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Research Paper

Biogas Generation from Domestic Solid Wastes in Mesophilic Anaerobic Digestion

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Abstract- *Biogas was generated from domestic solid wastes collected from residential area in the University of Lagos in a mesophilic laboratory-scale batch digester by anaerobic digestion over a retention time of 20 days at 40^{0}C. The wastes collected were characterized and organic wastes are used as feedstock in the setups. Two setups were adopted in the investigation namely digesters A and B. In digester A, 300g of the wastes was mixed water and in the digester B the wastes was blended with poultry dropping in ratio 2:1 and mixed with water, to form slurry in both cases. The volume of produced was monitored every day and 10ml of digestates were withdrawn at interval of four days for analysis to estimate the Total Solids(TS), Total Suspended Solids(TSS) and Total Volatile Solids(TVS). The average volumes of biogas generated in the setups were 40 and 44.45 ml day^{-1} respectively. This corresponded to 60 and 45 ml biogas (g l^{-1}VS) in the respective digesters over the retention time. Also, the average values of TS, TSS and TVS obtained during the digestion period were 70,167, 52833 and 14667 mg l^{-1} respectively for the digester A and 73500, 53833 and 10833 mg l^{-1} respectively for digester B. It was thus inferred that domestic solid wastes can be collected, and treated in a non-polluting, environmentally feasible cost effective process to produced biogas.*

Keywords: Domestic solid waste, Poultry droppings, Biogas, mesophilic, anaerobic digestion.

Introduction

Human engagements both at the domestic front and in industrial operations are inevitably accompanied by waste generation. Even in compliance to the goal or concept of cleaner production which requires that a higher percentage of raw materials are converted into products, solid waste generation is unavoidable. But the recycling option of cleaner production can be considered appropriate means of combating the menace of solid wastes. This usually involves the collection of the waste and reuse in the same or a different part of production (on-site recovery and reuse) or collection and treating wastes so that they can be sold to consumers or other companies. In line with this, biogas technology employs the use of anaerobic digestion of wastes to produce methane-rich gas known as biogas.

This has been an emerging technology that has become a major focus of interest even in waste management throughout the world [1]. It is an identified veritable option in the integrated waste management of municipal solid waste involve in waste-to-energy transformation [2]. Besides being a non-polluting, environmentally feasible and cost effective process, biogas generations have many applications such as for cooking, electricity generation and hatching of chickens [2-3].

Municipal wastes have been considered suitable for generation of biogas been richly endowed with high organic components. Wastes ranging from garden wastes to food scraps have been reported to contain high organic content [4]. This has been further corroborated by various reports obtained for the characterization of municipal wastes in Nigeria namely 76 % [5], 91.67 % [6] and 66.7 % [7] of organic matter. The organic waste contains required quantities of the nutrients for the growth and metabolism of the anaerobic bacteria resulting in the biogas generation [8,9].

The technology have been employed in the treatment of municipal and domestic wastes such as using both wet and dry anaerobic technologies as part of mechanical-biological treatment [10], processing of mixed source segregated biodegradable kitchen and garden wastes [11], production of biogas from municipal solid waste with domestic sewage [1] and anaerobic digestion of source-segregated domestic food waste [12]. However, there are few reports on anaerobic digestion of domestic organic wastes especially in Nigeria. Ojolo et al. [9,13] reported on comparative analysis of utilization of poultry, cow and kitchen wastes for biogas production and the analytical approach for predicting biogas generation in a municipal solid waste anaerobic digester respectively. Adeyosoye et al.[14] estimated the proximate composition and biogas production from in vitro gas fermentation of sweet potato and wild cocoa yam peels. Moreso, most studies in Nigeria that used municipal solid waste as substrate for the production of biogas have not thoroughly considered the contributing effect of the total solid on the production.

Therefore, this work was focused principally on the production of biogas from domestic waste obtained from selected staff quarter of the University of Lagos. The relational effect of a blend of the waste with poultry dropping and changes in the total solids were also studied in an experiment performed in mesophilic anaerobic digestion.

Material and Methods

Feedstock

The feedstock for this work is domestic solid waste which was collected from three sample flats in the staff residential quarter of the University of Lagos. The waste was hand sorted to separate organic wastes and characterized. Table 1 shows the composition of the waste. The organic waste was shredded to reduce the particle size before been fed into the digester. Poultry dropping obtained from a poultry farm was used in the experiment to enhance dilution and digestion by improving the total solids and seeding the digester. The mixing of domestic waste and poultry droppings was done outside the digester.

