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PRODUCTION OF BIOGAS FROM PLANTAIN PEELS

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ABSTRACT

Digester has been successful designed with local available material. The plantain peels were obtained from commercial fried plantain dealers in Canaanland Ota Ogun State directly opposite Cafetena 2. The cow dung was obtained from cafetena 1. The digester for the fermentation of the waste was a metal prototype of $0.3m^3$ capacity. Plantain peels blended with cow dung and water at mixture ratio of 2.5kg, 2.0kg and 4.14kg respectively, were used to produce biogas at ambient temperature range of 26^0C to 36^0C and influent temperature range of 32^0C to 42^0C with a retention period of 40days. Gas produced lighted Bunsen burner indicating that the methane content is at least 45%. The Ash content gives an indication of the mineral content of the waste showing that it would be a very good bio fertilizer providing enough mineral sources to the soil. This will provide a cheap source of energy as well resolving issue of producing carbon dioxide and clean environment.

KEYWORDS: digester, design, biogas, plantain peels, retention period.

INTRODUCTION

Energy is a very important part of living needed for everything in life, such as transportation, heat and electricity etc. presently, the demand for energy is more than the supply making the deployment of renewable energy such as solar, wind, biomass, and biogas necessary to meet the increasing energy demand (Ofoefule, et al, 2011).

The fossil fuels currently dominate the world's electricity system, contribute to global warming and emerging infectious diseases (Epstein et al, 2004).

Transportation is responsible for 65 percent green house gas emission. (U.S. Greenhouse Gas Emissions and sinks: 1990-2002. April, 2004). Reduction in the emissions is one of the motivations for this project.

Bioenergy is derived from material such as wood, straw or animal wastes. which can be burned directly to produce heat or power, and also be converted into **biofuels** (Karena, et al, 2004).

Biofuels are renewable energy sources from living organisms. They are chemical energy in plants converted through photosynthesis. Further conversion processes of decay, burning and heating of the chemical energy continues into the rest of the living world (Igoni et al, 2008).

Biogas consists of CH_4 and carbon dioxide, CO_2 (Karena, et al. 2004). The overall constituents of the biogas are given in **table 1** though the composition varies depending on the origin of the anaerobic digestion process.

Table 1: Typical composition of biogas (Krich, et al, 2005)

Typical composition of biogas		
Compound	**Chemical symbol**	**%**
Methane	CH_4	50-75
Carbon dioxide	CO_2	25-50
Nitrogen	N_2	0-10
Hydrogen	H_2	0-1
Hydrogen sulfide	H_2S	0-3
Oxygen	O_2	0-0

Anaerobic digestion is the conversion of organic matter into carbon dioxide, methane, and sludge by employing bacteria in an oxygen depleted environment.

A **Biogas Digester** is used to provide a renewable energy source with wide range of uses (McNeil Technologies Inc., 2005, Brown, 2004, Lichtman, 1982, Ilori et al, 2007).

The pre-treatment step is the removal of non-degradable waste and storing in a bunker before feeding into the digester. The biogas produced in the biogas digester contains about 70% methane. In this project, it will be used to light up a Bunsen burner/gas cooker.

Majority of the people living in rural area use firewood, dried cow dung and harvest residues as fuel. The rural households in India use the following quantities of non-commercial fuel per capita daily:

firewood: 0.62kg, dried cow dung: 0.34kg and harvest residues: 0.20kg. Rural households in the People's Republic of China the daily consumption of firewood is similar: 0-55-0.83kg per person.

1m^3 Biogas (approximately 6kWh/m^3) is equivalent to:
Diesel, Kerosene (approx. 12kWh/kg) 0.5kg, Wood (approx. 4.5kWh/kg) 1.3kg
Cow dung (approx. 5kWh/kg dry matter) 1.2kg, Plant residues (approx, 4.5kWh/kg d.m.)
1.3kg, Hard coal (approx. 8.5kWh/kg) 0.7kg, City gas (approx. 5.3kWh/m^3) 1.1m^3
Propane (approx. 25kWh/m^3) 0.24m^3 (Raymond, 2002).

