# (ICERD 08096) Biogas production from cassava waste

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**Abstract:** Anaerobic digestion is being taken seriously because of increasing concerns about the environmental hazards of wastes. The production of biogas, as an alternative source of energy was investigated in a designed and fabricated 200litre biogas reactor. The digester was operated on a batch-fed basis, and the feed stock was cassava waste which is readily available in Nigerian farms. The main aim was to explore other renewable sources as a means of less dependence on fossil fuels. A total of 1.94dm$^3$/60kg waste of biogas was produced in 40 days of hydraulic retention time (HRT) with the average yield of 0.048dm$^3$/day. The gas burned with a bluish colour indicating presence of methane (CH4). Temperature during the period of experiment varied between 27 and 33$^0$C. The pH of the slurry after the experiments averaged 3.21.

**Keywords**: Biogas, Cassava, Cassava peel, Digester.

## 1. INTRODUCTION

Anaerobic digestion and biogas production are promising means of achieving multiple environmental benefits and producing an energy carrier from renewable resources (Borjesson and Berglund, 2005).
The important characteristics of sustainable waste management include the recovery of materials and energy from the waste generated, and stabilization of the residues. In no distant future, many countries will be facing another problem due to shortage of fossil fuels. One of the alternative sources of energy, which may in the future compensate for the shortage of conventional fuels, is biogas, which is naturally produced from biodegradable waste (Hvid et al., 1998).
Biogas is produced by the process of anaerobic digestion of organic material by anaerobes. Biogas can be produced either from biodegradable waste materials or by the use of energy crops fed into anaerobic digester.
Biogas is one of the by-products of anaerobic decomposition of organic matter by microorganisms, mainly bacterial, a process referred to as anaerobic digestion.

Biogas, also called digester gas typically refers to methane produced by the fermentation of organic matter including manure, wastewater, sludge, municipal solid waste or any other biodegradable feedstock under anaerobic conditions. The content of biogas varies with the material being decomposed, and the environmental conditions involved. The gas generally composes of methane, carbon dioxide, nitrogen, hydrogen, and hydrogen sulphide (Anunputtikul and Rodtong, 2004). Potentially, all organic waste materials contain adequate quantities of the materials essential for the growth and metabolism of the anaerobic bacterial in biogas production. Organic waste has been mainly used for biogas production, and several kinds of waste materials has been exploited (Alvarez et al., 2006), Mahnet et al., (2005), Anunputtikul et al., (2004), Zuru et al., (1998), Aburas et al., (1996) and others.

Properly functioning biogas systems can yield a whole range of benefits for other users, including production of heat, light and electricity, transformation of organic waste into high-quality fertilizer, improvement of hygienic condition through reduction of pathogens, reduction of firewood collection and cooking, and environmental advantages through protection of soil, water, air and woody vegetation (Alvarez et al., 2005).

The production of biogas from anaerobic digestion of waste products is known to depend on the kind of materials added to the digestion, the solids loading, the temperature effect has been observed by many researchers. The biomethanation process at mesophillic and thermophillic ranges is relatively well understood and documented. However, concerning the temperature there is severe lack of fundamental knowledge here in Nigeria.

With respect to the retention time, the fermentation has been reported to become stable with a higher biogas yield, and reduction of volatile solids (VS) with an increasing retention time. Waste products have different retention times, not only due to the presence of complex organic compounds but also due to high concentration of ammonia and/or hydrogen, which affect anaerobic decomposition. The current practice in unheated biogas plant is to use a retention time of about 30-40days in warm climates and up to 55-60days in the colder hilly regions.

Several researchers have addressed the effect of increasing pressure in the anaerobic digestion. The prime effect relates to the increasing carbon dioxide concentration in the liquid phase caused by an increased pressure. Hayes et al., (1990), reports increasing methane content in the digester with higher pressure. Carbon dioxide is 40 times more soluble in water than methane, and a higher digester pressure therefore results in high concentration of carbon dioxide in the substrate, which drives the methane producing reactions forward and stimulates methane production. Toxicity effects can be avoided by charging the total gas pressure in a biogas digester. An increase of $CO_2$ partial pressure decreases the pH value, which reduces the non-ionized ammonia concentration. On the other hand, a decrease in $CO_2$ partial pressure increase the pH level which lowers the non-iodized hydrogen sulphide concentration (Vavilin et al., 1995).

## 1.1 The Process of Anaerobic Digestion

The process of anaerobic digestion consists of four steps. The first step is the decomposition (hydrolysis) of plant or animal matter. This step breaks down the organic material to usable-sized molecules such as sugars, amino acids or fatty acids.

