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# Improved Biogas Production from Corn Stalks, Pig Manure and Eggshell

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author UAA designed the study and the laboratory scale bio-gas digester; author IE managed the literature searches. Author YY performed the statistical analysis, authors TEBA and OLU wrote the first draft of the manuscript. All authors read and approved the final manuscript.*

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## ABSTRACT

The need for an environmentally friendly energy source in the world has led to major diversification in renewable energy. Biogas provides a renewable energy source that will replace fossil fuel inevitably. The experiment was carried out using a self-designed laboratory-scale anaerobic biogas digester. The study was carried out at room temperature from 25 - 31°C for 20 days using corn stalk as the main substrate while Pig manure and eggshell were used as co-substrates. The findings showed that the biogas produced from the sample containing a blend of corn stalk, Pig manure, and eggshell resulted in higher biogas volume than the sample containing corn stalk and eggshell, corn stalk, and pig manure as well as the sample containing only corn stalk. This implies that the use of the corn stalk blend is a source of renewable energy. Thus, ensuring the sustainability of biogas production in the future.

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*Keywords: Cornstalk; pig manure; eggshell; retention time; biogas.*

## 1. INTRODUCTION

The multiplicity of automobiles producing poisonous emissions due to the use of fossil fuels, in particular, the danger of environmental pollution is very critical due to the predominant dependence on petroleum oil exploration activities and gas flaring. Most of our energy comes from burning fossil fuels like petroleum, coal, and natural gas. These fuels provide the energy that we use daily and due to expanding population with increased demand for energy, these fuels are one of the major problems that the world is facing today because of their heavy use and problems associated with it such as asthma, lung infection, and global warming. Due to these problems caused by non-renewables, many alternatives to replacing fossil fuels have been researched and put to use. [1-3].

Biogas is a renewable energy source that has been recognized globally as a means of solving the rising problems in energy prices, waste treatment /management and also creating sustainable development. Biogas is a colorless, flammable gas produced by anaerobic digestion (fermentation) of human, plant, animal, industrial, and municipal waste to produce methane (50-70%), Carbon dioxide (20-40%), and traces of gases like nitrogen, hydrogen, ammonia, hydrogen sulphide, water vapour [4]. According to [5], every biomass has the possibility of been used as a substrate for biogas production, provided they have carbohydrates, proteins, fats, cellulose, and hemicelluloses as major components. However, the biogas composition and $CH_4$ yield are a major function of the feedstock type, the digestion system, and the retention time, and therefore, they need to be optimized. However, waste to biogas initiative has been one of the major solutions to the exponential increase of solid wastes in both rural and urban areas in Nigeria [6]. Therefore, Biogas plants can help in the fight against global warming by allowing the burning of methane from organic waste, instead of letting it escape into the atmosphere where it contributes to the greenhouse effect [7].

Solid waste management is one of the major environmental challenges encountered by urban and rural settlements in Nigeria. There are several types of waste: agricultural waste, commercial waste, municipal waste, and waste from demolition, hazardous waste, hazardous wastes (include radioactive waste, construction, and demolition waste). Effective waste management is a process that involves the collection, disposal, treatment, keeping, recycling, and disposal of waste to render it harmless to humans, and the environment. Nigeria with a population exceeding 170 million people generates approximately 32 million tons of solid waste every year, however, only 20–70% are properly collected [6]. Uncontrolled disposal of the wastes results in methane (CH4) emissions from manure, untreated organic wastes, and wastewater. It has been observed that the current waste disposal practices in most abattoirs in Nigeria are that they dump solid wastes at nearby designated sites while the liquid wastes are allowed to flow into the drains [8].

Anaerobic digestion of biodegradable wastes is broadly is classified as the best treatment option because it produces $CO_2$ and biogas rich in methane which is suitable for energy production [9]. Co-digestion is the simultaneous digestion of more than one type of waste in the same unit. Some of the advantages include better digestibility, improved biogas production, or higher methane yield arising from the availability of additional nutrients. The rate of biogas production was found to depend on several factors such as pH, temperature, C: N ratio, retention time [10]. Studies have shown that co-digestion of different substrates, such as banana and plantain peels, spent grains and rice husk, pig waste, and cassava peels [10]. A laboratory scaled results of co-digestion of food waste and dairy manure in a two-phase digestion system from [11-12] in their research, showed that the gas production rate of co-digestion was improved by 0.8 - 5.5 times as compared to the digestion with dairy manure alone. According to [13], the cumulative biogas production from different substrates (Cow Dung, Jatropha, and Iron Filins) showed that Jatropha exocarp was more viable for biogas production than the cow dung. The blend of the two samples showed improved results than the cow dung; though the result was not as good as that of Jatropha exocarp only [13], Biogas was equally produced from co-digestion of rice husk (RH), melon husk, (MH) and cow dung (CD) for 200 days at different rice-melon husk (RH: MH) ratios. It was observed that the maximum biogas yield was characterized for methane, carbon (iv) oxide, and carbon (ii) oxide to be 70%, 5%, and 5% respectively. Results equally showed that the temperature has a significant effect on the yield of biogas [9].

