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International Journal of Current Research
Vol. 4, Issue, 07, pp.071-074, July, 2012

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

PRODUCTION AND STORAGE OF BIOGAS FROM ASH-TREATED AND UNTREATED BAGASSE

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ARTICLE INFO

Article History:
Received 16th April, 2012
Received in revised form
17th May, 2012
Accepted 28th June, 2012
Published online 30th July, 2012

Key words:
Biogas Production,
Bagasse,
Gas Flammability,
Ash Treatment,
Storage.

ABSTRACT

A comparative study of biogas production from ash-treated and untreated bagasse and its storage was investigated. Both wastes were charged into two 200L metal prototype biodigesters in the ratio of 3:1 (water:waste). The first biodigester contained partially hydrolyzed untreated bagasse while the second contained bagasse which was soaked in ash-treated water for one week. Proximate analyses as well as total solids, volatile solids, carbon content and calorific value were conducted on the waste while microbial level, $_pH$ and temperature were determined on the slurry. The wastes were subjected to anaerobic digestion for 30 days at mesophilic temperature range of 25 to 33^oC. Relative humidity, ambient temperature, $_pH$, slurry temperature and volume of gas were monitored and recorded on daily basis throughout the retention period. Biogas yield of ash-treated waste (1184.3 L) was four times higher than that of untreated waste (288.8 L). Onset of gas flammability was observed on the 4th day for both samples and was sustained throughout the retention period. The gas produced in each case was analysed and found to contain 64% methane. Storage was achieved with a modified pressure pump and maximum pressure of 23.2 MPa was recorded with a corresponding cooking time of 3.75 hours.

INTRODUCTION

Energy has always been an important aspect of man's activities. Consequently, as the demand for energy is increasing excessively, the entire world has not rested in the search for the different forms of energy that will meet up with his activities. Renewable energy options such as biogas production from anaerobic digestion is a relatively cheap means of providing alternative energy that may serve appropriately for the rural energy needs and to a lesser extent urban energy requirements (Ofoefule et al., 2010). Raw biogas contains about 55–65% methane (CH_4), 30–45% carbon dioxide (CO_2), traces of other gases such as carbon (II) oxide (CO), nitrogen (II) Oxide (NO), water vapour, ammonia and hydrogen sulphide (H_2S) and fractions of water vapours (Kapdi *et al.,* 2005). Municipal and agricultural wastes can be recycled to produce biogas. However, most of these wastes are often improperly disposed as to constitute health hazards. Biological degradation of these wastes into biogas via anaerobic digestion remains the simplest and most environmentally friendly technology of treating them to minimize the public health hazard. Bagasse is the fibrous residue remaining after the extraction of sugar from sugar cane. About 270kg raw wet bagasse or 130kg dry matter is produced from each ton of sugar cane. Bagasse is actually burnt on land or discarded (Busari, 2004). Anaerobic digestion is a complex biochemical reaction which takes place in the following steps:

1. Hydrolysis $(C_6H_{10}O_5)_n + {}_n(H_2O) \rightarrow n(C_6H_{12}O_6)$

2. Acidification $C_6H_{12}O_6 \xrightarrow{acetobacter} 3CH_3COOH$

3. Methanation $CH_3COOH \xrightarrow{Methanogens} CH_4\,(g) + CO_2\,(g)$

$$4H_2 + CO_2 \longrightarrow CH_4 + 2H_2O$$

The methanogenic bacterium utilizes acetate, carbon dioxide and hydrogen to produce methane. Plant wastes are generally known from several reports to give low yield of biogsas when subjected to anaerobic digestion alone without blending with animal wastes or pre-treating with chemicals. This has been attributed to the presence of lignin and wax in plant tissues giving rise to slower rates of hydrolysis (Lucas and Bamgboye, 1998). Ishihara et al, 1988 reported that bagasse could be treated with 0.5% sodium hydroxide or 5% sodium chlorite solution to soften the bagasse and increase gas yield. The use of steam (120^{0}C) for bagasse treatment has also been reported (Ishihara et al, 1988). In this study, palm head waste ash was used as a treatment material which apart from being cost effective served as a way of mopping these spent palm heads from the environment. Biogas compression or liquefaction is very rigorous and costly because of its low density. As a result, its storage is a problem and only immediate use is common as efficient storage of the gas for utilization at any time of need has not been achieved. Therefore, this comparative study was carried out to

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investigate the biogas production and storage potentials of ash-treated and untreated bagasse.

