International Journal of Physical Sciences Vol. 4 (7), pp. 398-402, July, 2009
Available online at http://www.academicjournals.org/IJPS
ISSN 1992 - 1950 © 2009 Academic Journals

Full Length Research Paper

Biogas production from blends of cassava (*Manihot utilissima*) peels with some animal wastes

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Accepted 23 June, 2009

Cassava peels (CP) obtained after peeling cassava roots were anaerobically digested using 50L capacity fermentor and in blends with some animal wastes. The peels were blended with cow dung (CD), poultry droppings (PD) and swine dung (SD), in the ratio of 1:1. The mean flammable biogas yield of the cassava peels alone was 2.29 ± 0.97L /total mass of slurry. When blended with CD, PD and SD, mean flammable biogas yield was increased to 4.88 ± 1.73, 5.55 ± 2.17 and 5.65 ± 2.62 L /total mass of slurry respectively. Flammable biogas was produced by CP alone from the 59th day of the digestion period. The CP: CD and CP: PD produced flammable gas from the 9th day whereas CP: SD started flammable gas production from the 11th day. While the CP: SD had the highest cumulative gas yield of 169.60L/total mass of slurry, the CP: CD experienced fastest onset of flammable gas production. Overall results indicate that the relatively low flammable biogas production and slow onset of gas flammability of cassava peels can be significantly enhanced when combined with the animal wastes in definite proportions.

Key words: Cassava peels, biogas production, flammable gas production, waste blends, biogas yield.

INTRODUCTION

The rising cost of petroleum products is a serious problem facing most developing countries of the world including Nigeria. Again, excessive energy demands from both rural and urban dwellers imply that other natural sources of energy have to be explored. Hence, conversion of agricultural wastes into biogas could be a leeway to solving some of these energy problems. Biogas production is a complex biochemical process that takes place in the absence of oxygen and in the presence of highly sensitive micro-organisms that are mainly bacteria (Hashimoto et al., 1980). The predominant component of flammable biogas is methane (CH_4) and CO_2 with traces of other gases like, H_2S, NH_3, CO, H_2, N_2 and water vapour etc. It has a heating value of 22 MJ/m^3 (15.6 MJ/kg) (FAO, 1979). Consequently, biogas can be utilized in all energy consuming applications designed for natural gas (Ross, 1966).

$$n\,(C_6H_{10}O_5) + nH_2O \rightarrow n\,(C_6H_{12}O_6) \quad (1)$$

$$n\,(C_6H_{12}O_6) \rightarrow 3nCH_3\ COOH \quad (2)$$

$$3nCH_3COOH \rightarrow CH_4 + CO2 \quad (3)$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O \quad (4)$$

Biogas technology has been in use in Kenya since 1957 whereas in areas such as USA and in Asian countries like India, China and Parkistan, the gas has been fully utilized (Carl and John, 2002). The raw materials used in many places for the gas production are agricultural wastes ranging from animal manures to adverse selection of crop residues. Cassava solid wastes, amongst other plant wastes have been used. In a research finding of Kozo et al. (1996), cassava solid waste (peels +pulp) was utilized in anaerobic digestion process to produce biogas with methane content of 51 - 56%. Also Okafor (1998), utilized cassava peels and waste water to produce animal feed that was used to feed pigs. The feaces from the pigs were then converted to biogas. Cassava peels are obtained through processing of cassava roots to produce garri (a staple food eaten in the tropics especially in Nigeria) and cassava foo-foo. These peels could make up to about 10% of net weight of the roots and contain toxic cyanogenic glycosides. As a result of their reasonable large quantities in homes engaged in farming activities and industrial areas where commercial quantities are produced, these peels have become a nuisance and create

