

Production of Biogas from Residential Bio-waste with the Digestate as Soil Enhancer

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Abstract: The research involved the generation of biogas by the inoculation of a mixture of residential bio-wastes with fresh rumen from cow to produce biogas. The wastes were collected from residential areas, sorted out, and the bio-wastes was stored in polyethylene bags. They bio-wastes were further broken down into smaller bits and properly mixed with freshly collected cow dung and water to form paste, before they were transferred into the bio-digester. The bio-digester is an air tight cylindrical steel container where anaerobic decomposition of the bio-wastes occurs in the presence of methanogens. The experimental set up was connected and the biogas yield was monitored for a period of 30 days. The biogas generated was stored. The digestate was subjected to further tests, such as Kjeldahl analysis to determine the nitrogen content (0.28%), conductance analysis was also carried out to determine the phosphorus content (137.5µg/ml) and Atomic Absorption Spectrophotometer (AAS) for potassium content (1.78ppm). The results of the analysis carried out on the digestate showed that it can be used as a soil enricher or bio-fertilizer. The study showed that the residential bio-wastes generated at home can serve as a source for the generation of biogas and hence mitigate pollution arising from indiscriminate waste disposal.

Keywords: Biogas, Bio-digester, Digestate, Methane

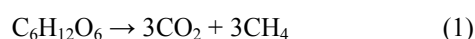
1. Introduction

The generation of Biogas from biomass and residential bio-waste is an eco-friendly strategy for energy production that is gaining popularity and the subsequent usage of the digestate as a soil conditioner or enricher. The anaerobic breakdown of biological matter in the absence of air leads to the generation of biogas. It is mostly made up of methane and carbon dioxide. The main energy component of biomass is Flammable methane with a composition of (50 - 85%), representing the main energy source. It can be used in boilers for heat generation. Biogas fuels finds usage as heating sources in boilers. Biogas production from local agricultural waste using a laboratory-scale digester was evaluated. Biogas

is generated in different environment that includes landfills, waste water treatment plants and bio-waste digesters during anaerobic degradation of bio-material. Biogas usually contains around 45 - 70% methane and 30 - 45% carbon IV oxide gas. Depending on the source, biogas can also contain nitrogen, hydrogen sulphide, halogenated compounds and organic silicon compounds [9]. Additionally the use of bio-methane does not increase the concentration of greenhouse gases in the atmosphere because carbon dioxide and other gases that create the greenhouse effect are released into the atmosphere during the decomposition process of organic matter. In preference to living species including humans, biomethane is one of the best ways to satisfy the increased need for energy without contributing to warming of the

planet which threatens their living [4].

In the biochemical processes occurring in a typical digester, the reactions occurring are classified into four distinct steps and they follow certain sequential stages such as, hydrolysis, acidogenesis, acetogenesis and methanogenesis [1, 11]. In each stage, specific microbes (bacteria) are used to aid or catalyze the digestion process and they access oxygen for their metabolic activities from sources other than the surrounding air. The microbes feed upon the biomass feedstock, which undergoes a series of reactions, converting it to intermediate molecules including sugars, hydrogen and acetic acid, before finally being converted to biogas. Overall the production reaction is simplified in the generic chemical equation (Eqn 1) [5]:



Biogas is considered a carbon IV oxide-neutral biofuel and if used as vehicle fuel, emits lower amounts of nitrogen, hydrocarbon and carbon II oxide emissions than petrol or diesel engines, interest in the use of biogas as vehicle fuel and in fuel cells has also increased [10].

There are several factors that influences the yield of biogas, and they include the type and nature of feedstock, inoculums, design of the biogas plant, C:N ratio of substrate and processing parameters such as pH of the medium, reaction time, reaction temperature, loading rate [4]. Others are concentration of slurry, total solid content, agitation of slurry, volatile fatty acids and amount of water in the slurry. The pH of the biogas plant is a function of the amount of CO_2 produced, HCO_3^- alkalinity of the medium and concentration of volatile fatty acids produced. For increased biogas yield a pH of 6.6 to 7.6 is adequate [1]. Biogas has varied end uses such as cooking, lighting and heating in household and from the industrial aspect such as combined heat and power (CHP) generation, transportation fuel (after being upgraded to biomethane) or upgraded to natural gas quality for other purposes [7].

Biogas technology is based on the phenomenon that when organic matter containing cellulose is fermented in the absence of air (anaerobically), methane as a major combustible gas is formed. Anaerobic biogas is a result of decomposition of organic material by micro-organisms in a humid environment in the absence of oxygen.

Biogas is a product of anaerobic degradation of organic substrates, which is one of the oldest processes used for the treatment of industrial wastes and stabilization of sludge. Lack of process stability, low loading rates, slow recovery after failure and specific requirement for waste composition are some of the limitation associated with it [12]. Biogas primarily consists of methane (CH_4) and carbon dioxide (CO_2) with small amounts of hydrogen (H_2), nitrogen (N_2), hydrogen sulphide (H_2S), oxygen (O_2), water (H_2O) and saturated hydrocarbons (i.e ethane, propane). The detailed composition of biogas is discussed in Table 1 [2].

