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Generation and Storage of Biogas Produced from the Mixture of Cassava Peels and Cow Dung

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Abstract

An experimental study of biogas production from cassava peels and cow dung was carried out using a polyethylene biodigester. Some important parameters such as the ash content, volatile matter, total solids and N.P.K were determined for the substrate before and after digestion. The work was carried out under operational and environmental conditions of temperature, pH, total solid, nature of waste using a 0.97m^3 of plastic digester over a retention time of 74 days. The results obtained showed that cow dung added as seed had great potential for gas production. The result further indicated that the cumulative volume of biogas produced was 1.960m^3. The biogas produced was stored under pressure in gas cylinders using modified gas compressor for portal uses in homes and other applications.

Key words: *Biodigester, polyethylene,anaerobic digestion, gas compressor, substrate.*

1. Introduction

The importance of energy in national development cannot be over-emphasized. It is the hub around which current world civilization revolves. Any distortion in the energy-chain-supply at any point in time has always resulted into serious economic and social hardships[1, 2]. Energy has been an essential input to all aspects of the modern age.

More than 80 percent of the people living in rural areas in the third world countries (Nigeria inclusive) depend on traditional fuel for fulfilling the house hold energy requirement, which is primarily managed by women [3, 4]. The material from plants and animals is called biomass. The energy stored in biomass can be released by burning the material directly, or by feeding it to microorganisms that use it to make biogas, a form of natural gas. Energy from biomass is still around the world for everything, from cooking and heating to generating electricity [5]. When biomass is used directly to provide energy, the product is called primary bio-fuel. The inefficient use of primary bio-fuels in most developing countries has caused many problems such as deforestation, desertification, erosion, and reduction of biodiversity. There is worldwide growing concern about the colossal rate of depletion and possible exhaustion of these fossil fuels. This is because their rate of formation is not commensurate with that of consumption [6]. In Nigeria for instance, there have been instances of severe scarcity of fuel in the past. The cost is another serious problem and it has continued to escalate. Within four years, the cost of gasoline has gone up several times. The result is the frequent and high increase in transportation cost. One possible way to resolve these two problems is the conversion of solid wastes into biogas through anaerobic digestion. Since energy is the basic requirements for life, biogas technology is a sustainable alternative source of energy especially for the rural people.

The study is aimed at the following as its focal objectives:

1) To desgn, fabricate and evaluate the performance of the polyethylene digester that will be leakage and corrosion free for biogas generation;
2) To determine the extent to which the mixture of cow dung and cassava peels generate biogas;
3) To determine the environmental and operational parameters that will facilitate optimum efficiency of biogas production; and
4) To store the biogas produced under pressure in portable gas cylinders for cooking in homes and other places of need using gas compressor.

Biogas Technology

Anaerobic digestion occurs when bacteria produce biogas by decomposing an organic matter in an environment without air (oxygen-free). Biogas is a cheap energy source which could be locally generated with low levels of technological input. Biogas generation yields two products; the biogas itself and the manure or bio-fertilizer called effluent or sludge[7, 8]. Biogas is a flammable gas produced by anaerobic fermentation of organic waste materials. Biogas is composed of methane (55-70%), carbon dioxide (30-40%), oxygen (0.1%) carbon monoxide (1-10%), hydrogen (1-3%), nitrogen and traces of hydrogen sulphide [9, 10]. Biogas is considered to be a source of renewable energy.

Biochemistry of Methonogenesis

Anaerobic digestion of biomass involves bacterial decomposition and it takes place in three main phases (a) the hydrolysis phase (b) an acid phase and (c) the methane phase [11]. The features of methane producing microorganism are that they are able to live without oxygen and they are among the very few creatures that can digest cellulose, the main ingredient of plant fibre.