This research work analyzed the rate of biogas production from corn stalk as the main substrate, Pig manure, and eggshell as the co-substrates. It equally analysed the optimum operating conditions (pH and retention time). The analysis was done without complete knowledge of the properties of the feedstock used in the production of biogas. Though the purity/fractional composition of the biogas was not analyzed. It was carried out at mesophilic temperature (25$^o$C – 42$^o$C).

## 2. MATERIALS AND METHODS

### 2.1 Bio-Digester Design

The bio-digester was fabricated using a gas cylinder adding the inlet using a PVC pipe and an outlet was added using a tap head, this outlet was used to collect the sample for pH and temperature check, each digester labeled A, B, C, and D. The fabricated digester would act as the bio-reactor for the hydraulic retention time which was connected to a tyre tube with pipes through a valve which was held in place with the use of metallic clips. The biodigester was filled to remove its original color and painted black to absorb heat energy from the sun during the day and provide supplementary heat during the night as digestion requires heat for better production of biogas.

A tyre tube was used as a storage vessel for the gas generated and a Bunsen burner was used in carrying out the flammability test. All apparatus was properly washed with a soap solution and allowed to dry overnight in the laboratory.

### 2.2 Materials

The following materials were used for this research work: Bio-digester, Thermometer (10 – 110$^o$C), Digital pH meter (PHS -3C), Weighing balance, Connecting tube, Mortar and Pestle, Heater, Oven, Bunsen burner, Funnel, Measuring Cylinder, Tyre tube, Valve, Beaker, Pig manure, Cornstalk, Eggshell, and Water.

### 2.3 Substrates Collection

The substrates used were collected from different sites in Igbinedion University, Okada, Nigeria. Corn stalks were collected from Okada, Nigeria, the Pig manure was collected from a Pig farm close to the governor's lodge inside the University' Crown Estate Okada, while the eggshell was collected from a fast food joint in Okada, Edo State. The corn stalks used for this study were chopped into smaller pieces using cutlass from the Engineering laboratory. This was to reduce their size and increase the surface area of the wastes for faster degradation. The Pig manure collected was sun-dried and thereafter crushed mechanically using mortar and pestle to ensure homogeneity of the pig manure and then weighed. The eggshell was crushed to a fine particle using a sieve of 1.18mm. All material was then brought to a water-waste ratio.

### 2.4 Substrates Pretreatment

All the substrates gathered except Pig manure needed pretreatment because they are lignocellulose materials. Physical pretreatment methods by chopping corn stalks and crushing eggshell to reduce the particle size were employed.

### 2.5 Experimental Procedure

For the experiments, the slurry combinations were formulated to contain 8% (0.63kg) solid content and each of the bio-digester was filled with slurry to 70% (9.8L) of the digester volume, leaving a headspace of 4.2L (30%) as the gas collecting chamber.

#### 2.5.1 Parameters of biogas production and their selected operating conditions

The research was carried out at room temperature (mesophilic temperature: 25$^o$C – 42$^o$C). pH arithmetic mean values for samples A, B, C and D were 6.26, 5.40, 6.08, 6.00, respectively, which were all within the pH range for biogas production. Also, a retention time of 20days was selected for this work.

### 2.6 Water Content

The water content for each sample was determined as reported by [3], that is, a total solid (TS) of 8% in the fermentation slurry. This was the basis for the determination of the amount of water to be added for any given mass of total solids. Hence the proportion of total solid to water was the same in the entire fermentation slurry sample. According to [3] in their work, they utilize 1.08kg to obtain 70% volume, this generated 17L. For this analysis, the digester was 25L.

