Trends in

Applied Sciences Research

ISSN 1819-3579

Academic Journals Inc.

www.academicjournals.com

Trends in Applied Sciences Research 2 (6): 554-558, 2007
ISSN 1819-3579

Biogas Production from Blends of Agro-industrial Wastes

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Abstract: Biogas production from blends of Agro-industrial wastes-Brewery Spent grain (BS), carbonated soft drink sludge (CS), soya bean cake (SB) and Powdered rice husk (PR) was investigated. The wastes were blended in the ratios of BS: SB (4:1), BS: PR (1:1), CS: SB (2.6:1) and CS: PR (2:3). Results obtained indicated increased biogas production when BS or CS was blended with either SB or PR. The mean biogas production of BS and CS were 7.5 and 6.8 L, respectively. When blended with SB or PR, biogas production of BS increased to 11.40 and 18.90 L, respectively, while an increase of 5.78 L in gas production was obtained from CS: SB combination. There was no significant increase ($p \leq 0.05$) in biogas production from the blend of CS: PR. Quantitative analysis of the biogas from BS: SB blends showed methane (68.3%), CO_2 (23.3%), H_2S (2.1%) and CO (6.3%) while for BS: PR blend, it was methane (71.9%), CO_2 (20.8%), H_2S (0.2%) and CO (7.1%). The overall results indicated that the low biogas and/or flammable biogas production of Brewery Spent grain and Carbonated Soft drink sludge could be enhanced significantly in the presence of either Soya bean cake or powdered rice husk.

Key words: Agro-industrial waste, flammable biogas, waste blends, biogas production, biogas yield

INTRODUCTION

Wastes from agriculture and agro-based industries have been a major source of biogas especially in areas where agriculture forms important part of the economy. These wastes if allowed to litter the environment could pose a lot of health problems as they are potential habitat for pathogenic micro-organisms. Some of them if not properly managed cause damage to soils and farmland. This arises from the processes they undergo in the industries. According to Garba *et al*. (1996), animal wastes, straws, spent grains, wastewaters, etc have been converted to biogas. Biogas which is formed when micro-organisms degrade biological matter (biomass) in the absence of oxygen in a process known as anaerobic digestion is a mixture comprising mainly methane (60-70%) and CO_2 (20-40%) with traces of other gases such as CO, H_2S, NH_3, N_2, O_2, water vapor etc. The percentage composition of each gas in the mixture is dependent on the source of waste and management of the digestion process (Energy commission of Nigeria, 2003). Biogas technology is environmentally friendly and inexhaustible.

Organic wastes as reported by Ofoefule and Uzodinma (2006) can be blended to improve on biogas yield both quantitatively and qualitatively through synergistic effect. Research findings have shown that waste blends such as cattle and pig, cattle and sewage, cattle and weeds, poultry and sewage, poultry and weeds, sewage and weeds (all in the ratio of 50:50), amongst others, yielded improved results (Srinivasan *et al*., 1997; Akinbami *et al*., 2001). Ezeonu *et al*. (2002) also reported an increase in biogas production of over 400% from blending brewery spent grain with poultry

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droppings at a ratio of 4:1. Blending of organic wastes as an optimization technique presents an alternative means of satisfying both rural and urban energy needs in Nigeria.

Brewery Spent grain (BS) and carbonated soft drink sludge (CS) are readily available in the country as a result of manufacturing activities. These wastes have been known to be good sources of biogas. However, on account of their low pH (acidic), the volume of flammable biogas produced is relatively low. Organic wastes like soybean cake waste (SB) and powdered rice husk (PR) with higher pH could be combined with these industrial wastes to enhance flammable biogas production. It is on this basis that these agro-industrial and organic wastes were blended. They were blended in the following ratios: BS: SB (4:1), BS: PR (1:1), CS: SB (2.6:1) and CS: PR (2:3).

MATERIALS AND METHODS

Brewery spent grain and the carbonated soft drink sludge used for this study were collected from Nigerian breweries limited and 7^{UP} bottling company plc, respectively at 9th mile corner, Enugu state, Nigeria. The powdered rice husk was procured from a rice mill at Adani, an agricultural center in Enugu state of Nigeria. The soybean cake waste was obtained from the local processors of soy milk in Nsukka town in Enugu state, Nigeria. The digesters used are the metal prototype digesters of 110 and 136 L capacities constructed locally at the National Center for Energy Research and Development, University of Nigeria Nsukka and the study was carried out from 2005 to 2006 at the same research institute. Other materials used were top loading balance (50 kg capacity. Five Goats model No. Z051599), water troughs, graduated buckets for measuring daily gas production, thermometer (-10-110°C), digital output pH meter (Unified National Inventory Database), hose pipes and biogas burner (fabricated in China) for checking gas flammability.

