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# Performance Evaluation of a Bio-Digester in Anaerobic Production of Biogas from Kitchen Wastes

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**ABSTRACT**

*The bad nature of the storage and transport facilities, overcooking and unnecessary spending causes a tremendous increase in food wastes in Nigeria which otherwise causes an environmental pollution to waterways and contributes to production of greenhouse gas emissions. This study evaluated the performance of an anaerobic bio-digester to generate biogas from food wastes collected from various homes, restaurants and hotels within Ede metropolis in Osun State. The wastes were sorted and foreign materials present other than food products were discarded. The food wastes were milled into finer particles using an electric blender and grinder. The proximate composition of the feedstock obtained through chemical analysis shows it has enough energy yielding nutrients capable of generating some biogas and also possess a relatively higher carbohydrate content ($p< 0.05$) which suggest that it has more capacity to generate more energy for microbes to thrive and enhance the decomposition process in biogas production. The biogas started forming on the second day and the yield increased from day 2 and peaked at days 12 and 14 while a reduction was noticed till day 22. A mix ratio of 40% feed stock and 60% water content gave the highest average yield ($1.96 \pm 0.39$ kg) while 10% feed stock and 90% water gave the minimum yield ($0.35 \pm 0.18$ kg). The proximate content of the food wastes shows that it has high energy yielding nutrients capable of generating some biogas which was enhanced leakage free type of the digester used. The biogas can be used as a fuel, for cooking or other purposes and the solid residue can be used as organic compost.*

**Keywords:** Biogas, Bioreactor, Fermentation, Food wastes, Renewable energy, Waste conversion.

## 1. INTRODUCTION

The wastage of food in Nigeria per citizen equates to an average of 189 kg of food every year, which sums up to 37.9 million (37,941,470) tons per annum is her continent (Ripples, 2021). The global UN report estimated that 931 million tons of food (about 17% of total food available to consumers in 2019), were apparently wastages by various homes, shops, stores and restaurants (Ripples, 2021). Additionally, every person wastes an average of 121 kg of consumer-level food annually, with households throughout the world contributing 74 kg of this waste. Unfortunately, most people don't seem ready to stop their habit because they like their way of life. In Nigeria, this may be due to factors like bad nature of the storage and transport facilities, overcooking and unnecessary spending (Gmpost, 2022).

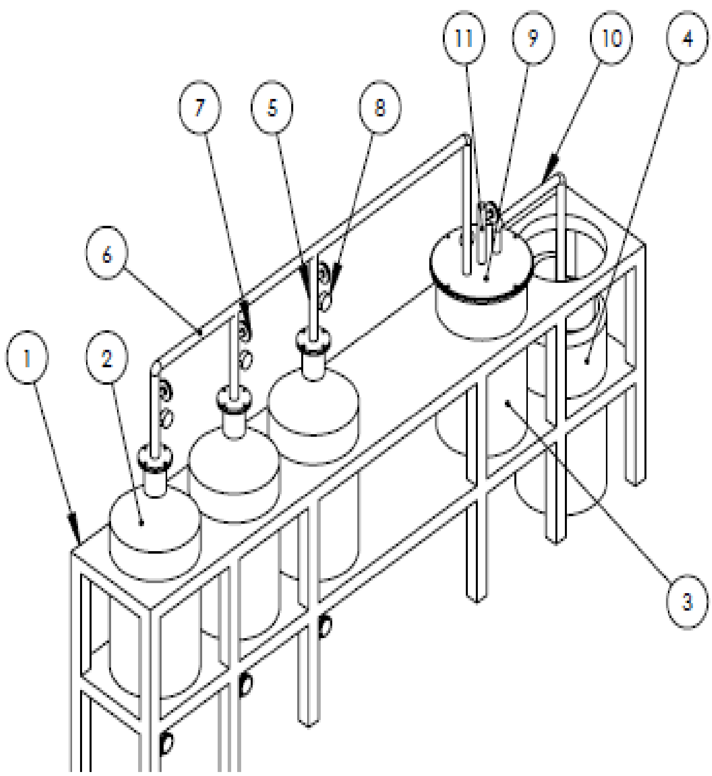
The food wastes causes an environmental pollution to waterways by removing organic waste and contributes to production of greenhouse gas emissions. Unfortunately, little is being done about food recycling and reuse either in direct or other forms in Nigeria. Recycling will produce other usable items like biogas which is a renewable source of energy produced through microbial digestion and fermentation (EESI, 2017). Anaerobic digestion, or methanization uses decomposition to break down organic matter from bio-wastes to produce biogas using a centralized system called anaerobic digester or bio-digester (Vasco-Correa *et al*., 2018). A digester is a sizable container where chemical or biological reaction takes place. The Carbon-Nitrogen (C/N) ratio, temperature, pH level, presence of volatile substances, and biological and chemical oxygen demand are the main factors influencing methanogenic reactions in a digester (Dioha *et al.*, 2013). Methane and carbon dioxide make up the majority of biogas, with lesser amounts of oxygen, nitrogen, hydrogen, hydrogen sulphide, and methyl-mercaptans (Dioha *et al.*, 2013). It devises from bacteria that are involved in the anaerobic biodegradation of organic material.

