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Comparative Study of the Biogas Potential of Plantain and Yam Peels

O. A. Makinde[1*] and L. O. Odokuma[2]

[1]Department of Microbiology, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria.
[2]Department of Microbiology, University of Port Harcourt, Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration between the two authors. Authors OAM and LOO designed the study, while author OAM performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. Author LOO supervised the research. Both authors read and approved the final manuscript.

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ABSTRACT

The biogas production potential of the co-digestion of plantain (*Musa parasidiaca*) peels, yam (*Discorea rotundata*) peels and cow (*Bos primigenius*) dung was investigated. Two waste combinations of plantain peels with cow dung (A) and yam peels with cow dung (B) were used for the biogas comparison. The waste was charged into a glass type digester of 1000 ml capacity within a retention period of 4 weeks. Biogas production was determined using water displacement method. Changes in the volume of biogas produced, the bacteria associated with biogas production and the pH of the slurry before and after the biogas production was determined. Bacteriological analyses showed the presence of *Pseudomonas sp, Klebsiella sp, Bacillus sp, Escherichia coli, Clostridium sp, Streptococcus sp, Micrococcus sp,* and *Bacillus sp, Escherichia coli, Clostridium sp* from the fresh and spent slurry respectively. The highest volume of biogas (428 ml) was obtained from the yam peels treatment option (B3) followed by (297 ml) also from the yam peels treatment option (B4) while the least (0 ml) was from the plantain peels treatment option (A1). The statistical analysis revealed that there was a significant difference among the treatment options during the retention period.

**Corresponding author: E-mail: doctormak4u@yahoo.co.uk;*

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1. INTRODUCTION

The increasing cost of fossil fuels, its epileptic supply to the end user and the prediction that current reserves may not last more than three decades has necessitated the need for alternative sources of energy in the developing countries [1]. Hence, the generation biogas and trapping of naturally produced biogas and the orchestrated biogas as an alternative energy. Biogas is the gaseous product of the anaerobic digestion (decomposition without oxygen) of organic matter. It is typically made up of 50-80% methane, 20-40% carbon dioxide and traces of other gases like C0, H_2S, NH_3, 0_2, H_2, N_2 and water vapour [2]. Biogas technology in which biogas is derived through anaerobic digestion of biomass, such as agricultural waste, municipal and industrial waste, is one such appropriate technology Africa as a whole should adopt to ease its energy and environmental problems [3].

In Nigeria, solid waste disposal has become a serious problem in the metropolitan cities. These wastes are generated during food preparation and consumption as well as industrial, farming and market operations [4]. According to [5], Nigeria accounts for about 70% of the world production of yam and as a result generates more waste from it. Plantain too generates a lot of waste since it's a major food staple in Nigeria, it can be boiled, fried, roasted and even used to produce "Agadagidi" an alcoholic beverage. These were the reasons behind the choice of wastes. This paper reports on the comparative studies of the biogas potential of plantain peels, yam peels and cow dung when used as a major feedstock or enhance the quality of others as a blend. The bacteriological content of the waste is also studied and presented.

2. MATERIALS AND METHODS

2.1 Sources of Sample

Plantain (*Musa parasidiaca*) peels and yam (*Discorea rotundata*) peels were collected from plantain and yam smokers within the University of Port Harcourt while cow (*Bos primigenius*) dung was collected from Choba abattoir near University of Port Harcourt.

2.2 Sample Preparation

All wastes except cow dung were macerated using 5.5 HP Honda GS160 grinding machine. The macerated wastes together with cow dung was mixed with water and stirred to form slurry in ratio 3:1 water to waste.

2.3 Experimental Set Up

The glass type digester consisted of a 1000 ml conical flasks. The digesters were labelled A1, A2, A3, A4, A5, B1, B2, B3, B4, B5 and each duplicated. Digester A1, A5, B1 and B5 are the controls (Table 1). Equal concentrations of the slurry were poured into the flask type digesters. The digesters were made air-tight by lubricating the open end with grease and operated with a rubber stopper (cork). A delivery tube was connected to the digesters which convey the gas to another 1000 ml conical flask containing a brine solution and another delivery tube connected from the conical flask containing a brine solution into an outlet. The digesters were set up and allowed to undergo anaerobic digestion for a retention period of four weeks. The amount of gas produced was measured using water displacement method adapted from [6] on weekly basis.