Charging of Digesters

For the charging of the pure Brewery Spent grain (BS) and carbonated soft drink sludge (CS), the 136 L capacity digesters were utilized while for waste blends, the 136 L capacity digester was used for BS:SB and BS:PR and the 110 L capacity digester was used for the CS:SB and CS:PR blends. A mixture of BS and water (ratio 1:3) and the mixture of CS and water (ratio 1:2) were charged into different digesters. BS: SB (4:1), BS: PR (1:1), CS :SB (2.6:1) and CS: PR (2:3) were mixed with water in the ratios of 1:1.7, 1:2, 1:2.3 and 1:3, respectively and these were subsequently charged into different digesters. The moisture contents of the wastes determined the waste to water ratios used. The digestion was batch operated. Volume of gas production was taken daily using the downward displacement of water (Itodo *et al*., 1995). pH of the system, ambient and slurry temperatures were also monitored throughout the period of gas production.

Analysis of Wastes

Proximate Analysis

Carbon and fat contents of the undigested blended wastes were determined using the Walkey and Black (1934) method. Crude protein and nitrogen were determined using micro-Kjedhal method (Pearson, 1976). Ash, moisture and fiber contents were determined using AOAC method (1990). Total and volatile solids were determined using Meynell (1982) method.

Microbial Analysis

Total Viable Counts (TVC) for both the pure and waste blend slurries were carried out to determine the microbial load of the samples. This was carried out every 5 days using modified Miles and Misra (1938) method.

Gas Analysis

The quantitative analysis of the flammable biogas was carried out to determine the composition of the gases in some of the blends. This was done using the Orsat apparatus in British Standards Institution (1971).

Data Analysis

The data obtained from the volume of biogas production was subjected to one-way analysis of variance. The significant difference in the mean was determined at $p \leq 0.05$.

RESULTS AND DISCUSSION

For the purpose of this study a retention time of 25 days was used. The ambient and influent temperatures for the digester systems ranged from 25-28 and 28-40°C, respectively. The pH of the BS system ranged from 5.03-6.60 while that of CS system ranged from 5.68-7.03 throughout the period of generation of flammable biogas. The production of flammable biogas from each of the systems took place at different lag periods (Table 1). Biogas production for all the BS systems (both pure and waste blends) commenced within 24 h post charging period while onset of gas production from CS was delayed up to 48 to 72 h (Fig. 1). The pure CS waste stopped production of flammable biogas after one and half weeks. This may have resulted from the reduced microbial load observed in the waste (Table 4). The growth of microbes responsible for biogas production is pH sensitive (Energy commission of Nigeria, 2003). Biogas production is usually optimal in the pH range of 6.5-7.5. Below this pH range, microbial load of biomass is drastically reduced. The pH of pure CS (5.20) evidently caused a marked reduction in the microbial load of the waste with a consequent reduction in the biogas produced. The pure BS waste produced flammable biogas after 20 days post charging period. This was achieved at a pH of 6.60. This observation underscored the need for the blending of agro-industrial wastes to achieve adequate biogas yield. Results in Table 2 and 3 show that the pH of SB and PR fell within 6.5-7.5 a pH range which favours anaerobic digestion. The blending process evidently stabilized the wastes for enhanced gas production. Further results of the physicochemical properties of the BS were not so poor as to cause delay in flammable gas production (Table 2 and 3). However, according to Brigas *et al*. (1981), Brewery spent grain is normally thrown out as waste after

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

Parameters	BS	CS	BS: SB	BS: PR	CS: SB	CS: PR
Lag period (days)	20.00	8.00	15.0	2.0	9.0	10.00
Cumulative gas yield (L)	183.60	168.00	285.3	470.9	312.6	184.00
Mean volume of gas production (L)	07.34	06.72	011.4	018.9	012.5	07.42

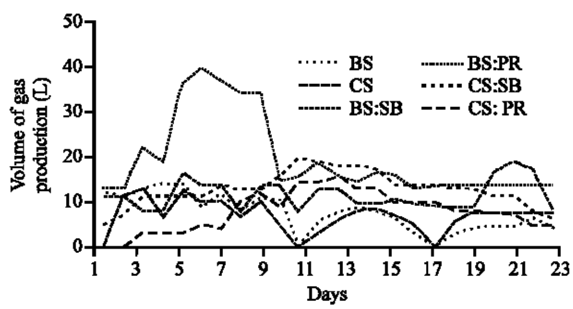

Fig. 1: Daily biogas production

Table 2: Physicochemical properties of the undigested agro-wastes

Parameters	BS	CS	SB	PR
Moisture (%)	14.10	71.35	62.50	10.60
Ash (%)	7.20	3.10	0.45	15.50
Fiber (%)	4.20	1.50	1.40	57.70
Crude nitrogen (%)	1.82	0.07	2.66	1.12
Crude protein (%)	11.38	0.44	16.65	7.00
Fat content (%)	7.30	3.60	13.65	Trace
Energy (Kcal g^{-1})	4.46	4.00	4.05	2.05
Carbohydrate (%)	28.60	21.00	5.95	8.85
pH	5.03	5.68	6.53	7.12

