Anaerobic co-digestion of water hyacinth with primary sludge

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Abstract

Water hyacinth (WH) and primary sludge (PS) from wastewater treatment plants can be used to generate energy which could save on the fossil fuels conventionally used as source of energy. In this study, the possibility was explored to mix water hyacinth with primary sludge in different combinations for anaerobic co-digestion, so that energy can be generated as biogas and at the same time digested sludge can be used as fertilizer for agricultural applications. Co-digestion of water hyacinth and primary sludge with required amount of water (W) was carried out in 250 ml batch digesters. Pretreatment of water hyacinth was done by alkali method. Anaerobic co-digestion was carried out in mesophilic temperature range (30°C to 37°C) with different fermentation slurries of 8% total solids (TS). Co-digestion was carried for a retention period of 60 days. The gas produced was collected by the downward displacement of water, and was subsequently measured and analyzed. Fermentation slurry PS3 (mixing ratio of 4: 26.14: 69.86 for WH: PS: W) was found to be optimum, which gave the highest biogas yield of 0.35 l/gVS with composition 69.6 % CH_4, 25.8 % CO_2, 0.8 % N_2 and 3.8 % O_2. The overall results showed that blending water hyacinth with primary sludge had significant improvement on the biogas yield.

Key words: Primary sludge, water hyacinth, biogas, anaerobic co- digestion, methanogenisis.

Introduction

The country's economy mainly depends on the energy resources available and utilized. Energy has been exploited since the prehistoric times. With the advent of industrial revolution use of fossil fuels began growing and increasing till date. The dependence on fossil fuel as primary energy source has led to global climate change, environment degradation and human health problems[1]. With increasing prices of oil and gas the world looks towards alternative and green energy resources. Anaerobic digestion (AD) offers a very attractive route to utilize certain categories of biomass for meeting partial energy needs. AD can successfully treat the organic fraction of biomass[2]. AD is the controlled degradation of biodegradable waste in absence of oxygen and presence of different consortia of bacteria that catalyze series of complex microbial reactions[3]. 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[4].

Water hyacinth (WH) is a perennial macrophyte belongs to the pickerelweed family. It is a free floating weed known for its production abilities and pollutant removal[5]. It is listed as one of the most productive plants on earth and is considered one of the world's worst aquatic plants. It can double its size in 5 days and a mat of medium sized plants may contain 2 million plants per hectare that weigh 270 to 400 Tonnes. These dense mats interfere with navigation, recreation, irrigation, and power generation[6]. Water hyacinth is blamed for reduction of biodiversity and increased evapotranspiration. It also acts as a good breeding place for mosquitoes, snails and snakes[7]. Therefore, there is a need to manage its spread through suitable control measures. However, the fact remains that the water hyacinth has successfully resisted all attempts of its eradication by chemical, biological, mechanical, or hybrid means[8]. Water hyacinth has attracted the attention of scientists to use it as a potential biomass as it is rich in nitrogen, essential nutrients and has a high content of fermentable matter. 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.

Co-digestion is the simultaneous digestion of more than one type of waste in the same unit. Advantages include better digestibility, enhanced biogas production/methane yield arising from availability of additional nutrients, as well as a more efficient utilization of equipment and cost sharing[9]. Studies have shown that co-digestion of several substrates, for example, banana and plantain peels, spent grains and rice husk, pig waste and cassava peels, sewage and brewery sludge, among many others, have resulted in improved methane yield by as much as 60% compared to that obtained from single substrates[10-13]. Co-digestion of sewage sludge with agricultural wastes or MSW can improve the methane production of anaerobic digestion processes[14-16]. Primary sludge is rich in anaerobic bacteria and is abundantly available nearby, also there is very limited academic literature available on using primary sludge in co-digestion of water hyacinth. Hence this study was undertaken to evaluate co-digestion of water hyacinth and primary sludge (PS) to improve biogas yield.

Material and Methods

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). Fermentation digestate from previous experiment was used as an inoculum in the present work.