Biogas Digesters

Different designs of biogas plants have been built but the two most popular are the floating gas holder and the fixed dome digester. The fixed dome plastic biodigester (Chinese Design) was constructed. The construction of the biodigester was carried out by detailed construction of individual components that make up the system

The digester system consists of the tank measuring 1m high and 3.2m wide. Its capacity is approximately 0.9713 m^3, its thickness is 1.5cm and can withstand a pressure of one bar (one bar = 10^5 Nm^{-2}). The major unit of the bio digester is the stirring unit. This is to increase the turning rate since the purpose of stirring is to break the scum that may prevent the release of gas from slurry as well as distribute the temperature evenly.

There are different operations of biogas plants and they may be classified under two headings: (1) the continuous plant in which the feedings is done every day and (2) the batch plant in which feeding is done at intervals. The plant is emptied once the process of digestion is completed. This is the operation that was adopted in this study. The fixed dome biogas plant built by the authors is shown in figure 1[8].

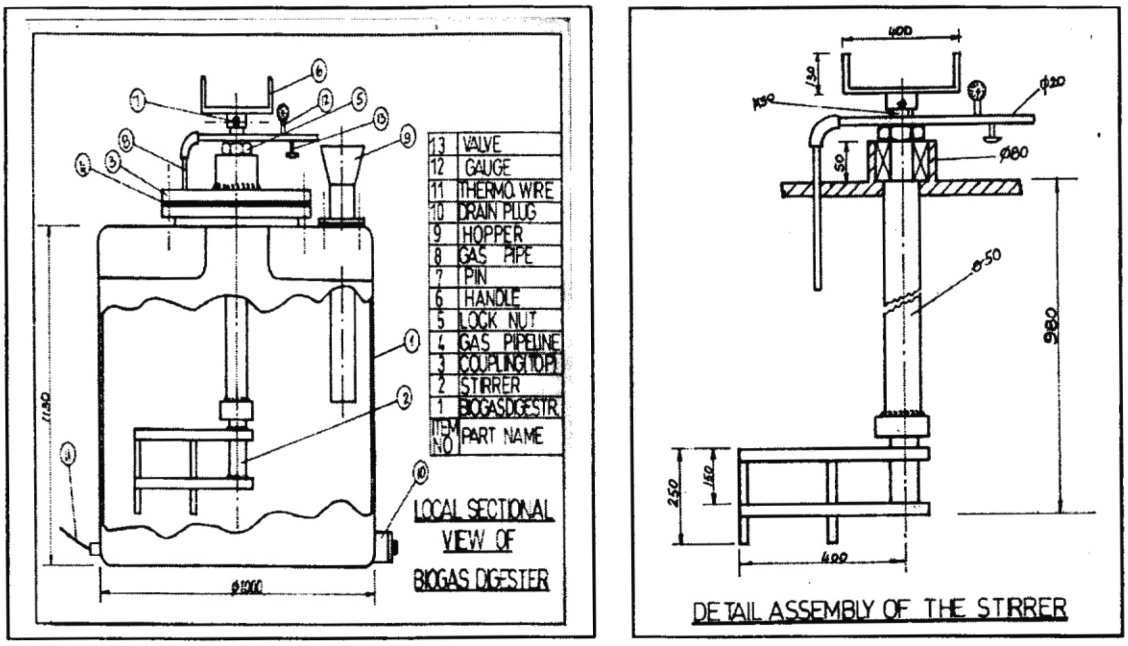


Fig.1: Plastic fixed dome biodigester and stirrer

Materials: Sources of Waste

The wastes used in this study were the cow dung from an Abattoir in Enugu State, while the cassava peels were obtained from Garri Mill Industry, Nsukka Market, Enugu State. The constructed plastic biodigester was used for this experiment at mesophillic temperature.

Preparation of the Sample

It was ensured that materials like earth, sand, gravel, sawdust, soap and detergents did not enter the digester or plant. The slurry was prepared by weighing 60kg of cassava peels and 60kg of cow dung using a "five goat" brand model Z059599 weighing balance which was graduated in metric scales of 0-50kg. Each weighed sample was poured into a small drum. Tap water weighed at 312kg was added to the waste inside the drum in the ratio of 1:2.5 (waste to water). The slurry was fully stirred manually with a piece of wood until there were no lumps. The waste was transferred to the plastic digester. The total mass of slurry was 432kg. The charging ratio was 50:50. The mode of operation used was batch operation.

