water but no air would enter the slurry thus, maintaining the anaerobic condition. After an incubation period of 50 days, the biodegradable volatile organic matter contained in the slurry almost gets completely degraded [13] and can be used as inoculums.

2.5 Fermentation slurry
Fresh water hyacinth (leaves, stem and root) on collection was chopped to small sizes of about 2 cm allowed to dry up under the sun for a period of 7 days, after which they were dried in an oven at 60^0C for 6hours. This oven-dried water hyacinth was then ground to fine particles using a grinding mill. The influence of primary sludge inoculums to biogas production was studied by varying primary sludge inoculums and total solid contents in biodigester. A series of laboratory experiments using 250 ml biodigesters were performed in batch operation mode. Each biodigester was fed with 3.186 g of volatile solid[†] (VS) by adding 4 g of finely dried and ground water hyacinth. This was mixed with various combinations of primary sludge inoculums and water, resulting in five different fermentation slurries PSI-0, PSI-25, PSI-50, PSI-75 and PSI-100 with different total solid contents of 3.8, 5.5, 7.2, 8.9 and 10.6% respectively. Digester PS-100 fed with pure PSI without water hyacinth is considered as blank. Table 1 presents detailed contents of digesters. All digesters were given 0.3 ml of 10% by volume of acetic acid. Biomethanation of these digesters were carried out in duplication with a retention time 60 days in the mesophilic range (30-40^{o}C). Cumulative biogas production, slurry temperatures were monitored throughout the period of the study.
[†]Biodegradable VS from PSI were negligible and were not accounted for VS added to each of the digester.

Table 1: Contents of digesters

Digester	Water hyacinth (g)	Water (g)	PSI (g)	Acetic acid 10% by Vol.(ml)
PSI - 0	4	100	-	0.3
PSI – 25	4	75	25	0.3
PSI – 50	4	50	50	0.3
PSI – 75	4	25	75	0.3
PSI -100	4	-	100	0.3
PS – 100	-	-	100	0.3

RESULTS AND DISCUSSION

3.1 Solids and pH analysis
Total solids are the sum of suspended solids and dissolved solids. Total solids analyses and pH are important for assessing anaerobic digester efficiencies. TS analysis is done using standard methods while pH is measured using pH meter (Systronics). The TS are composed of two components, volatile solids (VS) and fixed solids. The VS are organic portion of TS that biodegrade anaerobically.

TS and VS are calculated as given bellow.

TS, % = $\frac{(A-B)}{(D-B)}\times 100$ and VS, % = $\frac{(A-C)}{(A-B)}\times 100$

Table 2 gives the solid analysis and pH data of primary sludge and water hyacinth.

Table 2: Solid analysis and pH data

Material	% TS	% VS	pH
Primary sludge	15.00	51.84	6.8
Water hyacinth	16.89	82.85	6.4

3.2 The influence of PSI to cumulative biogas production

The trends of cumulative biogas production with time for all the digesters are given in Table 3. The specific biogas production is shown in Figure 2 which, shows biogas production rate tend to obey sigmoid function (S curve) as generally occurred in batch growth curve. Biogas production is slow at the beginning and the end period of observation. This is predicted due to the biogas production in batch condition directly corresponds to specific growth rate of methanogenic bacteria in the biodigester [17]. During the first 8 days observation, biogas production is low due to the lag phase of microbial growth. In the range of 10 to 35 days observation, biogas production is significantly increased due to exponential growth of microorganisms. After 35 days observation, biogas production tends to decrease again and this predicted trend is due to stationary phase of microbial growth

Table 3: Trend of biogas production

Digester → Time ↓(days)	PSI -0 (liters/g VS)	PSI -25 (liters/g VS)	PSI -50 (liters/g VS)	PSI -75 (liters/g VS)	PSI -100 (liters/g VS)	PS-100 (liters/g VS)
0	0	0	0	0	0	0
5	0.002	0.01	0.01	0.015	0.02	0.002
10	0.01	0.05	0.05	0.06	0.06	0.01
15	0.03	0.15	0.2	0.25	0.3	0.02
20	0.04	0.20	0.25	0.30	0.33	0.03
25	0.07	0.26	0.3	0.35	0.36	0.05
30	0.11	0.29	0.35	0.38	0.37	0.055
35	0.16	0.32	0.37	0.39	0.39	0.06
40	0.19	0.33	0.39	0.41	0.40	0.065
45	0.21	0.34	0.40	0.42	0.40	0.07
50	0.22	0.35	0.41	0.42	0.41	0.07
55	0.23	0.35	0.42	0.43	0.41	0.07
60	0.23	0.35	0.42	0.44	0.41	0.07

