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Generation of Biogas from Cassava Peels Blend as an Alternative Fuel for Cooking in Rural Areas

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ABSTRACT
This research is concern with the production of biogas from cassava peels blend as an alternative fuel for cooking in rural areas. This cassava peels fall under **Biomass resources** which are is a renewable source of fuel that always exist as residue of plant based organic waste with energy potential and which are indiscriminately discharged or disposed as Nigeria farmers produced peels in excess quantity. Due to high cost or inadequate supply of conventional fuel and its aftermath pollution to the environment when burnt, this research therefore focused on the use of blended cassava peels with pig dung in a specified ratio for the production of biogas via anaerobic digestion process (digestion in the absent oxygen). This study is aimed at producing Biogasfor cooking, saving money; make use of the residue in the digester after complete digestion as **fertilizer** for farming and help address environmental pollution and global warming issue as methane and carbon iv oxide which are greenhouse gases released during combustion of conventional fuels and opened decomposition of organic matter. A 34litres pilot airtight digester was developed using 18 gauge metal sheets for the anaerobic digestion process, with a **single loading method** used and thus, the digester is loaded once for the whole retention period of thirty days. Readings for ambient, digester temperatures and daily biogas volume measured via downward displacement of water were recorded at every one day interval, the sample of the biogas produced was burnt and observed to be flammable. A total volume of **4775cm^3**of biogas was generated. However, purification of the biogas to get **highe**r concentration of **methane** which better combustion is recommended as further work**.**

KEYWORDS: Single loading method, Anaerobic digestion process,Global warming, Greenhouse gases

I.INTRODUCTION

1.1Background to the Study

Energy is the driver of any Nation's Economic growth and Development. Energy serves as a saleable commodity that brings foreign exchange which is use in building public infrastructure. It also serves as important input in every home for cooking and for the production of goods and services in the Nation's industry, health, transport, agriculture and education sector. As population of our world continues to increase, there is corresponding increase in Energy demand to sustain the activities of Man. It follows that energy is a major determinant of every country's economic and social development.

According [1]. Energy for cooking has not been given better political backing in comparison to access to electricity. [2], has it that in developing country such as India, the National Project on Biogas Development was set up in 1981 for the promotion of household biogas plants using biomass like cattle dung and other biomass waste to produced methane for household cooking and lighting as an alternative fuel. In 2005, the authority of India started a scheme called National Biogas and Manure Management Programme (NBMMP) aimed at designing a multifunctional family size or household Biogas plant to minimise dependency on LPG and kerosene (fossil fuel) for cooking and lighting purposes, produce waste digestate fertiliser which can help reduce the use of manmade or chemical fertilisers, remove the need for fetching of firewood which reduces the drudgery on rural women and children who undertake this task as well help maintain forests reserves; and enhances cleanliness in villages by linking sanitary toilets with biogas plants. The rising cost of Energy derivable from non-renewable energy resources (conventional fuels) such as coal, oil, natural gas and nuclear substances which has manifested in the recent upward review of more than 50% of the electricity tariff in the face of dwindling economy in Nigeria calls for exploration and exploitation alternative sources. With present innovation in the power sector and the privatization of electricity generation and distribution sector, It is clear that for logistic and economic reasons, especially in the privatized power sector, villages which are far from the urban centres or have low power purchase potential will not be attractive to private energy investors. The rural areas which are inaccessible due to lack of good road network, have little access to conventional energy such as electricity, Electricity is therefore needed for economic growth, national development and improved standard of living [3]. The overall negative impact of the foregoing issues on the economic and social wellbeing of the citizenry has led to increasing level of poverty in the country. Apart from the closure of a sizable number of Industries which had previously offered employment for a number of people, the poor state of the power sector has created a situation whereby hundreds of thousands of small scale industries and self-employed artisans of all trades have gone out of business therefore rendering the beneficiaries unemployed.Petroleum product like Kerosene and Petrol are purchased in the rural area at 150% in excess of their official pump prices. Though the authority of India made subsidies for LPG to encourage its usage for cooking as fuel, the poor rural population density and bad access road network has limited its distribution [4]. The daily needs of the rural people for heat energy are, therefore, met almost from fuel wood.

In developing countries, cooking and water heating are primary consumers of energy and a lack of access to efficient technologies and clean cooking fuels presents particular challenges [4].The situation in the rural communities is that 70% of families depend on fuel wood for cooking and heating or drying of their farm products as a means of preservations (Sambo, 2006). Nigeria consumes over fifty metric tonnes of fuel wood annually, a rate which exceeds replenishment rate through various afforestation programmes. Sourcing fuel wood for domestic and commercial uses is a major cause of desertification in the arid zone states and erosion in the southern part of the country [3]. The extraction rate of fuel wood in Nigeria has been put at about 3.83 times the rate of regrown and almost ten times the rate regeneration, [5]. In most villages presently, with the depleting natural wood reserves, Women and Children have to trek 3 to 4 kilometres in search of fuel wood, thus wasting productive Man-hours. It is a common sight for young fresh tree to be cut down and left to dried for use as fuel wood for processing cassava, oil palm seeds, cooking and e.t.c thus, further putting pressure on the vegetation, this has adverse or negative impact on the sustainable environment, food availability and health of persons. Figure 1.0 below shows the gains of adopting biogas technology in rural areas

