International Journal of Physical Sciences Vol. 4 (8), pp. 535-539, September, 2009
Available online at http://www.academicjournals.org/ijps
ISSN 1992 - 1950 © 2009 Academic Journals

Full Length Research Paper

Comparative study of the effect of different pretreatment methods on biogas yield from water Hyacinth (*Eichhornia crassipes*)

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Accepted 8 July, 2009

A comparative study of the effect of different pre-treatment methods on the biogas yield from Water Hyacinth (WH) was carried out. The WH charged into metallic prototype digesters of 121 L capacity were pre-treated as: dried and chopped alone (WH-A), dried and treated with KOH (WH-T), dried and combined with cow dung (WH-C), while the fresh water Hyacinth (WH-F) served as control. They were all subjected to anaerobic digestion to produce biogas for a 32 day retention period within a mesophilic temperature range of 25 to 36°C. The results of the study showed highest cumulative biogas yield from the WH-C with yield of 356.3 L/Total mass of slurry (TMS) while the WH-T had the shortest onset of gas flammability of 6 days. The mean biogas yield of the fresh Water Hyacinth (WH-F) was 8.48 ± 3.77 L/TMS. When the water Hyacinth was dried and chopped alone (WH-A), dried and treated with KOH (50% w/v) (WH-T) and dried and combined with cow dung (WH-C), the mean biogas yield increased to 9.75 ± 3.40 L/TMS, 9.51 ± 5.01 L/TMS and 11.88 ± L/TMS respectively. Flammable biogas was produced by the WH-F from the 10th day of the digestion period whereas the WH-A, WH-T and WH-C commenced flammable gas production from the 9th, 6th and 11th day respectively. Gas analysis from WH-F shows Methane (65.0%), CO_2 (34.94%). WH- A contained Methane (60.0%), CO_2 (39.94%). WH-T contained Methane (71.0%), CO_2 (28.94%), while WH-C had Methane (64.0%) CO_2 (35.94%). The other gases were found in the same levels and in trace amounts in all the systems. The overall results showed that treating water Hyacinth with chemical did not have a significant improvement on the biogas yield. It also indicated that water Hyacinth is a very good biogas producer and the yield can be improved by drying and combining it with Cow dung.

Key words: Water hyacinth, biogas production, pre-treatment, biogas yield, flammable biogas production, biodigester.

INTRODUCTION

In recent times where fossil fuels are gradually depleting, in addition to rising costs and instability in the major producer countries, renewable energy has become one of the best alternatives for sustainable energy development. Biogas, a renewable source of energy which is also environmentally friendly, is generated via anaerobic digestion of biomass wastes (animal dung, plant residues, waste waters, municipal solid wastes, human and agro-industrial wastes etc). The gas comprises majorly of methane (50 - 70%), CO_2 (20 - 40%) and traces of other gases which includes CO, H_2S, NH_3 , H_2 , N_2 , O_2 and water vapour etc. (Energy Commission, 1998). Biogas production is a three stage biochemical process comprising hydrolysis, acidogenesis/acetogenesis and methanogenesis.

$(C_6H_{10}O_5)n + nH_2O \rightarrow n(C_6H_{12}O_6)$ - Hydrolysis
$n(C_6H_{12}O_6) \rightarrow n\,CH_3COOH$ - Acetogenesis/

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Acidogenesis
$3nCH_3COOH \rightarrow n\ CH_4 + CO_2$ - Methanogenesis

Biogas technology amongst other processes (including thermal, pyrolysis, combustion and gasification) has in recent times also been viewed as a very good source of sustainable waste treatment / management, as disposal of wastes has become a major problem especially to the third world countries (Arvanitoyannis et al., 2007a). The effluent of this process is a residue rich in essential inorganic elements needed for healthy plant growth known as biofertilizer which when applied to the soil enriches it with no detrimental effects on the environment (Energy commission, 1998). Various wastes have been utilized for biogas production and they include amongst others; animal wastes (Nwagbo et al., 1991; Garba et al., 1996; Zuru et al., 1998; Itodo and Kucha, 1998), industrial wastes (Uzodinma et al., 2007), food processing wastes (Arvanitoyannis et al., 2007b; Arvanitoyannis and Ladas, 2008; Arvanitoyannis and Varzakas, 2008), plant residues (Ofoefule and Uzodinma, 2008). Many are still being researched on as potential feedstock for biogas production.