Hydrolysis/Liquefaction Reaction:

Lipid → Fatty Acids
Polysacchaides → Monosaccharides
Protein → Amino Acids
Nuclei Acids → Purines and Pyrimidines

The second step is fermentation (acidogensis), where a further breakdown occurs producing ammonia, carbondioxide and hydrogen sulphide.

Chemical Equation:

$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + 2\ ATP$ (Energy Released: 118 kJ $mol^{-1}$)

Word Equation:

Sugar (glucose, fructose, or sucrose) → Alcohol (ethanol) + Carbon Dioxide + Energy (ATP)

The thirds step is acetogenesis where the products of acidogenesis are further digested to produce products such as carbon dioxide, hydrogen, and mainly acetate. Although a higher molecular-weight organic salts (e.g. proprionate, butyrate, valerate) are also produced.

Chemical equation:

$2\ CO_2(aq) + 4H_2(aq) = CH_3COOH(aq) + 2H_2O$

Word Equation:

Carbon Dioxide + Hydrogen → Acetic Acid + Water

In the fourth step called methanogenesis or biomethanation, the intermediates molecules are converted into methane gas. The bacteria called methane formers (also known as methanogenesis) in two ways produce methane either by means of cleavage of acetic acid molecules to generate carbon dioxide and methane, or by reduction of carbon dioxide with hydrogen. Methane production is higher from reduction of carbon dioxide. This is an important and widespread form of microbial metabolism. In most environments, it is the final step in the decomposition of biomass. Recently, it has been demonstrated that leaf tissues of living plants emit methane. (Kepler,F. 2006).

$CO_2 + 4\ H2 \rightarrow CH_4 + 2H_2O$

Carbon dioxide methane

$CH_3COOH \rightarrow CH_4 + CO_2$
Acetic acid

Most of the biogas researchers in Nigeria used animal dung as substrate; Zuru et al., (1998) Machido et al., (1996), Garba, (1995), and Fernado and Dangogo, (1986), Ojolo, (2005). A few have explored other substrates such as municipal solid waste (Ojolo, 2005), water hyacinth (Lucas and Bamgboye, 1998), aquatic weeds (Abbasi et al., 1990, and leaf liter (Mashanu and Sambo, 1991). There has not been any research on biogas using cassava (peel) waste in Nigeria. This work is therefore imperative because it will form a basis for further research on biogas production using cassava (peel) waste. The objective of this work involves the production of biogas from cassava (peel) waste in a design and fabricated medium scale biogas digester.

## 2. MATERIALS AND METHOD

### 2.1 Feedstock

Fresh cassava (peel) waste was collected from a cassava-processing outlet in Ikate, Surulere, Lagos. To obtain consistency of the raw material for biogas production experiments, the cassava peel were prepared by chopping the whole waste into pieces and stored in a black polythene sack to preserve its moisture content. It is also important to note that the raw materials were not catalyzed during period of experiments. Hence for faster degradability (natural), increase in surface area, it necessitated the chopping of the raw materials.

### 2.2 Apparatus

The experiments were carried out in a batch fed digester. The digester was equipped with inlet and outlet ports for feeding and effluent discharge, and also with a port attached with a gas valve for collecting gas. The digester was built with mild steel while the collecting gas bottle was made of glass. The digester was connected via its gas valve to a gas collecting bottle and also connected to a bunsen burner.

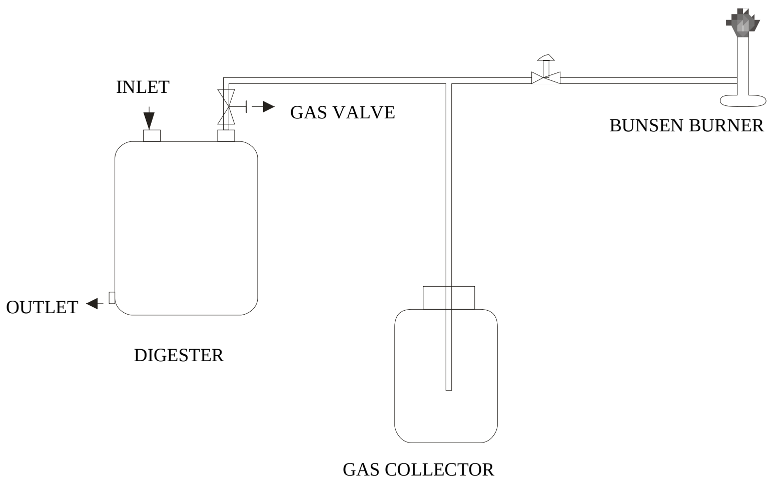


**Figure2.1: Schematic view of experimental set-up**

### 2.3 Experimental Procedure

Prepared cassava (peel) waste (60kg) was loaded into the digester tank and subsequently filled with water (to three –quarter (3/4)) of the digester volume for optimal biogas production. All openings (inlet, outlet and gas port) was wrapped with a threaded tape and closed back tightly to avoid any possible gas leakages.
The digester was operated under a batch feed basis and the experiment was observed for 40 days of hydraulic retention time (HRT). The establishment of a steady state in the digester was assessed by measuring the daily biogas production. The unit production biogas was measured by the liquid level rise method. This was the same method adopted by Anunputtikul and Rodtong, 2004, Alvarez et al., 2005 and Aburas et al., 1995.