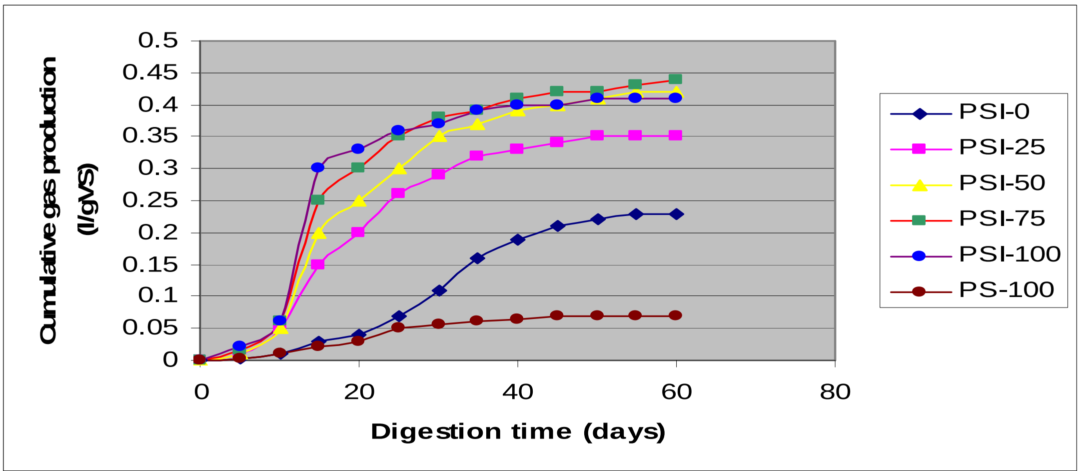

Figure 1. Daily biogas production

Figure 1 also shows fermentation slurries of water hyacinth and PSI (PSI-25, PSI-50, PSI-75 and PSI-100) exhibit higher biogas production than substrate that contain water hyacinth and water (PSI-0). In other words, specific biogas production per gram volatile solid added to digesters PSI-25, PSI-50, PSI-75 and PSI-100 are higher than PSI-0. The presence of primary sludge inoculums in feed increased cumulative biogas production almost two folds when compared to feed without primary sludge inoculums. This suggests that high concentration of anaerobic bacteria content in primary sludge inoculums works effectively to degrade organic substrate from water hyacinth. From Figure 2 also can be seen biogas production for PSI-25, PSI-50, PSI-75 and PSI-100 are higher than PSI-0. This indicated that the addition of primary sludge inoculums to feed will increase biogas production in comparison with feed without primary sludge inoculums. Finally, the most important finding from this research is that the primary sludge inoculums seeded to biodigester has significant effect on cumulative biogas production.

3.3 The effect of total solids content on biogas production

The effect of total solids content on biogas production was studied by varying total solids from 3.8% to 10.6 %. Figure 2 shows cumulative biogas production of PSI-25, PSI-50, PSI-75 and PSI-100 as 0.35, 0.42, 0.44 and 0.41 l/gVS respectively, while sample PSI-0 with 0 % PSI gave cumulative biogas production of 0.23 l/gVS. The best performance of biogas production is given by PSI-75 (TS of 8.9%) followed by PSI-50 (TS of 7.2%) and PSI-100 (TS of 10.6%). These results suggest that, TS content affects the biogas yield. This is similar to the findings of Balsam [18] [19] that the optimum solid content is in the range 7-9 % for highest biogas production. Furthermore, Baserja [20], reported that the process was unstable below a total solids level of 7% (of manure) while a level of 10% caused an overloading of the fermenter.

These results are expected due to the function of water in biodigester since the TS content will directly correspond to water content. According to Sadaka and Engler [21] water content is one of very important parameter affecting anaerobic digestion of solid wastes. There are two main reasons (a). Water makes possible the movement and growth of bacteria facilitating the dissolution and transport of nutrient; and (b) water reduces the limitation of mass transfer of non homogenous or particulate substrate. From Figure 2 it can be seen that PS-100 does not yield appreciable quantity of biogas in comparison with PSI-25, PSI-50, PSI-75 and PSI-100. Hence, in all digesters biogases produced originated only from substrate contained by water hyacinth.

CUMULATIVE BIOGAS PRODUCTION

Biogas production rate was studied by performing a series of laboratory experiments using primary sludge inoculums (PSI). The most important finding from this research is that the PSI seeded to biodigester has significant effect to cumulative biogas production and biogas production rate. PSI influenced biogas production rate and efficiency increased more than two times in comparision to water hyacinth substrate without PSI. The best performance for biogas generation will be obtained if PSI added is in the range of 50-75 %. Further increase of PSI does not improve the performance of reactor as it results in higher TS of the fermentation slurry. However, further research need to be carried out to study interaction effect of TS and PSI content to biogas production.

NOMENCLATURE

A	*Weight of dish + dried sample at 103^{0}C to 105^{0}C (grams)*
B	*Weight of dish (grams)*
C	*Weight of dish + sample after ignition at 550^{0}C (grams)*
D	*Weight of dish + wet sample (grams)*
PSI	*Primary sludge inoculums*
TS	*Total solids (%)*
VS	*Volatile solids (%)*
WH	*Water hyacinth*
W	*Water*

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