Comparatively, the designed digester for this experiment is 14L, leaving an allowable 9.8L space to achieve 70% volume

If 1.08kg to obtain 17L (70%) mark, then the required kg for the designed experiment will be
1.08kg = 17L
X = 9.8L
X =0.63kg

## 2.7 Total Solid Content

For this research, there were A: B proportions aimed at investigating the efficiency of stalks of maize in biogas production. The four proportions were as follows:

**Plate 1. Newly constructed bio-digesters**

**Plate 2. Pig Manure**

**Plate 3. Corn stalk**

**Plate 4. Eggshell**

## 2.8 Fermentation Slurry

Preparation of fermentation slurry was by the addition and vigorous mixing of total solid with an equivalent amount of water needed for maximum yield. This mixture was then sample contained in the digester.

### 2.8.1 pH test

A sample of the substrate was placed in a beaker and the pH of the substance was measured using a digital pH meter (PHS-3C).

## 2.9 Data Collection

Water displacement method was utilized to quantify the amount of biogas produced, the volume of water displaced from the first measuring cylinder into a big beaker represented the volume of gas produced. This is made possible because of gas pressure that is built up inside the vessels.

## 3. RESULTS AND DISCUSSION

The amount of biogas produced in ml as a result of the substrate, measured by the volume of water displaced from each bio-digester is shown in Table 2. The biogas took some days before production commences, for digester A, B, C, D, production started from the $4^{th}$, $2^{nd}$, $2^{nd}$, and $6^{th}$ day respectively. This could be because of the lag phase of the inoculums getting used to their new environment or the richness of the medium or probably due to the methanogens undergoing a metamorphic growth process by consuming methane precursors produced from the initial activity as suggested by [6,4].

The production rate increased with high pH level in Digester A until the $12^{th}$ day where they were a drop in pH level on the $14^{th}$ day, this pH level was within the range of production According to [1] which explained that at pH range of 6.5-8.2 will produce biogas optimally. From the $16^{th}$ day, a rise in pH level was observed which led to the highest production in digester A. while for digester C, the production rate increased with high pH level until the $16^{th}$ day, which led to the highest production of biogas. As for digester B, the pH range was within 5, which cause a very low production of biogas in the digester. A low pH in the digester inhibits the activity of microorganisms involved in the digestion process, particularly methanogenic bacteria. Lastly, for Digester D, the production rate increased with a high pH level until the $18^{th}$ day. The production was minimal for digester D, this might be as a result of the pH level not being within the range of 6.5-8.2 according to [1], and so therefore the environment was not conducive for methanogenesis bacteria to live.

The temperature and pH reading against retention time for digester A, B, C, and D respectively as shown in Table 3, the reading show that the temperature was fluctuating between 25 – 31$^{o}$C and the pH reading of the substrate decreases initially when organic material is first loaded into the digester and As shown in Fig.1, the composition of biogas production with time at different mixing ratio yield different result of biogas produced. Cornstalk + Pig manure + eggshell produced 6,540ml of biogas as its highest production with a total production of 21,310ml; this is as a result of the pH being within the necessary range for anaerobic digestion. While digester B produced 600ml of biogas as its highest production with a total production of 2540ml, this is as a result of low pH which has a strong effect on biogas production. This low pH inhibits biogas production because the methane bacteria cannot survive in such an environment, so they die off which causes the chain of biological reactions indigestion to cease. For digester C, the highest production of biogas was 3,460ml with a total production of 17,520ml, this is as a result of the pH being within the necessary range just as in digester A. And lastly, digester D has a production of 320ml as its highest production, this may be as a result of the pH not being within the necessary range for anaerobic digestion or it can also be that corn stalk alone cannot yield more gas except when combined with other substrates.

As shown in Fig 2, the cumulative volume produced in ml shows that digester A has the highest production of biogas. While digester D has the least production of biogas.

## 3.1 Flammability Test

After the hydraulic retention time was elapsed the residual gas was left to accumulate to a larger quantity and stored inside a tyre tube and then passed through pipes to a 2M $N_aOH$ solution made of 40g of $N_aOH$ in 500ml of water for purification which was connected to a Bunsen burner for testing. The test was carried out in a dark room and the gas was found to be flammable.