MATERIALS AND METHODS

The study was carried out at National Center for Energy Research and Development, University, of Nigeria, Nsukka. Bagasse used for this study was collected from Kalla, near Obodoukwu-Atani Road junction, Onitsha, Anambra State. Anambra State, Nigeria. The spent palm head was obtained from a local palm oil mill in Ukpor, Nnewi South L.G.A, Anambra state, Nigeria. The palm head was burnt and the ash collected for use in alkaline treatment of the bagasse. The chemicals used for various analyses were of analytical grade (A.R) procured from B.D.H Poole, England.

Preparation of the bagasse

The treated bagasse was prepared by mixing 3Kg of the ash from spent palm head with 37.5kg of bagasse and soaked in a plastic water bath for one week to allow for partial decomposition by aerobic microbes which are reported to facilitate breakdown of cellulosic materials (Fulford 1998). 37.5 kg of untreated bagasse was also soaked in a plastic water bath and left for one week.

Charging of the Digesters

200L metal prototype digesters were used. The wastes were charged up to ¾ of the digesters leaving ¼ head space for collection of gas. The treated bagasse was mixed into digester A with 112.5 kg of water while digester B contained 37.5kg of the untreated bagasse and 112.5kg of water. The ratio of waste to water was 1:3. The digester contents were stirred adequately and on a daily basis to ensure homogenous dispersion of the microbes in the mixture. Gas production measured in Litres was obtained by downward displacement of water by the gas.

Analyses of wastes

pH, ambient temperature, relative humidity, slurry temperature and flammability of the gas were monitored daily throughout the retention period. Fat, crude nitrogen and protein contents were respectively determined using soxhlet extraction and micro-Kjedhal methods (Pearson, 1976). Crude fibre content, moisture content and ash content determination were done using method described in A.O.A.C (1990). Energy Content was determined using AOAC method (Onwuka, 2005). Carbon Content was determined using Walkey and Black (1934) method. Determination of total solids and volatile solids were done using Renewable Technologies (2005) method. Microbial analyses were done weekly using Miles and Misra method described in Okore (2004).

Storage of biogas produced

Gas produced was analyzed with gas analyser (Unigas 3000 +BTU, make: Eurotron; made in U.S.A.) and stored in a gas cylinder using a modified pressure system as shown in Figure 1. Gas pressure was measured using a pressure guage and total cooking time determined with the stored gas on daily basis.

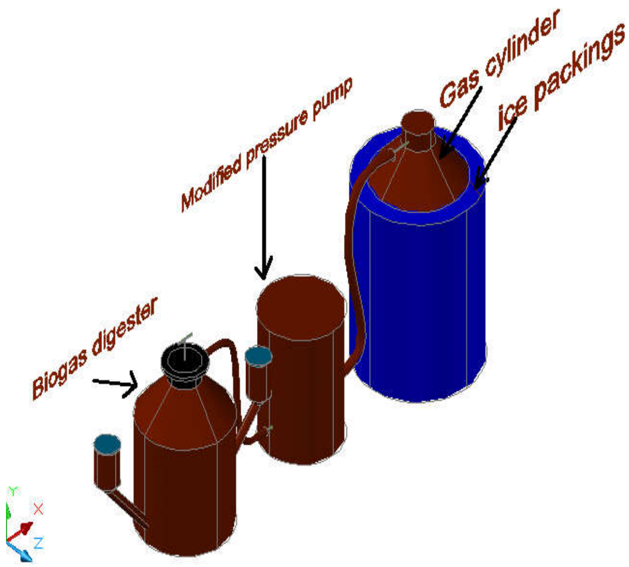

Figure 1: Storage of flammable gas using modified pressure system

RESULTS AND DISCUSSION

The daily mean ambient temperature ranged from 25 to 33^{o}C throughout the retention period of thirty days. As shown in Figure 2, biogas production commenced on the first day.

