

Comparative Study of Biogas Production from Sugarcane Bagasse and Cow Dung

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Abstract

Renewable energy such as the Biogas has recently been receiving attention. This may be connected to numerous advantages including energy security, and sustainability. However, several challenges including amount of gas produce, nature of substrate, high cost of production remains a problem. This research aimed at investigating biogas production from sugarcane bagasse, cow dung and co-digestion of the two substrates. In this research, sugarcane bagasse which is one of the most common wastes cellulosic materials was used as substrate to generate gas and to compare the rate of production with the most common substrate use (cow dung). Sample of sugarcane bagasse and cow dung were obtained from Katsina metropolis. Samples were initially, processed (dried, and ground to powder) before preparing slurry in a specialized bioreactor that was constructed using a 900g tin. Three different sets of biogas were made including reactor containing co-digestion of bagasse with cow dung, cow dung alone and sugarcane bagasse alone. The gas generated was allowed only one passage via a tube and collected by downward delivery. The result shows that the digester containing co-digestion of sugarcane bagasse and cow dung has the highest cumulative biogas generation of 74.00 cm³, followed by the digester containing cow dung only which produces a total volume of 52.00 cm³, while the digester containing sugarcane bagasse only has a cumulative biogas generation of 39.00 cm³ with a pH range of 4.6 - 6.6. It was found that, agricultural wastes such as groundnut shell, rice straw maize cobs and sugarcane bagasse which naturally have been dumped carelessly as domestic waste especially when co-digested can provide an alternative substrate for efficient biogas production.

Key words: Sugarcane bagasse, Biogas, Cow dung, co-digestion

INTRODUCTION

The global interest in renewable energy is receiving researcher's attention worldwide (Verstraete *et al.*, 2005). The conventional energy sources such as the fossil fuels are believed to be causing ecological and environmental problems including oil pollution and acid rain (Sreerishnan *et al.*, 2004). Biogas technology offers an interesting opportunity of utilising different organic materials including agricultural and domestic waste to generate energy (Angelidaki and Ellegaard, 2003; Sreerishnan *et al.*, 2004). Biogas can be compressed and use in automobiles, cooking gas and in generating electricity or heat. It is a promising source of energy and was thought to have the potentiality of replacing the conventional methane (Korres *et al.*, 2011). For instance, in United State, 50% of energy needed could be achieved if there is proper implementation of renewable energy technology (Pimentel *et al.*, 2002).

Biogas production involves the anaerobic decomposition of organic materials by microorganisms to release energy in the form of bio-methane (CH₄) and traces of other gases

including carbon dioxide (CO₂) and hydrogen sulphide (H₂S) (Korres *et al.*, 2011). The microbial community involved in biogas production may differ depending on the nature of substrate used and environmental conditions (Korres *et al.*, 2011). Moreover, biogas production occurs in three major stages. The hydrolysis stage which involved the enzymatic mediated transformation of complex organic materials including the high molecular weight compounds such as lipid, proteins and fats to low molecular weight or single units such as amines, then followed by (second stage) the conversion of this low unit molecules to acetic acid, hydrogen and carbon dioxide and finally (third stage) the conversion of those compounds (acetic acid, hydrogen and carbon dioxides) to methane (Roth, 1983). Similarly, different microorganisms including bacteria (*Clostridia*, *streptococci*, *methanogens*) and fungi (*Rhizopus* and *Aspergillus*) are involved in a different stage of production with methanogens dominating the final steps (Roth, 1983) while the action of Archaea and Eubacteria is regulated by environmental factors.

