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Biogas Production: A Comparative Study of Chicken Droppings (Poultry Waste) and Banana Peels as the Gas Source

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Abstract

Biogas has been increasingly used in generating energy in the deregulated energy market. Biogas production has been identified as a sustainable approach to mitigating the effect of climate change and global warming. This work conducted a comparative study of biogas production from poultry waste (Chicken droppings) and banana peels under the same operating conditions. 100g of each sample was mixed with 200cm^3 of water for poultry waste and 400cm^3 for banana peels and loaded into four cylindrical digesters. Each container was shaken to ensure a homogenous mixture and fermentation. Biogas was measured using the water displacement method for 14 days at an average of 27.7^{o}C. The pH, temperature, and concentration were observed to affect biogas production. Within 14 days, 1556cm^3 and 755cm^3 of biogas were produced for poultry waste and banana peels. This shows that poultry waste produces more biogas than banana peels. Hence, it can be deduced that poultry waste is potentially a more promising feedstock for biogas production than banana peels; and can provide an alternative energy source for the local community in place of the conventional fossil fuel source.

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1. Introduction

The role that energy plays in the growth of a nation cannot be overemphasized. Any nation's growth and industrialization depend on its access to energy. It is proven that any disruption in the energy supply chain results in severe

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economic and social hardship [1]. The need for efficient, affordable, stable, and environmentally friendly energy sources is thus paramount. Despite the detrimental ecological and environmental repercussions of fossil fuels, many countries depend on them as their source of energy generation [2]. However, there is a growing interest in using renewable energy sources such as biogas due to the fluctuating cost and environmental implications of using conventional energy sources (mainly crude oil). As a result, using renewable energy sources is increasingly becoming more promising due to the damaging impacts of greenhouse gas emissions from using conventional fuel on the environment [3].

The non-renewability and depletion of conventional fossil fuel sources are other concerns for sustainable energy generation [4]. Research shows biogas can be generated from chicken droppings [5-6]. Chicken droppings are always stored in poultry farms for days or even months before utilizing it as fertilizers or other use. Peels of bananas include a variety of chemical components, including cellulose and hemicellulose, among others. These compounds are made up of acidic organic molecules that can be utilized as substrates in biogas generation[7].

The production of biofuels has been identified as a promising strategy to mitigate the carbon footprint. During the past decade, the commercial production of biofuel has attracted the attention of companies and governments across the globe. However, achieving a competitive production cost and sustainable biofuel remains the challenge. In this regard, various feedstock has been examined for this objective, where the majority have not complied with the sustainability expectations, although not utilized in various sectors. Poultry waste (chicken droppings) has emerged as one of the most promising feedstocks in biogas production.In this research, a comparative study of biogas production from chicken droppings and banana peels was conducted using an experimental approach.

1.1. Evolution of Biogas

The processes used to convert organic waste into biogas have existed for a long time. Communities in rural areas met their energy demand using cow manure and municipal wastes for methane generation. This operation has existed for years as a method of producing clean fuel and a source of fertilizer in places like England, Taiwan, and India [8].

1.2. Composition of Chemicals

Biogas is highly corrosive due to the presence of Hydrogen sulfide (H_2S), Carbon dioxide (CO_2), and water (H_2O); this necessitated the usage of unique materials, and Different production methods resulted in various unique compositions. The composition of biogas issued from a digester depends on the substrate, organic matter load, and the feeding rate of the digester [9].

2. Materials and Methods

2.1. Sample Collection and preparation.

Samples used in this research work are Chicken droppings and Banana peels. The chicken droppings were collected from the abattoir, Off Ramat Road UngwanRimi Kaduna. At the same time, the Banana peels were collected from UngwanRimi market in Kaduna state, Nigeria. Figure 1 shows the diagram of the bio-gas collection process adapted in this research using four digesters and water as a collection medium. The waste substrates were weighed on a weighing balance. Polyvinyl Chloride (PVC) rubber hose was used as a water trough, and 500cm^3 measuring cylinders were used as gas collectors. Rubber tubes were connected from cylindrical tin outlets into the inverted measuring cylinders placed in the water trough. Aradite epoxy glue was used to fill the gaps; of small holes in the digester through which the rubber tubes pass. This makes the digester airtight. All apparatus was washed and cleaned. The four cylindrical tins (600g) were labelled asX_1, X_2 (Digesters for chicken Droppings), and Y_1, Y_2 (Digesters for Banana peels).