Table 1: Physicochemical properties of the wastes

Parameter	Ash- treated bagasse	Untreated waste bagasse
Fat (%)	1.64	1.88
Ash (%)	8.04	4.55
Moisture (%)	15.24	14.38
Protein (%)	4.50	5.24
Fibre (%)	40.36	42.01
Carbohydrate (%)	30.22	31.94
Total solids (%)	84.76	85.62
Volatile solids (%)	65.20	60.34
Carbon content (%)	30.51	37.36
Calorific value (KJ/kg)	16,921.92	19,314.69
Nitrogen (%)	0.72	0.84
Carbon: Nitrogen	42.38	44.48

Cumulative biogas yield for the untreated and ash-treated wastes were 288.8 L and 1184.3 L respectively while onset of gas flammability for both wastes was on the 4th day and sustained throughout the retention period. The $_{P}$H of the treated bagasse ranged from 7.2 to 7.8 while the untreated bagasse ranged from 4.8 to 5.8. This affected the production as the methanogens that convert wastes to flammable biogas are highly pH sensitive and operate optimally at a pH range of 6.5 to 8.5 (Anon, 1989). The $_{P}$H range obtained for the treated waste sample was favourable for microbial growth and therefore volume of biogas. The volume of biogas produced as a result of this treatment was about 400% higher than that of the untreated waste. This method of treatment gave better gas yield compared with 180 and 210% reported by Ishihara et al., 1988 using sodium hydroxide and sodium chlorite respectively. Hence, the ash provided cheap source of alkali, better gas yield and a means of mopping up spent palm head from the environment. Also, the quality of flammable biogas produced were favourable containing up to 64.7% and 60.2% methane for the treated and untreated waste respectively.

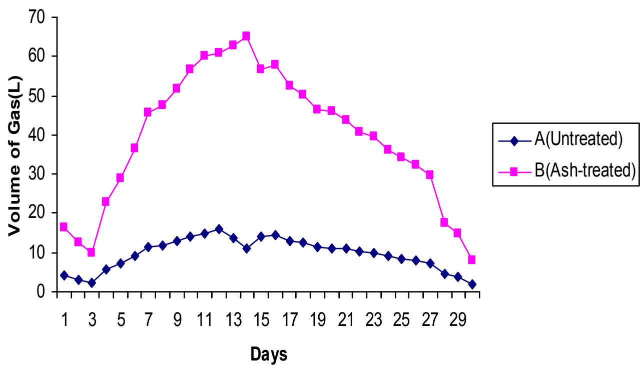

Figure 2: Daily volume of biogas production from the ash-treated and untreated wastes