The aim of this research work is to generate biogas from residential bio-waste for possible use as an alternative energy

source and also to investigate usage of the digestate as a soil nutrient improver.

Table 1. Composition of biogas.

Components	Concentration/ volume
Methane (CH_4)	40-70%
Carbon dioxide (CO_2)	15-60%
Water (H_2O)	1-5%
Hydrogen Sulphide (H_2S)	20-20,000 ppm (2%)
Ammonia (NH_3)	0-5000 ppm
Nitrogen (N_2)	0-5%
Oxygen (O_2)	0-2%
Hydrogen (H_2)	Traces

2. Materials and Methods

Digester, Kjeldahl flask, Bunsen burner, Atomic Absorption Spectrophotometer (Buck scientific, model 210VGP), household bio-wastes (Pineapple peels, Bananas peels, Paw Paw peels, decomposed vegetables), Cow dung. All chemicals used were BDH grade and includes calcium hydroxide $\text{Ca}(\text{OH})_2$, nitric acid (HNO_3), hydrogen peroxide (H_2O_2), sulphuric acid (H_2SO_4), copper sulphate (CuSO_4), sodium hydroxide, zinc metal, boric acid, methyl red indicator.

2.1. Experimental

A partially decomposed household bio-wastes were accurately weighed (10.5 kg), 3.5 kg of cow dung were properly mixed with the bio-wastes and introduced into the digester. The mixture in the digester was added 2 liters of water, stirred and allowed to undergo complete decomposition. The mixture in the digester was sealed and the gas delivery tube connected. The experimental set up was monitored for a specific time interval (15.00 hrs) at an ambient condition until a decline in gas production was observed. During the period of the experiment, the temperature and volume of gas were measured daily for 30 days. The content of the digester was continuously stirred to ensure that they are set at random motion. The amount of gas produced was monitored by measuring its volume and the average temperature which was maintained at the range of 25-29°C.

2.2. Analytical Analysis

2.2.1. Determination of Nitrogen Content (Kjeldahl Method)

The determination of the nitrogen content was carried out according to Jiang *et. al.* [6]. The 0.5 g of the sample (digestate) was weighed into a Kjeldahl flask, 10 g of NaSO_4 was added, followed with 20 mL of conc. sulfuric acid and about 1 g CuSO_4 was added. The mixture was heated with Bunsen burner till solution digest completely, allowed to cool and solidify for 24 hours. Add 60 mL of 40% NaOH to the digested sample and 2 g of zinc dust, pour the mixture into a round bottom flask of distillation column. In a labeled conical flask, 100 mL of 4% boric acid was added followed

by 2 drops of methyl red indicator, placed on the receiving end of the distillatory apparatus.

Titrate the distillate (content in the conical flask) (20ml) with 0.1 mL H₂SO₄.

Calculation:

T=Titrate value

Weight of sample = 0.5

$$\% \text{ Protein} = \frac{100 \times T \times 0.0014 \times 6.25}{0.5} = 1.75\%$$

% Protein = %Nitrogen \times 6.25

$$\% \text{ Nitrogen} = \frac{\% \text{ Protein}}{6.25} = \frac{1.75}{6.25} = 0.28\%$$

% Nitrogen = 0.28%

2.2.2. Determination of Phosphorus Content (Conductance Method)

The determination of the phosphorus content of the digestate was carried out according to Kweon *et al.* [8]. This involved the pipetting of 100 mL of the sample into a conical flask. Subsequently 100 mL of distilled water that served as control was also pipetted into another conical flask. 1mL of 18 M H₂SO₄ and 0.89 g of ammonium persulphate were added to both conical flasks and gently boiled for 90 mins, the volume was made up to 50 cm³ with distilled water. It was allowed to cool down, a drop of phenolphthalein indicator was added and neutralized with the 2 mL NaOH solution. The pink colour was discharged by drop wise addition of 2ml HCl, and the solution made up to 100ml with distilled water. For the colorimetric analysis, 20 mL of the sample was pipetted into test tubes, 10 mL of the reagent was added, shaken and left to stand for 10 mins before reading the absorbance at 690 nm on a spectrophotometer, using 20 mL of distilled water plus 1mL of the reagent as reference.

Table 2. Result of Sample Absorbance.

S/N	Absorbance
A	1.57
B	1.68
C	1.70
Average	1.65

Using the Standard formulae

$$Y = 0.012X$$

Where Y= Absorbance

X= Concentration absorbance = 0.012 concentration

$$\text{Conc. of P} = \frac{\text{Absorbance}}{0.012}$$

The average absorbance of the sample = 1.65.

Therefore,

$$\text{Concentration of phosphate in the sample} = \frac{1.65}{0.012} = 137.5\mu\text{g/ml}$$

2.2.3. Determination on Potassium Content (Using AAS)

Digestion of sample for analysis using Atomic Absorption Spectrophotometer according to Christopher *et al.* [3]. First, the sample was ashed in a furnace at 600 – 800 °C, after ashing the sample, 1g of the powdered ash was measured and added 10 mL of HNO₃ heated in a hot plate for 30 mins. After cooling down, the mixture was added 10 mL of H₂O₂ and 10 mL of distilled water, placed back in the hot plate, heated again for 30 mins, after which the whole content was transferred into 50 mL volumetric flask and made up to the mark with distilled water, placed in machine and read.