**Table 1. Composition of materials in each sample**

| Sample | Mass of corn stalks Kg | Mass of Pig manure Kg | Mass of eggshell Kg | Total mass Kg |
|---|---|---|---|---|
| Slurry A | 0.21 | 0.21 | 0.21 | 0.63 |
| Slurry B | 0.32 | 0.32 | | 0.63 |
| Slurry C | 0.32 | | 0.32 | 0.63 |
| Slurry D | 0.63 | | | 0.63 |

**Table 2. Volume of biogas produced ($cm^3$) within 20days Retention time**

| Day | Bio Digester (A) (Corn Stalk, Pig Manure, and Eggshell) Vol. Of Biogas (ml) | Cumulative Volume Produced (ml) Bio Digester (A) | Bio Digester (B) (Corn Stalk and Pig Manure) Vol. Of Biogas (ml) | Cumulative Volume Produced (ml) Bio Digester (B) | Bio Digester (C ) (Corn Stalk and Eggshell) Vol. Of Biogas (ml) | Cumulative Volume Produced (ml) Bio Digester (C ) | Bio Digester (D) (Corn Stalk) Vol. Of Biogas (ml) | Cumulative Volume Produced (ml) Bio Digester (D) |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 180 | 180 | 250 | 250 | 0 | 0 |
| 4 | 200 | 200 | 210 | 390 | 810 | 1060 | 0 | 0 |
| 6 | 240 | 440 | 290 | 680 | 1000 | 2060 | 80 | 80 |
| 8 | 250 | 690 | 600 | 1280 | 1890 | 3950 | 110 | 190 |
| 10 | 1850 | 2540 | 320 | 1600 | 2200 | 6150 | 140 | 330 |
| 12 | 2530 | 5070 | 290 | 1890 | 2470 | 8620 | 280 | 610 |
| 14 | 5340 | 10410 | 210 | 2100 | 2860 | 11480 | 320 | 930 |
| 16 | 6540 | 16950 | 210 | 2310 | 3460 | 14940 | 310 | 1240 |
| 18 | 2460 | 19410 | 170 | 2480 | 1580 | 16520 | 230 | 1470 |
| 20 | 1900 | 21310 | 60 | 2540 | 1000 | 17520 | 120 | 1590 |

