



(RESEARCH ARTICLE)



## Monitoring of produced biogas volume and composition from co-digestion of Cow-dung and organic-kitchen-waste

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GSC Advanced Research and Reviews, 2022, 13(01), 133–141

Publication history: Received on 05 September 2022; revised on 11 October 2022; accepted on 14 October 2022

Article DOI: <https://doi.org/10.30574/gscarr.2022.13.1.0265>

### Abstract

This is an experimental study on produced biogas volume and composition from co-digestion of cow dung and food waste. This study was carried out at ambient condition. A gas meter was used for the measurement of gas composition, biogas production rate and digester operating parameter were measured using a multi meter while gas volume was obtained from the observation of the floating drum. Four floating drum digesters were used for the experiment. The digesters held 3300 g of feed each with varying ratios of 70:30 (Sample A), 50:50 (Sample B), 40:60 (Sample C), and 30:70 (Sample D) of cow dung to kitchen waste respectively. The dilution ratio was 1:3 of feed to water which had a retention time of 30 days. The gas composition (CH<sub>4</sub>, CO, CO<sub>2</sub>, H<sub>2</sub>S), substrate pH and temperature were monitored to observe the changes. The results gotten were graphed and tabulated. The gas gotten from the biogas burnt which shows that the biogas produced methane (CH<sub>4</sub>) of more than 40% of the gas composition at certain points during the retention time.

**Keywords:** Biogas; Organic-Kitchen-waste; Cow-dung; Bioenergy; Biodigester

### 1. Introduction

The importance of energy in our day-to-day life cannot be overemphasized. Inadvertently, energy is one matter that humans cannot do without even in centuries to come. As the world evolves and application of technology is growing, energy still remains one of man's strongest backbone.

The various forms of energy ranges from electrical energy, mechanical energy, heat energy, motion energy, amongst others is been explored. Energy can be classified as renewable and non-renewable. Fossil fuels are non-renewable forms of energy. Due to resultant emission of anthropogenic pollutants associated with the burning of fossil fuel. The need for cleaner renewable energy is very important and this is clear to all stockholders of the energy industry. The prominent renewable energies are hydro, wind and solar energy. Biogas which has being in use by the Sumerians since 3000 BC (1) is becoming attractive and is merging in the contest for a better source of energy with the ability to secure a cleaner environment as against fossil fuels.

Biogas technology, also known as anaerobic digestion (AD) technology, is the use of biological processes in the absence of oxygen for the breakdown of organic matter and the stabilization of these material, by conversion to biogas and nearly stable residue (digestate). Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen (2). Biogas is a mixture of methane (45–75%) and carbon dioxide (25–55%); the actual proportion depending on the feedstock (substrate) used and processes employed. For biogas to be flammable, the methane content must be  $\geq 40\%$ , apart from methane and carbon dioxide, biogas may also contain small amounts ( $\leq 3\%$ ) of impurities, such as hydrogen sulphide, ammonia, carbon monoxide, and other gases (1, 2).

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The aim of this experimental research is to study the variation in composition of biogas produced from admixture of two substrate. The choice of feedstock for this project is cow dung and organic kitchen waste as co-substrate due to the abundance of cattle and organic kitchen waste in geography location of the research, Nigeria. From all the types of digesters described in the literature survey, with respect to the scope of this research work, the digester selected for the production of biogas using cow dung and organic kitchen waste is the 'Floating drum digester'.

According to FAO, 2010(3), Nigeria has the highest rate of deforestation in the world, with 55.7% (9,587,577 hectares) of her primary forest lost between 2000 and 2005. Fifty million tons of wood fuel is consumed in Nigeria per annum. Records also show that Nigeria ranks number 8 in the world in methane emission with about 20 billion m<sup>3</sup> of methane emission (13% of world emission). 69% of Nigeria's methane emission actually comes from gas flaring while 28.8% comes from untreated organic wastes (4). According to Akinbami et al., 2001(5), if biogas displaces kerosene, at least between 357 - 60,952 tons of carbon dioxide emission will be avoided.

To support the claim by Akinbami et al., 2001(5), Akau, 2017(6) outlined that biogas can be used;

- As a low-cost fuel in any country for any heating purpose, such as cooking, etc.
- In modern waste management facilities where it can be used to run any type of heat engine, to generate either mechanical or electrical power.
- After compression, much like natural gas, and used to power different energy chains. It is a renewable fuel, so it qualifies for renewable energy subsidies in some parts of the world.

