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Optimum Mesophilic Temperature of Biogas Production from Blends of Agro-Based Wastes

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Abstract: The optimum mesophilic temperature of biogas production from blends of agro-based wastes was determined under constant supply of heat. Cassava waste water (CW), Brewery spent grain (BS), Powdered rice husk (PR), Cow dung liquor (CD) and Swine dung (SD) were blended in the ratios of CW: SD (2:3), BS: PR (1:1) and BS: CD (1:3). Biogas production from the waste blends was monitored under the mesophilic temperatures of 25, 30, 35 and 40°C. Results obtained indicate steady increase in biogas production at temperatures of 35 and 40°C for all the blends while maximum cumulative gas yield was observed at the temperature of 40°C. The BS:CD blend gave the highest biogas yield of 2.51 L followed by the BS: PR blend with the cumulative yield of 1.21 L. The CS: SD blend had the least cumulative biogas yield of 1.13 L. These results indicate that increased and steady biogas production can be achieved under the optimum mesophilic temperature of 40°C when these agro-based wastes are blended in different proportions.

Key words: Agro-based wastes, biogas production, biogas yield, mesophilic temperature, waste blends

INTRODUCTION

The anaerobic digestion process is carried out by a delicately balanced population of various bacteria. These bacteria can be very sensitive to changes in their environment and temperature is a prime example. The two types of bacteria (acidogens and methanogens) which are actively involved in the anaerobic digestion operate at three different temperatures; psychrophilic or ambient temperature (< 25°C), mesophilic (25-40°C) and thermophilic (45-60°C) (El-Mashad, 2004). Fluctuations in temperature can result to either decrease in bacterial activity or death of bacteria subsequently leading to decrease in biogas production. Insulation, heat exchangers, heating elements, water-baths and steam injections are all means which have been used to control digester temperature. Temperature control is an important consideration when designing digesters. (http: file:// A:\ Design -Tutor. htm., 2003). Even though, anaerobic digestion can occur at room temperature, any method of maintaining digester temperature constant near the optimum will improve digester performance. Thermophilic fermentation is characterized by rapid digestion, high gas yield and short retention time. This process is used for disposal of excreta and other wastes because of good disinfection it achieves. Fermentation at the mesophilic range has the advantage of lower energy consumption as the decomposition of the feedstock is slower. This process is widely adopted throughout the world (Anonymous, 1989). Digestion at the mesophilic range also has the additional

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advantage of slower death rate for specific microbes (bacteria) resulting to more stability of the waste in the digester. Duran and Speece (1997) reported the death of faecal *Coliform*, *Salmonella* and *Entrococcus* to be slow under this mesophilic conditions. Watanabie *et al*. (1997) also discovered that *Salmonella* and *Mycobacterium paratuberculosis* were inactivated within 24 h under thermophilic conditions leading to decrease in biogas production whereas, Sahlstrom (2003) reported that it took months for the bacteria to be inactivated under mesophilic conditions. Nigeria as one of the regions close to the equator (Latitude 40°N and 15°N) is within the tropic regions where mean total solar radiation received is as high as 5.08 Kw m^{-2} per day (World Energy Council, 1993). As a result, the sunshine potential is fairly distributed throughout the country. Yet due to seasonal changes, the use of solar energy to maintain the mesophilic temperature is difficult. At ambient temperature, anaerobic digestion is much influenced by earth temperature which is related to the atmospheric temperature and this leads to decreased yield in gas production (Dioha *et al*., 2006). This effect is even worse for surface digesters which may be in the form of concrete, metal prototypes or commercialized plastic designs. Chang *et al*. (2006) reported that a sudden decrease in temperature from 55 to 20°C for a digester system under thermophilic condition at different retention times resulted to almost stoppage of gas production, rapid accumulation of free fatty acid accompanied by decrease in pH. Anaerobic digestion for optimum biogas production is temperature dependent (Hashimoto and Varriel, 1979; Smith *et al*., 1979; http: file:// A:\ Design-Tutor. htm, 2003). While Hashimoto and Varriel (1979) and Smith *et al*. (1979) reported 40 and 55°C as optimum temperature for anaerobic digestion at mesophilic and thermophilic range, respectively, http: file:// A:\ Design-Tutor. htm. (2003), reported 35°C as an ideal temperature for anaerobic digestion. This report though not specific on the basis of mesophlilc or thermophilic conditions, highlight the need to take into consideration other environmental conditions that may influence the exact temperature at which optimum biogas production occurs especially at the mesophilic range. One of such environmental conditions is change in pH which usually occurs when agro-wastes are blended in the different proportions. Earlier reports (Hashimoto and Varriel, 1979; Smith *et al*., 1979; http: file:// A:\Design-Tutor. htm, 2003). were based on results obtained with single agro or organic wastes. A survey of current literature shows that no investigation has been carried out to establish the optimum temperature for biogas production from waste blends in the mesophilic range. Against this background, this study was undertaken to determine the optimum mesophilic temperature for the digestion of some blends of agro-based wastes. Cassava waste water (CW), Brewery spent grain (BS), Powdered rice husk (PR), Cow dung liquor (CD) and Swine dung (SD) were blended in the ratios of CW: SD (2: 3), BS: PR (1:1) and BS: CD (1: 3).