Methodology

The digester was stirred occasionally with the in-built stirrer that was attached to the digester. The effect of different parameters on biogas production was observed. The technology for biogas production is greatly influenced by environmental factors such as temperature, pH and nutrient concentration as well as operational factors such as retention time, loading rate, solid concentration, stirring, mixing and nature of raw materials. A pH meter was used to measure the pH every week. It ranges from 5.0 -7.2. The temperature of the slurry was observed daily through the thermocouple wire that was inserted into the digester. The thermocouple wires were connected to the thermocouple digital thermometer, which measured the slurry temperature. The ambient temperature was also measured with the digital thermocouple thermometer. These temperature readings fell within (20-45^{0}C) which corresponds to the mesophillic range.

The pressure of the gas produced was recorded daily using the pressure gauge that was fixed on top of the digester. The pressure gauge (a VDO pressure gauge) which ranges from 0-0.6 bar was used. The pressure of biogas produced was between 0.00-0.09 bar.

The biogas generated was measured by downward displacement of water. The volume of water displaced was measured daily. The highest volume for a given day of the experiment was 72 litres on the 2nd and 7th days. Proximate analysis of waste is the determination of the major components of waste which include moisture content, ash content, total solids, volatile solid, nitrogen, carbon content, potassium and phosphorus.

The proximate composition of cow dung and cassava peels was carried out by the methodology of the Association of Official Analytical Chemists (AOAC). This was done before and after digestion of the wastes [12]. All these were done at the Department of Crop Science Laboratory at the University of Nigeria, Nsukka. The percentage contents of all these components mentioned above were recorded and are presented in table 1. From this table the carbon/nitrogen ratio is 5:1.

Table 1: Proximate Analysis of Cow Dung/Cassava Peels

Components	Analysis before digestion (%)	Analysis after digestion (%)
Nitrogen	0.84	0.90
Carbon content	4.15	8.49
PH	7.2	6.00
Ash	2.75	5.25
Moisture content	89.35	83.55
Phosphorous	4.94	5.57
Potassium	48.08mg/100g	48.18mg/100g
Volatile solid	87.05	45.74
Total solid	95.00	74.19

Determination of Total Viable Count (TVC)

Determination of microbial load in cow dung/cassava peels was done using the method of surface viable count. Nutrient Agar (Oxoid)-bacteria and Saboroud Desetose Agar-fungi were used for the cultivation and counting of total bacteria and fungi respectively. This was done in the Pharmacy Department of the University of Nigeria, Nsukka.

Sample 1: The cassava peels and cow dung dilution factor is 10^5. The number of colonies in each factor were 27.0, 27.5, 30.5, 28.5, 38.0, 32, 31 c.f.u (colony forming units). The Mean Count/Drop was 30.563, approximately 31 c.f.u. The volume/drop used was 0.15ml. The mean count drop dilution factor and volume/drop values were used to calculate the total viable count (TVC) of cassava peels and cow dung.

Mean Count/Drop = 31 c.f.u

Dilution factor = 10^5

Volume/Drop = 0.015

$$TVC = \frac{\text{Mean Count/Drop x Dilution factor}}{\text{Volume/Drop}}$$

$$TVC = \frac{31 \text{ X } 10^5}{0.015} = 20.67 \text{ X } 10^7$$

For fungi, the number of colonies in each of the factors was none and the mould was 2 moulds. The microbial population was 20.67 x 10^7 for bacteria and 2 moulds for fungi.

Sampling and Analysis of Biogas from Cassava peels and cow dung by Orsat Approach

To identify and quantify the different components of biogas produced, Orsat Apparatus was used. Biogas produced through this experiment was trapped in a gas cylinder using gas compressor and the sample was analyzed using Orsat Apparatus. The measuring principle of the Orsat Apparatus is the measurement of the reduction in volume which occurs when individual constituents of a gas are removed separately by absorption in liquid reagents. All measurements during an analysis were made at constant (atmospheric) temperature and pressure.