From the review of other studies, it was observed that experiments whose temperature and pH were controlled and maintained at around 35°C and 7 respectively yielded more biogas due to the absence of fluctuations in the temperature and pressure of the digester. A substrate ratio of 1:1 is commonly used. It was also noted that the addition of cow dung to any substrate gives rise to an increase in the biogas production because it acts as a buffer. Under the same operating conditions of room temperature without sunlight, cow dung produced 0.35m<sup>3</sup> of biogas, Food waste produced 0.32m<sup>3</sup> of biogas and Fresh Organic waste produced 0.27m<sup>3</sup> of biogas (7). Also, cow dung contains more nutrients which provides more food (organic) for the bacteria to decompose and digest when compared to other animal waste.

## 2. Material and methods

A biogas digester is the medium used to anaerobically decompose organic matter (from plant or animal) to produce biogas through bacteria actions. Four biodigesters were used during the course of these experiments, each of the biodigester is made up of the following components:

- Biodigester: This is where the organic matter (cow dung and kitchen waste) is loaded.
- Gas holder: This is a smaller drum which is called "the gas holder drum". It is a plastic bottle which is completely immersed into the paint bucket filled with the substrates in order to create an air-tight environment to create the anaerobic environment needed for biogas production.
- Gas Outlet Pipe: This is a small pipe fitted on the top of the gas holder drum that allows the passage of gas to any external holding such as a burner for cooking or heating purposes.
- Gas Valve: This is a flow control device used to control the flow of the biogas.

### 2.1. Collection of substrates



**Figure 1** Kitchen Waste



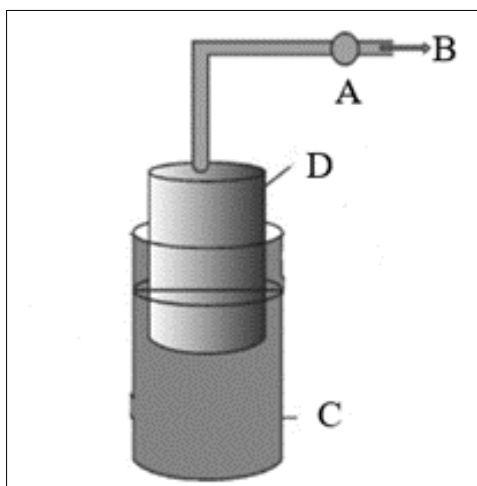
**Figure 2** Cow Dung

- Cow Dung: cow dung was collected from Agricultural Livestock Farm in University of Port Harcourt, Port Harcourt, Nigeria.
- Kitchen Waste: it was collected from restaurants around Choba, Port Harcourt, Nigeria. These restaurants are Sammie and De Choice at a rate of ₦150/kg. the constituents of these kitchen waste are: Rice (jollof rice and fried rice), Spaghetti, Chicken (Flesh and bones), Turkey (Flesh and bones), Fish (Flesh and bones), Veggies (green beans, carrot, peas, cabbage and tomatoes). See Figure s 1 and 2.

Water was used to achieve the optimum dilution needed for the quantity of cow dung and kitchen waste used. It was also used to wash other equipment before and after use and calibrate the gas holder drum.

## 2.2. Design consideration

With respect to the scope of this research work, the biodigester considered for the production of the biogas using cow dung and kitchen waste is the “floating drum digester”.



LEGENDS: A: Gas Valve; B: Gas Outlet Pipe; C: Plastic Bucket; D: Calibrated Cway Bottle

**Figure 3** Floating Dome Digester

The following factors are considered for the selecting the floating drum in the production of biogas using cow dung and kitchen waste;

- The operation of the plant is easy to understand and operate.
- The gas drum is air tight
- The digester has a constant gas pressure as a result of the weight of the drum.
- Increase in gas-volume is easily recognized by the position of the drum.
- The designing and fabricating of the floating drum digester is cost effective.
- It is durable depending on the nature of material used in fabrication.