The adoption of biogas as a renewable energy source will aid future energy security, improve use of natural resources, and halt the depletion of fossil fuels and other traditional energy sources (Sawyerr *et al.*, 2019). A gaseous fuel produced from waste fermentation called "biogas" is useful for creating electricity, heat, and biofuels for cars (Awe *et al.*, 2017; Itabiyi, *et al.*, 2019; Caposciutti *et al.*, 2020). This study designed a bio-digester and evaluated the yield of biogas produced from kitchen waste.

## 2. METHODOLOGY

### 2.1 Wastes Collection, Sorting and Preparation

Fresh food wastes were collected from various homes, restaurants and hotels within Ede metropolis in Osun State. The wastes were sorted and foreign materials present other than food products were discarded. The food wastes were milled into finer particles using an electric blender and grinder (Nima brand, 150 W, 220V, 16 × 0.93 cm, Japan). The milled bio-wastes were mixed with water in different proportions and fed into the digester as presented in Figure 1 and plate 1 (located in home economics kitchen, federal polytechnic, Ede, Osun State, Nigeria).




| ITEM NO. | PART NUMBER |
|---|---|
| 1 | Standind frame |
| 2 | Digester |
| 3 | Gass Collection Cylinder |
| 4 | Gas Cylinder |
| 5 | Gas-Collecting Pipe 3 |
| 6 | Gas-Collecting Pipe |
| 7 | Non-Return Valve |
| 8 | Pressure Guage |
| 9 | Gas Collection Unit Part |
| 10 | Gas-Collecting Pipe 4 |
| 11 | Gas-Collecting Pipe 5 |

**Figure 1:** Isometric View of Bio – Digester

**Plate 1:** Constructed Biogas Digester

**2.2 Feedstock Analysis**

The collected food waste samples and cow dung with intestinal content which serves as organic catalyst that aids anaerobic digestion were chemically analyzed in accordance with AOAC (2005). Parameters determined include Total solids, Volatile Solids, Ash, Fiber, Phosphorus, Potassium, Protein, pH. The feedstock composition was carried out using proximate analysis according to the method described by Tolera and Alemu (2019).

**2.3 Biogas Yield Measurement**

The volume of biogas produced was obtained by weighing the collection cylinder every 24 hours using a 300 kg ($\pm$ 0.001) digital platform scale (Camry, built in rechargeable battery, foldable pole platform, 40 cm by 50 cm base size).

**2.4 Bio-Digester Description and Mode of Operation**

The majority of existing biogas digesters are designed and built with bricks, cement, metals, and reinforced concrete. However, most run into problems like leaks at the brick structure's edges after a short period of operation and some reinforced plastic digesters that quickly degrade and develop holes as a result of ultraviolet (UV) radiations while the metallic digesters corrode easily. This justified the choice of stainless steel for the construction of the bio-digester used in this study. The digester has three tanks each measuring 75 liters. The feedstock were fed into the digester (up to 60% volume of each tank) where microbe decomposes the wastes in the chamber under bio- chemical reaction. Leakages were inspected by passing water through the digestion chamber to ensure a complete anaerobic environment to allow the microorganisms to break down the organic material and convert it into biogas. The biogas yield was collected over water to aid proper filtration.

## 3. RESULTS AND DISCUSSION

The proximate composition of the feedstock is presented in in Table 1 while the biogas yield is presented in Figure 2 and Table 2. Table 1 shows that the feedstock has enough energy yielding nutrients capable of generating some biogas and it also possess a relatively higher carbohydrate content ($p < 0.05$) which suggest that it has more capacity to generate more energy for microbes to thrive and enhance the decomposition process in biogas production. The crude fat and crude protein showed significant concentrations of energy yielding nutrients in the food wastes may suggest that the kitchen wastes use as feedstock would provide more energy for the microorganisms to live and sustain the process. The moisture level shows adequate water content for microbes to also multiply successfully.