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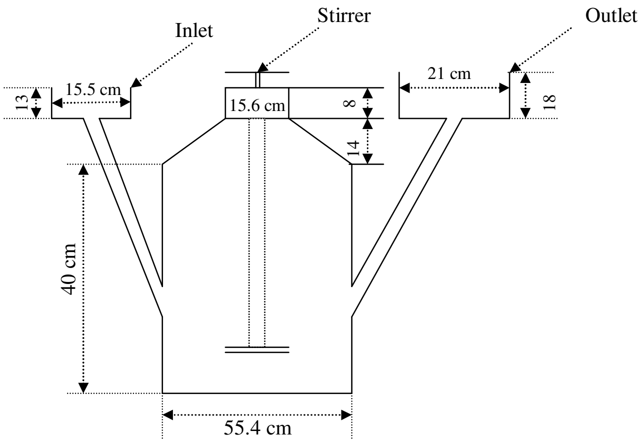

Figure 1. Schematic diagram of the biodigester.

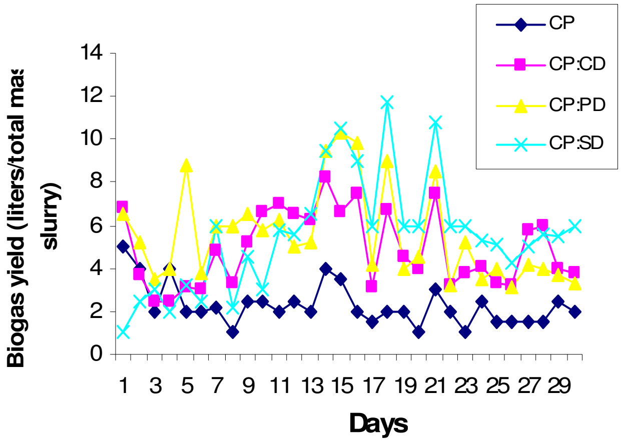

Figure 2. Biogas production for the pure and blended CP.

waste disposal problems. Initial digestion studies carried out on the peels showed that the peels are poor producers of biogas probably as a result of their content of toxic cyanogenic glycosides (Okafor, 1998). As a result, they require treatment to enhance their yield of biogas and onset of gas flammability. This study was then undertaken to investigate the effect on these two parameters of cassava peels when blended with some animal wastes. The peels were combined with animal wastes; Cow dung (CD), poultry droppings (PD) and Swine dung (SD) in the ratio of 1:1 for each of the blends.

MATERIALS AND METHODS

The cassava peels used for this study were obtained from the local processors of garri, while poultry droppings and swine dung were obtained from the Animal and Veterinary farms, University of Nigeria, Nsukka, Enugu state. The cow dung was procured from an abattoir at Nsukka town of Enugu state, Nigeria. Cassava peels were collected between December, 2006 and January, 2007 while the experimental studies were carried out between May and June, 2007. Biodigesters of 50 L working volume were used for the fermentation studies and the reactors were constructed from a galvanized metal plate of gauge 16”. Other materials used were weighing balance 50 kg capacity (“Five Goats” with model No: Z051599), water troughs, graduated transparent plastic buckets, K- thermocouple thermometer (Hanna Instrument - HI 8757…), digital pH meter (Jenway, 3510), hose pipes, biogas burner fabricated locally for checking gas flammability and Manometer for taking pressure readings.

Experimental studies

The cassava peels used for the experiment were allowed to dry up and degrade for about four months to reduce the toxicity of the waste. They were then soaked in a big metallic drum for one week to allow partial decomposition of the peels by aerobic microbes. The animal manures were used as collected without further treatment. The moisture content of the feed stocks determined the water to waste ratios during the charging. The blending ratio was chosen as 50:50 as a starting combination from the other possibilities (60:40, 70:30, 80:20 and 90: 10), Srinivasan (1997). The wastes were mixed with water in the ratio of 1:2.7 (10kg of waste: 27 kg of water). The anaerobic digestion process was batch operated for 30 days under mesophilic temperature conditions of 25.3 - 29.9°C (for the ambient temperature) and 27.0 - 42.0°C (for the influent temperature). Daily biogas production, ambient and slurry temperatures, pressure and pH at alternate days were monitored. The total viable microbial loads of the wastes undergoing digestion were also monitored at different times (At charging, at the point of being flammable, at the peak of gas production and towards the end of the digestion).