## 2.3. Measuring equipment

- Weighing Balance: The model of this weighing balance is WTB-2000, it was used to measure the waste used in this research work.
- Gas Analyzer: This gas analyzer was used to measure the component gases in biogas produced. Its model is “MSA ALTAIR 5X VER 1.09.02”, it is capable of measuring up to 5 gases simultaneously.
- Measuring Cylinder: The measuring cylinder has a capacity of 500ml. it was used to measure the desired quantity of water. It was also used to calibrate the gas holder drums.

## 2.4. Experiment

2.4.1. Calibration of Gas Holder Drum

The gas holder drum was calibrated by making sure the valve is closed, then water is poured in to fill the gas pipe after which the first 500ml of water from the measuring cylinder is poured into the gas holder drum and marked. This process is repeated until the gas holder is filled with water. The water is poured out of the gas holder drum and allow to dry.

2.4.2. Charging of The Biodigesters

Four digesters were used for the experiment. The digesters held 3300g of feed each with varying ratios of 70:30 (Sample A), 50:50 (Sample B), 40:60 (Sample C), and 30:70 (Sample D) of cow dung to kitchen waste respectively. The dilution ratio was 1:3 of feed to water which follows Ojolo et al., 2007(8) experiment.



Figure 4 Diluted Feed

A total of 9.9 litres was used to dilute the substrate in each paint bucket in other to achieve optimum slurry concentration. The presence of water provides a favourable environment for microorganisms. A total mixture of about 13.1 litres was fed into the bowel in other to recreate adequate allowances for the gasholder drum which was used to cover the paint bucket and to keep the environment anaerobic for a 30 days retention time.

Daily gas production was measured using the calibrated gas holder drum. This is achieved as the floating drum rises due to pressure in the paint bucket as gas produced increases. The value of gas produced is equal to the markings on the gas holder drum that coincident with the top of the paint bucket. The pH, temperature and gas composition were measured every five (5) days.

3. Results

The result of the experimental research is presented in this section, starting with the graphs, Figure s 5 to 19.

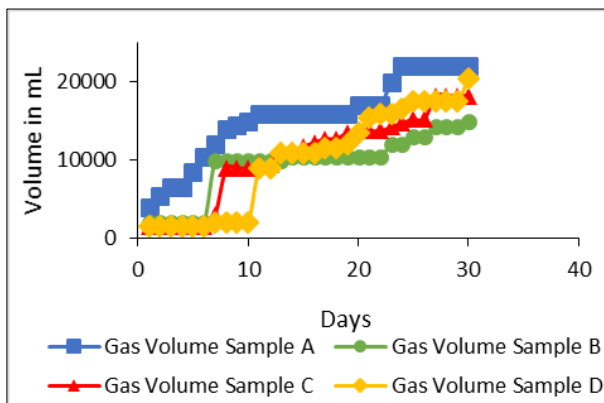


Figure 5 Cumulative Gas Volume across All Samples

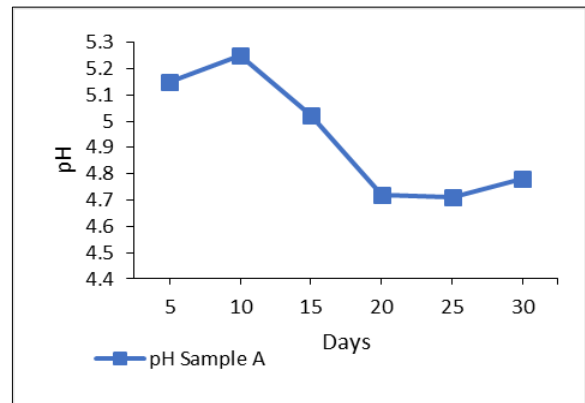
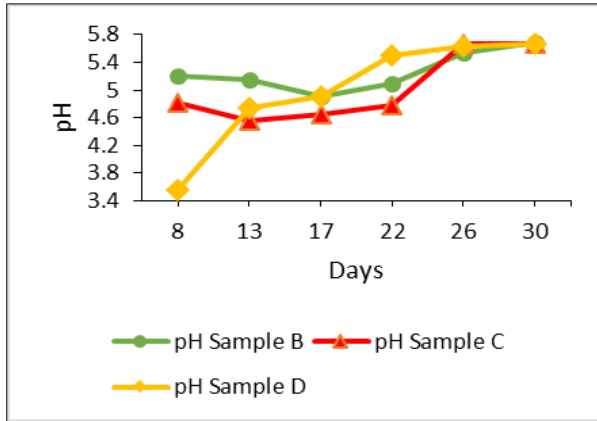
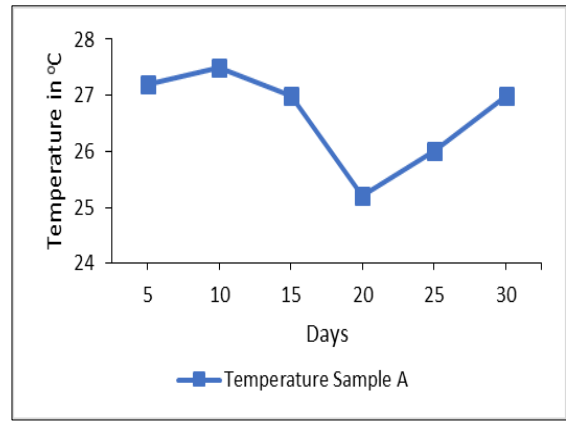


