

DEVELOPMENT OF A BATCH FEED BIOGAS DIGESTER FOR PRODUCTION OF COOKING-GAS

Kabri, H.U., Burmamu, B.R., Abdullahi, B. and Ajayi, T.D.

Department of Agricultural and Environmental Engineering, Modibbo Adama University, Yola, P.M.B. 2076, Yola, Adamawa State, Nigeria

Corresponding email: burmamuriji@yahoo.com

ABSTRACT

Energy is an important aspect of life needed to achieve socio-economic activities such as transportation, heat and electricity and so on. Presently, the demand for energy is more than its supply making the deployment of renewable energy such as solar, wind, biomass, and biogas necessary to meet the global increase in energy demand. Thus, this study focused on the design and construct of a batch feed digester for the production of biogas as a renewable energy source for domestic use. The digester was made with plastic container equipped with inlet port for feed, digesting chamber and the burner. The digester was tested using compost of cassava, plantain peels and cow dung. The findings of the study showed that the volume of gas produced was 0.04 m³ with a mass of 0.027 kg at a density of 0.678 kg/m³, a pressure of 89.9N/m² and at a temperature of 39°C. The percentage of gas produced was 65% methane (CH₄), 30% carbon dioxide (CO₂) and 5% water vapor (H₂O). This result shows that biogas generation could be achieved in the kitchen to aid household production of cooking gas. Biogas production if carried out at commercial scale would not only provide an alternative source of energy but would also be a means of waste disposal technique.

Keywords: Batch, digester, biogas, cassava, plantain-peels, cow-dung

1 INTRODUCTION

Energy is a component of life needed for transportation, heat and electricity making the deployment of renewable energy such as solar, wind, biomass, and biogas necessary to meet the global increasing energy demand [1]. According to [2], recent rapid increase in human population has put pressure on energy generation and utilization all over the world. As standard of living increases in developing countries, the average consumption and need for energy has increased drastically. Thus, it has been forecast that in a long-run, there would be a depletion of conventional energy resources and if drastic measures are not taken, there could be insufficient energy available to meet the ever increasing demands by the populace. Majority of the people living in rural areas use firewood, dried cow dung and harvest residues as fuel. Hence, there is urgent need to seek alternative and renewable sources of sustainable energy that are environmentally friendly [3]. It has been shown that biogas is a renewable energy resource generated by bio-degradation of organic substances under anaerobic conditions [4]. It was asserted that anaerobic digestion can convert energy stored in organic matter of manures into biogas. Anaerobic digestion is a biological process whereby micro-organisms convert complex organic matter into biogas. It is found that biogas consists of about 65% methane (CH₄) and 35% carbon dioxide (CO₂) saturated with water [5]. Using renewable energy resources such as biogas to replace fossil fuels closes the carbon cycle and thus reduces the amount of carbon dioxide in the atmosphere. As an energy resource, plant biomass may be used as solid fuel, or converted via a variety of technologies to liquid or gaseous forms for the generation of electric power, heat or fuel for locomotive power. Biomass resources are considered renewable as they are naturally occurring and when properly managed, may be harvested without significant depletion. As the forests

disappear there is a need to replace firewood by another cheaper fuel of proven value for domestic and industrial uses. People cannot really afford liquefied natural gas and kerosene from their limited incomes, most of which goes on school fees and food. The use of renewable biomass wastes to generate energy in form of biofuel will not only provide efficient and inexpensive sources of energy, but also help to solve environmental problems. In Nigeria, the average consumption of fuels equates to three gallons or 12 liters per day [6; 7]. That is for every man, woman and children of the population. The Nigerian economy is based mainly on income from fossil fuel which is for non-renewable and hence gets depleted on daily basis. Nigerian oil reserves may be totally depleted in 37 years unless alternative sources of fuel are introduced [8]. Therefore, there is a need to research into alternative means of sourcing cheap energy to curb the problem of environmental pollution and deforestation by recycling of agricultural waste products into biogas while after producing the biogas, the remnants can serve as manure. This study was aimed to use cassava and plantain peels mixed with cow dung to produce valuable biogas which will serve as an alternative to fuel for general purposes especially for cooking at home through the design and construction of a batch feed biogas digester.

2 MATERIALS AND METHODS

2.1 Materials

Preparation of sample of fresh cassava peel wastes (Plate 1) were collected from a local farmer to obtain consistency of the raw materials for biogas production experiments, the cassava peels of about 15.6kg were collected and prepared by chopping the whole wastes into pieces and stored in a black polythene sack to preserve its moisture content. Whereas, plantain peels (Plate 2) were collected from Jimeta Modern Market, Yola and the Cow dung (Plate 3) was sourced within the university cattle shed. Control valve, pipe, inlet feeder, burner and plastic rubber were purchased from Jimeta Modern Market, Yola, while base frame was designed and constructed.



