IMPACT OF DRY/WET SEASONS ON BIOGASIFICATION OF ABATTOIR WASTE IN OWERRI (NIGERIA)

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Abstract
Batch digesters were set-up for anaerobic digestion at ambient temperatures for 15-days retention period; one set in the dry season, the other set in the rainy season. The feedstock used was gastro-intestinal content (GIC) of slaughtered beef cattle. Biogas samples were collected daily and measured using water displacement method, while biomethane content was determined using a RKI GX 2012 gas monitor. The cumulative biogas/biomethane yields for the dry season experiments were 1577 mL/1353 mL (47.79 mL g^{-1} TS / 41 mL g^{-1} TS) respectively, while 745 mL/670 mL (13.47 mL g^{-1} TS / 12.12 mL g^{-1} TS) were recorded for biogas/biomethane yields respectively in the rainy season. The feedstock used in the dry season had a pH of 7.1 (34^{o}C), total solids of 11%, and volatile solids of 81.82%; while that used in the wet season had a pH of 6.2 (30.5^{o}C), total solids of 18.43%, and volatile solids of 80%. The Minimum, mean, and maximum temperatures records were higher in the dry season. On the other hand temperature fluctuations were more sporadic in the rainy season. Statistical analysis revealed highly significant differences in the volumes of biogas (and biomethane content) produced in both seasons. Significant differences were also observed between minimum, mean, and maximum temperatures respectively of both seasons.

Keywords: anaerobic digestion, gastro-intestinal content, biogas, season.

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1.INTRODUCTION

One of the nagging environmental problems of today's society is the continuously increasing production of organic waste. In many countries, sustainable waste management has become a major political priority, representing an important share of the common efforts to reduce pollution and green house gas (GHG) emissions, and to mitigate global climate changes. Uncontrolled waste dumping is not acceptable today and even controlled landfill disposal, and incineration of organic wastes are no longer considered fashionable practices with emerging environmental standards (Al Seadi et al., 2008).

Anaerobic digestion (AD) of organic waste, such as animal waste and energy crops for bio-energy production, is a widely accepted and applied technology (Angelidaki et al., 2009). Abattoir wastewater is well suited for AD because of its high organic matter content (Mittal, 2006). The suitability of abattoir waste for biogas production has been confirmed by many workers (Rabah et al., 2010a; Rabah et al., 2010b; Budiyono, 2011; Nda-Umar and Uzowuru, 2011).

Basically, in developed nations with advanced technology and readily available energy options, AD is principally applied to the stabilization of organic waste; whereas in developing countries, where energy is in short supply and expensive, AD has far greater relevance. In such countries, apart from its use in waste treatment and management, AD has been primarily focused on energy production via biogas plants. This thrust is particularly strong in Asia, with China and India leading (Abassi et al., 2012).

Documented reports suggest that AD can take place at different temperatures ranging from below 20^{o}C to 60^{o}C (Al Seadi et al., 2008). However, for efficiency, anaerobic digesters are designed to operate typically in either mesophilic (20 – 40^{o}C) or thermophilic (50 – 60^{o}C) temperature ranges (Nordberg, 2006; Balasubramaniyam et al., 2008). Though biogas yield and quality (methane content) improves with increasing overall process temperature (Ogejo et al., 2009), in terms of production cost efficiency, the mesophilic temperature range of 32-35^{o}C appears to favour optimum biogas production (Omer, 2011). This therefore suggests that, tropical climatic temperatures for most part of the year are conducive for biogasification of organic waste.

In Nigeria, prevailing climate permits average solar radiation as high as 5.538 kWh/m^2/day, thus, making the country operate under mesophilic temperature at ambient condition (Ofoefule et al., 2010). Accounts of researchers operating in different parts of Nigeria, experimenting on biogas production from various organic wastes, have demonstrated that ambient temperatures in Nigeria are ideal for significant biogas generation from different biomass: from banana and plantain peels (Ilori et al., 2007); from poultry dung, cow dung, and kitchen waste (Ojolo et al., 2007); from cassava waste (Eze, 2010), from swine, rabbit, and goat dung (Ofoefule et al, 2010); from maize bract waste (Uzodinma et al, 2011); from horse dung (Yusuf et al., 2011); from municipal solid waste (Agulanna et al., 2012); from cowpea waste (Rusell et al., 1981).