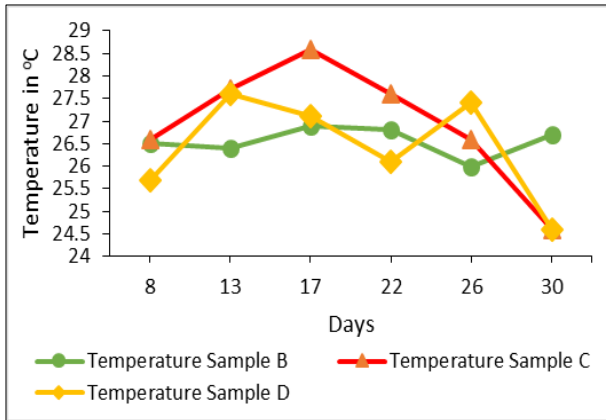
Figure 6 PH of Sample A



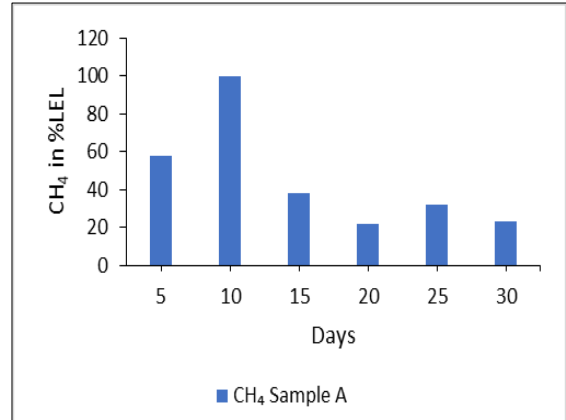
**Figure 7** PH of Samples B, Sample C and Sample D



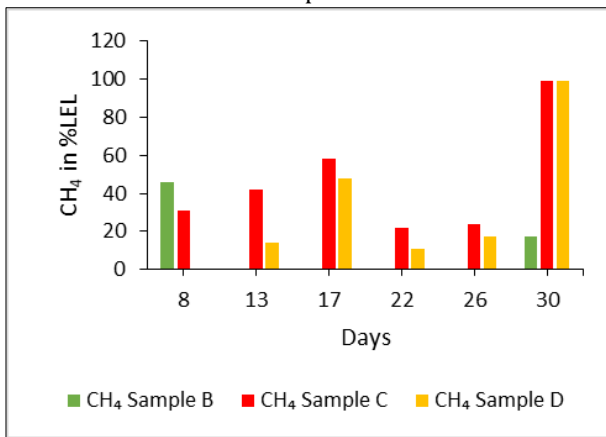
**Figure 8** Temperature of Sample A



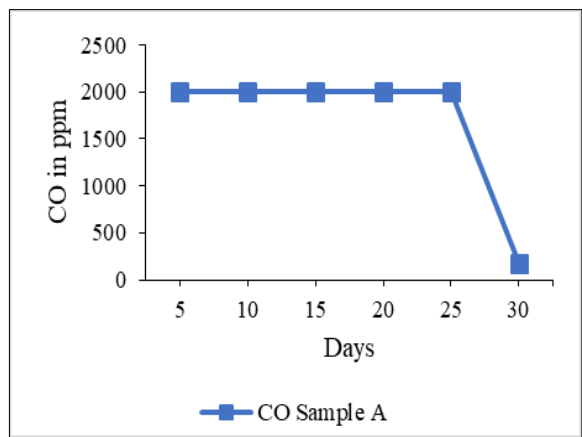
**Figure 9** Temperature of Samples B, Sample C and Sample D