2.4 Microbiological Analysis

Serial dilution of the fresh and the digested slurry samples were carried out up to 10^{-5}. An amount, aliquot was obtained using a sterile pipette from the 10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5} tube and inoculated onto already prepared nutrient agar by spread plate method. A modified Mackintosh and Filgles pattern of anaerobic jar was used to incubate the plates at 37°C for 96 hr. Bacteria colonies that emerged on plates were counted and recorded as colony forming units per milliliter (cfu/ml) of the sample. The colonies were also subcultured repeatedly on fresh plates to obtain pure isolates. The pure bacteria isolates were examined and further identified using biochemical tests which were based on the criteria of [9] and [10].

2.5 Physicochemical Analysis

The following physicochemical parameters were assessed using standard method [11]. Hydrogen concentration, total organic carbon, nitrogen content, C:N ratio, total solids, moisture content, volatile matter and the ash content of the samples were determined.

3. RESULTS AND DISCUSSION

In Table 2, the physicochemical characteristics of the substrates used are presented. Most substrates revealed similar physicochemical characteristics. However, cow dung revealed higher ash content, higher total solid, higher pH and lower C:N ratio 12.8:1. The C:N ratio of yam and plantain peels were very high with 45:1 and 40.9:1 respectively.

Fig. 1 reveals biogas production in each digester. All the treatment option produced biogas at the end of the retention period except A1, with the highest yield from B3, B4 and A4 having a total of gas production of 428 ml, 297 ml and 257 ml respectively.

Table 1. Loading of digesters

Digester	Composition
A1	100% plantain peels in 150ml of water (i.e. 50g of plantain peels).
A2	75% plantain peels and 25% cow dung in 150ml of water (i.e. 37.5g of plantain peels and 12.4g of cow dung).
A3	50% plantain peels and 50% cow dung in 150ml of water (i.e. 25g of plantain peels and 25g of cow dung).
A4	25% plantain peels and 75% cow dung in 150ml of water (i.e. 12.5g of plantain peels and 37.5g of cow dung).
A5	100% cow dung in 150ml of water (i.e. 50g of cow dung).
B1	100% yam peels in 150ml of water (i.e. 50g of yam peels).
B2	75% yam peels and 25% cow dung in 150ml of water (i.e. 37.5g of yam peels and 12.5g of cow dung).
B3	50% yam peels and 50% cow dung in 150ml of water (i.e. 25g of yam peels and 25g of cow dung).
B4	25% yam peels and 75% cow dung in 150ml of water (i.e. 12.5g of yam peels and 37.5g of cow dung).
B5	100% cow dung in 150ml of water (i.e. 50g of cow dung)

Adapted from [7]; [8]