Plate 1. Cassava peels



Plate 2. Plantain peels



Plate 3. Cow dung



Plate 4. Mixture of the wastes

2.2 Preliminary Investigation

The preliminary investigation of this work was the physical properties and chemical properties of plantain peels, cassava peels relevant to the biogas digester. The determination of sample sizes of cassava peels and plantain peels was by cutting the peels into equal sizes of 2 cm length and 1.5 cm width and the thickness was measured using the vernier caliper in the workshop. The mass of cow-dung, plantain peels and cassava peels were determined using the same method. Materials used for carrying out the practical were: digital weighing balance, container, shredded cassava peels, shredded plantain peels and pounded cow-dung.

2.3 Design Consideration

Factors influencing the selection of materials used for this study include: strength of materials, availability of the materials, durability of materials, cost of the materials, ease of transportation, resistivity, corrosiveness, workability and ease of construction. Hence, these factors were put into consideration during the analysis and selection of materials for the bio digester development.

2.4 Description of Biogas Digester

The biogas digester for producing biogas (Figure 1, Plate 5) consists of inlet feed port (1) where the cassava and plantain were decomposed, the drum digester (3) which serves as a reactor, the control valves (2) which regulates the flow of the biogas, supporting base frame (4), wastes outlet pipe (5), Burner holder (6) which supplies the flame, Burner furnace (7) where the flame of heat is to be produced.

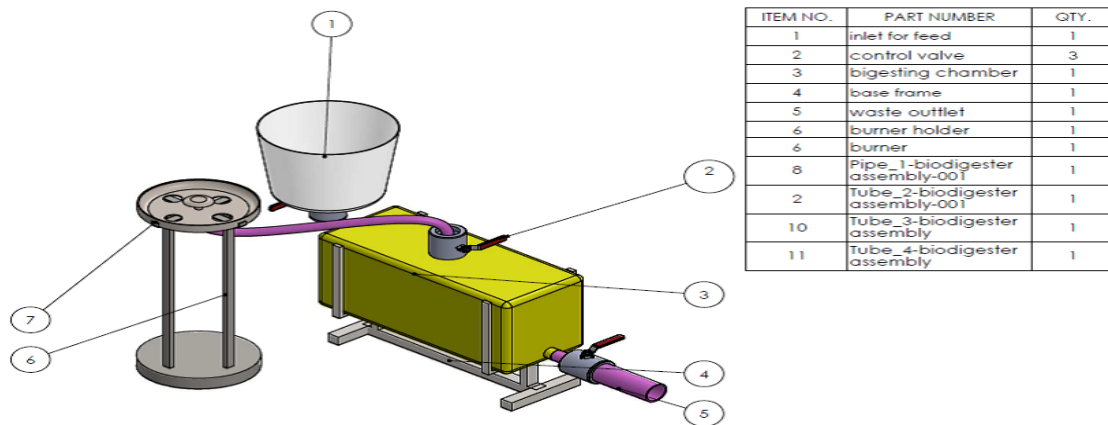


Figure 1. Split view of Biogas Digester



Plate 5. Developed Biogas digester

2.5 Design of Components

2.5.1 The drum digester capacity

The volume of the digester (V_d) was calculated as:

$$V_d = L \times B \times H \quad (1)$$

Where V_d = volume of digester (m^3), L = length of digester, B = breadth (m), H = height of digester (m).

2.5.2 Determination of hopper capacity (V_h)

This was calculated as given by [5].

$$V_h = \frac{1}{3}\pi h (SR + Sr + R^2 + r^2) \quad (2)$$

Where h = Height of frustum (h) = 0.1 m, S = Slanting length of frustum (S) = 0.28 m, R = Radius at the top of the hopper (R) = 0.14 m, r = Radius of the frustum (r) = 0.1 m.

2.5.3 Volume Occupied by the Slurry

The volume occupied by the slurry (V_s) was determined using.

$$V_s = V_{cd} + V_{pp} + V_{cp} + V_w \quad (3)$$

Where V_s = Volume of slurry (m^3), V_{cd} = Volume of Cow dung (m^3), V_{pp} = Volume of Plantain Peel (m^3), V_{cp} = Volume of Cassava Peel (m^3), V_w = Volume of water (m^3).

2.5.4 Volume of Cow Dung

The volume of Cow dung in the slurry was determined as:

$$V_{cd} = M_{cd} / \rho_{cd} \quad (4)$$

Where M_{cd} = mass of cow dung in the slurry, ρ_{cd} = the density of cow dung.