For CO_2 analysis, the reagents used were potassium hydroxide solution 400g/dm^3, with absorbing power as 40ml of CO_2 per dm^3 of solution. The percentage by volume of each constituent was calculated as follows:

Volume of constituent = $V_2 - V_1$

Where

V_1 = burette reading (milliliters) before removal of constituent.

V_2 = burette reading (milliliters) after removal of constituents.

$$\text{Percentage of constituent} = \frac{V_2 - V_1}{V} \times \frac{100}{1}$$

Where V = volume of gas in burette before removal of constituents

V_2 = 14.50ml

V1 = 5.3ml

Volume of gas V = 60ml

$CO_2\,\% = \frac{V_2 - V_1}{V} \times \frac{100}{1}$

$= \frac{14\,0\,50 - 5.3 \times 100}{60} = 15.33\%$

For H_2S, the reagent used was 30% lead acetate solution in 3m acetic acid.

$H_2S\% = \frac{6.1 - 6.0}{60} \times \frac{100}{1} = 0.16\%$

For CO analysis, the reagent used was alkaline cuprous chloride

$CO\% = \frac{8.6 - 7.2}{60} \times \frac{100}{1} = 233\%.$

Table 2: Percentages of the Components of Biogas from Cassava Peels/Cow dung

Components	**Percent**
Carbon dioxide ($C0_2$)	15.3
Hydrogen sulphide (H_2S)	0.2
Carbon monoxide (C0)	2.3
Methane and water vapour	82.2

Calculation of Specific Gas Production Rate Fall for Cassava Peels/Cow Dung.

The specific gas production rate fall was also calculated for the sample using the following formular [13].

Specific Gas Production =

$$\frac{\text{Volume of gas produced}}{\text{Retention} \times \text{Volume of digester}}$$

The volume of digester used for the experiment was 0.971336m^3. The cumulative gas production for the sample was 1.96m^3. The retention time is 74 days.

Therefore, specific gas production for cassava/cow dung

$$\frac{1.96}{74x.0971336} = 0.027$$

Calorific Value of Biogas: Heating Value

The amount of energy generated when a unit mass of fuel is burnt completely is known as the colorific value of the fuel. The calorific value of Biogas produced was calculated using the formular [14].

Calorific Value (CV) of Biogas from cassava peels and cow dung is given by[15]

$$\text{Calorific Value (CV)} = \frac{\text{Heat Produced}}{\text{Mass of biogas burnt}}$$

$$CV = \frac{M \times S \times (T_2 - T_1)}{W_1 - W_2}$$

Where W_1 = weight of cylinder with biogas ; W_2 = weight of empty cylinder

M = mass of kettle and water; S = specific heat capacity

T_1 = initial temperature of water; T_2 = final temperature of water

$$CV = \frac{8415 \times 47.9}{0.2} = \frac{403078.5}{0.2}$$

$$= \frac{2015392.5}{1000} = 2015.39kg$$

Calorific value is 2015.39kg

Figures 2 and 3b show where the stored biogas was used to boil water.

Data Collection

The volume of biogas produced from cassava and cow dung was recorded on daily basis. The mean daily gas yield was drawn in figure 7. The experiment was monitored for ten weeks and 5 days (Table 3).

Table 3: Gas production by cassava peels and cow dung classified by months

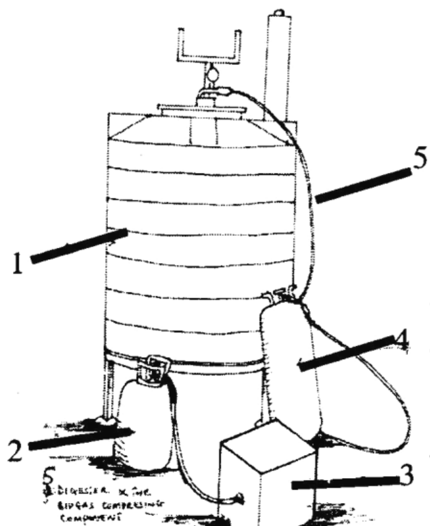
Months	Biogas produced (m^3)
April	0.800
May	0.830
June	0.330

The daily ambient temperature over this period varied from 20^0c to 45^0c, the average was 32.5^0c which falls within the mesophilic range (see figures 5 and 6).