Therefore, potassium (K) content in sample = 1.78ppm.

3. Results

The measurement of the Biogas collected per day was recorded as follows:

Table 3. The volume of biogas yield per day.

Days	Volume (cm ³)	Temperature (°C)	Days	Volume (cm ³)	Temperature (°C)
1	—	25	16	16	24
2	—	25	17	18	24
3	—	25	18	20	26
4	—	25	19	20	26
5	—	25	20	19	26
6	—	25	21	17	26
7	—	25	22	16	26
8	2	24	23	16	26
9	4	24	24	15	26
10	5	24	25	13	26
11	6	24	26	12	26
12	8	24	27	12	26
13	10	24	28	11	26
14	12	24	29	10	26
15	14	24	30	8	26

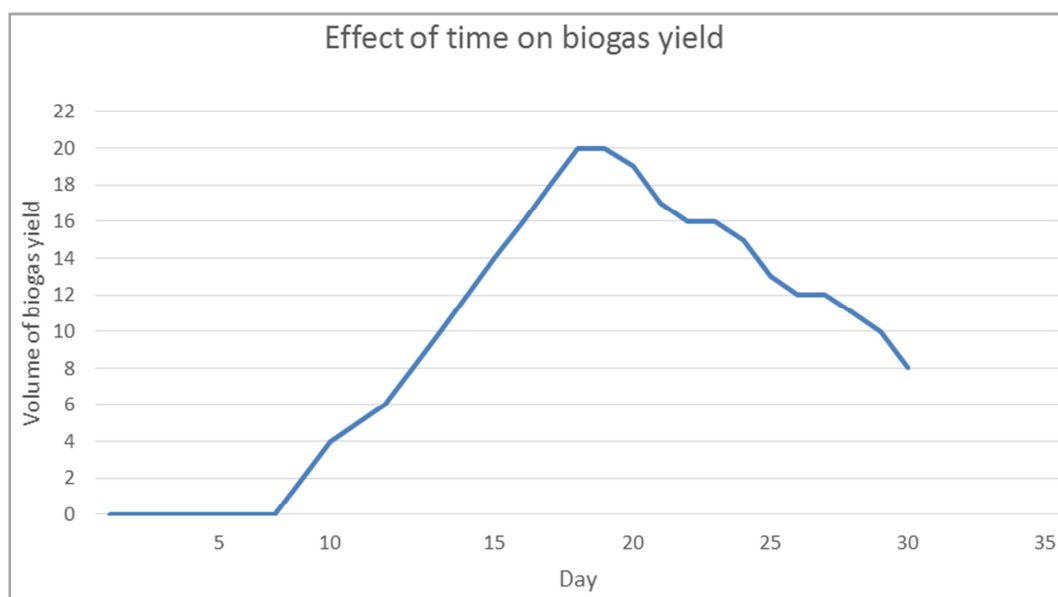


Figure 1. A plot of volume versus day for biogas yield.

Figure 1 showed the amount of biogas yield per day, it was observed that the generation of biogas started on the 8th day and there was a continuously generation even up to day 20th and afterwards gas yield started decreasing as a result of decrease in the amount of the bio-degradable feed stock.

Table 4. Results of Analysis.

Sample content	Results
Nitrogen	0.28%
Potassium	1.78ppm
Phosphorus	137.5µg/ml

4. Discussion

In this work the amount of biogas generated was monitored by measuring the volume and average temperature daily. The temperature in the digester was maintained at the range of 24 to 27 °C throughout the period of the experiment. The results showed that the volume of biogas generated from the first day to the seventh day were zero but at the eighth day it readily changed, the gas generated on the eight day was quite low though an increase in biogas generation was subsequently observed as the days progressed. After the 20th day that could be regarded as the peak, there was gradual reduction in the volume of gas produced due to the fact that the micro-organisms responsible for biogas production have converted a large amount of the starch present in the feedstock to biogas and water. The pH of the digester remained considerably within the range of 6.0 – 6.7, a situation that would favour the micro-organisms needed for optimum performance.

However, after the production of biogas, the substrate was collected and analyzed to investigate the amount of NPK (nitrogen, potassium and phosphorus) content in the sample. Nitrogen content according by kjeldahl analysis gave 0.28% composition of nitrogen, the potassium content according to AAS was 1.78ppm, and the phosphorus content using the

conductance method was 137.5µg/ml. The result showed that the sample substrate can be used to generate biogas while the digestate also can be used as organic manure having contained significant amount of nitrogen, potassium and phosphorus in the small quantity that was analyzed. This work showed that there are benefits such as biogas generation that can be used for heating and bio-fertilizer from residential wastes.

5. Conclusion

In conclusion, the study showed that residential bio-wastes can be used to generate biogas and the wastes can also serve as a source for soil enricher. Rather than open disposal of the wastes they can be sources of energy. There is another dimension of the study because it can serve as an additional source of income if the research is undertaken at a larger scale.

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