



COMPARATIVE STUDY OF BIOGAS PRODUCTION BOTH FROM PLANTAIN PEELS AND ROTTEN ONION BLENDED WITH POULTRY DROPPINGS

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Adewuyi A. S. (2022): Comparative Study of Biogas Production both From Plantain Peels and Rotten Onion Blended With Poultry Droppings. *Journal of Engineering and Engineering Technology* /16(1), 68-73

Received 06-02-21

Accepted: 05-11-21

Abstract

A comparative study was carried out on biogas production potential of plantain peels and rotten onion blended with poultry droppings. Three digesters labeled A, B and C were fabricated with Digester A fed with a mixture of rotten onion and poultry droppings (OP) in a ratio 1:1, Digester B fed with a mixture of plantain peels and poultry droppings (PP) also in the same ratio but Digester C fed in a ratio 1:2:1 of rotten onion, plantain peels and poultry droppings (OPP). The rate of production over a retention period of 40 days was measured using a digital weighing balance to measure the weight of gas retained in each of the circular rubber tube connected to each digester. The effect of the variation in average daily temperature on biogas yield of each feedstock was also analyzed. The co-digestion of rotten onion, plantain peels and poultry droppings yielded most with value of 705.5 g compared to either of plantain peels and rotten onion blended with poultry droppings which has cumulative gas yield of 348.1 g and 199.9 g respectively. It can be concluded that the blending of poultry droppings with agricultural wastes will greatly improve biogas yield.

Keywords: Comparative, biogas, plantain peels, rotten onion, poultry droppings

Introduction

Organic wastes constitute a larger portion of wastes generated in Nigeria (Egun, 2012) and represent a specific waste produced by all the wholesale markets and by many companies in the food industry. Most of these wastes are short duration and perishable food crops which are generated during postharvest operations such as transportation, storage, marketing and processing. Due to their nature and composition, they deteriorate easily. Idah *et al.* (2007) quoted that about 3.8 million tonnes of onions, 6 million tonnes of tomatoes and 15 million tonnes of plantain etc. as annual production levels of some vegetables and fruits, faces postharvest losses which amounts to 35-45% of the annual production.

Energy is a very important part of living needed for everything in life, such as transportation, heat and electricity and over the years, the generation of energy from waste has been a method devised by most developed and a few developing countries to minimize waste generation (Grisel *et al.*, 2013; Wang *et al.*, 2013). As gathered from literature, there are several methods by which wastes can be used as a source of renewable energy which hangs on the type, nature, constituents and so on, of the waste being considered. Since plantain peels and onion waste, as considered in this study have very high moisture contents, biochemical processes such as anaerobic digestion are the most suitable conversion method for the waste-to-energy process (Information and Advisory Service on Appropriate Technology, 2015).

AD is a widely used method for bioconversion of wastes into fuel. It is regarded as the simplest technique due to its very limited environmental impact (Esposito *et al.*, 2012) and high energy recovery potential (Carrère *et al.*, 2010). Biogas through AD has significant advantages over other forms of bioenergy production and also offers a promising substitution for fossil fuels. AD process is dependent on specific microbial consortium for degradation of biomass through four main stages namely hydrolysis, acidogenesis, acetogenesis and methanogenesis. Anaerobic digestion can be classified as liquid, semi-solid and solid or dry state when the total solids of substrate are less than 10%, 0 – 15%, or greater than 15% respectively (Li *et al.*, 2011). Bio-gas is a mixture of gases but mainly consist of methane and carbon-dioxide, produced from the biodegradation of organic matter and which can further be converted to heat energy or electricity with the aid of several emerging technologies (Ajiboye *et al.*, 2018).

This paper aims to use the technology of AD to generate biogas using rotten onion and plantain peel with both blended with poultry droppings.

Materials and Methods

Materials

Materials used for the construction of the digesters are three black plastic kegs of 25 litres capacity each (both serves as the main digester chamber), two tyre tubes of 380-10cm circumference and internal diameter (used

to collect the gas produced), Flexible rubber hose (used to connect the tyre tubes to the digesters), ½ inch back nuts, stop corks, ½ inch pressure pipes, 4 min Aradite and Top git glues (all used for both the inlet and outlet of the digesters), thermometer, pH meter, weighing scale and syringe (all used for various parameter's measurement).