2.5.5 Volume of Cassava Peel

The volume of Cassava peel in the slurry is determined as.

$$V_{cp} = M_{cp} / \rho_{cp} \quad (5)$$

Where M_{cp} = Mass of Cassava peel, ρ_{cp} = Density of Cassava peel.

2.5.6 Volume of Plantain Peel

The volume of Plantain Peel in the slurry is determined as.

$$V_{pp} = M_{pp} / \rho \quad (6)$$

Where M_{pp} = Mass of Plantain peel, ρ = Density of Plantain peel, ρ was 890 kg/m^3 .

2.5.7 Volume of Water in the slurry

The volume of the cow dung mixed with water in the ratio of 2:1; hence the volume of water in the mixture was half the volume of cow dung, i.e.

$$V_w = \frac{1}{2} V_{cd} \quad (7)$$

5.2.8 Construction of biogas digester

Table 1. Materials and specifications of fabricated digester

SN	Parameters	Specifications
1	Drum digester	Mild steel (L x B x H) 500 mm x 200 mm x 250 mm
2	Inlet feed	Plastic material, 25 liters
3	Gas pipe	2/3' flexible rubber pipe, 40 cm long, 16 mm diameter
4	Drain pipe	1/2' plastic pipe,

2.5.9 Operation Principle

The maximum height of the biogas plant was 70 cm, which an average individual can feed the digester with much ease without spilling the slurry on the digester to avoid rust. Then for the initial feeding, one bucket of the slurry (cow-dung and water) was poured into the digester on the first day

with some quantity of inoculums (methane producing bacteria). A quantity of $18.317 \times 10^{-4} \text{m}^3$ of the slurry was added daily until the drum was two third full.

2.5.10 Performance Evaluation of the digester

The test was carried out after biogas digester development where the slurry was put into the feeder, then after two days the gas was tested by lightening the burner to confirm if actually gas was produced. It was observed that a flame came out from the port; thus, it was successful. The digester was operated under a batch feed basis and the contents were observed for 14 days of hydraulic retention time (HRT). The unit production biogas was measured by the liquid level rise method. Plantain peels were chopped into smaller units and 10.8 kg of it was soaked in water. 15.6 kg of cassava peels were separately, soaked in water also but was not chopped because it was already in small pieces, and the aim was to soften the substrates so that the micro-organisms involved during the anaerobic digestion to have access for quick production of biogas.

2.5.11 Experimental Procedure

Prepared masses of cassava peels, plantain peels, Cow dung 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) were 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 14 days of hydraulic retention time (HRT) [8]. 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 [9]. 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 2 minutes [10]. Also, 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 [11].

3 RESULTS AND DISCUSSION

Table 2 shows the design result of the digester.

Table 2. Design Analysis Results

S/N	Parameters	Results
1	Volume of drum digester	0.025m^3
2	Hopper capacity	0.0298m^3
3	Volume occupied by slurry	$18.317 \times 10^{-4} \text{m}^3$
4	Maximum pressure of digester	7.796KN/m^2

Table 3. Performance evaluation results

SN	Parameters	Results
1.	Volume of gas	0.04m^3
2.	Mass of gas	0.027 kg
3.	Density of gas	0.678kg/m^3
4.	Pressure of gas	89.9N/m^2
5.	Methane (CH_4)	60 %
6.	Carbon dioxide (CO_2)	30 %
7.	Water vapor (H_2O)	5 %
8.	Temperature	390°C

Table 3 shows the performance evaluation results. It shows that Pressure generated due to production of gases was obtained as 0.35 bars at a temperature of reactor of 390°C . [4] Reported a result very closed to this value. The percentages of gases produced during anaerobic respiration were calculated as 65% methane (CH_4), 30% carbon dioxide (CO_2) and 5% water vapor (H_2O). The volume of gas produced was 0.04m^3 with a mass of 0.027 kg at a density of 0.678kg/m^3 and pressure of 89.9N/m^2 or $8.9 \times 10^{-4} \text{Bar}$.

4 CONCLUSIONS

A portable renewable biogas production digester has been designed and fabricated. The digester was used to handle the production of biogas from cassava and plantain peels blended with cow dung at a cumulative gas volume of about 0.04 m³ produced in 14 days with a mass of 0.027 kg at a density of 0.678 kg/m³ and pressure of 89.9 N/m². The percentages of gases produced during anaerobic respiration were 65% methane (CH₄), 30% carbon dioxide (CO₂) and 5% water vapor (H₂O). The findings of the study showed that biogas production if carried out at commercial scale would not only provide an alternative source of energy but would also be a means of waste disposal method. It was recommended that proper sealing of the biogas digester unit should be done to avoid the case of gas leakage/flaring.

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