Substrate Used in Biogas Production

Biogas production provides a sustainable solution to recycle and re-use waste in a cost-effective approach (Okot-Okumu and Nyenje, 2011). A number of organic substrates have been utilised in biogas production including sewage sludge, chicken droppings, cow dung and pig manure. Other agricultural waste includes sugarcane bagasse and rice husk (Kalra and Panwar, 1986; Mahadevaswamy and Venkataraman, 1986; Fan *et al.*, 2006; Carrère *et al.*, 2009). In general, cheap and relatively abundance substrates are utilised to support the 3R concept (Reduce, re-use and recycle). Sugarcane bagasse is one of the major agro-industrial by-products. It is a cellulosic by-product of sugar industries obtained by complete extraction of sugar juice from sugarcane. Bagasse composed of about 50% cellulose, 25% lignin, and 25% hemicellulose and is utilised in a different process including the manufacture of pulp and building materials (Pandey *et al.*, 2000). In recent years, researchers have focused towards utilizing agro-industrial waste including bagasse in renewable energy generation. A number of reports have indicated the use of sugarcane bagasse in ethanol production (Martin *et al.*, 2002); butanol and in heat generation (Rabelo *et al.*, 2011) other chemical and metabolites products may include alkaloids, protein-enriched animal feed (single cell protein) (Pandey *et al.*, 2000). Today, high demand of energy especially the conventional fossil fuel has resulted in the over exploitation of these resources. The conventional fuels are toxic to the environment and cause a lot of negative consequences. In lieu of the circumstances, Studies have shown the use of agro-industrial waste including sugarcane bagasse and food ruminant in biogas generation. However, not much has been reported on the use of sugarcane bagasse in biogas production. These may be connected to difficulty in hydrolysis stage and other growth supplements resulting in low output volume (Rodríguez-Vázquez and Díaz-Cervantes, 1994; Kivaisi and Eliapenda, 1995; Pandey *et al.*, 2000; Sreekrishnan *et al.*, 2004; Osman *et al.*, 2006). Consequently, the aim of this research is to study the effect of sugarcane bagasse and cow dung in biogas generation. This study will also compare and determine the rate of biogas production from co-digestion of sugarcane bagasse and cow dung.

MATERIALS AND METHODS

Sample Collection

Sample of sugarcane bagasse were collected from the sugarcane sellers at Katsina metropolis. The samples were processed (i.e. dried and ground to powder) at the Umaru Musa Yar'adua University Biology laboratory. Similarly, Cow dung was collected from cattle market located at abattoir in Katsina metropolis, the sample was also processed at the same laboratory for further analysis.

Locally made biogas digester was constructed after Abubakar (2017). The laboratory biogas set up involves the construction of digesters, the slurry preparation and the generation of the gas.

Construction of Digesters

Three sets of 900g tin were used as digesters. Peak milk tin was washed using a brush, a small hole was made to serve as the channel to which the gas produced will be passed to the collecting cylinder. The hole and the tin were tightly and well created to prevent linkage /escape of the gas. The process was done taking into consideration of protocol reported by Abubakar (2017).

Preparation of Slurry

Three sets of improvised bioreactors were cleaned and level as **A**, for cow dung, **B** for sugarcane bagasse and **C** for the mixture of sugarcane bagasse and cow dung respectively. The slurry was prepared after Abubakar (2017). 30g of cow dung and sugarcane bagasse were introduced into the digester labelled **A** and **B** respectively containing 1000 ml of deionized water. The digesters and were gradually and thoroughly stirred. The prepared rubber cork is put in to the openings to ensure air tightness (Figure1). The same procedure was repeated with 15 g of sugarcane bagasse mixed with 15 g of cow dung and pour into digester labeled **C** containing 1000 ml of deionize water. The connecting tube of the digesters were connected in such a way to allow the passage of the gas produced to be collected by downward delivery and measured using inverted cylinder. The downward displacement of water in the measuring cylinder was recorded as the volume of gas produces at 24 hrs intervals for 10 days. The initial temperature and pH of slurry was initially recorded and also the laboratory temperature was recorded daily over the same period.



Plate 1: The Digester Set-up for the Production of Biogas.

Microbial Enumeration of Digested Sample

Immediately after the biogas experiment, sample of the digested slurry from the three digesters were taken for microbial extermination. This mainly includes the total number of bacteria presences in the sample. A serial dilution was carried out and a dilution factor of 10^6 was used to inoculate fresh Nutrient agar plates (which was prepared using standard techniques as described by its manufacturer) plates were incubated at 37°C for 24hrs under anaerobic condition, the colonies developed were counted using colony counter.