Storage of Biogas

A gas compressor is a mechanical device that increases the pressure of a gas by reducing its volume. Compression of a gas naturally increases its temperature. Compressors are closely related to mechanical pumps: both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas, whereas the main result of a pump raising the pressure of a liquid is to allow the liquid to be transported into cylinder [15].

Two cylinders were constructed; one of the cylinders has valves at the top and by the side of its base. The other cylinder has a valve only at the top. Two pipes of 1cm in diameter were welded to the two openings or pistons on the compressor's body. A base was fixed on one of the pipes and connected to the valve of one of the cylinders while another hose was connected to the second pipe and fixed on the valve at the base side of the other cylinder. The hose from the digester was fixed on the valve at the top of this same cylinder. Biogas is compressed in the storage cylinder by two pistons (Fig. 2).



1. **Digester**
2. **Gas Cylinder where the Biogas was stored**
3. **Gas Compresso.**
4. **Gas Cylinder thı sucked out from tne Digester**
5. **Rubber Hose**

Fig. 2: Digester & the Biogas Compressing Component

The biogas stored in the cylinders can be used at home or stored Biogas was passed to a burner and it consumed or burnt with blue flame (Fig. 3b) [8].

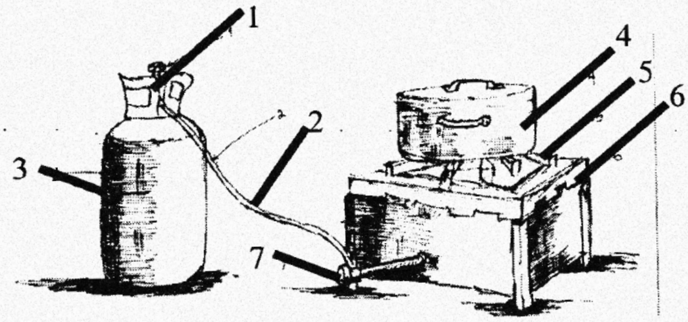


Fig. 3b: Using stored biogas for cooking

1.	**Cooking Valve**	**2.**	**Rubber Hose**
3.	**Gas cylinder**	**4.**	**Iron pot**
5.	**Iron Seater**	**6.**	**The Burner**
7.	**Valve**		

Discussion of Results

The total volume of the constructed plastic biodigester was $0.97m^3$. The digester was charged with cassava peels and cow dung in the ratio of 1:2.5. About 432kg of the mixture or slurry was fed and stirring was done at least once a day for 74days.

There was no lag time for these samples. Production of gas started immediately the digester was charged. Flammability test was conducted on the gas produced from the 2nd day and it was discovered not to be flammable, until on the 50th day when the biogas produced was combustible. The biogas produced through this experiment was stored in gas cylinders for 24 days using a gas compressor. The plant is able to boil 4 litres of water in 30 minutes (Fig. 3b)

Fifty percent of cassava peels was added to the fifty percent of cow dung, the cow dung acted as seed or inoculum. Normal biogas fermentation is impossible without sufficient quantity of biogas microbes. It is these microbes that perform the function of anaerobic degradation of organic substances to yield methane. Inocula of different sources contain different colonies of biogas microbes. Cow dung acted as the inoculum which enriched the bacteria of the digester and enhanced their action on the substance and hence on the quantity as well as quality of the biogas generated. For 74 days, the cumulative gas produced was $1.960m^3$ (Fig. 4a).

