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Biogas production from blends of powdered rice husk with some agro-industrial wastes

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Abstract

Biogas production from powdered rice husk (RH) and blends of rice husk with other agro-industrial wastes was investigated. The RH was blended with waste streams such as brewer's spent grain (SG), cassava waste water (CW) and carbonated soft drink sludge (SL). These wastes were blended in the ratios of SG: RH (1:1), CW: RH (1:2.3) and SL: RH (1: 1.5). The daily mean flammable gas production was 5.5l.When blended with SG or CW, flammable biogas production increased to 18.8 and 19.5l respectively while an increase of 7.7l mean gas yield was obtained for SL: RH combination. There was significant increase in biogas yield at 95% confidence level for all the blends. Flammable gas was obtained from RH alone from the 16th day of the anaerobic digestion process while, SG: RH combination exhibited the shortest lag time of 2 days (CW: RH and SL: RH had lag days of 6 and 10 respectively). Gas analysis from SG: RH blend shows, methane (70.6%), CO_2 (23.3%), CO (6.3%) and H_2S (2.1%), CW: RH contained methane (77.8%), CO_2 (19.5%), CO (2.1%), H_2S (0.6%) while SL: RH combination, the values are, methane (73.5%), CO_2 (18.9%), CO (7.5%), H_2S (0.6%). The overall results indicated fastest onset of flammable biogas production from SG: RH combination. In addition, the relatively low flammable biogas production of RH was shown to be significantly enhanced when it was combined with SG or CW in definite ratios.

Keywords: Biogas production; Waste blends; Flammable biogas, Mean gas yield; Cumulative gas yield

1. Introduction

Biogas generation from microbial conversion of biogenic organic wastes under anaerobic condition has become attractive globally because of its importance as a method of waste treatment and resource recovery. Besides, the growing energy needs for both rural and urban populace and the fear of depletion of fossil fuels (Petroleum, Coal, Natural gas, etc) in the near future require that biogas technology should be given urgent attention. Biogas production is a three stage complex biochemical process involving solublization, acidification and methane formation. The major components of this gas are methane (55-70%) and carbon dioxide (20-40%) with traces of other gases like N_2, NH_3, H_2S, H_2, CO and water vapour etc. (Energy commission, 1998). It becomes flammable when methane content of the biogas system is at least 45% (http DesignTutor htm, Waste Digester Design, 2003). The general composition of biogas mixture depends on the source of feed stock and the management of the digestion process (Wantanee and Sureelak, 2004). Biogas Systems are highly temperature and pH dependent and the methanogens survive within pH range of 6.6 to 7.6 and in some instances up to 8.5 (Speece and McCarthy, 1964) . The methanogens (which are the methane- forming bacteria) can also operate within three temperature ranges; Psychrophilic or ambient temperature (< 25^oC), Mesophilic (25 to 40^oC) and Thermophilic (45 to 60 ^{o} C) (El- Mashad, 2004). Several organic wastes from plants and animals have been exploited for biogas production as reported in the literature (Tambuwal et al., 1980; Gramms et al., 1971; Garba and Ojukwu, 1998). Plant materials include agricultural crops such as sugar cane, cassava, corn etc, agricultural residues like rice straw, cassava rhizome, corn cobs etc, wood and wood residues (saw dust, pulp wastes, and paper mill (etc). Others include molasses and bagasse from sugar refineries, waste streams such as rice husk from rice mills and residues from palm oil extraction and municipal solid wastes, etc. However, plant materials such as crop residues are more difficult to digest than animal wastes (manures) because of difficulty in achieving hydrolysis of cellulosic and ligninic constituents (Kozo et al., 1996). Rice husks are mostly found in large quantities at rice mills and past records showed that rice husk has been employed as fuels in process steam and in the technology of fluidized bed combustion boilers (Aggarwal, 2003). This is because it has high fiber and ash contents, low moisture and it has good calorific value (Stowell and Tubb, 1980). Sahota and Rajinder (1997) reported that the addition of rice husk soaked in water at the level of 20 percent to the cattle digester increased biogas production. Eze (1995) reported that the addition of poultry droppings to rice husk at an average temperature of 29.4 ^{0}C resulted to cumulative methane yield of 39.70 l/g. TS with only 18.37l/g. TS gas yield obtained from rice husk alone at the same conditions and within the same 18 days retention period. These results emphasize the need for blending of rice husk with other biogas producing organic wastes to optimize gas yield. The current study further verified the potential of powdered rice husk to produce flammable biogas when combined with other agro-industrial wastes. The powdered rice husk was combined with agro - wastes such as brewer's spent grain (SG), cassava waste water (CW) and carbonated soft drink sludge (SL) in the ratios of SG:RH (1:1), CW:RH (1:2.3) and SL:RH (1: 1.5).