Water hyacinth (*Eichhornia Crassipes*) is aquatic biomass specie that exhibits prolific growth in many parts of the world. It is a floating perennial herb of pickerel weed family (*Pontederiaceae*) which propagates itself profusely and has constituted a menace to navigation by obstructing channels with impenetrable masses of tightly bound plants (Garba and Ojukwu, 1998). With an increase in the amount of water hyacinth clogging our waterways, better use of the plant for energy generation is being given attention. It has been suggested as a strong candidate for production of methane because of its high biomass yield potential (Klass, 1974). Studies have been carried out which establish that methane can be produced from water hyacinth (Wolverton et al., 1975; Chin and Goh, 1978; Ryther, 1979; Lucas and Bamgboye, 1998). However, plant materials are more difficult to biodegrade than animal manures. This is because hydrolysis of cellulose materials of crop residues is a slow process and can be a major rate determining step in anaerobic digestion process (Kozo et al., 1996). Optimization of the biogas process can be in the form of blending, size reduction, pre-decaying in water, chemical treatment (NaOH / KOH, $Ca(OH)_2$ etc., addition of inoculum and metals (CO, Ni, Fe, Ca, Mg) to the wastes at required levels etc. Earlier work carried out by Lucas and Bamgboye (1998) attributed the poor yield of biogas from water hyacinth to absence of seeding material, sheathing of biodigestible materials by a relatively thin-impervious outer layer on the plant and the presence of lignin in the cell wall. The present study was undertaken to investigate the effect of different pre-treatment methods on the biogas yield from water hyacinth (WH), by using methods like drying alone (WH-A), drying and blending with cow dung (WH-C) (1:1) and drying and treating with KOH/Acetic acid (WH-T).

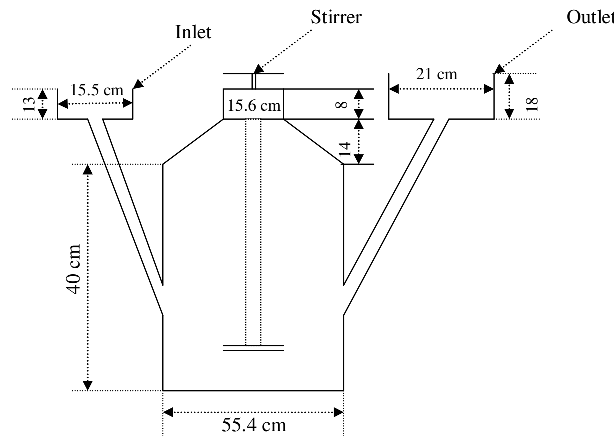

Figure 1. Schematic diagram of the biodigester.

MATERIALS AND METHODS

The water hyacinth used for the study was obtained from Niger River at Onitsha in Anambra State, Nigeria. The cow dung was procured from an abattoir at Nsukka town. The chemicals were used as procured without further purification. The potassium hydroxide (99%) made by Avondale laboratories, England and Acetic acid (99%) made by Sigma -Aldreich laboratories, Germany were procured from a chemical scientific shop also at Nsukka town. The water hyacinth was collected between March and April, 2008, while the experimental studies were carried out between May and June, 2008. The biodigesters used were of metallic prototype of 121 L capacity constructed at the National Centre for Energy Research and Development, University of Nigeria, Nsukka (Figure 1). Other materials used were weighing balance 50 kg capacity ("Five Goats" with model no Z051599), water troughs, graduated transparent plastic buckets, K- thermocouple thermo meter (-Hanna HI 8757), water bath for soaking the wastes. Jenway digital pH meter- 3510, hose pipes, biogas burner fabricated locally for checking gas flammability.