The purpose of this study is to evaluate the impact of prevailing seasonal (dry and wet) temperatures in Nigeria on biogas yield from gastro-intestinal content (GIC) of slaughtered beef cattle (abattoir waste) in a batch AD operating at ambient temperatures. Gastro-intestinal content of slaughtered beef cattle constitutes over 65% of abattoir waste in Nigeria (Chukwu et al., 2011). Owerri city (5.4850° N, 7.0350° E), located in southeastern Nigeria, with a documented mean ambient temperatures of 27±4^{o}C and 31±2^{o}C in rainy and dry seasons respectively (www.en.wikipedia.org), was the chosen location where the experiments for this investigation were carried out.

Materials and Methods

Sample collection.

The gastro-intestinal content (GIC) of slaughtered beef cattle was collected immediately after slaughter from an abattoir in Owerri North local government area of Imo state (Nigeria).

Preparation of feedstock slurries

For each digester, 300g of GIC (feedstock) was thoroughly mixed in 300mL of untreated borehole water to form homogenous slurry.

Experimental set-up

Each feedstock slurry was subjected to anaerobic digestion using 0.23m^3 (2262.9cm^3) stainless steel anaerobic jars operated as batch digesters at ambient temperatures for a retention time of 15 days. The candle jar method was used to achieve anaerobiosis (Wistreich, 2003). The batch digesters were mixed daily manually by gently shaking or swirling them. Both dry and wet season experiments were performed in triplicates. The dry season digestion was commenced on 17th November, 2012, while that of rainy season was started on 23rd July, 2013. Both set-ups were operated for a retention time of 15 days.

Collection and measurement of gas samples

Biogas samples were collected and measured daily by measuring the downward volume displacement of water in a transparent calibrated vessel (Nda-Umar and Uzowuru, 2011). Biomethane measurements were taken using a RKI GX2012 gas monitor.

Daily temperatures

Daily temperatures were obtained from Weather Underground (www.wunderground.com).

Physicochemical analysis

The temperatures of the feedstock slurries and digestates were measured using a thermometer, while their pHs were determined with a Hanna Instrument pH meter (Model: H196107). Total solids (TS) and volatile solids (VS) were determined using standard procedures described by Pillai (2009).

Data analysis

All biogas/biomethane readings recorded were the computed average of triplicate experiments. Graphs and ANOVA were generated using Microsoft Excel 2003 software.

Results and Discussions

Table 1 displays the pH of feedstock slurries and digestates; total solids (TS) and volatile solids (VS) of feedstock. The feedstock used in the wet season had higher total solids but lower pH values than the feedstock used in the dry season.

Table 1. pH, Total solids, and Volatile solids.

	Dry season	Wet season
pH (feedstock slurry)	7.1 (34°C)	6.2 (30.5°C)
pH (digestate)	7.4 (29°C)	6.5 (27°C)
Total solids (TS) of fresh wet mass (feedstock)	11%	18.43%
Volatile solids (VS) of TS (feedstock)	81.82%	80%

Figures 1 and 2 show the daily biogas readings during the dry and rainy seasons respectively. While Figure 1 gives a picture of a progressive pattern of biogas production during the dry season, Figure 2 depicts a regressive pattern during the rainy season. The total biogas production during the dry season was 1577 mL or 47.79 mL g^{-1} TS (daily average of 105.13 mL) with 85.80% biomethane content, while total biogas production during the rainy season was 745 mL or 13.47 mL g^{-1} TS (daily average of 49.67 mL) and with a 90% biomethane content. The seemingly high biogas/biomethane readings of days six and two of Figures 1 and 2 respectively were due to gas accumulation during the previous days when no gas readings were taken.

Figures 3 and 4 show temperature readings obtained from Weather Underground (http://www.wunderground.com), Figure 3 shows a relatively regular temperature differentia during dry season, while Figure 4 reveals a rather sporadic pattern during the rainy season.