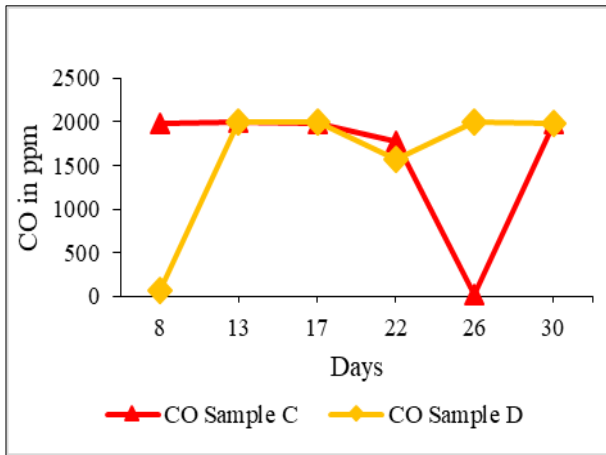
**Figure 10** Methane Content of Sample A



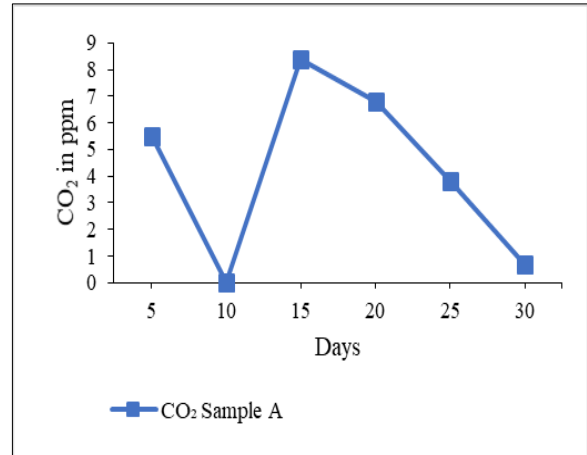
**Figure 11** Methane Content of Samples B, Sample C and Sample D



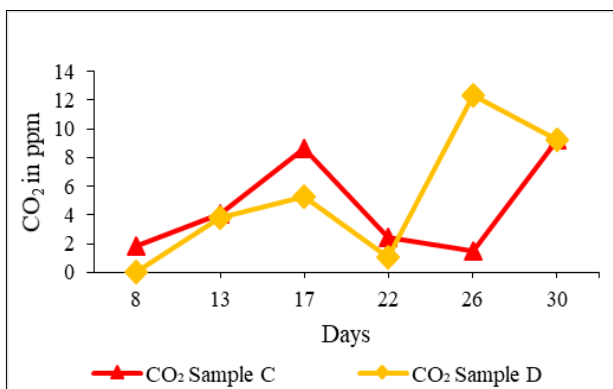
**Figure 12** CO Content of Sample A



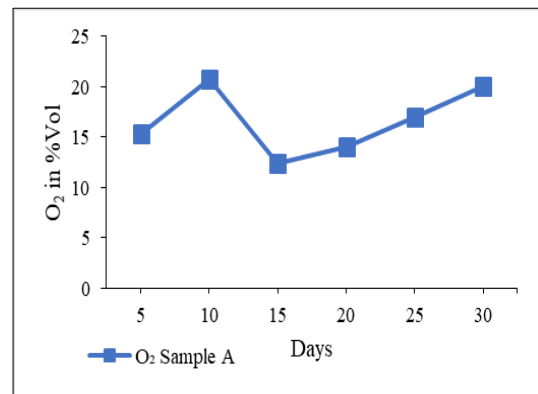
**Figure 13** CO Content of Samples B, Sample C and Sample D