Digester Design and Construction

A hole was drilled on each of the 25 litres containers at the bottom of about 1.5 cm in diameter to serve as the

outlet. External diameter hose of 1.5 cm was then connected to the container while the hose with internal diameter of 0.9 cm served as the gas outlet from the digester to the gas collection tube, a 2 cm sized back nut and stop cork was then placed to serve as the outlet through which the slurry was taken for the pH test. Attached to each of the digester's lid is a thermometer. All perforated spot were properly sealed with rubber tubes and glue to make the whole bio-digester systems airtight. The schematic diagram is shown in Figure 1.

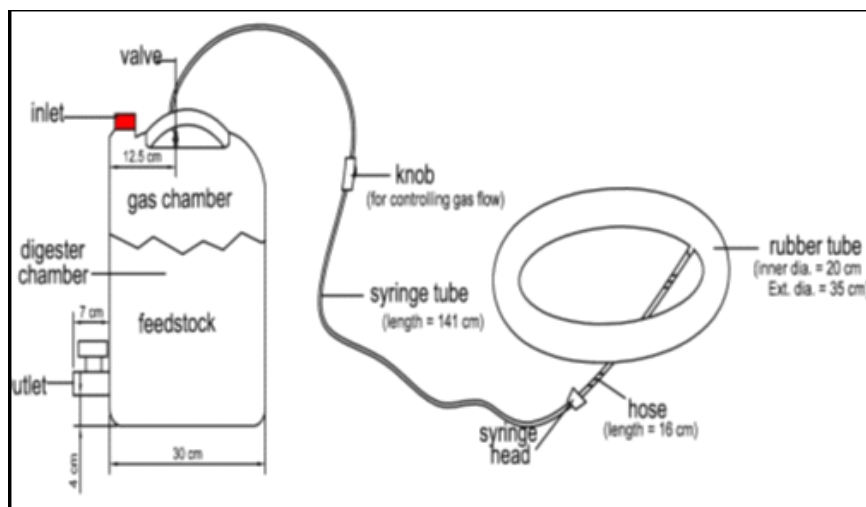


Figure 1: The fabricated digesters and accessories

Collection and Pre-treatment of Plantain Peels and Rotten Onions Bulb

The PP used was collected from local plantain chips sellers at Oja-Oba in Akure while discarded and rotten onion bulbs were obtained from Shasha Market along Benin-Owo Expressway in Akure, Nigeria respectively. Poultry droppings were also collected from B.J farms, a poultry farm located at Ire-akari Estate, Orita Obele, Akure, Nigeria. After collection of the feedstock, pre-treatment measures were carried out. The plantain peels were extracted from the plantain and left for three days for them to undergo self-degradation. These extracted peels were then sundried and shredded into smaller sizes in order to increase its surface area. The rotten onion bulbs were initially sliced into smaller sizes after which some quantity of table salt (*NaCl*) was spread on them; water was also added to dissolve the salt in the solvent. The wet sliced onions were then sundried. The presence of salt damages the cell wall, causing it to rupture and decompose immediately.

Mixing of Feedstock and Loading of the Digesters

The three digesters were each fed with different mixtures as in Table 1. The batching was by volume with the aid of a 21- litres capacity graduated bucket and in the ratio 2:1 of wastes to water. The batching by volume was possible as the wastes were poured into the graduated bucket in layers and preceding layer compressed before the succeeding, to get the volume required. One-third of the volume of the digester was made available for gas collection. The mixed feedstocks were batch loaded into the 25 litres capacity experiment digesters labeled A, B and C respectively. The digesters were manually agitated every morning and evening to prevent formation of scum and layers that could inhibit the bacteria activities in the digesters thereby halting further gas production. Plate 1 shows the experimental set-up for the selected mix ratio.