2.2. Experiment setup and Procedure

Figure 2 shows the actual experimental setup showing the level of gas collected before and after biogas production. The waste substrates, Chicken droppings and banana peels were labelled as samples X and Y, respectively. Each sample was put into two digesters, each making four digesters for both substrates. Readings were taken daily at noon, and the temperature was also recorded.It can be seen that the air column increases, which in turnraises the water level in the water container.

Table 1. Composition of Biogas [10]

S/N	SUBSTANCE	SYMBOL	PERCENTAGE
1.	Methane	CH_4	50-70
2.	Carbon dioxide	CO_2	30-40
3.	Hydrogen	H_2	05-10
4.	Nitrogen	N_2	01-02
5.	Water Vapour	H_2O	0.3
6.	Hydrogen sulphide	H_2S	Trace

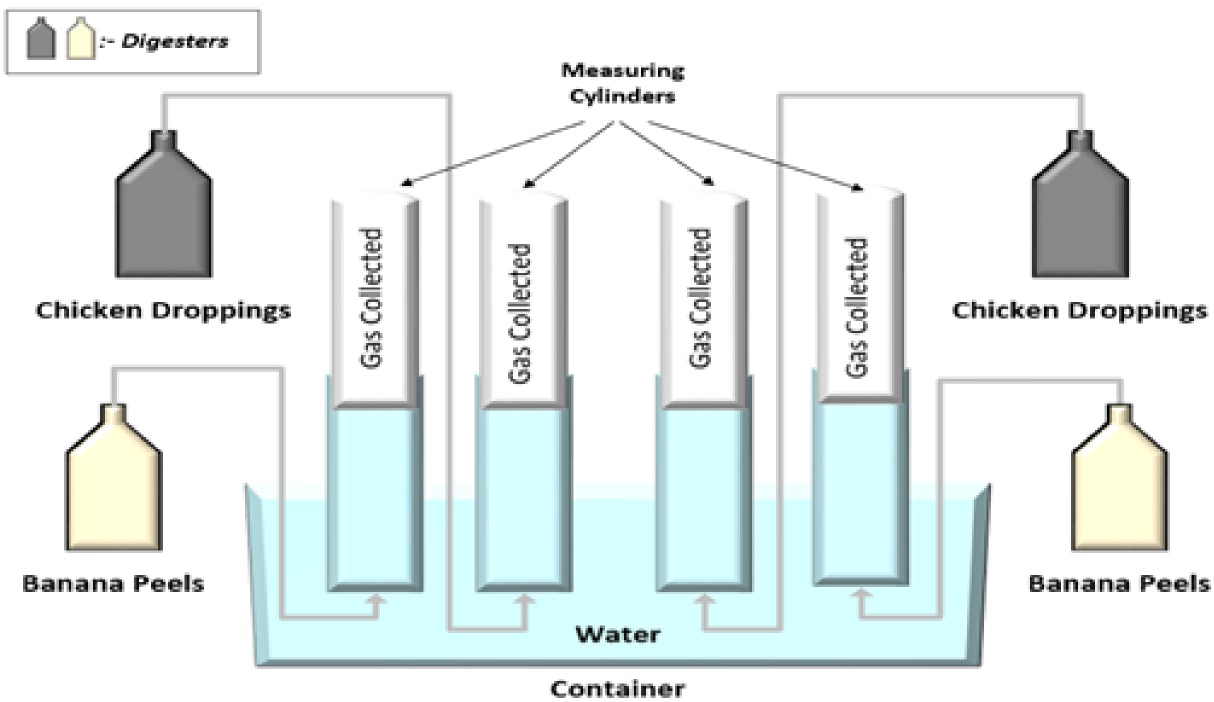

Figure 1. Bio-gas Collection Process Flow

100g of each sample was weighed and put into the irrespective digesters. 200cm3 of tap water was added to digesters X_1 X_2 (100g each of Chicken droppings) to obtain a slurry with the sample-to-water ratio of 1:2 (neither too thick nor too light). Also, 400cm^3 of tap water was added to digesters Y_1Y_2 (100g each of banana peels) to get a slurry with a sample water ratio1:4 neither too light nor too thick. Each cylindrical tin containing the samples with water respectively wash and shaken to ensure a proper homogenous mixture and aid fermentation. The biogas produced for14 days was observed, and the readings were