Anaerobic digester

Figure 1 shows the schematic diagram of the setup used in carrying out the experiment in this study. This involved two laboratory-scale anaerobic batch digesters (500ml conical flasks) in line with [15], which say with a batch digester a smaller experimental system may be suitable as the digester has only to be loaded once and may not even need to be stirred. (See Figure 1)

This study comprised of two experimental setups (digester A and B) which was carried out anaerobically at mesophilic situation (40^{o}C). Digester A is fed with 300g of the feedstock and water was added in ratio 1:1 while Digester B contained 200g of the feedstock blended with 100g of poultry droppings and water was also added in ratio 1:1(substrate: water) to form slurry. The digester is connected to calibrated measuring cylinders with water displacement arrangements to measure the volume of biogas produced. The digester was placed in water bath throughout the duration of the experiment to maintain a constant temperature of operation. But the content of the digesters were rigorously agitated intermittently at 4-day interval over the retention period of 20 days.

Analytical methods

The total solid, suspended solid and volatile solid of the effluent are determined every four-day interval for the duration of digestion based on standard methods [16].

Results and Discussion

Characterization of the wastes

The wastes were collected from three sample flats occupied by family size of six, seven and eight person and total wastes is 5266g for three days. This is an indication that average waste of 1755.33g was generated per day and 83.59g/day per head. The composition of the generated waste is given in the Table 1.

It can be observed from the table above that the amount of wastes generated from the sample area was substantial and a large part of it, that is about 63 % consistitute food scraps which are readily putrescible and served a good substrate for generation of biogas [8,9]. Adding the percentage of paper generated as waste to the food scraps will result into 87.3% organic matter. This amount correlates with the result obtained in previous works of 76 % [5], 91.67 % [6], 66.7 % [7] and 90.6% [1] though there is little difference which may be due to locations.

Biogas generated

After a digestion period of twenty days the total amount of biogas generated in digesters A and B were found respectively to be $2700\ \frac{m^3 gas}{kg\ solids}$ and $3000\ \frac{m^3 gas}{kg\ solids}$ while the average volume of biogas generated in digesters A and B were thus, 40 and 44.45 $\frac{ml}{day}$ respectively. This corresponded to 60 and 44.45 $\frac{ml\ Biogas}{days}$ in the respective digesters over the retention time in digesters A and B, respectively. The results are summarily presented in Figures 1 and 2 for Cumulative production of biogas over a retention time of twenty days and average daily production of biogas in the digesters respectively. Figure 2.

It was observed that the rate of yield of biogas within the first 10 days was very high in both digesters. This was most probably due to the fact that the waste samples had been kept, away from oxygen, in the storage bags and the acetogenic methanogenic bacteria required for methane production were already active at the beginning of the experiment. This process has reduced (or eliminated) the lag time as it was observed in the works of Zuru *et al*. [8] for goat slurry and Ojolo *et al*. [9] for Lagos inland municipal solid waste. Thus, immediately the digesters were set-up, they began to yield biogas. It was also observed that both digesters had a peak production on the second day amounting to 460 and 570 ml in digesters A and B, respectively.

This observation can therefore led to an inference that biogas can be generated from the domestic waste with or without blending (inoculum). Similar observation was made by Ojolo *et al*. [9].

Over the next ten days however, the daily yield of biogas reduced showing that most of the nutrients or the putriscible parts of the waste were already exhausted and this could also mean that the bacteria required for biogas production had begun to die.

Relational effect of the total solids

Figures 3, 4 and 5 show how the total solids, total suspended solids and total volatile solids, respectively, varied as digestion time progressed. (See Figure 3,4,5,6).

In this study it was found that solid concentration was decreasing with digestion period. The average values of TS, TSS and TVS for the samples were 70167, 52833 and 14667 $\frac{mg}{l}$ respectively for sample A, and 73500, 53833 and 10833$\frac{mg}{l}$, respectively for sample B. Volatile solid is an important parameter used to determine biodegradability, being the component which is directly converted to biogas, that is, it indicates the metabolic status of some of the most delicate microbial groups in the anaerobic system [1] and the rate of their disappearance was proportional to the rate of production of biogas. Solids in digester B had a higher concentration of volatile solids than A and the reduction rate of these solids were also higher. This was most likely due to the presence of poultry droppings in B which have been found to have sufficient water content, decomposable and soluble organic matter. These characteristics consequently enhanced high degree of digestibility of the solids in B, making it generate more biogas. Solids in A also had a high concentration of volatile solids which reduced considerably overtime, thus a large volume of biogas was produced in it as well.