Analyses of wastes

Ash, moisture and fiber contents were determined using AOAC method of 1990. 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.

Microbial analysis

Total viable counts (TVC) for both pure and the blended slurries were carried out to determine the microbial load of the samples using modified Miles and Misra method as described in Okore (2004).

RESULTS AND DISCUSSION

Daily biogas production from the cassava peels and the blends are graphically displayed in Figure 2. Biogas production for all the systems commenced within 24 h of charging the digesters though the quantity of gas produced varied as shown in the figure. The flammable gas production of each of the system also commenced at different lag periods (which is from the time of gas production to onset of gas flammability) (Table 2). Biogas systems become flammable when the methane content is at least 45%. If it does not burn, it means the methane content is less than 45% and contains mainly CO_2 (http: file: //A:\Design-Tutor.htm. 2003). The pure cassava peels system produced flammable biogas 58 days post charging period with low cumulative gas yield of 68.70 liters/ total mass of slurry. The pH change was mainly from aci-

Table 1. Physicochemical composition of pure and undigested wastes.

Parameters	CD	PD	SD	CP	CP:CD	CP:PD	CP:SD
Moisture (%)	22.62	16.20	58.05	14.25	21.35	6.70	10.05
Ash %	42.05	37.90	40.15	21.90	20.05	29.90	31.02
Fiber (%)	21.25	28.70	51.05	32.00	23..50	23.45	33.60
Crude Nitrogen (%)	1.40	2.94	1.47	1.40	1.40	2.17	1.43
Crude Protein (%)	8.75	18.38	9.19	8.74	8.75	13.56	8.96
Fat Content (%)	0.45	0.35	0.10	0.75	0.75	0.05	0.15
Total Solids (%)	77.38	13.95	51.94	68.25	71.93	69.53	70.09
Volatile Solids (%)	35.33	7.02	17.02	33.87	30.75	40.53	41.52
Carbon Content (%)	26.87	13.80	15.25	41.27	44.02	30.27	63.28
C/N Ratio	19.20	4.70	10.37	30.00	27.00	20.00	25.00
pH	8.11	7.82	7.43	5.68	7.16	7.68	7.05

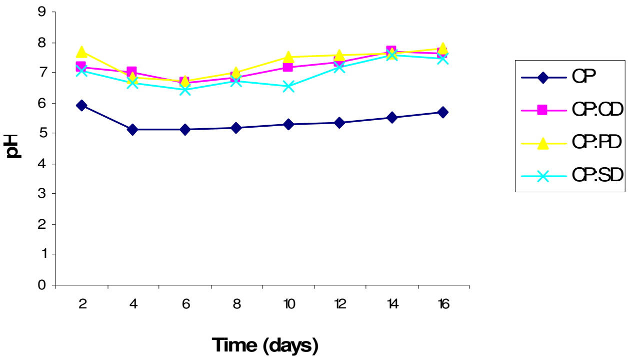

Figure 3. pH changes in the first two weeks of the digestion.