Table 1: Volume of feedstock according to mix ratio

Digesters	Feedstock	Volume (L)
Digester A	Rotten Onion	5.5
	Poultry droppings	5.5
	Water	6.0
Digester B	Plantain peel	5.5
	Poultry droppings	5.5
	Water	6.0
Digester C	Rotten Onion	3.0
	Plantain peel	5.0
	Poultry droppings	3.0
	Water	6.0



Plate 1: Experimental Set-up for the selected mix ratio

Analysis of the Waste

The feedstocks were analyzed for temperature, pH, moisture content, total solid and volatile solid. The Moisture Content (MC), Total solid and Volatile solid were determined in accordance with the method provided in section 2540 E of American Public Health Association- Standard Methods (APHA *et al.*, 2012). Readings of temperature and volume of gas produced were taken twice daily both in the morning and evening. Temperature readings were taken with thermometer attached to the digesters; digital pH meter (*Hanna Instruments*) was used to measure the pH once daily. The volume of gas produced was calculated by weighing the tyre tubes with a digital weighing balance (*HR-60, 0.1 mg readability*). The initial mass of the tubes was measured to be 1.2 kg, then the volume of gas produced daily was determined using Equation 1

$$\text{Density} = \frac{\text{Mass of Gas}}{\text{Volume of Gas}} \quad (1)$$

The average density of biogas used is 1.15kg/m^3 as adopted by Ajiboye *et al.* (2018). The daily and cumulative bio-gas yields were presented.

Results and Discussion

Physiochemical Properties of the Waste

The physiochemical properties of the waste are shown in Tables 2. The moisture content present in rotten onion is 86.09% and is greater than moisture present in plantain peel which is 79.24%. The volatile solid VS which is the biodegradable constituent of the total solid TS is about 54.73% of the total solid of the plantain peel and 46.07% of the total solid of rotten onion. The total solid is the combination of both the organic and inorganic composition of the feedstock; the VS largely determine the amount of biogas that was be produced by the decomposition of the feedstock. The pH of the poultry droppings is noted to be higher than that of plantain peel and rotten onion.

Table 2: Physiochemical Tests on Substrate Materials¹

Feedstocks	Moisture Content (%)	Total Solids (%)	Volatile Solids (%)	pH
Plantain peels	79.24	20.76	54.73	5.01
Rotten Onion	86.09	13.91	46.07	4.36
Poultry Droppings	78.00	22.00	73.00	7.25

Average Daily Biogas Yield of Substrates

Figures 2, 3, 4 and 5 show the plots of the average daily gas yield (in gram) against the retention period (in days) respectively.