Conclusion

The reduction of total volatile solids concentration with time shown that there was good substrate degradation, therefore it was thus inferred that domestic solid waste either blended or not, served as a very good substrate of generating biogas. Wastes degradation which was advantageous to the environment was also achieved in the process, thus disposal problems of wastes can be solved alongside energy generation.

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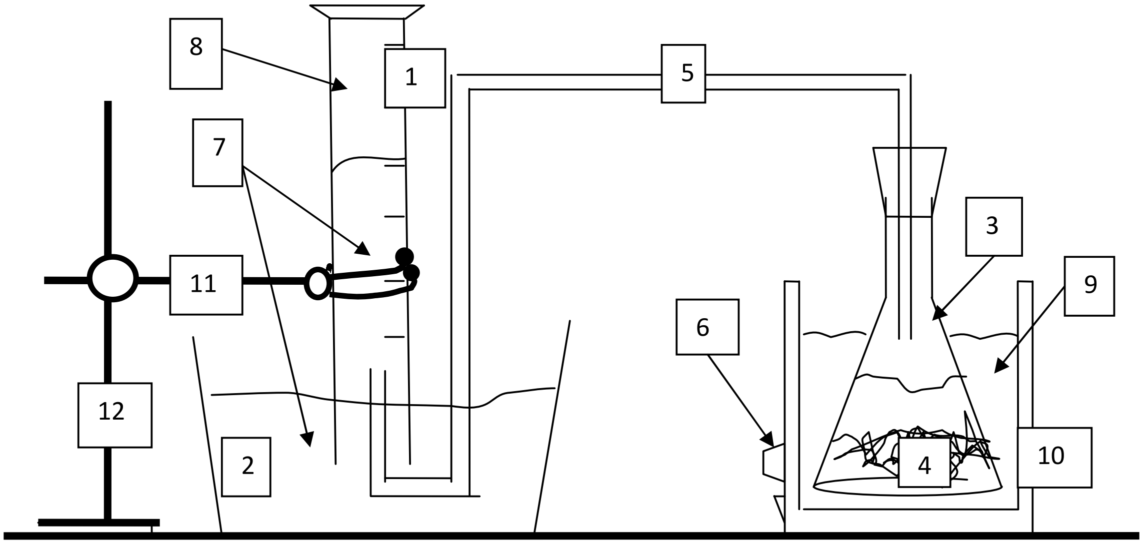

Figure 1: Schematic Diagram of the Setup

(Key 1- Measuring Cylinder (Gas Receiver),2- Water Bath, 3- Digester, 4- Digester Feed, 5- Connector to Gas Receiver (Tube), 6- Temperature Adjuster Dial, 7- Dilute Sodium Hydroxide solution, 8- Biogas, 9- Water, 10- Heating water bath, 12- Clamp, 13- Tripod Stand).

Table 1: Characterization of Waste Generated From Residential Area of University Of Lagos

Waste content	Weight (gram)	% Composition
Paper	1300.7	24.7
Plastic	183.8	3.5
Food scrap	3295.3	62.6
Sand	-	0.0
Cans	203.3	3.8
Nylon and others	282.9	5.4