2. Materials and methods

The Cassava wastewater was obtained from one of the local processors of Garri (a staple food in the Eastern part Nigeria) while the powdered rice husk procured from a local rice mill in the same area. The Brewer's spent grain and carbonated soft drink sludge were procured from Nigerian breweries limited and 7Up bottling company Plc, respectively at 9th mile corner, Enugu State of Nigeria. The biodigesters used were the Chinese model metal prototypes of working volume 117 and 136l, constructed locally at the National Centre for Energy Research and Development, University of Nigeria, Nsukka. The study was carried out between January and February, 2006, at the same Research Institute. Other materials used were top loading balance (50 kg capacity "Five goats" model No Z051599), water troughs, graduated plastic buckets for measuring daily gas production, thermometer (-10 to 110 ^oC), digital pH meter (Unified National Inventory Data base), hose pipes and biogas burner (fabricated locally) for checking gas flammability.

3. Fermentation studies

The powdered rice husk (RH) was charged into a biodigester of 117l capacity while the waste blends, SG:RH, CW: RH and SL: RH were charged differently into the digester of 136l capacity. The powdered rice husk (RH) used for blending the Brewer's spent grain (SG) was soaked in water (1:1) for one week before charging into the digester, while the SG was pre-decayed for the same period prior to charging. The moisture content of the feed stocks determined the water to waste ratios used for digester charging. Preliminary analysis of the physicochemical properties of the pure wastes determined the blending ratios. Powdered rice husk was mixed with water in the ratio of 1:2 whereas SG: RH (1:1), CW: RH (1:2.3) and SL: RH (1:1.5) were mixed with water in the ratios 1:3, 2.7:1 and 1:3, respectively. The experiment was batch operated under atmospheric pressure conditions. The study was monitored for 25 days. Volume of gas production was taken daily using downward displacement of water (Itodo et al., 1995, Wantanee and Sureelak, 2004). pH of the system, ambient and slurry temperatures were also monitored throughout the period of gas production.

3.1. Analysis of wastes

3.1.1. Proximate analysis

Ash, moisture and fiber contents were determined using AOAC method (1990). Fat content, crude protein and nitrogen contents were determined using soxhlet extraction and micro - Kjedhal methods described in Pearson (1976). Carbon content was determined using Walkey and Black (1934) method while total and volatile solids of both pure and combined waste slurries were determined using standard method.

3.1.2. Microbial analysis

Total viable counts (TVC) for both the pure and the blend slurries were carried out to determine the microbial load of the samples.

3.1.3. Gas analysis

The composition of the flammable biogas produced from each of the biogas system was carried out using the Orsat apparatus of British Standards Institution (1971).

All experiment was carried out under daily mean ambient temperature range of 25.10 to 30.50 ^{0}C throughout the period of flammable gas production. The pH of RH system at charging was 7.12 while those of the unblended wastes were 5.03 for SG, 3.30 for CW and 5.68 for SL.

3.1.4. Data analysis

The data obtained from the daily volume of gas production was subjected to statistical analysis using SPSS version 11 computer package.

4. Results and discussion

Daily biogas production from RH and the various blends are shown graphically in figure 1. Biogas production for

SG: RH and CW: RH systems commenced within 1 day of charging the digesters, while that of SL: RH and RH were delayed up to 2 days to 3 days (Fig 1). The production of flammable biogas took place at different lag periods (Table1). The pure RH system produced flammable biogas after 15 days post charging period with low cumulative biogas yield of 137.6 liters (Table 1). Rice husk has higher carbon content as shown in Table 2, which indicates that rice husk contains a lot of cellulose, hemicelluloses, pectin, lignin and plant wax. Lignin and plant wax are difficult to degrade and can be a major rate determining step in anaerobic digestion process (Kozo et al., 1996). The mean volume of biogas production from SG: RH and CW: RH combinations were about twice more than that of SL: RH blends (Table 1). The CW: RH waste blend gave the highest mean and cumulative volume of biogas yield, though it had relatively poor physicochemical properties (Table 3). Adequate physicochemical properties (volatile solids, nutrients, pH and C/ N ratio) are known to favour biogas production. This result may be attributed to the cyanide in the cassava waste water. Acids and bases are used to de-lignify plant structures to make the cellulose and hemicelluloses available for use (Matthewson, 1980) and the presence of hydrocyanic acid in the CW (pH 3.30) may have de-lignified the fibrous rice husk thereby giving the methanogens access to more digestible nutrients. The SG: RH system gave very interesting results. It had the shortest lag period of 2 days and appreciable cumulative flammable gas yield which was slightly lower than that of CW: RH (Table1). This may be attributed to the fact that the RH and SG wastes were pre-decayed in water at the level of 50 percent for one week prior to blending and charging of the wastes. According to Brigas *et al.*, (1981), brewery spent grain is normally thrown out as waste after sparging operation in the brewing process. This gives rise to death of most of the microbes that should be inherent in the waste after the operation. As a result, brewery spent grain obtained in this way are normally attacked by moulds which inhibit the growth of the bacteria in the waste. Therefore, for the brewery spent grain to produce flammable biogas, it had to be pre-decayed to increase the microbial load in addition to blending the waste. The SG: RH waste blend also had high volatile solids and C/N ratio (Table 3). The results of the physicochemical compositions of the undigested blends in Table 3 also show very good properties (high volatile solids which is the biodegradable matter in the waste, nutrients – carbohydrate & protein, pH and C/N ratio which optimum value has been recommended to be in the range of 20-30: 1 (Kanu, 1988; Viswanath et al.,1992). These are key parameters for anaerobic digestion to take place optimally. The amount of carbon and nitrogen nutrient source affects the growth of micro organisms and the biogas production. The total microbial viable load (TVC) in Table 4 further showed the digestion pattern for the different organic wastes. Quantitative analysis of biogas components for the waste blends indicates that methane content was high for all the blends whereas CO_2, H_2S and CO was found in variable proportion according to the source of the organic wastes.