Table 3: Physicochemical properties of the undigested wastes of BS, CS and the blends

Parameters	BS	CS	BS:SB	BS:PR	CS: SB	CS:PR
Crude nitrogen (%)	01.82	0.07	0.36	01.20	03.40	0.42
Total solids. (%)	67.30	47.50	78.20	75.60	79.90	75.80
Volatile solids (%)	14.84	05.94	19.60	16.80	6.60	6.10
Carbon content (%)	47.20	01.67	07.10	31.25	0.16	8.43
C/N Ratio	25.90	23.90	19.70	26.0	21.30	20.00
pH	05.03	05.68	06.31	06.50	06.63	6.30

Table 4: Total Viable Count (TVC) for the pure and blended wastes during the period of digestion

Days	BS	CS	BS: SB	BS: PR	CS: SB	CS: PR
0	1.27×10^6	2.8×10^6	1.50×10^6	4.6×10^6	1.4×10^6	1.77×10^6
5	3.83×10^6	6.83×10^6	2.30×10^7	6.6×10^7	2.3×10^7	2.4×10^7
10	4.54×10^7	3.2×10^6	2.70×10^7	4.5×10^7	5.1×10^7	2.6×10^6
15	6.15×10^7	1.06×10^6	1.10×10^6	5.2×10^7	7.3×10^7	6.2×10^6
20	3.10×10^7	1.47×10^7	2.10×10^7	1.6×10^7	1.5×10^7	5.3×10^6
25	2.15×10^7	1.2×10^5	3.20×10^7	1.5×10^7	2.2×10^6	4.5×10^6

Table 5: Analysis of components of flammable biogas for the blends with enhanced yield

	Components (%)			
Waste blends	CO_2	CO	H_2S	CH_4
BS: SB	26.5	7.8	0.2	65.5
BS: PR	23.3	6.3	2.1	68.3
CS: SB	20.8	7.1	0.2	71.9

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 viable load in addition to blending the waste before anaerobic digestion. Results in Table 4 showed enhanced level of viable microbial load as the days progressed for the pure and waste blends. The low flammable gas production of the BS and the CS was enhanced significantly from blending of the two wastes with soybean cake and powdered rice husk as shown by mean volume of gas production (Table 1). There was no significant increase ($p\leq 0.05$ within 95% confidence level) in the biogas production from the blend of CS: PR. This could be accounted for by the fact that CS waste is mainly carbonaceous and has high moisture content (71.3%) and PR waste has high fiber (57.7%), low nutrients (carbohydrate, protein and fat which is in trace amount) and least energy content (Table 2). The low yield of gas production of the CS: PR blend is further indicated by the result of the viable microbial load in Table 4 which was generally lower than the other blends. The BS: PR blend had the shortest time lag and the highest mean volume gas yield (Table 1). In addition to the effect of pre-decaying the waste for about one week before anaerobic digestion took place, the blend had high volatile solids (the biodegradable matter in the waste) and the C/N ratio which is a key parameter for anaerobic digestion was the highest (Table 3). This value is close to the recommended value of 30:1 as anaerobic bacteria use up carbon 30 times faster than nitrogen (Kanu, 1988). This was followed by the CS: SB blend with a lag time of 9 days and mean biogas volume yield of 12.5 L. The result of the quantitative analysis of the flammable biogas components of the blends with enhanced yield is shown in Table 5 and indicates that methane was highest in all the blends while CO_2, H_2S and CO were found in various proportions depending on the type of the waste.

CONCLUSIONS

The overall results indicated that the low flammable biogas production of Brewery spent grain and carbonated soft drink sludge could be enhanced significantly in the presence of either soybean cake waste and/or powdered rice husk. The blending of BS with PR gave the best optimization result in terms of onset of flammable biogas production and cumulative yield of gas produced. Waste stabilization for reasonable biogas production was achieved by blending these wastes. This is expected to provide a lee-way for effective utilization of these two agro-industrial wastes for efficient biogas production. Further investigation on the blending ratio of BS with PR to achieve the optimum enhanced flammable biogas yield will constitute a separate report.

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