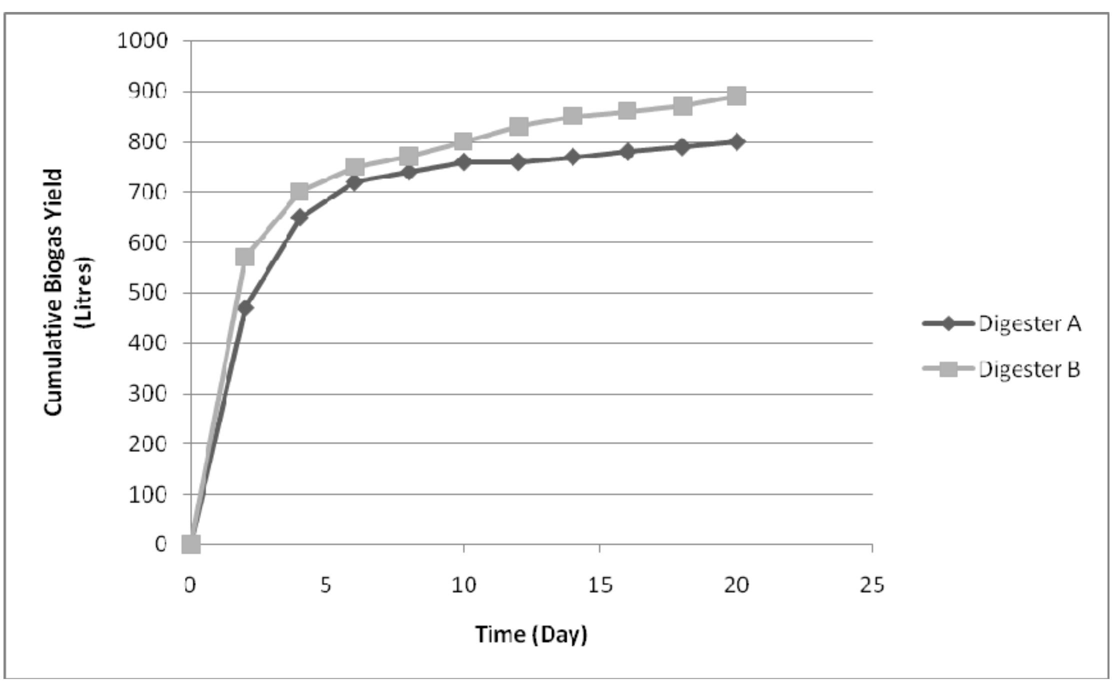

Figure 2: Cumulative Production of Biogas over a Retention Time of Twenty Days

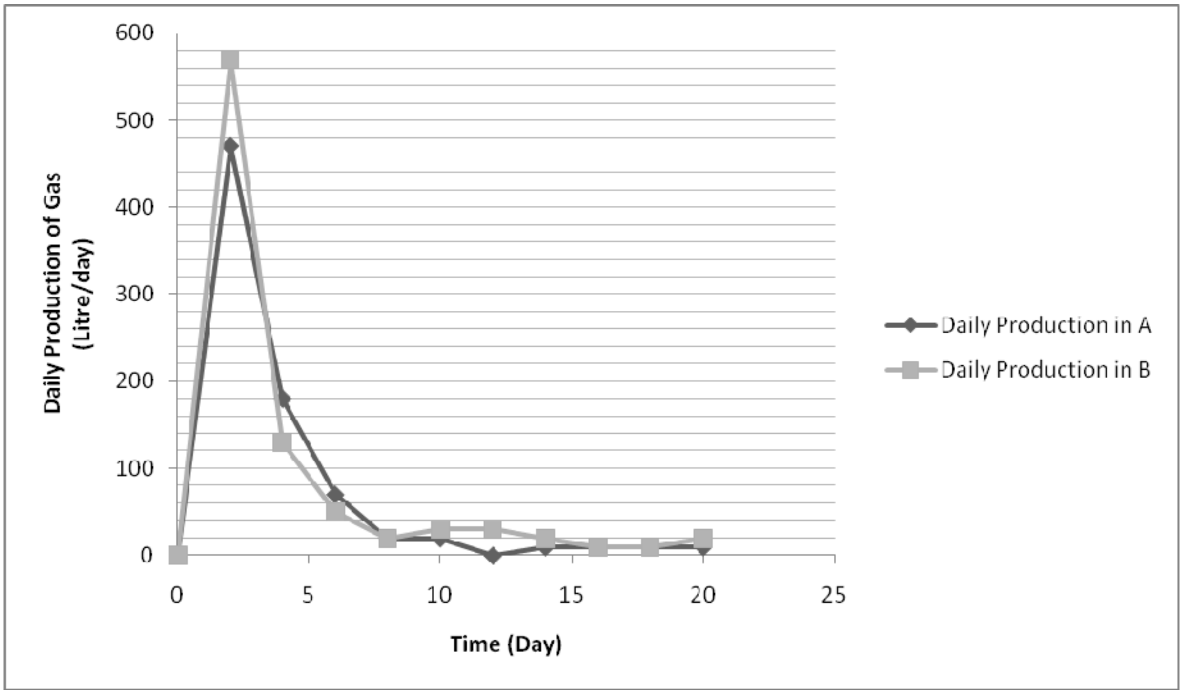

Figure 3: Average Daily Production of Biogas in the Digesters

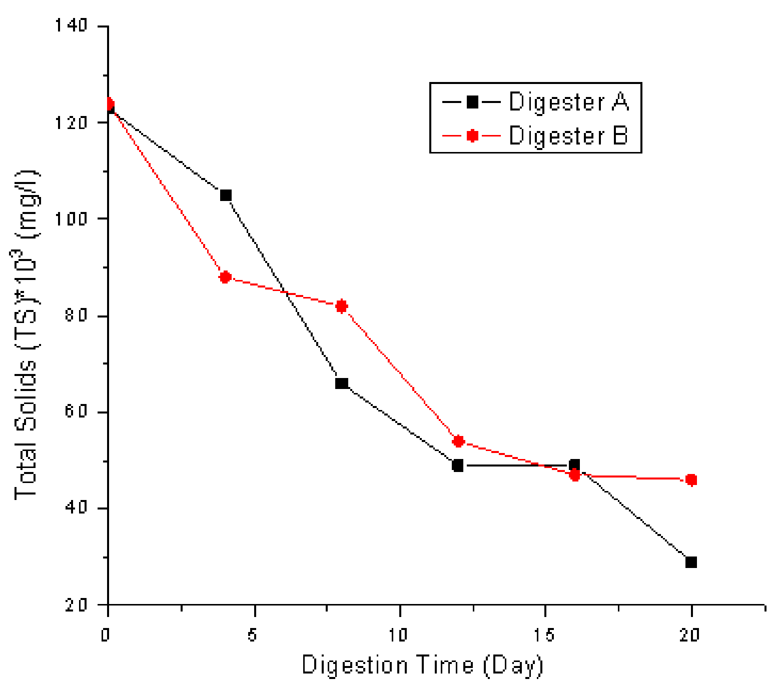