MATERIALS AND METHODS

The Cassava waste water used for this study was obtained from one of the local processors of Garri (a staple food in Eastern part of Nigeria), while the powdered rice husk was procured from a local rice mill in the same area. The cow dung liquor was obtained from an abattoir. The swine dung was collected from the vertinary farm, University of Nigeria Nsukka. The Brewery spent grain was collected from Nigerian breweries Limited, Enugu. Nigeria. The study was carried out at the National Center For Energy Research and development, University of Nigeria, Nsukka in 2006. The digesters used were 1liter Buckner flak constructed as micro digesters. Other materials used are 2 L glass measuring cylinders (Pyrex) for measuring biogas production, plastic water troughs, metal stand and clamp, hose pipe, thermostatically controlled water bath (Gallenkamp), thermocouple, digital weighing balance and digital pH meter (unified National inventory database).

Charging of Digester

The waste blends were charged using 1 L micro digesters. A 150 g of each of the waste blends were charged into the different digesters. CW: SD (2:3), BS: PR (1:1) and BS: CD (1:3) were mixed with water in the ratio of 1:1, 1:2 and 1:1, respectively and were subsequently charged in the different digesters. The moisture contents of these wastes determined the waste to water ratios used. The experiment was carried out in the laboratory using thermostatically controlled water bath as the source of heat. The digestion was batch operated. Volume of gas production was taken daily using downward displacement of air over water at temperatures of 25, 30, 35 and 40°C. The slurry temperature of the systems were recorded using thermocouple. Ice block was occasionally used to lower the temperature of the water bath to the desired mesophilc temperature of 25°C. pH of the systems were also monitored throughout the period of gas production.

The ambient temperature of the laboratory was 28°C throughout the period of the experiment while that of the water bath ranged between 29 and 30°C.

Analysis of Waste Blends

Total and volatile solids were determined using Meynell (1976) method. Crude nitrogen content was determined using the Micro-Kjedahl method (Pearson, 1976) while carbon content was determined using Walkey and Black (1934) method.

RESULTS AND DISCUSSION

A retention period of seven days was used for the experiment. Gas production commenced within 24 h post charging period (Fig. 1-3). The results in these figures also indicate that volume of gas production was generally low at 25°C for all the waste blends. This may be attributed to the low temperature because at that temperature, the methanogens are not sufficiently activated for enhanced biogas production. This will consequently lead to low biodegradation of the organic wastes and poor yield of gas production. At the temperatures of 35 and 40°C, there was higher biogas yield as a result of higher rates of biological degradation (Fig. 1-3) (Huan *et al*., 1982). The cumulative biogas yield for each of the waste blends, show the highest performance at 40°C (Table 1). The BS:CD blend had the highest cumulative biogas yield of 2.51 L. This observation underscores the superiority of cow dung

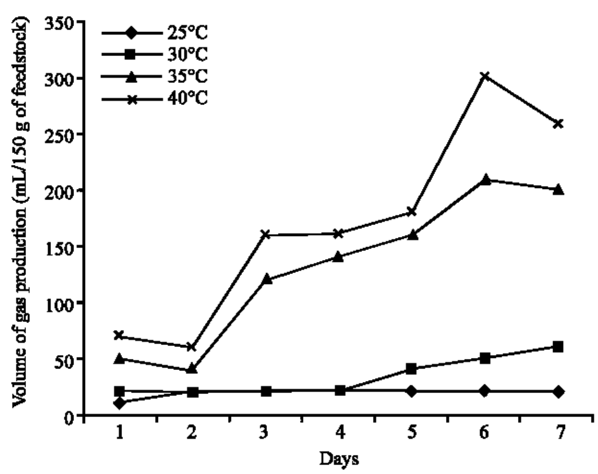

Fig. 1: Daily biogas production for the CW: SD blend. (Cassava waste water (CW): Swine dung (SD)