recorded daily at noon when the temperature was sufficient for optimum biogas production. The digesters were hand shaken twice daily to aid fermentation. The gas produced in the tins was released into the gas collection chamber, and it was by the downward displacement of water in the inverted measuring cylinders [11].

2.3. Determination of Moisture Content

Two dry and clean weighing glass discs were labelled:X For (Chicken Droppings) and Y For (Banana peels). 2g each of chicken waste and Banana peels were weighed (labelled as W_0), transferred into their respective discs, and reweighed (labelled as W_1). The discs, together with their content, were weighed and placed in an oven for 5hrs at 105^{0}C. The discs with the content were later removed and allowed to cool, and each was reweighed (labelled as W_2). The percentage moisture content was calculated for each sample.

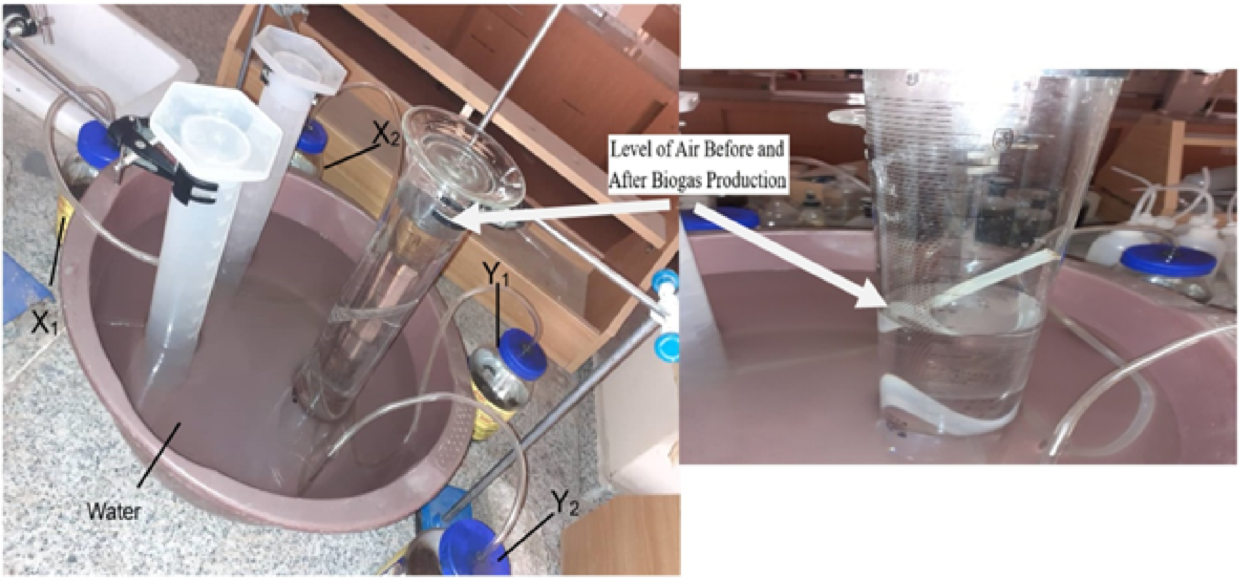

Figure 2. Experiment Setup for Biogas Production

2.4. Determination of Ash Content

Two dry and clean crucibles were labelledas:X or (chicken droppings) and BF or (Banana peels). The crucibles were weighed initially and (labelled as W_0) .2g each of sample X and sample Y were added to the irrespective crucibles. The crucibles, together with their contents, were put in a muffle furnace at 600^0C for a period of 3hrs.The samples were allowed to cool and reweighed (labelled as W_2). The percentage ash content was calculated.