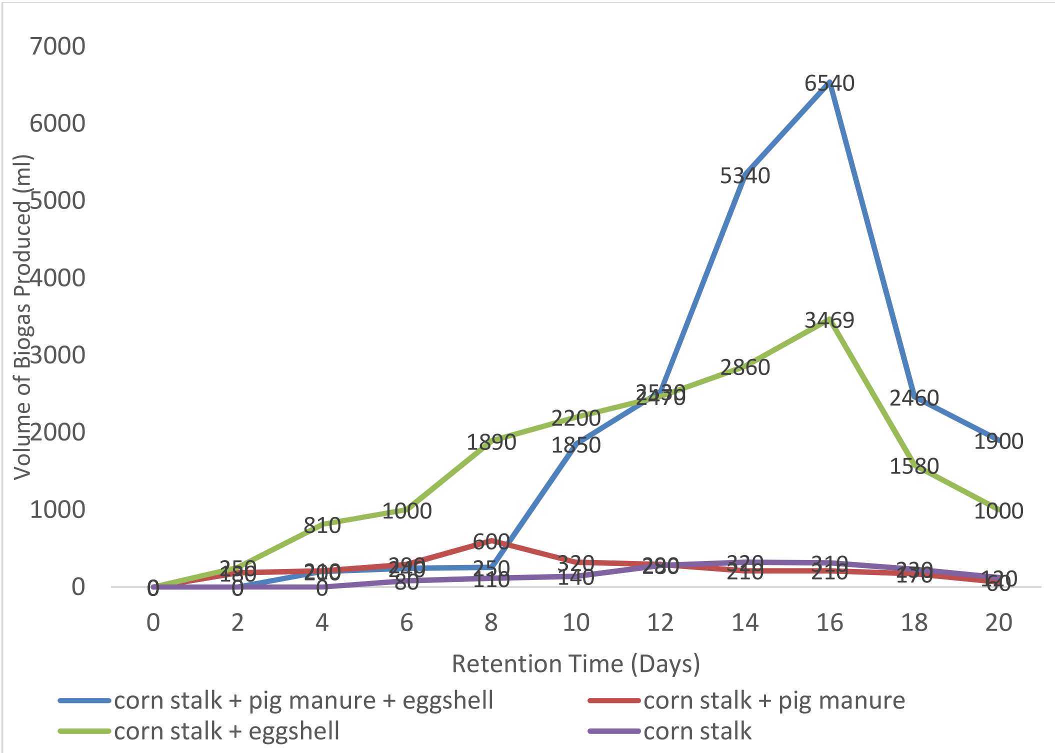


**Fig. 1. Biogas production with time at the different mixing ratio**

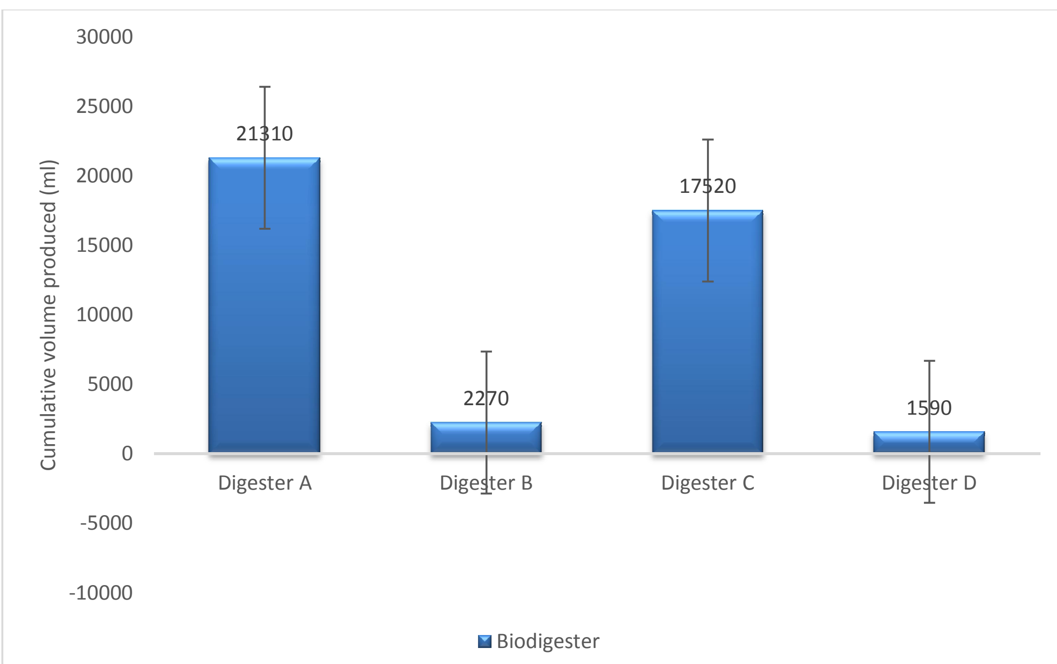


**Fig. 2. Cumulative volume produced (ml) against biodigester**

**Table 3. Recorded values of temperatures and pH in each of the biodigester**

| DIGESTER A | | DIGESTER B | | DIGESTER C | | DIGESTER D | | |
|---|---|---|---|---|---|---|---|---|
| **DAY** | **T(°C)** | **pH** | **T(°C)** | **pH** | **T(°C)** | **pH** | **T(°C)** | **pH** |
| 0 | 24 | 6.7 | 27 | 6.02 | 26 | 6.4 | 28 | 6.09 |
| 2 | 26 | 5.48 | 24 | 5.61 | 27 | 5.58 | 27 | 5.62 |
| 4 | 27 | 5.49 | 27 | 5.43 | 31 | 5.2 | 27 | 5.75 |
| 6 | 27 | 5.55 | 29 | 5.39 | 30 | 5.38 | 26 | 5.85 |
| 8 | 25 | 5.82 | 30 | 5.28 | 31 | 5.71 | 27 | 6.9 |
| 10 | 28 | 6.23 | 30 | 5.34 | 30 | 6.08 | 27 | 6.11 |
| 12 | 27 | 6.63 | 28 | 5.38 | 31 | 6.43 | 28 | 6.11 |
| 14 | 28 | 6.57 | 27 | 5.3 | 29 | 6.48 | 30 | 6.15 |
| 16 | 28 | 6.83 | 29 | 5.26 | 29 | 6.7 | 28 | 6.2 |
| 18 | 27 | 6.82 | 27 | 5.22 | 28 | 6.5 | 29 | 6.22 |
| 20 | 26 | 6.77 | 31 | 5.22 | 29 | 6.46 | 28 | 6.1 |

## 4. CONCLUSIONS

The result of this study shows that corn stalk, when combined with Pig manure and eggshell is a good substrate for a biogas plant with a short retention time of 20days especially when pH is within the necessary range for anaerobic digestion.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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