For proper mixing of the content, to maintain contact between micro-organisms and substrates, to enhance digestion of substrate, and also for optimal biogas production, the digester tank was subjected to periodic agitation by hand once a day for about 2mins. This mimicked the practice adopted for rural digester, in India which is normally mixed only once a day (Alvarez et al., 2005).

To reduce temperature fluctuations, the digester was covered with black polythene. The pH of the digested substrate was determined by using a pH meter, and gas produced was burned to study the physical characteristics of its flame.

## *3. RESULTS AND CONCLUSION*

The result of biogas production from cassava (peel) waste is shown in the figures below.

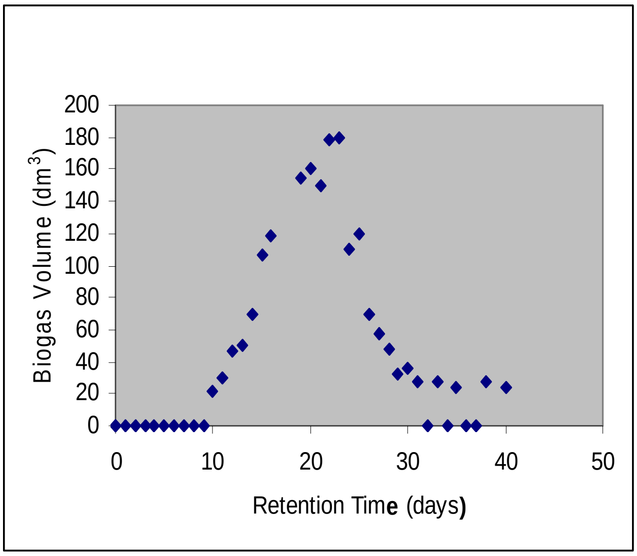


**Figure 3.1: Biogas production against retention time**

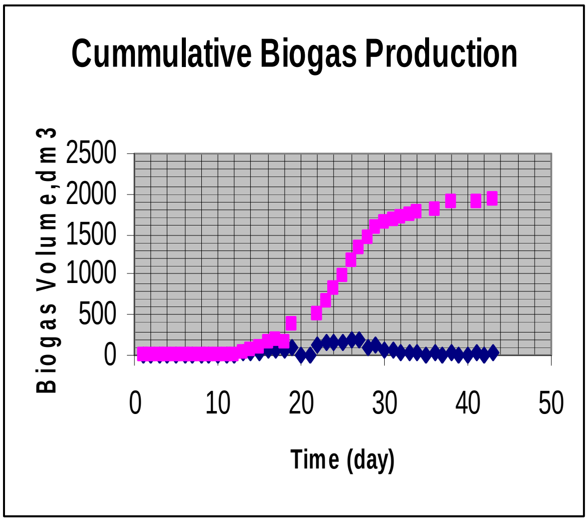


**Figure 3.2: Cumulative biogas production**

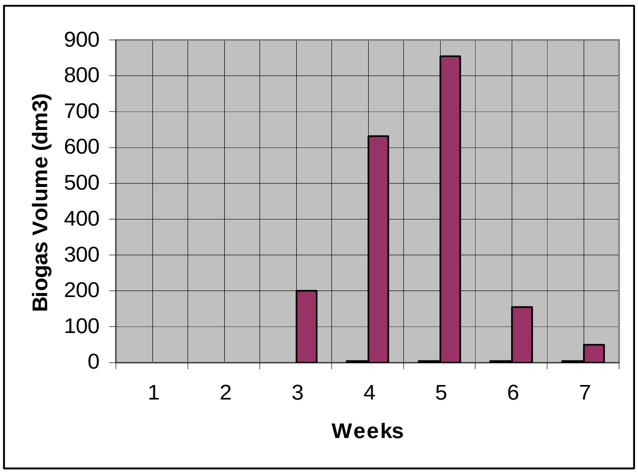


**Figure3.3: Cumulative (weekly) Volume of Biogas Produced.**

The results obtained indicate a lag-time of nine days before traces of biogas generation became observable. Biogas yield commenced in the second week (figure 1) and this follows a log-growth curve into the third week of operation. It was also observed that biogas production was at its peak in the fourth week, and more gas was produced on the24th day of experimental period. Biogas production dropped sharply after the 4$^{th}$ week of operation.