Sample analysis: Water hyacinth and primary sludge were analyzed for the following parameters
pH measurement: pH measurement was monitored using a glass electrode pH meter (Systronics)
Total solids (TS) and total volatile solids (VS)[17]: 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).
Biogas collection and composition: Biogas produced by anaerobic co-digestion was collected by water displacement method. The composition of the gas was measured using a gas chromatography (CHEMITO).

Inoculum: Pre-digested material from earlier experiments containing all the essential microbes (hydrolyzing, fermentative, acetogenic and methanogenic bacterial consortium) was used as inoculum for early start up of biomethanation process[18].

Biomethanation unit: A schematic diagram of biomethanation unit is shown in Fig. 1. It consists of a temperature controlled thermo bath which is maintained at 35^{0}C 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.

Fermentation slurry: Fresh water hyacinth (leaves) on collection was chopped to small sizes of about 2 cm. The alkali (NaOH) treatment was effected by soaking chopped water hyacinth in 1% NaOH (by volume) solution[19]. After two days the alkaline solution was removed and leaves were allowed to dry up under the sun followed by drying in oven at 60^{0}C for 6hours. This oven-dried water hyacinth was then ground to fine powder. Material balance was made and different slurries with 8% total solids were prepared by varying the amount of water hyacinth and primary sludge. The contents of each digester are shown in shown in the table 1.

Results and Discussion

Solids and pH analysis: Total solids are the sum of suspended solids and dissolved solids. Total solids analysis and pH are important for assessing anaerobic digester efficiencies. TS analysis was done using standard methods while pH was 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.

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

Where A is weight of dish + dried sample at 103^0C to 105^0C (grams).
B is weight of dish (grams), C is weight of dish + sample after ignition at 550^0C (grams) and D is weight of dish + wet sample (grams).

Table 2 gives the solid analysis and pH data of primary sludge and water hyacinth and Table 3 gives quantity of volatile solids added to different digesters.

Impact of co-digestion: The cumulative biogas production with time for all the digesters is presented in table 4. The specific biogas production is shown in fig. 2 which, shows biogas production rate tend to obey sigmoid function (S curve) as generally occurs in batch growth curve. Biogas production commenced after four days from digesters PS1, PS2, PS3, PS4 and PSB while digester WHB commenced after eight days. This indicates that digester WHB does not have essential microbes for early start up of biomethanation process which is the reason for longer lag phase. Digesters PS1, PS2, PS3, PS4 and PSB produced flammable biogas on 9^{th} day, while digester WHB produced on 13^{th} day. The cumulative biogas production was maximum for PS3 (0.35 l/gVS) with biogas composition 69.6 %, 25.8 %, 0.8 % and 3.8 % for CH_4, CO_2, N_2 and O_2 respectively. This performance could be because of optimum balance between the anaerobic bacterial consortium and amount of volatile solids (5.4 g). The biogas compositions from the other reactors were also found to be in the same range. Other digesters PS2, PS4 and PS1 produced biogas 73%, 67.6% and 51.4% more than the control digester WHB which contains only water hyacinth with no primary sludge. This indicates co-digestion of water hyacinth and primary sludge improves biogas yield significantly.

Conclusion

Water hyacinth is a very good biogas producer needs minimal pre-treatment (drying and grinding) to enhance the biogas yield. The use of pretreated water hyacinth for biogas generation therefore, will be a good energy source for those residing in the coastal areas, which face the menace of clogging of waterways by the weed.
The result of the study has shown that anaerobic co-digestion of dried and ground water hyacinth with primary sludge shows better gas production rate and also increase in quantity of gas produced. Fermentation slurry PS3 was found to be optimum and produced 89.2% more biogas than the control digester WHB with composition 69.6 % CH_4, 25.8 % CO_2, 0.8 % N_2 and 3.8 % O_2.