RESULTS

Gas Production

Based upon the gas production result, sugarcane bagasse digester produces less volume of gas with a value 39 cm^3 when compares with cow dung digester which produces 52 cm^3 (Figure 1) after 10 days. However, a much higher volume of gas was observed when combine effect of cow dung and sugarcane bagasse was used with a total volume of 74 cm^3 (Figure 1) of gas generated after 10 days.

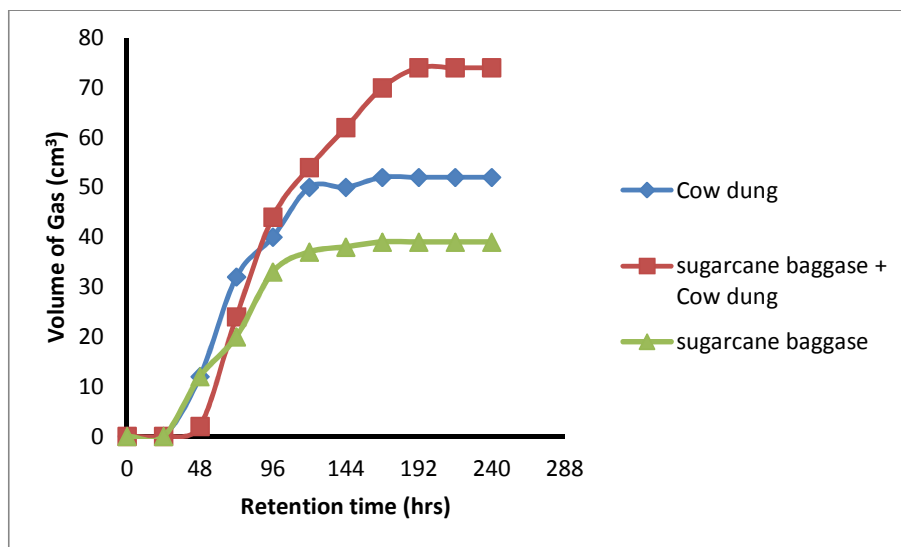


Figure 1: The Rate of Gas Production From Different Substrate

Similarly, comparing biogas production among the three setup (Cow dung, sugarcane bagasse and co-digestion) using analysis of variance has revealed a significant different amongst the three reactors ($p < 0.05$). The analysis of variance has revealed differences between cow dung and sugarcane bagasse reactor after 5 days.

Physico-Chemical Parameters

During the experimental processes, the temperature range between 32°C to 36.5°C. while for the pH a fluctuation was observed among the three digesters and in this, Digester C (containing mixture of cow dung and sugarcane bagasse) has 4.6 to 6.6 and differs with digesters containing A cow dung and sugarcane bagasse only B which has between 5.49 to 6.1 and between 4.1 to 6.2 respectively.

Bacterial Population in the Biogas Digesters

The microbial count conducted to estimate the microbial population in different digesters shows a higher bacterial count in the digester containing the mixture of cow dung with sugarcane bagasse (8.2×10^6 cfu/ml) when compared with the digesters containing cow dung and sugarcane bagasse which has 5.7×10^6 cfu/ml and 5.4×10^6 cfu/ml Respectively.

DISCUSSION

Renewable energy such as the Biogas is currently receiving researcher's attention all around the world. This is connected to its potential in replacing the conventional methane which possess problems including increase in greenhouse gasses among others. Biogas is easy to produce and requires cheap labor; Although production depends on factors such as nature and type of substrate use, microbial population presence, and other physical conditions, the gas has a number of prospects including energy security, less emission and reuse and recycle of waste materials.