The cumulative rate of biogas produced against retention time (Figure 3.1 and 3.2) compare well with those in literature (Alvarez et al., 2005, Philip et al 2005, and Ojolo et al., 2005). Thus biogas production from cassava peel waste follows the trend observed using other waste materials such as cow, horse, goat and sheep dings, poultry droppings, water hyacinth and municipal solid waste (MSW).

Burning of the gas generated gave a bluish colour, smokeless and less offensive odour which indicated that the gas generated had less hydrogen sulphide that gave off offensive odour and less sulphur content in the raw material. It is also an indication that gas generated from cassava waste has better characteristics than those derived from other waste products such as animal waste which gave off much offensive odour.

The gas burned cleanly and smooth with a “whoosh” sound. The odour observed at the time of burning was much less offensive than at the beginning of experiment. Observation made during burning of the gas also confirms with the literature that methane unlike most other fuel does not give off poisonous carbon monoxide when burnt. So, it is safe to use in the home than other gases for cooking and heating.

The gas produced in this work was able to boil 100 ml of water in three minutes six seconds while home cooking gas and kerosene stove boil 100 ml of water in two minutes twenty-seven seconds and three minutes forty-two seconds respectively.

This shows that the gas generated has a higher heating value and more efficient than the kerosene cooking stove. Presence of impurities in the gas produced was as a result of the difference observed in above experiment. And total removal of impurities will improve its characteristics. It was also observed that accumulation of the gas produced in the digester gave a foul smell which was as a result of hydrogen sulphide (Pharaoh, 1976)

Scrubbing of the gas generated is encouraged to improve its characteristics, physical and chemical. And the scrubbing of gas derived from cassava waste would be less expensive due to its low content in hydrogen sulphide ($H_2S$) and carbon-dioxide ($CO_2$) compared to other gas generated from animal waste products.

Agitation of the substrate in the digester tank (due to the absence of stirring mechanism) was observed to affect the digestion process. Insufficient mixing of substrate lead to uneven spread of microorganisms in the digester which then leads to incomplete/partial digestion of the substrate (Lucas et al., 1993).

The result of this work also shows a total of 1,937x10$^{-3}$ dm$^3$ / 60 kg of biogas were produced in 40 days of hydraulic retention time (HRT). The average yield of biogas produced gave 0.0484 dm$^3$. This value compares favourably with other works done with animal waste. For anaerobic digestion of animal waste, the values obtained are 0.040, 0.066 and 0.071 dm$^3$/kg for horse, sheep and goat dung respectively. (Zuru et al., 1998). And 0.044 – 0.050 dm$^3$/kg obtained by Bamgboye (1994) for different water hyacinth harvested at Ibadan and Lagos. However, this value is lower than average biogas yield which varies from 0.308 dm$^3$/kg for 10 kg to 0.517 dm$^3$ for 20 kg of municipal solid waste (Ojolo, 2005).

The odour of the substrate was found to be less offensive after the experiment than during the early stages of operation. The biodegradability of the substrate was also confirmed from the physical observation before and after the experiment. There was a reduction in the fiber content of the feedstock and particle sizes of the waste component after the experiment.

The pH of the residue gave 3.21, probably indicating that the methanogenic bacteria were inhibited. Since they operate by transforming the acids produced by the acidogenic bacteria into methane, neutralizing the medium and increasing the pH (Ribas et al., 2003). The pH could have been maintained by adding sodium bicabonate to increase digester alkalinity (Anunputtikul and Rodtong, 2004) for more biogas yield.

The major problem encountered in this work was gas leakage, and equipment (Gas Chromatography) to analyze the gas produced. With the gas chromatography, the composition of the gas produced could have been determined. The leakages became obvious due to increase pressure build-up in the digester. There was shut down of operation on the 17th day, to rectify the leakage. Hence no experimental data was collected on 17th and 18th day of operation.

Being able to burn gas produced indicate that the experiment worked and it can conclusively be stated that the digester was actually under anaerobic condition. It has also shown that biogas can be derived from cassava peel waste. Hence cassava waste could be used as a source for alternative fuel which can be used in home and/or process industries. The gas generated can at least be used for heating purposes in cassava processing factories/industries.

Though staple foods such as starch, flour are products derived from cassava, this work has also revealed that biogas can be generated from cassava peel waste. It therefore calls for development/improvement in technology for biogas generation from cassava (peel) waste for the cassava process industries/ factories, farms and our homes.

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## ***CONCLUSION***

The result of this study shows that technically it is feasible to produce biogas from anaerobic digestion of cassava (peel) waste. The daily biogas yield is highly dependant on the temperature, retention time, but the characteristics for the feedstock content are also significant factors although to a less extent than the temperature.

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