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Fig.-1: Biomethanation unit

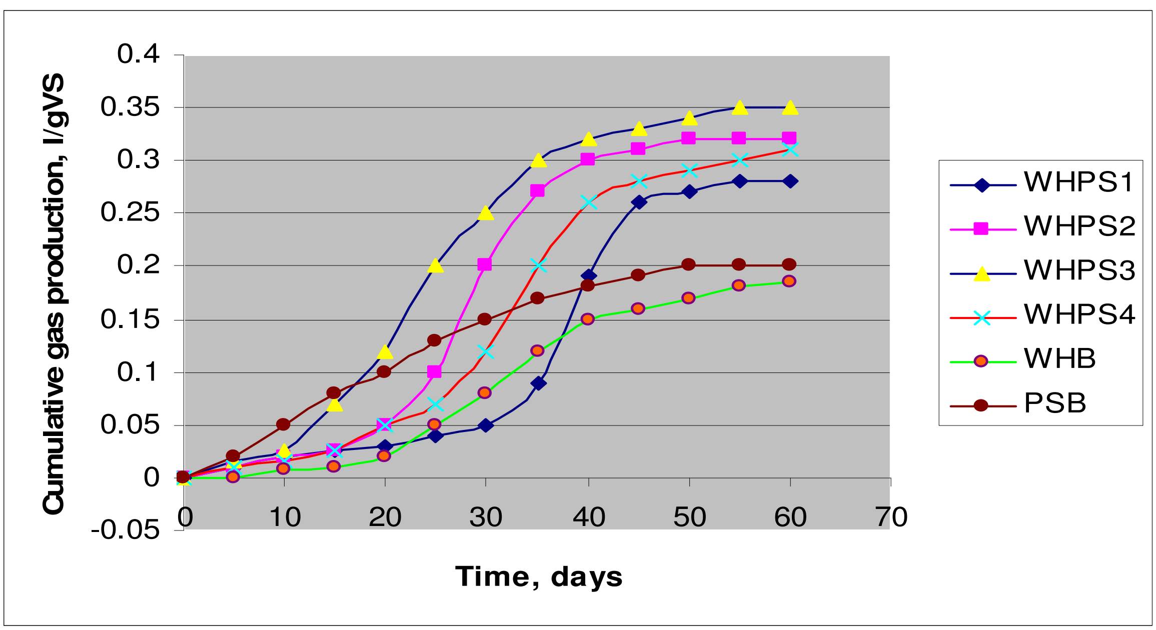

Fig-2: Daily biogas production

Table-1: Contents of digesters

Digester	Water hyacinth (g)	Primary sludge (g)	Water (g)	Inoculums (g)	Acetic acid(ml)
WHB	8	-	92.00	10	0.3
PS1	2	39.22	58.78	10	0.3
PS2	3	32.68	64.32	10	0.3
PS3	4	26.14	69.86	10	0.3
PS4	5	19.60	75.40	10	0.3
PSB	-	52.23	47.77	10	0.3

Table-2: Solid analysis and pH data

Material	% TS	% VS	pH
Primary sludge	15.33	51.84	6.8
Water hyacinth	16.89	82.85	6.4

Table-3: Volatile solids added to different digester

Digester	VS added from WH (g)	VS added from PS (g)	Total VS added (g)
WHB	6.64	-	6.64
PS1	1.66	3.12	4.78
PS2	2.49	2.60	5.09
PS3	3.32	2.08	5.40
PS4	4.15	1.55	5.70
PSB	-	4.16	4.16

Table-4: Trend of biogas production

Digester → / Time ↓(days)	PS1 (liters/g VS)	PS2 (liters/g VS)	PS3 (liters/g VS)	PS4 (liters/g VS)	WHB (liters/g VS)	PSB (liters/g VS)
0	0	0	0	0	0	0
5	0.01	0.01	0.015	0.01	0	0.02
10	0.02	0.02	0.025	0.015	0.008	0.05
15	0.025	0.025	0.07	0.025	0.01	0.08
20	0.03	0.05	0.12	0.05	0.02	0.10
25	0.04	0.10	0.20	0.07	0.05	0.13
30	0.05	0.20	0.25	0.12	0.08	0.15
35	0.09	0.27	0.30	0.20	0.12	0.17
40	0.19	0.30	0.32	0.26	0.15	0.18
45	0.26	0.31	0.33	0.28	0.16	0.19
50	0.27	0.32	0.34	0.29	0.17	0.20
55	0.28	0.32	0.35	0.30	0.18	0.20
60	0.28	0.32	0.35	0.31	0.185	0.20