Figure 4: Reduction in Total Solids Concentration with Digestion Time

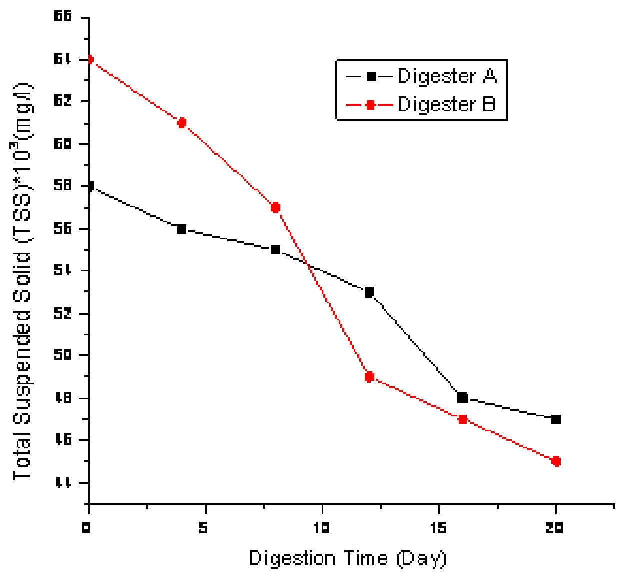

Figure 5: Reduction in Total Suspended Solids Concentration with Digestion Time

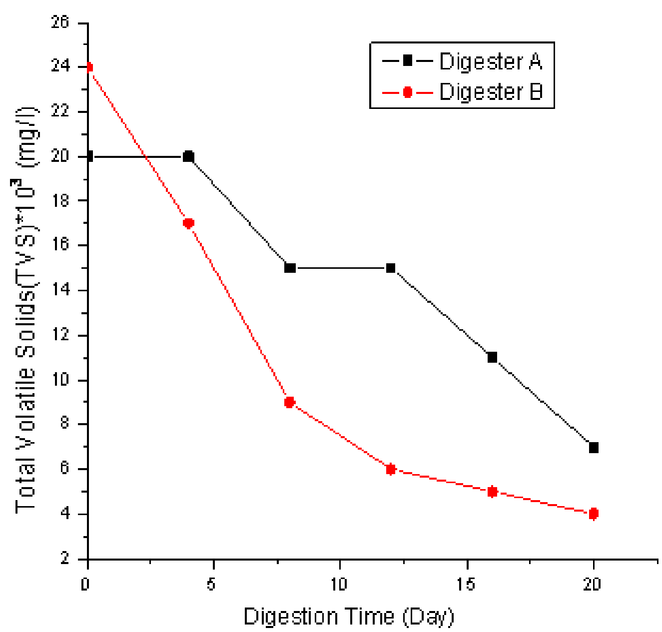

Figure 6: Reduction in Total Volatile Solids Concentration with Digestion Time