5. Conclusion

The overall results indicated that the low flammable biogas production of powdered rice husk could be enhanced significantly in the presence of cassava waste water and brewer's spent grain. Cassava waste water combination gave the highest mean volume of biogas production while brewer's spent grain gave best result in terms of on set of flammable gas production. This signifies that blending of these wastes with powdered rice husk can be a very good source for provision of immediate energy needs to both rural and sub-urban populace of developing counties such as Nigeria where small scale processing industries and rice mills are scattered all over rural and sub-urban areas. The effect of cyanide in cassava waste water on other plant / crop residues is currently in progress and will constitute a separate report.

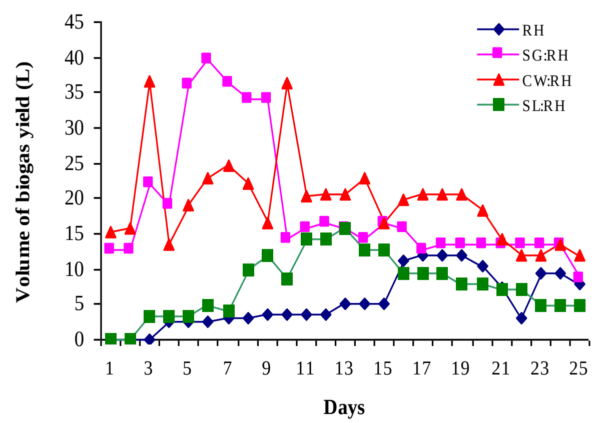

Fig.1. Daily biogas production.

Table 1
Lag period, cumulative and mean volume of gas production for pure and waste blends

Parameters	RH	SG:RH	CW:RH	SL:RH
Lag periods (days)	15	2	6	10
Cumulative gas yield (l)	137.60	471.90	487.30	192.50
Mean volume of gas (l)	5.50	18.80	19.50	7.70

Table 2
Physico-chemical composition of the undigested pure organic wastes

Parameters	RH	SG	CW	SL
Moisture (%)	10.60	14.10	93.50	71.35
Ash (%)	15.85	7.20	1.00	3.10
Fibre (%)	57.7	4.20	0.00	1.50

Crude Nitrogen (%)	1.12	1.82	0.21	0.07
Crude Protein (%)	7.00	11.8	1.31	0.44
Fat Content (%)	Trace	7.30	0.70	3.60
Carbohydrate (%)	9.10	28.8	3.50	21.00
Carbon Content (%)	30.32	47.12	0.79	1.60
C/N Ratio	27.07	26.00	3.80	23.90
pH	7.12	5.03	3.30	5.68

Table 3
Physico-chemical composition of pure and undigested blended agro wastes

Parameters	RH	SG:RH	CW:RH	SL:RH
Moisture (%)	10.6	17.4	11.00	23.23
Ash (%)	15.85	6.9	6.9	16.4
Fiber (%)	57.7	3.3	1.75	2.45
Crude Nitrogen (%)	1.12	1.20	0.14	0.42
Crude protein (%)	7.0	7.50	0.88	2.63
Fat Content (%)	Trace	Trace	Trace	Trace
Carbohydrate (%)	9.10	64.90	79.47	55.32
Total Solids (%)	74.89	89.80	90.89	82.50
Volatile Solids (%)	47.03	62.00	38.59	20.50
Carbon Content (%)	30.32	31.25	2.88	8.43
C/N Ratio	27.07	26.0	21.00	20.00
pH	7.12	6.50	6.10	6.30

Table 4
Total viable count (TVC) for the blended wastes during the period of digestion

Days	SG: RH	CW:RH	SL:RH
0	$4.6x10^6$	$2.7x10^6$	$1.77x10^6$
5	$6.6x10^6$	$2.7x10^6$	$2.4x10^7$
10	$4.5x10^7$	$2.0x10^7$	$2.6x10^6$
15	$5.2x10^7$	$2.4x10^7$	$6.2x10^6$
20	$1.6x10^7$	$7.4x10^6$	$5.3x10^6$
25	$1.5x10^7$	$8.8x10^6$	$4.5x10^6$

Table 5
Analysis of components of flammable biogas for the blends

Waste Blends	cmponents(%)			
	CO_2	CO	H2S	CH4
SG: RH	23.3	2.1	6.3	68.3
CW: RH	19.5	0.6	2.1	77.8
SL: RH	18.4	0.6	7.5	73.

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