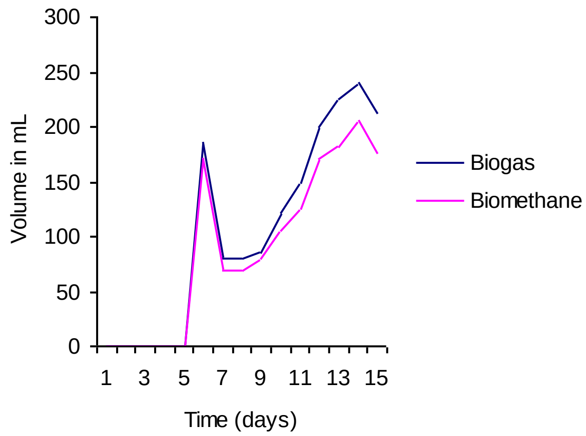

Figure 1. Daily biogas readings in dry season

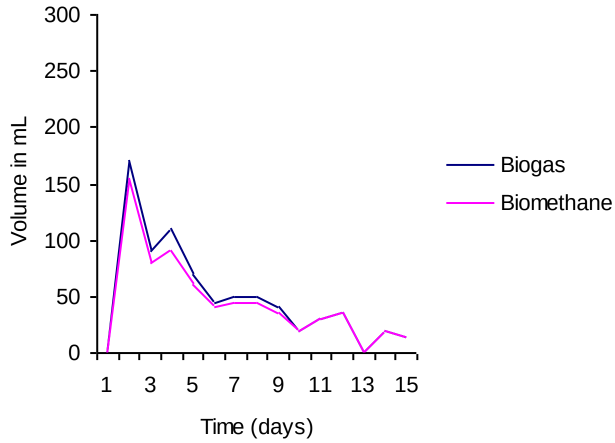

Figure 2. Daily biogas readings in rainy season

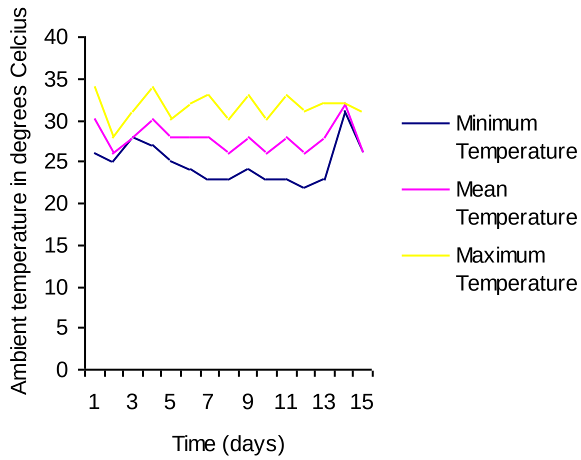

Figure 3. Ambient daily temperatures in dry season
**Source: http://www.wunderground.com*

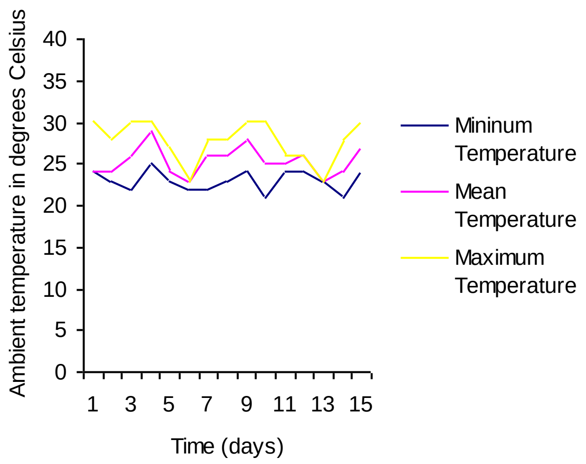

Figure 4. Ambient daily temperatures in rainy season.
*Source: http://www.wunderground.com