2.5. Determination Of Organic Matter Content

The organic matter content can be obtained for each sample using the formula below % Organic matter content =100– (% Ash content + % Moisture content) [12].

2.6. Determination Of Sample pH

The pH readings of the two samples, both digested and undigested, were taken and recorded by adjusting the knob of the pH meter;the sample in the 400g cylindrical tins waslabelled as;X= (chicken droppings) and Y= (banana peels). The samples were recorded using an electrical pH meter.

3. Results and Discussion

The biogas production from Chicken droppings and banana peels for 14days 2weeks. Figure 3 shows the production hours for samples x1 and y1 within 14 days retention period. The volume varies from 220cm^3-10cm^3 for x1 and 430cm^3-0cm^3 for y1. These volume ranges indicate a thermal stage of biogas production (24^{o}C-30^{o}C). The reaction rate is slow because of the effect of the environmental temperature. The maximum biogas produced for each sample was attained on day 4 for X1 and day 2 for Y1, in which the temperature these days is 29^{o}C and 26^{o}C, respectively.

Figure 4 shows the production hours for samples x2 and y2 within 14 days retention period. The volume varies from 260cm^3-0cm^3 for x1 and 390cm^3-0cm^3 for y2. These volume ranges indicate a thermal stage of biogas production (24^{o}C-30^{o}C). In this stage, the reaction rate is slow because of the effect of the environmental temperature. The maximum biogas produced for each sample was attained on day 4 for X2 and day 2 for Y2, in which the temperatures were 29^{o}C and 26^{o}C, respectively.

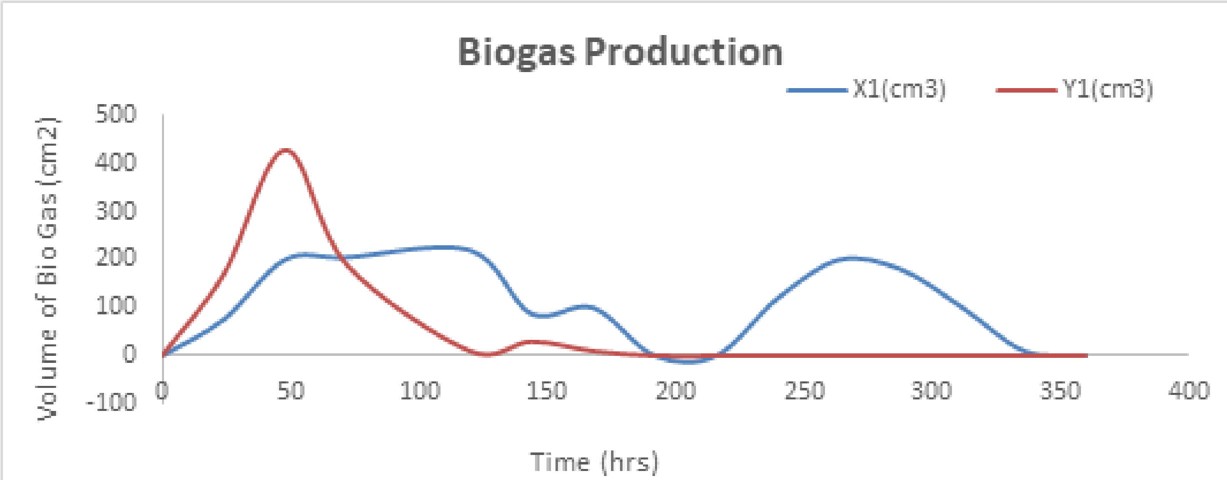

Figure 3. Volume of biogas produced for a period of (2 weeks) comparing x1 and y1