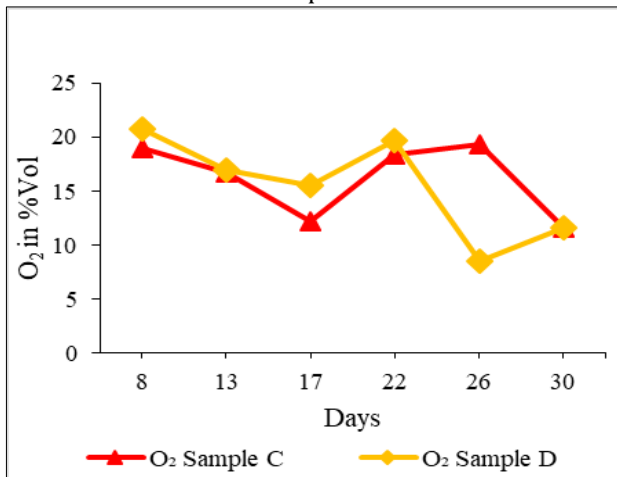
**Figure 14** CO<sub>2</sub> Content of Sample A



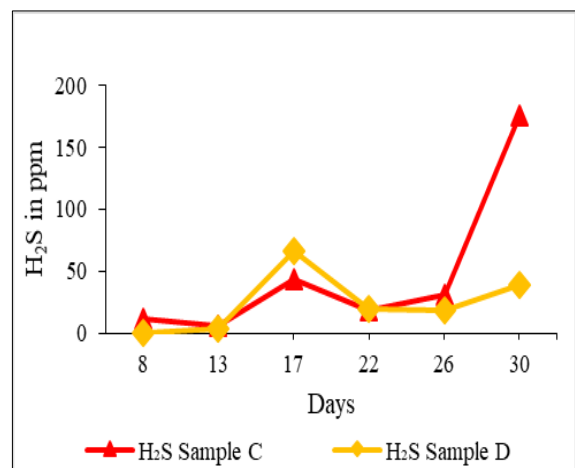
**Figure 15** CO<sub>2</sub> Content of Sample B, Sample C and Sample D



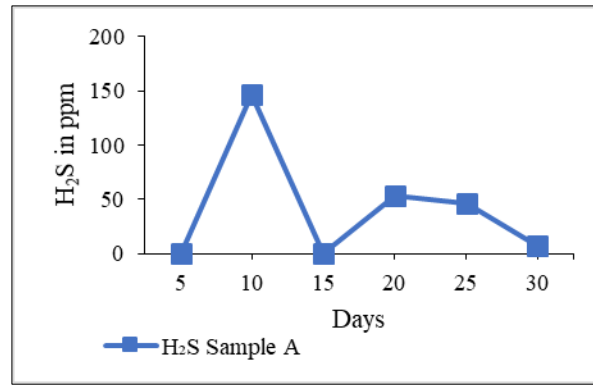
**Figure 16** O<sub>2</sub> Content of Sample A



**Figure 17** O<sub>2</sub> Content of Sample B, Sample C and Sample D



**Figure 18** H<sub>2</sub>S Content of Sample A



**Figure 19** H<sub>2</sub>S Content of Sample B, Sample C and Sample D

## 4. Discussion

### 4.1. Volume of Biogas Produced

Cumulatively, from Fig. 5, Sample A (70:30) produced more gas followed by sample D (30:70). Sample B (50:50) had the least cumulative gas production with Sample C (40:60) as third highest.

### 4.2. Biodigester Operating Condition and Gas Composition

Sample A's experiment kicked off days before sample B. Sample C and sample D, so they can't be graphed on the same viewing rectangle. From Fig. 6, the pH of sample A went it from less acidic to more acidic (5.15 to 4.78) which agrees with Otun et al.,2016(9), while from Fig. 7, sample B, sample C and sample D went it from more acidic to less acidic which agrees with Dahunsi and Oranusi, 2013(10)

From Fig. 8, sample A had an average temperature of 26.65°C while from Fig. 9 sample B, sample C and sample D had average temperatures of 26.55°C, 26.95 °C, and 26.42 °C respectively. All four samples' temperature where within same range hence, this experiment occurred under mesophilic temperature which agrees with Otun et al., 2016(9).