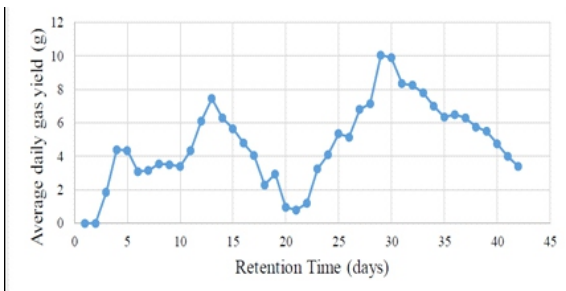


Figure 2: Average daily gas yield in digester A

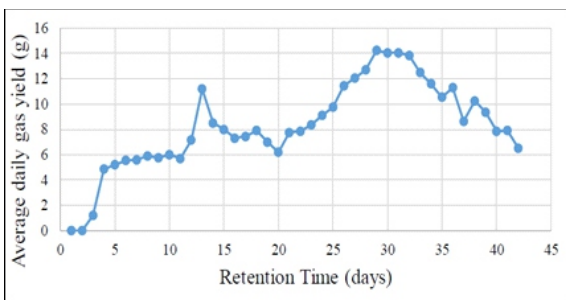


Figure 3: Average daily gas yield in digester B

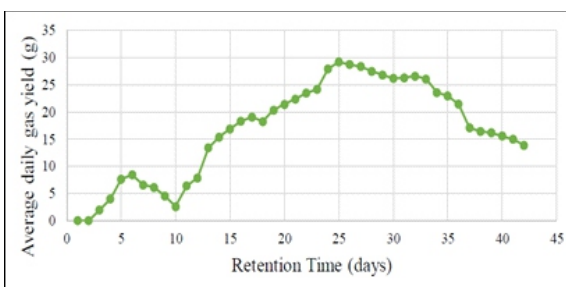


Figure 4: Average daily gas yield in digester C

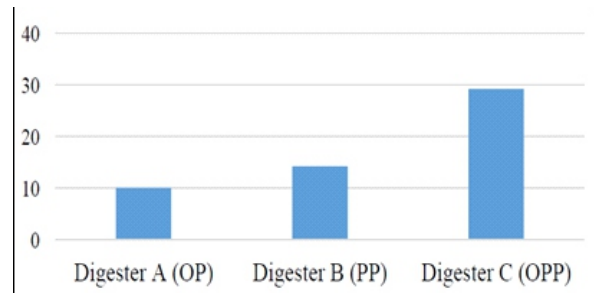


Figure 5: Highest average daily biogas yield for each feedstock

It can be seen from Figures 2, 3, 4 and 5 that the co-digestion of rotten onions and plantain peels both mixtures blended with poultry droppings (OPP) has the highest average daily biogas yield with a mass of 29.20 g, which is twice that of plantain peels with poultry droppings, PP (14.25 g) and three times as much as the highest average daily biogas yield of onion waste with poultry droppings, OP (10.05g).

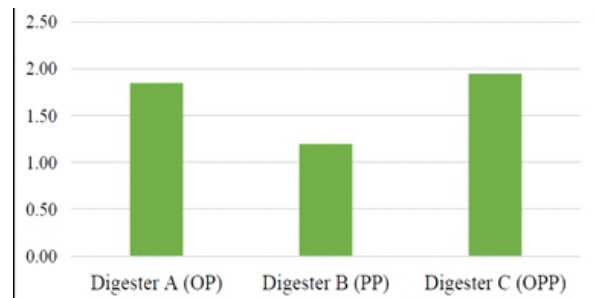


Figure 6: Initial biogas yield of the feedstock after loading

Figure 6 shows the initial biogas yield of each of the feedstock in their respective digester after two days of loading. It can be seen that Digester C (OPP) showed a quicker microbial activity starting with a biogas yield of 1.95 g, followed by Digester A (OP) and then by Digester B (PP) both starting with a biogas yield of 1.85 g and 1.20 g respectively.

Also, from Figures 2, 3 and 4, it can be seen that there are instances where the plots slope downward, either over a short or long retention time, describing a decrease in the average daily gas yield. This may be as a result of exposure of the digester to harsh weather (constitutes with constant rainfall) consequently resulting in a drop in temperature. However, the

downward slope in Figures 2 and 4 may not only be due to temperature changes but may also be due to the acidic contents present in onion bulb thereby affecting the rate of production of biogas in Digesters A and C.

Cumulative Biogas Yield of Substrates

Figures 7, 8 and 9 show plots of the cumulative gas production (in gram) against the retention time (in days) respectively.

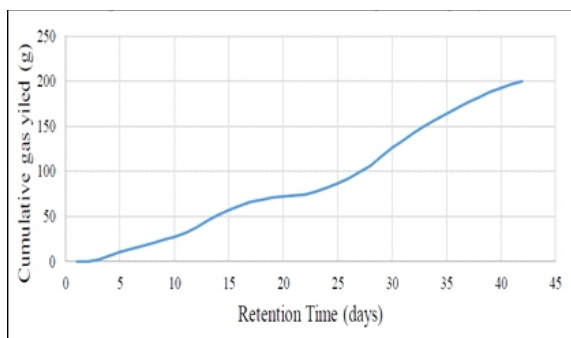


Figure 7: Cumulative biogas yield for digester A (OP)