Experimental set -up

The whole water hyacinth (leaves, stem and root) on collection was allowed to dry up under the sun for a period of one month to reduce the moisture content of the waste. They were chopped to small sizes of about 2″. They were then soaked in big water baths for 2 days to allow for partial decomposition of the waste by aerobic microbes which are known to be better at breaking down cellulose (Fulford, 1998). They were charged into the biodigesters as; dried and chopped water hyacinth alone (WH-A), dried, chopped and treated water hyacinth (WH-T), dried and chopped water hyacinth combined with cow dung, 1:1 (WH-C), while the fresh water hyacinth (WH-F) served as control. The chemical treatment was effected with 200 ml KOH (50% w/v), while 75 ml of acetic was used to correct for pH when the alkalinity was exceeded. The wastes were mixed with water in the ratio of 1:3 (25 kg of waste: 75% of water). The anaerobic digestion was batch operated for 32 days. Daily biogas production, pH, ambient and slurry temperatures were monitored throughout the period of study.

Analyses of wastes

Ash, moisture and fibre contents were determined using AOAC (1990) method. Fat, crude nitrogen and protein contents were determined using soxhlet extraction and micro-Kjedhal methods as described in Pearson (1976). Carbon content was determined using Walkey and Black (1934) method, while total and volatile solids were determined using Meynell (1976) method.

Analysis of gas

The quantitative analysis of the flammable biogas was carried out to determine the composition of the gases from the different systems. This was carried out using "Crowcon Gasman" gas analyzer by the "Direct reading engineering method" (DREM).

RESULTS AND DISCUSSION

The trend of the daily biogas production from all the digested systems is graphically shown in Figure 2. Biogas production for WH-A and WH-C commenced with 24 h while WH-T and WH-F started gas production from the 2nd day. Flammable gas production for each of the systems also commenced at different lag periods (from the time of charging the wastes to onset of gas flammability) (Table 1). Fresh water hyacinth commenced flammable gas production 10 days post charging period with a cumulative gas yield of 271.2 l / TMS. The pH of the waste on soaking it in water was 6.2, which was just slightly acidic. On drying, the pH increased to 6.8 (close to neutral). Unlike most plant wastes whose pH range from 3 - 5, WH- F exhibited a rare quality not found in other plant wastes. This suggests that the level of lignin in water hyacinth is low when compared to other plant wastes (Fulford, 1998). The methanogens that convert the wastes to gas are pH sensitive, consequently effective biogas production requires a pH range of 6.5 to 8.5 (Anonymous, 1989). Adequate physicochemical properties are also necessary for efficient biogas production. The C/N ratio of the WH- F was below the recommended level of 20 - 30: 1 for optimum gas production (Kanu, 1988; Polprasert, 1989), its volatile solids (which is the biodegradable portion of the waste) was also the least, hence the need for some level of pre-treatment. All the other pre-treated systems produced relatively higher cumulative biogas yield with shorter lag periods (Table 2). The WH- C had the highest cumulative gas yield (Table 2) with reduced lag period of 6 days. Its volatile solids was also the highest. The C/N ratio was close to the required level for optimum gas production. It had adequate nutrients required for the methanogens to act on. Its pH was neutral showing that blending of the waste stabilized the system to favour gas production. These may be responsible for the enhanced performance of the system. This performance also confirms the earlier reports by other researchers that combining animal dung with plant wastes catalyzes the biogas production with consequent increased yield (Radhika et al., 1983; Ezeonu et al., 2002; Uzodinma and Ofoefule, 2009). The WH-A had a relatively high cumulative biogas yield though it was slightly lower than that of WH-C. The pH was close to neutral (6.8), its C/N ratio was also within the

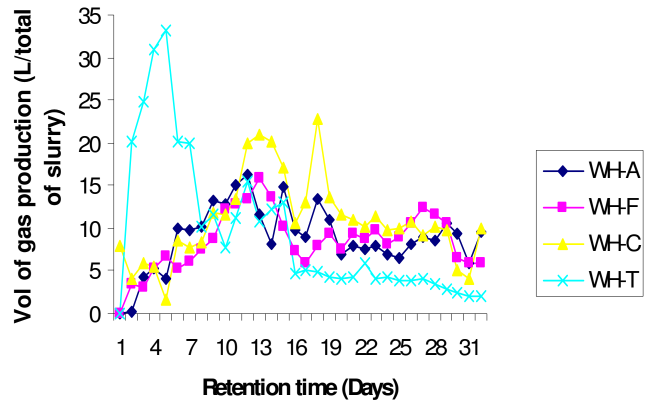

Figure 2. Daily biogas production.