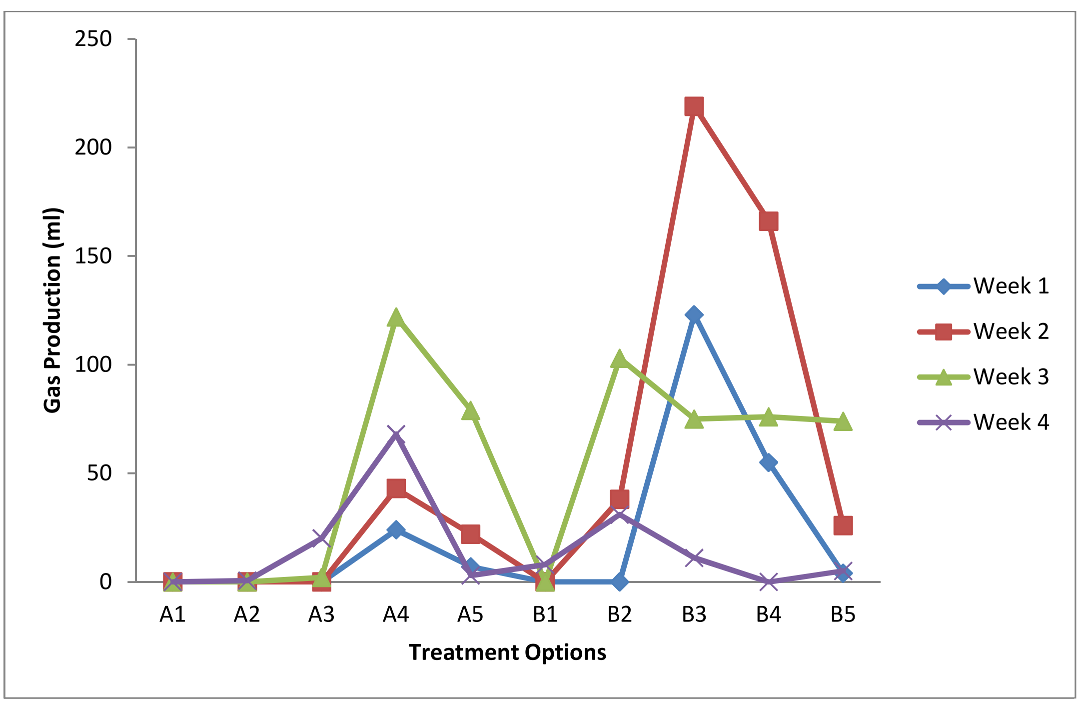

Fig. 1. Gas production of the treatment options

Table 2. Physicochemical characteristics of the substrates

Parameters	Plantain peels	Yam peels	Cow dung
Moisture	87.40%	81.22%	75.10%
Total organic carbon	4.50%	5.40%	5.105
Nitrogen content	0.11%	0.12%	0.40%
Ash content	8.10%	12.60%	20.80%
Total solid	12.60%	18.78%	24.90%
Volatile matter	4.50%	6.18%	4.10%
pH	4.7	4.9	6.8
C:N ratio	40.9:1	45:1	12.8:1

pH is an important factor that affects biogas production. Bacteria responsible for biogas required a neutral environment [12]. From the result in Table 3, the treatment of the two substrates with cow dung increases the pH level of the substrates from the original acidic pH level to a slightly neutral pH. This creates an enabling environment for the production of biogas because the microbes that convert waste to biogas are highly pH sensitive. The pH of the set up that produce high biogas yield range from 6.0 – 7.4 before and after the study which is in agreement with [13] who reported that pH range of 6.8 through neutral to 7.4 is required for optimum biogas production.

Table 3. pH before and after the experiment

pH	Before	After
A_1	4.7	5.0
A_2	5.2	6.1
A_3	5.8	6.9
A_4	6.2	7.1
A_5	6.8	7.0
B_1	4.9	6.2
B_2	5.4	7.1
B_3	6.0	7.4
B_4	6.3	7.2
B_5	6.8	7.1

Table 4 revealed the microbial population of each digester before and after the experiment. Digester B5, A5, B4 and A4 had the highest no of microbial population having 1.49 x 10^7, 1.48 x 10^7, 1.29 x 10^7 and 1.21 x 10^7 respectively at the beginning of the experiment while digester A4, B2, B3 and A5 had the highest number of microbial population at the end of the retention period having 4.1 x 10^3, 3.4 x 10^3, 3.1 x 10^3 and 2.3 x 10^3 respectively. This suggests that there are still activities going on in those treatment options that probably would have produced more gas if given time.

The C:N ratio is also an important factor in biogas production because the bacteria responsible for anaerobic process require both elements, as does all living organisms but they consume carbon faster than nitrogen. The C:N ratio of the treatment option that produces high biogas yield falls in the range of 15.1:1 and 28:1 (Table 5) which is in accordance with [14] and [15]. These authors reported high biogas yield between 15.5 - 19 and 20 – 30 respectively. Although the C:N ratio of cow dung from the result of this study is somehow lower compared to C:N ratio of cow dung of in other studies, the variation may be due to different feed stock given to the cows. It is possible that the fodder given to the cows are not rich enough with nitrogen.