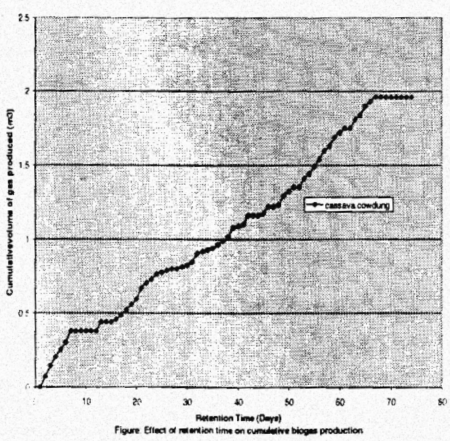


Figure 4a: Effect of retention time on cumulative biogas production

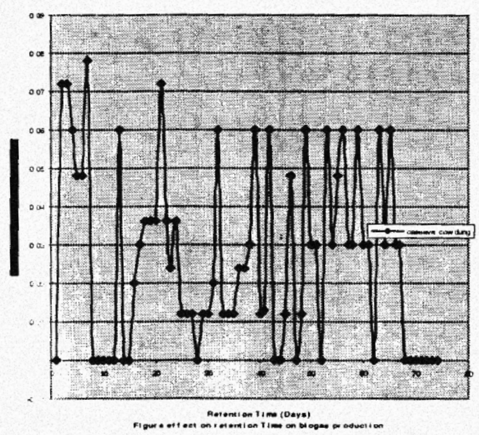


Figure 4b: Effect of retention time on biogas production

The analysis of slurry before and after digestion showed marked differences in the concentrations of various elements. The nitrogen, phosphorous, and potassium concentration increased with

0.06%, 0.63% and 0.1% respectively after digestion as can be seen in table 1. This was because the complex molecules had been broken down to smaller units thereby making the elements more available for utilization. Potassium is a soft iron which helped to reduce the acidity and increase the gas production. It also helps to increase the quality of bio-fertilizer. The phosphorus helps to increase the quality of bio-fertilizer. This is why the bio-fertilizer is rich in nitrogen, phosphorous and potassium (NPK). Carbon and Nitrogen were present in the ratio of 5:1. The optimum pH for the production of the biogas was from 5.0 – 7.2. Gas production occurred between pH 6.0 -7.2.

Temperature, the nature of the organic matter and its solid concentration were among the parameters that affected the performance of the biogas plant (Fig. 5). The optimum yield of the biogas was obtained with mesophillic range of temperature (20 – 45^0C). The temperature of the inside digester was (19.7 -40.5^0C) throughout the period of study (Fig. 6). The highest pressure of the gas was 0.09 bar and the gas produced that day was 72 litres or $0.072m^3$ (Fig. 4b). The mesophillic range may be preferred since, (1) it is easy to maintain the digester at this temperature (2) mesophillic bacteria are more stable than thermophyllic bacteria (3) They produce high quality sludge and (4) significantly higher rates of methane production can be achieved with the mesophillic process. The gas produced was stored in the cylinder using gas compressor (Figs. 2 and 3b).