From Figure 1, the digester containing mixture of cow dung and sugarcane bagasse has the highest gas production when compared with digesters containing the single substrate (cow dung or sugarcane bagasse). This may be attributed to combination effect of cow dung and sugarcane bagasse that probably favors microbial population. Sugarcane bagasse is high in cellulose (carbon) while cow dung has higher number of microorganisms so it's possible that, a smaller number of microorganisms participate in sugarcane bagasse digester due to limited amount of other growth factors such as amines, lipid and vitamins. However, the production is a bit higher in cow dung digester because there is

a presence of growth factors but a bit low concentration of sugar (carbon source). This in conformity with findings by Yavini *et al.* (2014) who report that, general dominance of carbohydrate material in agricultural waste especially bagasse at the expense of protein and lipids is responsible for low volume of biogas production from sugarcane bagasse.

Similarly, the production volumes observed after 10 days may probably agrees with results reported by Kivaisi and Eliapenda (1995); Sreekrishnan *et al.* (2004); Osman *et al.* (2006) if left for a longer time. For instance, Osman *et al.* (2006) uses bagasse to achieve a total of 84.75 L/kgVS of biogas (including carbon dioxide) after 40 days. Moreover, studies by Janke *et al.* (2015) have also reported $150 \text{ Nm}^3 \cdot \text{ton}_{\text{FM}}^{-1}$ of biogas was recovered from sugarcane bagasse. However, difficulty, especially in hydrolyses stage, has been a challenge (Rodríguez-Vázquez and Díaz-Cervantes, 1994; Kivaisi and Eliapenda, 1995; Sreekrishnan *et al.*, 2004; Inyang *et al.*, 2010; Janke *et al.*, 2015) and this is due to high lignin content in bagasse (Rodríguez-Vázquez and Díaz-Cervantes, 1994; Kivaisi and Eliapenda, 1995; Osman *et al.*, 2006). To overcome this problem, new techniques including steam explosion, acid and alkaline pre-treatment method have been employed to enhance bagasse digestion and improve gas production (Amjed *et al.*, 1992). Using this approach, up to 75% digestion of bagasse have been reported (Rodríguez-Vázquez and Díaz-Cervantes, 1994). Regrettably, up to 25% of bagasse may be left as residue but could potentially be re-used.

It was also observed that, gas production declined with time and as the temperature increases the rate of production also increases. The decrease in gas production in relation to the time may be due to limited substrate concentration and accumulation of waste production which inhibit microbial proliferation as reported by Inyang *et al.* (2010) that shows decline in microbial population due to substrate limitation in biogas production. Production of biogas from cow dung is slow, although different study has been carried out (Iteunet *et al.*, 2009) reported that 14 days was optimum for biogas production from cow dung and that cow dung takes 2-4 days before gas production. However, if the production started it also decreases with the increase in time. This may be due to the presence of inhibitory substances that may influence the proliferation of the methanogens. Such inhibitory substances may include ammonium ion and its relatives (Yavini 2014).

Mursec *et al.* (2009) reported that the methanogens required at least NH_3N for its

maximum specific growth rate and minimum doubling time, but at the same time exposure to higher levels of ammonia was toxic to methanogens. This result indicated that the process of biogas generation from the mixture of agricultural waste such as cow dung and sugarcane bagasse proceeds better than when the agricultural waste was digested alone (Angelidaki and Ellegaard, 2003). This further reveals why biogas production rate is never constant but prone to fluctuation due to the variations of loading rates, inner and outer operating conditions, possible inhibitors etc (Zupančič and Grilc, 2012). Similarly, this research further shows the potentiality of using other agricultural waste including groundnut shell, rice straw and maize cobs which naturally have been dumped carelessly as domestic waste as feedstock for efficient biogas production.

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CONCLUSION

The search for alternative sources of energy such as biogas is intensified so that ecological disasters like deforestation, desertification and erosion can be arrested. It was observed that, the stabilization of agricultural waste was obtained from co-digestion of these waste which gives a reasonable biogas production. Therefore, from the result shown, it can be concluded that agricultural wastes such as groundnut shell, rice straw maize cobs and sugarcane bagasse which naturally have been dumped carelessly as domestic waste especially when co-digested can provide an alternative feedstock for efficient biogas production. It is recommended that more research should be conducted to further study evaluate the effect of co-digestion in biogas generation from sugarcane bagasse.

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