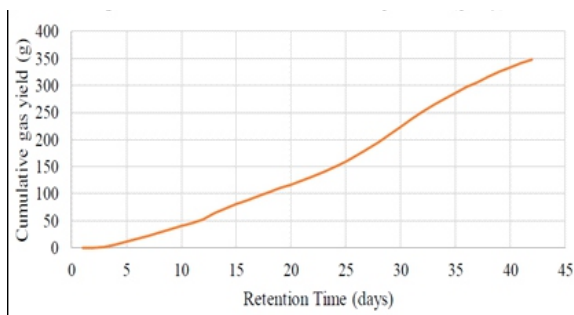


Figure 8: Cumulative biogas yield for digester B (PP)

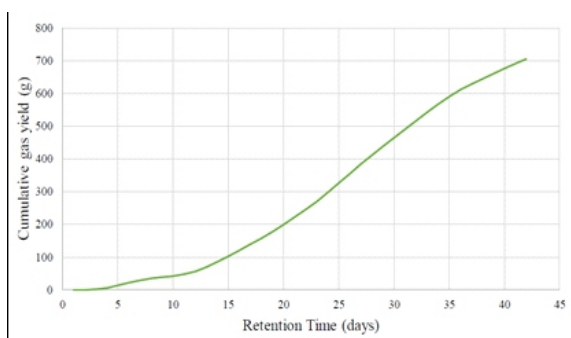


Figure 9: Cumulative biogas yield for digester C (OPP)
From the cumulative plots, it can be seen that OPP has the highest cumulative biogas yield (705.5 g) followed by PP (348.1 g) and the least, OP, with a cumulative biogas yield of 199.9 g.

Effect of Variation in Average Daily Temperature on Daily Biogas Yield

The variation of the average daily temperature observed through-out the retention time is presented in Figure 10.

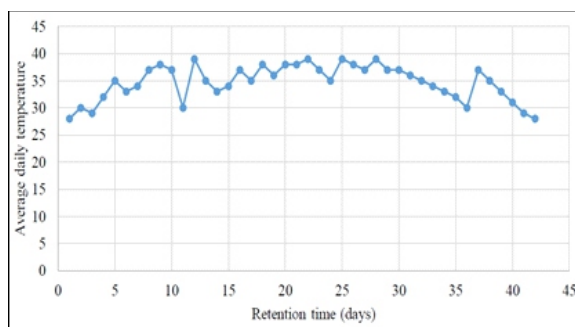


Figure 10: Average daily temperature measured over retention period

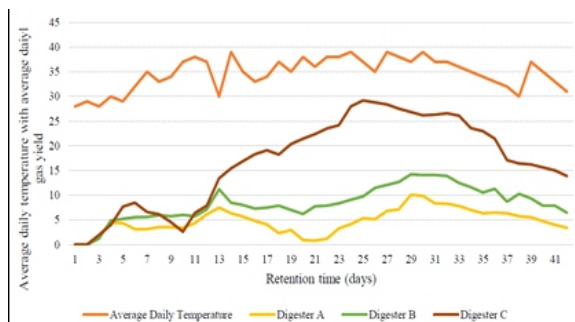


Figure 11: Variation in average daily temperature and the average daily biogas yield of the substrates.

It can be noticed from Figure 10 that the variation in the average daily temperature falls within the mesophilic temperature range (i.e., between 25 –45°C). As temperature is a very important factor to be considered in anaerobic digestion process. Its influence on the average daily biogas yield can be observed in Figure 11. The drop in biogas yields as noticed in the Figure can be related to the effect of varying average daily temperature, especially the cold night temperature. However, there are other factors that could have been responsible such as the material the digester was made of and the expansion of the gas in the tube due to heat from the sun.

Conclusion

From the results obtained in this study, the following conclusions are made that; Co-digestion of plantain peels and poultry droppings gives the highest biogas production potential when compared to either the co-digestion of plantain peels or rotten onion with poultry droppings.

The anaerobic biodegradability of onion bulb is low due to acidification which affected the microbial activity of the hydrolytic bacteria. Drop in temperature

also directly affects biogas production. Therefore, there exist a linear relationship between the surrounding temperature and the biogas produced.

It was also discovered that gases expand when heated up and therefore becomes lighter in weight as their density reduces in the process. This could be a factor responsible for the low masses of biogas yield and the constant drop in biogas yield experienced.

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