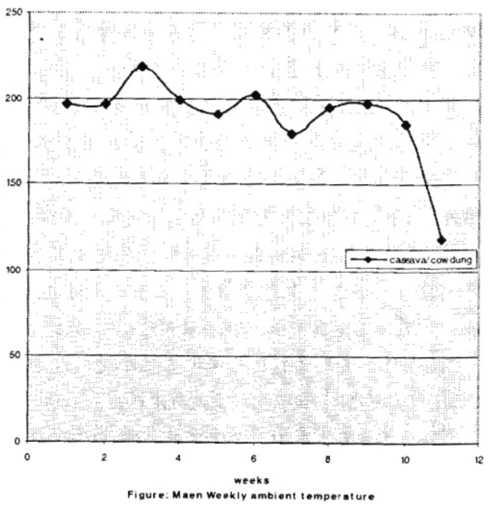


Figure 5: Mean Weekly ambient temperature

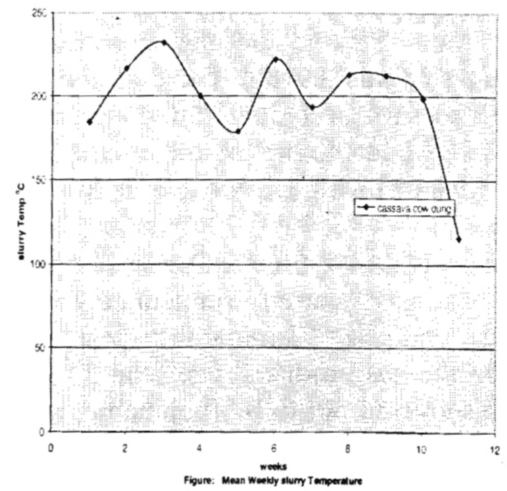


Figure 6: Mean Weekly slurry temperature

The weekly change in gas production was shown in (Fig. 7).

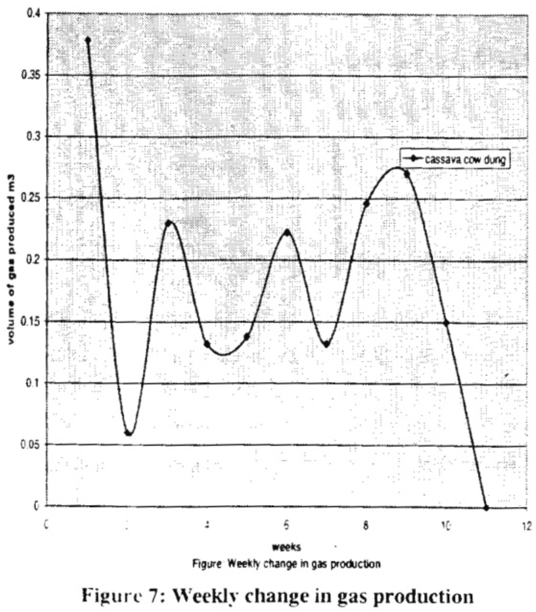


Figure 7: Weekly change in gas production

Conclusions

An experimental study of biogas production from cassava peels and cow dung was carried out using a polyethylene biodigester. The performance of the polyethylene biodigester was very satisfactory in the provision of clean fuel and good quality fertilizer. Some important parameters such as the ash content, volatile matter, total solids and N.P.K were determined for the substrate before and after digestion. The work was carried out under operational and environmental conditions of temperature, pH, total solid, nature of waste using a $0.97m^3$ of plastic digester over a retention time of 74 days. The results obtained showed that cow dung added as seed had great potential for gas production. The result further indicated that the cumulative volume of biogas produced was $1.960m^3$. It was also observed that cow dung acted as good inoculum to cassava peels. It acted as a pre-rotten material or set-up which enriched the cassava material with microbes before it entered the digester and guaranteed that there were enough seeding bacteria for the waste fermentation. The problem of storing the produced biogas was solved by the use of a modified gas compressor which stored the biogas under pressure into a portable storage cylinder for uses in homes and other applications.

This work offers an immediate and economic means of providing alternative energy for heating applications in rural communities and at the same time reduces the use of fuel wood. This in turn will reduce the rate at which forests are being converted into areas prone to soil erosion and desertification. In addition the slurry or bio-fertilizer produced after fermentation is known to be a good soil conditioner for physical and chemical properties of the soil.

Recommendations

In the preparation of programmes for the promotion of biogas the following points may be taken into consideration:

a) To increase the gas yield, the slurry should be seeded with bacteria and digestion carried out at mesophllic temperature with occasional stirring of slurry.
b) The stirring shaft should reach the bottom of the digester to ensure thorough stirring of solid wastes that ordinarily would settle at the bottom while liquid content of the slurry is displaced upwards. This will ensure even distribution of the solid waste in the slurry, more uniform temperature, improved gas production, and easier discharge.
c) Since the overall volume or quantity of gas produced was increased with repeated evacuation, constant extraction of the gas is necessary for more gas production. This was enhanced as more quantity of gas was stored in the cylinders.
d) Government agencies should take an active part in biogas projects as is done in other counties like India and Nepal.

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