**Table 1:** Proximate Composition of the Feed Stock

| Parameters | Food waste (%) |
|---|---|
| Ash (g/kg) | 2.69 $\pm$ 0.89 |
| Crude fats (g/kg) | 1.75 $\pm$ 0.04 |
| Crude protein (g/kg) | 0.52 $\pm$ 0.23 |
| Carbohydrates (g/kg) | 59.21$\pm$ 0.99 |
| Moisture (g/kg) | 35.45 $\pm$ 0.15 |
| pH | 7.1 |

The biogas started forming on the second day of the experiment (Table 2). It was observed that the yield increased from day 2 and peaked at days 12 and 14 while a reduction was noticed till day 22 (Figure 2). A mix ratio of 40% feed stock and 60% water content gave the highest average yield (1.96 $\pm$ 0.39 kg) while 10% feed stock and 90% water gave the minimum yield (0.35 $\pm$ 0.18 kg). The high biogas yield may be as a result of the earlier ventilation test to ensure no leaks, which will result to more biogas yield and production, this is in tandem with reports of Ziauddin and Rajesh (2015); Olieveira and Doelle (2015). This was achieved by passing 100% $CO_2$ into the digesters under very high pressure and physically checking out for leakages (Obileke *et al*., 2020).

**Table 2:** Biogas Yield

| Feedstock (food waste + Water) (kg) | Minimum (kg) | Maximum (kg) | Average (kg) | Standard Deviation |
|---|---|---|---|---|
| 10:90 | 0.35 | 1.27 | 0.67 | 0.34 |
| 20:80 | 0.49 | 1.21 | 0.76 | 0.28 |
| 30:70 | 0.55 | 1.65 | 0.82 | 0.35 |
| 40:60 | 0.97 | 1.96 | 1.54 | 0.39 |
| 50:50 | 0.99 | 1.62 | 1.33 | 0.34 |
| 100:0 | 0.83 | 1.31 | 0.92 | 0.23 |

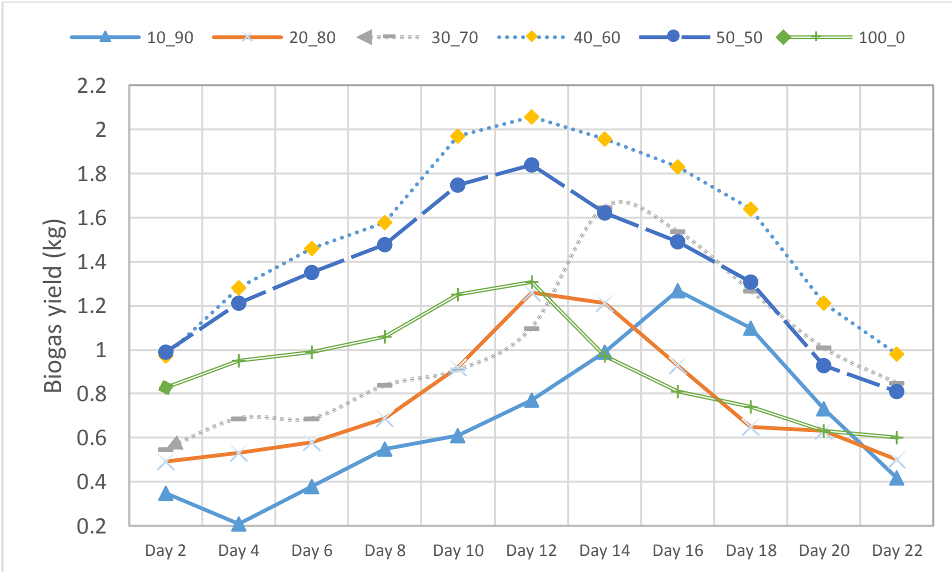



**Figure 2:** Biogas Yield Obtained at Varying Feedstock: Water Ratio

## 4. CONCLUSION

The food wastes generated in Nigeria is currently a menace to both individuals and the environment. This study evaluated the biogas yield generated from kitchen wastes using an anaerobic bio-digester. The proximate content of the food wastes shows that it has high energy yielding nutrients capable of generating some biogas and also possess a relatively higher carbohydrate content which suggest that it has more capacity to generate more energy for microbes to thrive and enhance the decomposition process in biogas production. The biogas yield obtained shows that the wastes could be used as an alternative source of renewable energy.

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