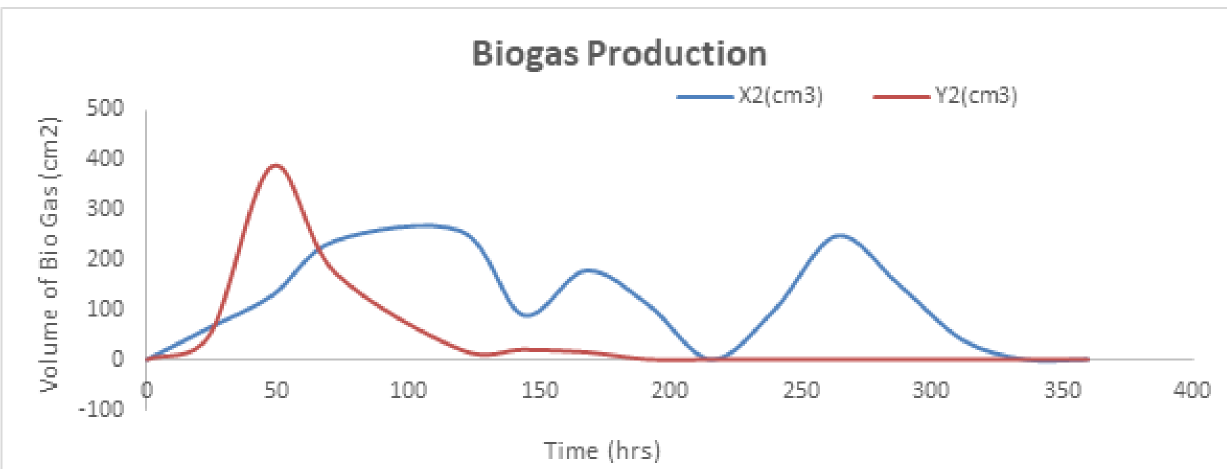

Figure 4. Volume of biogas produced for a period of (2 weeks) comparing x2 and y2

Table 2. Proximate compositions of sample X and sample Y

Sample	Moisture content (%)	Ash content (%)	Organic matter content (%)
Sample X (Undigested)	3.5±1.4	4.5±0.7	90±4.9
Sample X (Digested)	32.51±6.2	37.5±7.7	28.01±1.3
Sample Y (Undigested)	5.25±1.0	9.0±0.00	85.7±1.0
Sample Y (Digested)	36.5±6.3	29.51±2.0	34.01±8.0

3.1. Proximate analysis of the digested and undigested samples X and Y

The results for the proximate compositions of digested and undigested sample X Chicken droppings and sample Y Banana peels.

3.1.1. Ash and moisture contents of sample X and sample Y

Ash content measures the total amount of minerals present in each sample. It is often a good determining factor for the mineral content of plant-based samples. The higher the ash contents, the more the mineral content of that sample [13].

Table 3. pH of samples X and Y, both digested and undigested

Sample	**pH Reading**
Sample X (Undigested)	6.76
Sample X (Digested)	5.88
Sample Y (Undigested)	6.82
Sample Y (Digested)	6.01

Table 4. Total volume of biogas produced from each sample for two weeks

Sample	**Volume of Biogas obtained**
Sample X (Chicken droppings)	$1556cm^3$
Sample Y (Banana Peels)	$755cm^3$

From table 2 above, the ash content of the undigested sample and sample is lower than that of the digested samples. This shows that the digested samples contain more mineral elements due to adsorption during the anaerobic digestion of the substrates. This also indicates that the digested samples X and Y are better bio-fertilizers than the undigested samples. Sample X produced more bio-fertilizer than sample Y due to higher ash and moisture contents.