Table 4. Total viable count of each treatment option before and after the experiment

Treatment option	Before	After
A_1	3.7 x 10^6	1.0 x 10^3
A_2	6.5 x 10^6	1.3 x 10^3
A_3	6.9 x 10^6	1.8 x 10^3
A_4	1.21 x 10^7	4.1 x 10^3
A_5	1.48 x 10^7	2.3 x 10^3
B_1	6.2 x 10^6	1.4 x 10^3
B_2	8.5 x 10^6	3.4 x 10^3
B_3	1.04 x 10^7	3.1 x 10^3
B_4	1.29 x 10^7	1.2 x 10^3
B_5	1.49 x 10^7	2.1 x 10^3

Table 5. C:N ratio of each treatment option

Treatment option	C:N Ratio
A_1	40.9 : 1
A_2	25.5 : 1
A_3	18.8 : 1
A_4	15.1 : 1
A_5	12.8 : 1
B_1	44.3 : 1
B_2	28.0 : 1
B_3	20.1 : 1
B_4	15.7 : 1
B_5	12.8 : 1

The results from the study shows that *Pseudomonas sp*, *Klebsiella sp, Bacillus sp, E. coli, Clostridium sp,* and *Micrococcus sp.* were present at the beginning of the experiment while *Bacillus sp.*, *E. coli*, *Clostridium sp. Lactobacillus sp,* and *Bacteroides sp* were present at the end of the experiment which invariably responsible for the biogas production. *Bacillus sp* been the most common bacteria isolated and identified after the study may be due to the organism's ability to produce spore which could help it withstand the harsh anaerobic conditions or heat evolved during biogas production. These observations are in line with that of [16] in which *Bacillus*, *Yersinia* and *Pseudomonas* sp. were found to be responsible for biogas production from cow dung and also with the observations of [17] in which *Bacillus* Sp. appear to overlap from one stage to another during biogas production. It was also observed in Table 4 that the microbial load before and after the experiment of the yam peels treatment option produced higher counts than plantain peels treatment option. This may have influenced the higher biogas yield from this option. The higher microbial count that was experienced before the experiment may be due to the large populations of aerobic and facultative anaerobic organism. I was unable to isolate and identify the methanogens due to laboratory constraints.

The yam peels treatment options produced the higher volume of gas compared to the plantain peels treatment options with the highest yield from B_3, followed by B_4, A_4, and B_2 respectively. A1 did not produce any gas at all during the retention period but that does not mean it cannot produce gas, it may require a longer retention time for it to produce and this may be due to the unavailability of organisms which have been seen to enhance the production in subsequent treatment options in which cow dung is added to that particular substrate. Cow dung also produced a significant amount of gas. The high yield of gas production from yam peels treatment option may be due to high amount of highly hydrolyzed polysaccharide, which includes starch and biodegradable organic matter compared to higher amounts of cellulose and lignin which are not easily digestible [18]. Lignin suppresses biodegradation. The higher the lignin content, the lower the biogas yield [19]. It was observed from the physicochemical characteristics of the substrate that yam peels had higher volatile matter content than plantain peels and cow dung which contributed to the more biogas yield. Although plantain peels and cow dung have almost similar amount of volatile matter but the ability of the cow dung to produce biogas earlier than plantain peels may be due to the readily available microorganism responsible for the activities.

Statistical analysis revealed that there's a significant difference in the microbial counts across the treatment options before the experiment with *P* value of .00 and the microbial counts across the treatment options after the experiment with *P* value of .0002. There was also a significant difference with *P* value of .00 when the microbial counts before and after the experiment was compared. There's a significant difference in gas produced in week 1 with *P* value of .00, week 2 with *P* value .0001, week 3 with *P* value .00 and week 4 with *P* value .0004 across the treatment options. The physicochemical characteristic of the substrates has no level of significant difference having a *P* value of .99 which is greater than .05. There's no significant difference in the pH across the treatment options before the experiment with a P value of .76, and the pH across the treatment options after the experiment with *P* value of .12. However, there was a significant difference with *P* value of .00 when the pH before and after the study were compared, which is less than .05 level of significance.

4. CONCLUSION

In this study, yam peels yielded more biogas than plantain peels, suggesting its higher susceptibility. The study has shown that the co-digestion of plantain and yam peels with cow dung improved biogas production compared to the individual substrates. Therefore, yam and plantain peels should not only be limited to feeding of animals or relegated to waste bins, but they should also be utilized for biogas production that will serve as a source of cheap and renewable energy source.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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