dic to slightly acidic for a long period (Figure 3). Figure 3 shows the pH changes for CP system and the blended wastes within the first two weeks of the digestion period. One of the major problems associated with biogas production from cassava roots (cassava wastewater, cassava solid waste and cassava tuber) is acidification (low pH) (Barana and Cereda, 2000; Kozo et al., 1996; Wantanee and Sureelak, 2004). The thin brownish outer membrane of cassava root consists of lignified cellulosic material while the white inner portion comprises parenchymateous material known to contain most of the toxic cyanogenic glycosides and linamarin, in the entire cassava root, (Okafor, 1998). The linamarin is broken down with the production of the hydrocyanic acid during the processing. Consequently, effective biogas production from the wastes would require a pH between 6.5 and 8.5 (Anonymous, 1989). This is because the methanogens that produce flammable gas from the waste are highly pH sensitive. Hence, in most of the work done on biogas production using cassava materials, inoculums and neutralizers has been applied to the slurry to bring the pH to neutrality (Wantanee and Sureelak, (2004), Kozo et al., 1996). All the blends as shown in Figure 2 produced relatively higher cumulative gas yield with reduced number of lag days in comparison with the cassava peels alone (Table 2). CP: SD had the highest cumulative gas volume. From the profile of pH changes in the first two weeks of digestion, it was observed that blending of the cassava peels with these animal wastes stabilized the waste for gas production (Figure 3). This could be as a result of its high fiber and carbon contents (Table 1). Swine in this part of the country are normally fed with spent grains occasionally, which may contain a lot of fiber. The presence of hydrocyanic acid in the cassava peels may have brought about the de-lignification of the fibrous plant structure of the spent grain observed in the swine waste making nutrients available for the methanogens during the digestion period (Mathewson, 1980). The CP: PD combination had a cumulative gas yield close to that of CP: SD (Table 2) but faster onset of gas flammability. This may be as a result of its low total solids (TS) of the undigested single poultry waste (Table 1). Adequate physicochemical properties are known to favor biogas production. A higher TS level for poultry droppings implies high ammonia content of the slurry. Shivaraj and Seenayya (1994) reported that digesters fed with 8% TS of poultry waste gave better biogas yield than the higher TS levels. Again, earlier work carried out by Waksman and Hutchings (1936), pointed out the significance of organic sources of nitrogen in the decomposition of lignin in plant materials. They asserted that lignin-decomposing microbes prefer organic protein-nitrogen to inorganic forms. Tinsley and Nowkawski (1959) also submitted that, application of poultry droppings as fluid slurry to Brewer's spent grain brought an abundant and vigorous micro-flora immediately into contact with feedstock substrate. They further explained that as uric acid is decomposed, ammonia is produced which diffuse rapidly so that the cellulose-decomposing organisms were well supplied with nitrogen from an early stage. This organic source of nitrogen as biogas production catalyst was also highlighted in the report of Ezeonu et al. (2002) in the biomethanation of Brewery spent grain (BSG) with chicken droppings and Cow rumen liquor. The system with BSG / droppings ratio of4:1 had the highest gas yield when compared with the other ratios of 5:1 and

Table 2. Lag period, cumulative and mean volume of gas production for pure and waste blends.

Parameters	CP	CP:CD	CP:PD	CP:SD
Lag period (days)	58	9	9	11
Cumulative gas yield (Liters/total mass of slurry)	68.70	146.50	166.50	169.60
Mean volume of gas production (Liters/total mass of slurry)	2.29	4.88	5.55	5.65
Standard Deviation (SD)	±0.97	±1.73	±2.17	±2.62

Table 3. Total viable counts for the pure and blended organic wastes during the digestion period (cfu/ml).

Period	CP	CP:CD	CP:PD	CP:SD
At charging	1.13×10^6	2.73×10^6	4.93×10^7	1.53×10^7
At point of flammability	1.59×10^6	1.09×10^7	2.26×10^7	1.84×10^7
At the peak of production	1.45×10^7	4.15×10^7	5.55×10^7	7.32×10^7
Towards end of the digestion	2.05×10^6	1.07×10^7	1.39×10^7	1.59×10^7

3:1. This explanation might account for the faster onset of gas flammability of poultry blended system in the current study, unlike the other blends which may contain only the native microbial flora. The result of the microbial loads during the digestion period shows that the population of microbes was still high even when the experiment was tending to end (Table 3). The CP: CD had the same onset of gas flammability as the CP: PD even though the cumulative gas yield was the least. Cow dung has been acknowledged as the best biogas producer amongst most animal wastes. As such it was expected that combining it with the cassava peels should improve its gas yield, however, this did not happen but only affected the onset of gas flammability. Probably the synergy in existence between cow dung and cassava peels is low when compared to other wastes.

Conclusion

The overall results indicate that the low biogas yield and slow onset of gas production / flammability of digested cassava peels can be enhanced significantly when combined with animal wastes. The blend with cow dung and poultry droppings had the fastest onset of gas flammability while that with swine dung had the highest cumulative volume of gas production. Hence, cassava peels which is considered a nuisance can be converted to a useful source of energy by combining it with these or any other animal wastes. Investigation of other ratios will constitute a separate report.

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