Table 2: The cost for this digester is as follows;

PARAMETERS	COST X QTY	COST
Labour	10,000	N10,000
Knots and bolts	1,200 x 4	N4,800
Metal and fittings	20,000	N20,000
Gas holder	2,000	N2,000
Hose	800	N800
Metal Clips	100 x 2	N200
Total cost		N38, 800

Plantain is commonly consumed in tropical countries like Nigeria. Apart from individual family consumers, the peels abound as wastes and their disposal also poses a challenge to the consumers with the poor waste management system available especially in the developing countries.

Table 3: Biological composition of plantain peels composition per 100g
[USDA National Nutrient Database for standard reference, released 2010 www.nal.usda.gov]

PARAMETERS	COMPOSITION
Water	65.28g
Energy	122kcal
Fat	0.37g
Protein	1.3g
Carbohydrate	31.89g
Sugar	15.0g
Dietary fibre	2.3g
Potassium	499mg
Phosphorus	34mg
Iron	0.6mg
Sodium	4mg
Magnesium	37mg
Calcium	3mg
Zinc	0.14mg
Selenium	1.5μg
Vitamin C	18.4mg
Vitamin A	1127IU
Vitamin B_1 (Thiamine)	0.052mg
Vitamin B_2 (Riboflamine)	0.054mg
Vitamin E	0.14mg
Vitamin B_3	0,656mg
Vitamin B_5	0.260mg
Vitamin B_6	0.299mg
Vitamin B_9	22mg
Saturated fats	0.143g
Monosaturated fats	0.032g
Polyunsaturated fats	0.069g

Utilizing the peels as feedstock for biogas production would provide a cheap source of energy while resolving the problem of waste management. Consequently, the need to explore its potentials for biogas production becomes exigent (Raymond, 2002).

To achieve a shorter retention period in this batch flow digester, there is need to;
1. Provide a hospitable working environment so as to help the bacteria produce more easily (Karena, 2004)
2. Pre-processing the waste to make it degradable requires fewer Bacteria (Cliff, 2003).
3. Mixing the sludge and providing higher water content will give bacteria greater access to substrate (Karena, 2004, Zeller, 2003, Abubakar, 1990).

METHODOLOGY

The Digester Design

The digester is a closed prone cylinder with plumbing fittings, fabricated from Mild Steel. The lid of the digester is tightly screwed with a spanner and glued at the top so that it is a prone cylinder. The up-side down position is for a number of reasons stated below
1. To minimize the chance of gas leaks through the lid
2. To enable "easy" access to gas agitation jet and solids outlet in the event of an overhaul
3. To provide easier assembly of the gas outlet, effluent inlet and outlet.

The digester is an airtight cylinder with Inlet where the peels fed into the digester chamber and the gas Outlet where the gas is removed.

The gas holder material has the following specifications
Tensile Strength = 320Mpa, Yield strength = 170Mpa
A manual mixer is used to ensure:
i. Homogeneity of the mixture of plantain peels and water.
ii. Improve the activity of bacteria
iii. Fresh and fermenting substrate are mixed properly.
iv. Providing uniform distribution of temperature inside the digester.

The heat required for this anaerobic digester is dependent on the Mesophilic surrounding working condition of atmospheric temperature between 25^{0}C – 30^{0}C. The digester was carried to the second floor of the college of science and technology Covenant University for optimum temperature which is in the range of 33^{0}C that aided speed of digestion.

The plumbing fittings required for this project include ball valves as shut off and isolating elements, rubber hose; to serve as gas pipe, purchased from the market.

In an anaerobic digester, combustible gases are produced; adequate ventilation is required at the surrounding and environment of the digester.

The Design of a 0.3m^3 Digester

In designing of the biogas digester, the estimation of the daily available quantity of plantain peels to meet the requirement, the time and money costs associated with maintenance were considered in this project.

Digester Sizing

Feed Rate S_d

The daily substance input quantity is determined by the retention time R_T and the chosen volume of the digester V_d

$$S_d = \frac{V_d}{R_T} \quad 1$$

Where V_d = digester volume = 0.3m^3 (assumed)
R_T = Retention time = 40days

$$S_d = \frac{V_d}{R_T} = \frac{0.3m^3}{40days} = 0.0075m^3/day$$

The amount of water determines the substrate input to give to solid content of 4-8% for the design, plantain peels to water ratio obtained as

S_d = Biomass (B) + Water (W) 2

The total amount of plantain peels to be used is 8% of total solid of the mixture.