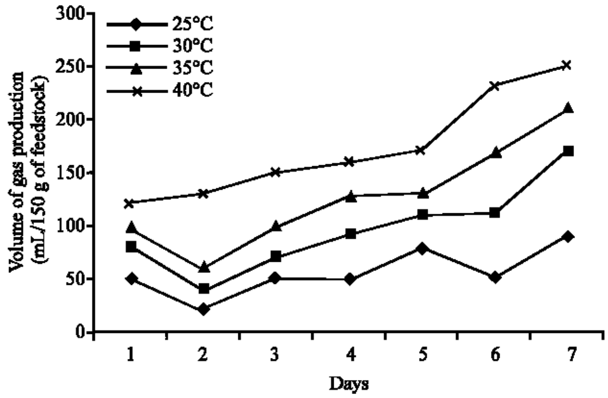

Fig. 2: Daily biogas production for the BS: PR blend. (Brewery spent grain (BS): Powdered rice husk (PR)

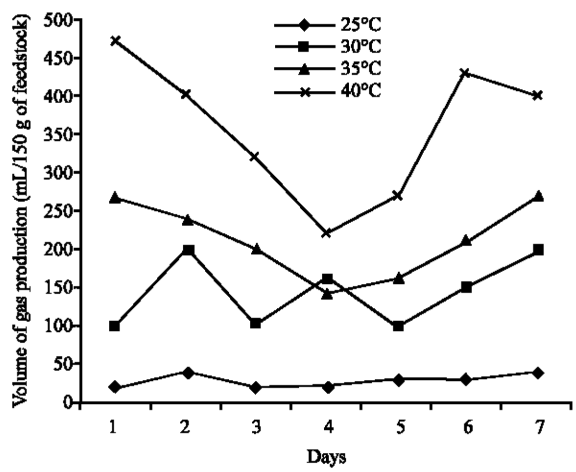

Fig. 3: Daily biogas production for the BS: CD blend. (Brewery spent grain (BS): Cow dung (CD)

Table 1: Cumulative biogas yield for the waste blends. Yield at various temperatures (L/150 g of feedstock) for seven days

Waste blends	25°C	30°C	35°C	40°C
CW: SD (2: 3)	0.13	0.23	0.92	1.13
BS: PR (1: 1)	0.39	0.67	0.90	1.21
BS: CD (1: 3)	0.20	1.01	1.49	2.51

to other wastes in quantitative and qualitative biogas production (Odeyemi, 1987; Dioha *et al*., 2005; Ofoefule and Uzodinma, 2006). In addition to temperature, Biogas production is dependent on so many other factors working together to ensure effective biogas production. These factors include biodegradability of the feedstock, pH, carbon to nitrogen ratio etc. The relative low volume of gas production observed for the CW: SD blend at the various mesophilic temperatures when compared with the other waste blends could be attributed to the low C:N ratio which was the least and below the acceptable limit (26:1-30:1) (Kanu, 1988; Garba *et al*., 1996). Anaerobic bacteria use up carbon 30 times faster than nitrogen. Apart from the increased temperature at 40°C, the result of the physicochemical properties of the waste blends indicates that the BS:CD blend had high enough volatile solids and the pH which fell within the acceptable limit (Table 2). It also contained relatively adequate C: N ratio.

Table 2: Physicochemical properties of the undigested waste blends

	Waste blends		
Parameters	CW: SD (2:3)	BS: PR (1:1)	BS:CD (1:3)
Total solids (%)	53.20	93.060	75.60
Volatile solids (%)	13.50	4.630	16.80
Carbon (%)	4.86	5.700	31.25
Nitrogen (%)	0.20	0.220	1.20
C.N ratio	24.30	25.900	26.00
pH	7.37	6.500	6.53

CONCLUSION

The results show that the upper limit of the mesophilic range gives a higher biogas yield. The Optimum temperature observed from the experiment is at 40°C. Therefore to achieve enhanced and constant generation of biogas for effective distribution and end use, it is expected that a constant temperature be maintained through the use of insulations, heating elements, heat exchangers, steam injections or water baths. Secondly, maintaining the pH of agro-based waste blends at optimum for biogas production is important in achieving the optimum mesophilic temperature for biogas production.

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