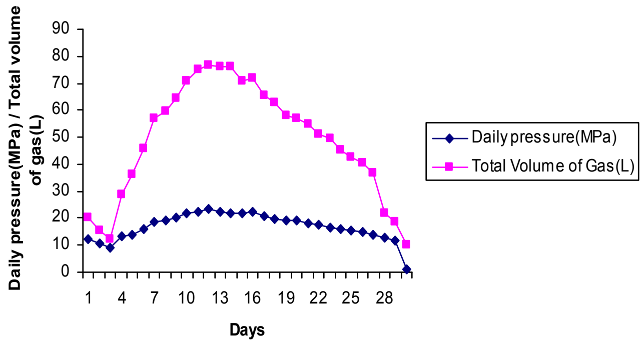

Figure 3: Daily pressure and total volume of the gas stored in gas cylinder

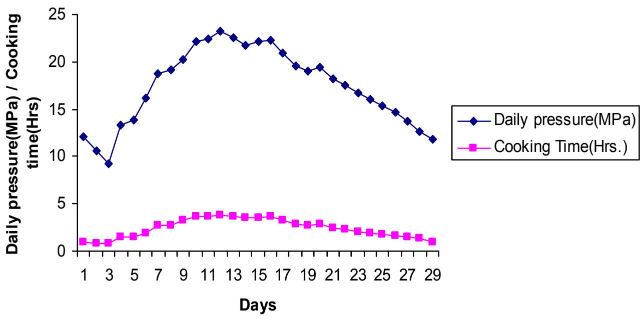

Figure 4: Daily pressure/ cooking time Vs days of the gas stored in gas cylinder

The results obtained for of the physicochemical parameters show that fat, protein, fibre, carbon content, total solids and carbohydrate presented in Table 1 show that the raw materials (wastes) contained suitable nutrients needed for anaerobic digestion and were slightly higher for untreated waste compared with those of the treated waste. This indicates that the treatment had effect on these parameters. In addition, as a result of the alkaline hydrolysis, more volatile solids (which is the biodegradable portion of the waste) were more available for digestion in the treated waste. Calorific values were higher for the untreated wastes because of the higher carbon content of the wastes since materials of high carbon content normally release high energy on combustion. The carbon – nitrogen (C: N) ratio in the wastes were higher than the optimum range of 20-30:1 (Dennis and Burke, 2001) because the bagasse has very high carbon content. This trend was also reported in the comparative study of the effect of chemical treatments on cassava peels for biogas production (Ofoefule *et al.,* 2010).

Table 2: Total Viable Count (cfu/ml) during anaerobic digestion for the ash-treated and untreated wastes

Wastes / Days	A(Treated)	B(Untreated)
0	$1.6x10^6$	$2.8x10^4$
5	$1.9x10^7$	$3.0x10^4$
10	$4.2x10^7$	$3.4x10^4$
15	$3.5x10^7$	$2.8x10^4$
20	$2.8x10^7$	$7.1x10^3$
25	$1.8x10^7$	$5.9x10^3$
30	$1.1x10^7$	$4.7x10^3$

Microbial analysis showed that *E. coli, pseudomonas spp, Bacillus subtilis, yeast, proteus spp, mucor and Aerobacter aerogens* were isolated and identified in the treated wastes while *Pseudomonas spp, Asp. Spp, Bacillus subtilis, Yeast, proteus spp, Klebsiella, E. coli and Salmonella spp* were also isolated and identified in the untreated wastes. These identified pathogenic microbes from the wastes can cause numerous diseases in human beings and animals. They include skin infections, urinary tract infectious, wound infections and food poisoning. The identification of these microbes makes it imperative for the users of biogas to be extremely careful in handling the wastes. As shown in Table 2, the microbial load (Total viable count) was higher in the treated waste. However, the trend for both wastes was an initial increase of microbial load to the 10th day which was period of peak of production and a gradual decrease till the end of the retention period. For the gas stored in gas cylinder, Figure 3 shows there was a direct relationship between the daily pressure and volume of the gas while figure 4 shows a direct relationship between daily pressure and cooking time. In recent times, alternative storage for biogas has been designed by Gale group, University of Missouri Colombia (Higgins and Konky, 2002). The design uses carbon nanopores as the material for alternative fuel storage. All these attempts at storage have not been successful because they are not easily and conveniently available to the end users. Some of them could not sustain cooking for up to thirty minutes. As shown in Figure 1, biogas was stored in gas cylinders that were covered with ice during filling. A maximum pressure of 23.2 MPa was obtained using the modified pressure system. The gas in the cylinder was used to cook for a maximum total time of 3.75 hours.

CONCLUSION

This study has shown that bagasse is a good source of biogas. It was discovered that the volume of biogas produced by bagasse can be greatly increased by treatment of the bagasse with ash from palm head waste. The development of the biotechnology of bio-derivable energy from agricultural residues if effectively harnessed will help alleviate the energy problems of developing countries such as Nigeria and also help in environmental sanitation. The use of the ash from palm head waste provides a cheap and convenient means of masking reagent to adjust pH to suit production. In this study, biogas has been successfully stored. People can now conveniently use biogas for cooking in their respective homes if this storage technique is further explored.

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