Table 1. Physicochemical composition of the undigested wastes.

Parameters	WH-F	WH- A	WH-C	WH- T
Moisture (%)	47.24	3.40	38.42	3.60
Ash (%)	0.79	0.74	6.52	65.40
Crude fibre (%)	19.10	17.80	10.40	40.88
Fat content (%)	1.89	1.05	3.90	1.40
Crude protein (%)	6.88	2.38	4.69	7.00
Crude nitrogen (%)	1.10	0.38	0.75	1.12
Total solids (%)	52.76	96.60	61.58	96.40
Volatile solids (%)	20.18	28.89	33.65	25.90
Carbon content (%)	16.18	19.45	29.65	26.45
C/N Ratio	17.80	28.41	30.50	23.62
pH	6.20	6.80	7.40	7.32

Table 2. Lag period, cumulative and mean volume of gas production for the wastes.

Parameters	WH-F	WH- A	WH- C	WH- T
Lag Period (Days)	9	8	6	5
Cumulative gas yield (L/total mass of slurry)	271.20	292.41	356.30	285.21
Mean vol. of gas production (L/total mass of slurry)	8.48	9.75	11.88	9.51
Standard Deviation (SD)	3.77	3.40	5.01	8.63

acceptable limit for effective biogas production. Table 2 shows that WH-A possessed adequate physicochemical properties required for efficient biogas production. Drying alone improved these properties from what they were in the fresh water Hyacinth with special regards to the volatile solids and the C/N ratio. WH-T had the shortest onset of gas flammability of 5 days. Acid and bases are

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

Wastes	CH_4 (%)	CO_2 (%)	CO (ppm)	NH_3 (ppm)	H_2S (ppm)
WH-F	65	34.94	0.03	0.01	0.02
WH-A	60	39.94	0.03	0.01	0.02
WH-C	64	35.94	0.03	0.01	0.02
WH- T	71	28.94	0.03	0.01	0.02

known to de-lignify plant structure (Mathewson, 1980). The treatment with the KOH / acetic acid may have aided the breakdown of the lignin and cell wall of the water hyacinth with an improved pH for the methanogens to gain access to the nutrients trapped in the plant. However, chemical treatment did not bring about a significant increase in biogas yield when compared with the fresh water hyacinth. WH-T had the least biogas yield when compared with the other pre-treated systems (Table 2). It also had a shortest retention time and highest methane content (Table 3). Figure 2 shows that though it experienced an initial increase in gas production, however from the 16th day the volume of gas production dropped sharply and tapered down till production stopped. This may be explained firstly, by the fact that the thin lignin and cell wall were quickly broken down by the KOH/ acetic acid mixture, releasing all the nutrients and digestible matter within a very short period. This will make this particular feedstock very attractive for production of bottled biogas as it will bring about a high turnover on processing given the short retention time with high yield of product. Secondly, it may also be attributed to the level of some of the physicochemical properties like the volatile solids and the C/N ratio which were lower than the other variants. The result of the quantitative analysis of the flammable biogas components of the systems is shown in Table 3 and indicates that methane was highest in WH-T while the other variants had reasonable level of methane. The other gases; CO_2, H_2S, CO and NH_3 were found in lower proportions.

Conclusion

The result of the study has shown that dried and chopped water Hyacinth combined with cow dung (WH-C) had the highest cumulative biogas yield followed by dried and chopped water hyacinth alone (WH-A), while the chemically treated water hyacinth (WH-T) had the shortest onset of gas flammability. These results indicate that water Hyacinth does not require chemical treatment. It also shows that drying and chopping to smaller sizes is a more effective pre-treatment method as well as blending with animal wastes. Unlike most plant wastes studied so far, the present study has revealed that water Hyacinth is a very good biogas producer needing minimal pre-treatment to enhance the biogas yield. The use of pre-treated 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.

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