Biogas yield potential increases with total solids content of substrate (Al Seadi et al., 2008). Though the feedstock used in the rainy season had a higher TS content than that used in the dry season, it still yielded lower biogas/biomethane volumes. This therefore eliminates the TS factor as the reason for lower biogas yields during the wet season. However the lower pH of feedstock used in the wet season could have been a factor to its poor biogas yield as metabolism is considerably suppressed for most methanogens at pH<6.7; only *Methanosarcina* is able to withstand lower pH values (Deublein and Steinhauser, 2008). The lower pH of feedstock in the wet season may be related to diet. Dry grass is lower in carbohydrates than the fresh plants (Uzodinma et al., 2011), and low dietary carbohydrate content in turn increase the intestinal pH of cattle (Rusell et al., 1981). Hence the forage the cattle grazed on may have contributed indirectly in biogas yields by adjusting intestinal content pH levels. This is of great importance since the GIC evaluated in this study was from nomadic grazing cattle whose diet is basically herbage.

ANOVA revealed significant difference at 1% and 5% levels of significance between dry and rainy seasons for biogas and its biomethane contents. Significant difference was seen in the minimum, mean, and maximum temperatures of both seasons respectively at 1% and at 5% levels of significance. Significant difference between seasons for minimum, mean, and maximum temperatures respectively was also observed – significant difference was seen at 1% and 5% levels of significance for mean and maximum temperatures, and at only 5% level of significance for the minimum temperatures. Though variation in ambient operation temperature affects biogas yield, AD and subsequent biogas production appear to be affected even more by temperature fluctuations (Mahanta et al., 2005). Bouskova and co-workers reported that instantaneous temperature changes caused an initial disturbance in digester performance, which however stabilized after 30 days (Bouskova et al., 2005). Mesophilic AD is said to be considerably stable in temperature variations of up to 5^{o}C, unlike in thermophilic AD where small variations in temperature (0.5 – 2^{o}C) causes a substantial decrease in the process. This is attributed to the fact that thermophilic methanogens are more sensitive to temperature changes than mesophilics (Navickas et al., 2013). It has also been documented that temperature fluctuations at higher mesophilic temperatures are better tolerated than fluctuations at lower mesophilic temperatures (Choorit and Wisarnwan, 2007; Chae et al., 2008; Gao et al., 2011). According to Gao *et al*. (2011) temperature shocks are to be expected more with temperature shifts at the edge between psychrophilic/mesophilic temperatures (25^{o}C) and mesophilic/thermophilic temperatures (45^{o}C). Though there were lower average temperatures in the rainy season, temperature fluctuations were actually evident in both dry and rainy seasons. However fluctuations occurring at lower mesophilic temperatures, rather than just the issue of lower ambient temperatures may have principally accounted for the drastically reduced biogas and biomethane output during the wet season. The lower ambient temperatures in the rainy season and sporadic temperature fluctuations, in turn, may have been caused by series of intermittent rainfalls occurring during the period. There were about six rainfalls during the period of the rainy season set-up, while there was no rainfall during the dry season set-up.

Conclusions

Biogas and biomethane productions were reduced by 52.24% and 50.48% respectively in the rainy season. It is apparent that season had a highly significant effect on biogas production for a batch digester operated at ambient temperature in Owerri of southern Nigeria. From results obtained in this research, ambient temperatures and pH of feedstock were most implicated. Results from this work may be said to hold true for the whole of southern Nigeria which share a very similar weather pattern, except for the coastal communities where slightly lower temperatures abound and rainfalls are more frequent. Southern Nigeria is defined by its tropical rainforest climate, with 60 – 80 inches of annual rainfall, and bordered by the Gulf of Guinea on the Atlantic Ocean in the south. Northern Nigeria, on the other hand, is characterized by a savannah climate with no coastal borders, annual rainfall of 20 – 60 inches, and an encroaching Sahara desert in far north. Hence, the Northern part of Nigeria with higher annual ambient temperatures and lower rainfalls may promise a better all year round biogas yield for digesters operating at ambient temperatures. Nevertheless, very simple designs may be adopted in Southern Nigeria with a view to elevating and stabilizing operational temperature, such as: digester lagging or burying (partially or completely) digesters underground. Another way may be to situate the digester in a greenhouse (glasshouse), where elevated temperatures will be retained for longer periods.

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