3.1.2. Organic matter content of sample X and sample Y

Organic matter contains remains of dead organisms, such as plants and animals found in the environment. The mechanism of biogas production involves the conversion of dead organic matter into biogas by bacterial organisms. So this means that the undigested samples X and Y should contain more organic matter; as observed above, the digested samples contain lower organic matter because it was converted to biogas by the bacteria [14].

3.1.3. The pH values of sample X and sample Y

The pH is one factor that affects biogas production and dramatically influences the substrate. The pH measures the acidity or alkalinity of an aqueous solution. Solutions with pH values greater than 7 are said to be basic or alkaline, and those with pH less than 7 are said to be acidic. Usually, methanogens cannot survive in a very acidic or alkaline solution, and it needs a pH within the range of 6.4–7.2. Microorganisms require a neutral or widely alkaline medium [15].

The results indicate that the undigested substrates (by consideration of the pH values) will produce more biogas than the digested substrates, which are pretty acidic. This is attributed to the fact that microorganisms can survive within a pH range of 6.4–7.2.

3.2. Biogas production

The volume of biogas produced from sample X (chicken droppings) and sample Y (banana peels) is summarized in the chart below. Sample X was transferred into X_1 and $X_{2,}$ while sample Y was transferred into digesters Y_1 and $Y_{2,}$respectively.

The results above indicate that sample X (poultry waste) and sample Y (banana peels) are very good substrates to be used in biogas production.

3.2.1. The volume of biogas produced from sample X (poultry waste) for two weeks

The actual volume of biogas produced from digesters X_1 and X_2 for two weeks commencing from the second day, when the volume of biogas produced was $140cm^3$ at a temperature of 30^oC. Higher volumes of biogas were observed to be continuously produced daily towards the beginning of the 1^{st} week, and production stopped at the end of the 2^{nd} week. The biogas production was minimal in the 2^{nd} week and automatically terminated in the 2^{nd} week. The gas production terminated because of temperature change, exhaustion of bacterial activities, and change in the pH value of the solution in the digester. During the 2^{nd} week, only small traces of biogas production was noticed and stopped because of the final exhaustion of bacterial activities.

3.2.2. The volume of biogas produced from sample Y (Banana peels) for a period of 2weeks

The actual volume of biogas produced from digesters Y_1 and Y_2 for weeks commenced from the 2^{nd} day with a volume of 220cm^3 at the same temperature of 30^{o}C.Biogas was observed to be continuously produced daily towards the 2^{nd} week and stopped gradually towards the end of the 2^{nd} week. The biogas production was terminated in the 2^{nd} week. This termination of biogas production was because of changes in temperature, pH, and exhaustion of bacterial activity in the digester.

4. Conclusion

As part of the global efforts to mitigate the effects of climate change and global warming, A comparative study of biogas production from Chicken droppings and Banana peels was carried out using the water displacement method for 14 days at an average temperature of 27.7^{o}C. The results showed that Chicken droppings had significant potential for producing a high volume of biogas with yields of 1556cm^{3}and 755cm^{3}for Banana peels due to the high proximate content presence; its use should be promoted in terms of biogas production. The volume yield of biogas production has also been discovered to be affected by temperature variation and pH, and the temperature ranges also denote a thermal stage of biogas production (24–30^{o}C).The temperature at which the manufacture of which the production of biogas was at the maximum for each waste (chicken droppings and banana peels) was attained on day 4 for chicken droppings and day 2 for banana peels, with the temperature for these days being 29 and 26^{o}C, respectively, Finally, it was observed that the pH drops as the retention time goes up, which explains why the generation of biogas gradually shifts from hydrolysis to acidogenesis, where the slurry becomes acidic and forms substrate before producing biogas. This study is to be extended by exploring the product experimentally and examining the co-processing of fossil feeds and chicken droppings feedstock. At the same time, it's recommended testing other animal biomass to have further insight into the optimum feedstock for biogas production in integrated systems.

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