From Fig. 10, sample A had its highest methane content (100%LEL) on the 10<sup>th</sup> day after which it started reducing steadily. From Fig. 11, sample B had a methane content of 46%LEL on the 8<sup>th</sup> day and then 17%LEL on the 30<sup>th</sup> day. Sample C and sample D had similar behavior. Both increased steadily with their first peak hitting 58%LEL and 48%LEL on the 17<sup>th</sup> respectively after which they both reduced and went as high as 99%LEL on day 30. The methane content produced conforms with literature one of which is; for biogas to be flammable the methane content must be ≥ 40% (11).

Subsequently, Sample B was not graphed due to inadequate data which was as a result of no production on the stipulated days for checking gas composition. According to Sorathia et al.,2012 (12); "If not stirred, the slurry will tend to settle out and form a hard scum on the surface, which will prevent release of biogas. This problem is much greater with vegetable waste than with manure, which will tend to remain in suspension and have better contact with the bacteria as a result".

From Fig. 12, the CO content of sample A was 2000ppm until day 30 where it dropped to 167ppm. From Fig. 13, the CO content of sample C started higher than that sample D until day 13 through day 17 where both had the value. both sample C and sample D experienced a drop in value from day 17 through day 22 with sample C still superseding sample D until a sudden downward slope occurred with sample C which in turn made sample D higher. At day 30, both sample C and sample D had the same value.

From Fig. 14 and 15, the CO<sub>2</sub> content of sample A, sample C and sample D followed a zigzag pattern having their highest peaks at 8.4%Vol on day 15, 8.6%Vol on day 17 and 12.3%Vol on day 26 respectively. Both sample C and sample D had 9.2%Vol on day 30 which agrees with Kavuma, 2013 (13).

From Fig. 16 and 17, the O<sub>2</sub> content of sample A, sample C and sample D followed a zigzag pattern having their highest peaks at 20.8%Vol on day 10, 19%Vol on day 8 and 20.8%Vol on day 8 respectively. Both sample C and sample D had 11.6%Vol on day 30.



From Fig. 18 and 19, the H<sub>2</sub>S content of sample A, sample C and sample D followed a zigzag pattern having their highest peaks at 147ppm on day 10, 176ppm on day 30 and 66ppm on day 17 respectively. Sample C and sample D didn't have same value on day 30. According to Suyog, 2011 (2), the H<sub>2</sub>S content should be between 20-20,000ppm

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## 5. Conclusion

The results obtained from the experiment carried out using cow dung and kitchen waste showed that;

- Agricultural waste such as cow dung and food waste like rice, spaghetti, cabbage and so on can be utilized to produce biogas as an alternative form of energy.
- Cow dung to Food waste (70:30, Sample A) pH moved from less acidic to more acidic while that of B (50:50), C (40:60), and D (30:70) of cow dung to food waste respectively moved from being more acidic to being less acidic.
- Sample A, B, C, and D had an average temperature of 26.65°C, 26.55 °C, 26.95 °C, and 26.42 °C respectively hence, the experiment was carried out under mesophilic temperature.
- The biogas produced had very minute impurities. This was deduced from the blue flames gotten from the biogas which agrees with Elgas, 2021 (14). This shows that despite the fluctuations in gas compositions, the biodigesters produced CH<sub>4</sub> gas of more than 40% of the gas composition at certain points during the retention time.
- According to Adiotomre et al., 2015 (15), it is possible to produce biogas using kitchen waste since it has more nutrients than cow dung.

### *Recommendation*

It is recommended that;

- For gas volume with behaviour similar to mine, gas composition and necessary operating parameters should be measured for days gas produced irrespective of the day (even if it's outside the scheduled timeframe) in to get to the actual root cause of the behaviour.
- The design should also cater for agitation so as to free trapped gases within the digester mixtures.
- Continuous feeding should also be considered to help break up the surface and provide a rudimentary stirring action
- There should be provision for the production of microbial catalyst to support the concerted action of the anaerobic digester component
- Government should encourage commercial or industrial sized biogas plant in other to help waste management authorities reduce municipal wastes.
- Farmers should be oriented about converting their waste (plant and animals) to wealth (biogas) and using the digestate (slurry) as manure.

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## Compliance with ethical standards

### *Acknowledgments*

We wish to acknowledge the assistance of the Center for Gas, Refining and Petrochemical Engineering, University of Port Harcourt. Thank you for the research support.

### *Disclosure of conflict of interest*

We wish to state that there is no conflict of interest and that this is the original work of the authors.

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