The concept of the biomass to water ratio is taken from the work of (Ojolo et al., 2007). Then assuming 8% of total solid,

Total solid = 0.08 x 0.75 kg/day = 0.06kg/day

Dilution water required = mass of moisture peels-mass of dry peels 3

= 0.75kg/day – 0.06kg/day

= 0.69kg/day (including the moisture in the peels)

To achieve plantain peels: water dilution ratio

$$= \frac{mass\ of\ wet\ plantain\ peels}{mass\ of\ water} = \frac{0.75kg/day}{0.69kg/day} = 1.087 \quad 4$$

This is also the same as

$$Plantain\ peels: water = 1: 1/1.087 = 1:0.92$$

Digester Dimensioning

In determining the dimension of the digester, it is assumed that the diameter of the digester (D) is equal to its height (H).

$$V_d = \frac{\pi D^2}{4} H \quad 5$$

Since D = H

$$V_d = \frac{\pi D^2}{4}$$

From which the diameter of the digester is obtained as

$$D = H = \sqrt{\frac{4V_d}{\pi}} = \sqrt{\frac{4 \times 0.3}{\pi}} = 0.381m$$

Fig. 1: Picture of constructed biogas digester.

Gas holder Sizing

To minimize the size and keep cost as low as possible, 25% of the volume of the digester (to the top) is assumed to be used in holding the gas. The drum will contain 25% of the volume of the total daily gas production.

=25% x 0.3m^3 = 0.075m^3 gas holder required.

The actual size/dimension of the gas holder is determined by

$$V_d = \frac{\pi D^2}{4} H$$

Since D = 0.381

From this the height of the gas holder obtained as

$$H - \frac{4V_d}{\pi D^2} - \frac{4 \times 0.075}{\pi \times 0.381^2} - 0.0658m$$

An initial study carried out on biogas production from plantain peels alone showed that though it had the capability to produce biogas, however, the biogas production and gas flammability were not sustained due to the acidic nature of the waste slurry. One treatment method for improving the biogas production potentials of various feedstocks is blending with animal and/or plant wastes (Ojolo, et al, 2007, Zehnder et al, 1982, Zuru et al, 1998). The potential of biogas from plantain peels when co-digested with some animal waste was investigated. It was then combined as plantain peel and cow dung (PP: CD) and in the ratio 1:0.8.

MATERIALS AND METHODS

The plantain peels were obtained from commercial fried plantain dealers in canaanland Ota, Ogun State directly opposite cafeteria 2. The Cow dung was obtained from cafeteria one (1), also in canaanland while the water was procured from the college of science and technology, Covenant University, Ota, Ogun State. The digester for fermentation of the waste was a metal prototype of $0.3m^3$ capacity constructed (Fig. 1). The study took place between April and December 2012. Other materials used were; Top loading balanced (100kg capacity)-(from the civil engineering laboratory, Covenant University, Canaanland, Ota), grinder for grinding the peels, water trough, gas cylinder for collecting volume of gas production, thermometer (-10 to 110^0C), hosepipe and Bunsen burner from the chemistry laboratory of Covenant University for checking gas flammability.

Preparation of Wastes

The plantain peels was grinded in a day to aid faster digestion. It was then soaked in a plastic water bath overnight for partial decomposition of the peels by aerobic microbes which has been reported to aid faster digestion especially for plant wastes (Fulford, 1998), and the weight was noted. For the blends (PP: CD), 2.5kg of Plantain peel was mixed with 2.0kg of the cow dung giving a total of 4.5kg of waste and they were then mixed with 4.14kg of water, all giving water to waste ratio of approx. 0.92:1. The moisture content of the waste determined the water to waste ratio as seen in table 4.

RESULTS AND DISCUSSION

The experiment was carried out under ambient temperature range of 26^0C to 36^0C and influent temperature of 32^0C to 42^0C within a retention period of 40 days. The daily biogas production is graphically presented in Fig 2. The digester systems commenced biogas production within 24hrs of charging the digester. According to literatures previously considered the plantain peels alone has short onset of gas flammability of 1day with low cumulative biogas yield. Even when the lag period is short, the system drastically reduces gas production to almost nil after 5days and throughout the retention period while the little gas produced will no longer be flammable. The methane content of at least 45% is required for cooking/lighting (Dangogo et al, 1986). The Ash content (table 4) gives an indication of the mineral content of the waste showing that it would be a very good bio fertilizer providing enough mineral sources to the soil. Its volatile solid (VS) (which is the biodegradable portion of the waste) was good enough.

Table 4: Physicochemical properties of the waste PP: CD = Plantain peel: cow dung (1:0.8).

Parameters	PP:CD
Moisture (%)	2.60
Ash (%)	31.75
Fiber (%)	32.60
Crude nitrogen (%0	1.43
Crude protein (%)	8.93
Fat content (%)	2.60
Total solids (%)	97.40
Volatile solids (%)	65.65
Carbon content (%)	27.78
Energy (Kcal/g)	3.54
C/N ratio	20.00

The energy content shows that it would be a very good feedstock for biogas production if properly utilized. Adequate physicochemical properties are known to favour effective and efficient biogas production.

The microbes that convert wastes to biogas take up carbon 30 times faster than nitrogen. Plants difficult to biodegrade due to Lignin, cellulose, hemicelluloses, pectin and plant wax in the wastes with attendant acidic condition (Fulfold, 1998).

Cow dung and swine dung are reported to be very good biogas producers and have been used in blending other wastes like agricultural and industrial wastes that are difficult to biodegrade. Animal wastes are known to be good starters for the poorer producing ones since they are better biogas producers. They have also been used for optimizing biogas production for various plant wastes. The blend with cow dung brought the C/N ratio within the optimum range [range of 20-30:1] needed for effective biogas production while improving the other physicochemical properties like the nutrients (fat and protein, volatile solids, energy etc) as well as stabilizing the waste for sustained gas flammability. The result of the microbial Total viable count (TVC) shows the progression of the microbes that converted the wastes to biogas (table 5).

Table 5: Total Viable Count for Pure and waste blends (cfu/mL)

Period	PP:CD
At the point of charging	$5.83x10^6$
At the point of flammability	$2.25x10^7$
At the peak of production	$5.56x10^7$
Towards the end of production	$4.58x10^7$

The microbial load started out lower, increased towards the peak of gas production and reduced towards the end of the retention period which shows the death curve of the microbes.

Table 6: Lag period, cumulative and mean volume of gas production for the waste

Parameters	PP:CD
Lag Period (days)	10
Cumulative gas yield (dm^3/kg)	8.06
Mean volume of gas production ((dm^3/kg slurry)	0.18±0.11

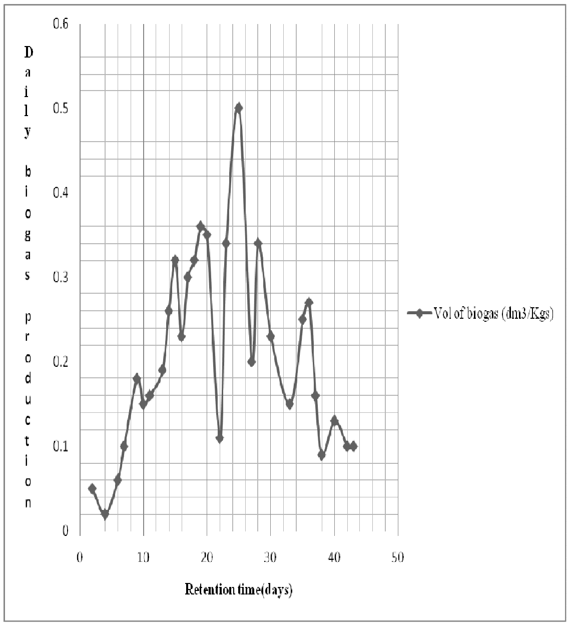

Fig 2: Graph showing daily gas production

CONCLUSION

We were able to design a digester using local available material that was used to demonstrate that plantain peels have potentials and capability to generate biogas. Blending of the peels with animal wastes tremendously improved the biogas production and retention time. Apart from swine and cow dung, other animal wastes like rabbit, goat and poultry wastes can be utilized to optimize the biogas production from plantain peels.

The developed biogas technology could be developed in rural areas.

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