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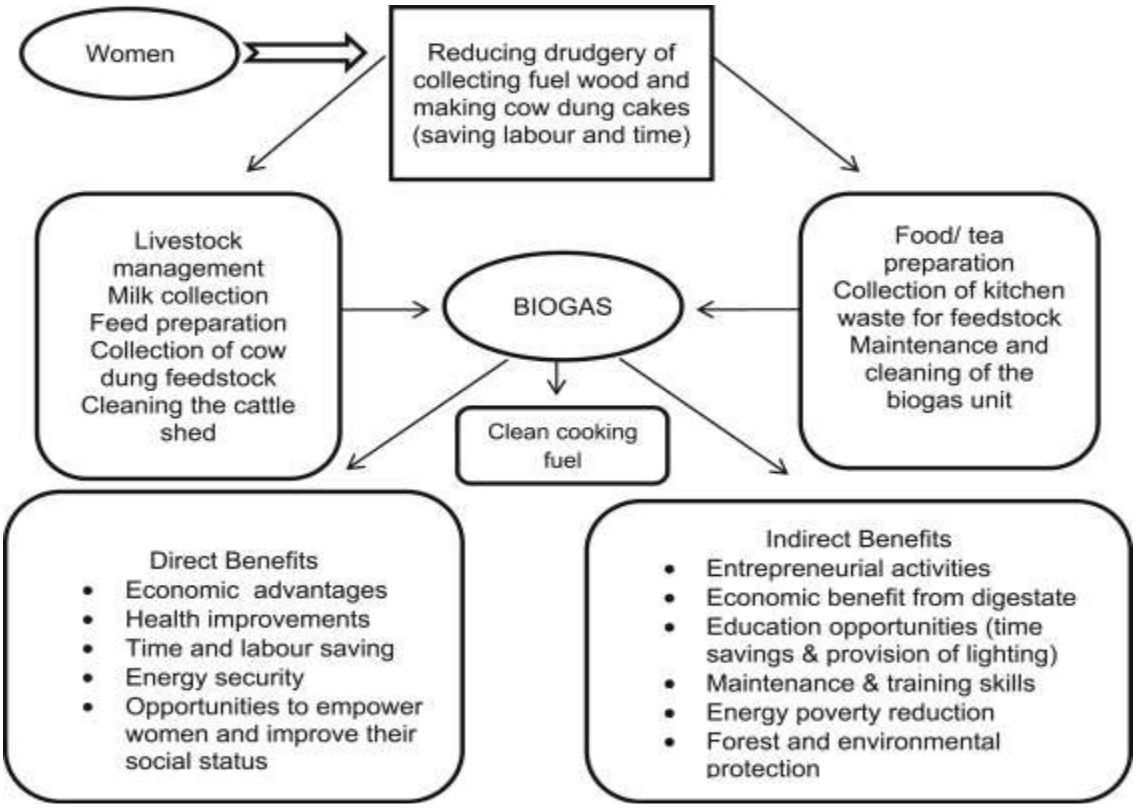

Figure 1.0 The Gains Of Adopting Biogas Technology In Rural Areas

Source: [4]

Biomass resources are considered renewable as they are naturally occurring and can be harvested without noticeable depletion [6]. Biomass is plant materials and animal waste such as Cow Dung, Night Soil (human excreta), Piggery Waste, Poultry Droppings, Rice Husk, Cassava Peel, Palm Kernel Shell, Corn Shell, Corn Stalks, Leaves (Vegetable) that can be used as sources of energy. Residues derived from agriculture are also good sources of fuel when dried, they are burned as starter or supplement material with fuel wood and also for feeding livestock and roofing thatched houses in the village.There are potentials for further processing for higher energy contents via anaerobic fermentation. [7], utilized cassava peels and waste water to produce animal feed that was used to feed Pigs. The faeces from the pigs are then converted to biogas. The raw materials used in biogas production are agricultural waste like cassava peel which has constitute nuisance and waste disposal problem in some farm settlements, thus, It is vital to subject these excessive cassava peel to complex biochemical or anaerobic digestion process that takes place in absence of oxygen and in the presence of catalyst. biogas technology represents a viable alternative due to its simple technology and rural possible adaptability [3].Biogas is a fuel gas consisting of a mixture carbon dioxide (CO_2), methane (CH_4), traces of hydrogen sulphide (H_2S), hydrogen (H_2) and nitrogen (N) produced through microbial processes under anaerobic conditions from bio-degradable materials, [8]. It is a renewable high quality fuel that burns without leaving soot or particulate matter. The make-up of biogas is typically carbon dioxide (CO_2)30-40% methane (CH_4) 50-70% and the rest is made up of traces of hydrogen, nitrogen and hydrogen sulphide [9].

1.2 Aim and Objectives

The aim of this research work is to generate biogas from cassava peels/pig dung blend as an alternative source of fuel for domestic heating in rural areas

While the research objectives are to;

(i) Generate biogas as an alternative fuel from cassava peels/pig dung blend

(ii) Save money and reduce over dependence on fossil fuels which is one the majors causes of environmental pollution and global warming

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(iii) Save time and reduce drudgery of collecting fuel wood
(iv) Preserved our forest reserves by promoting non-wood fuel biomass as an alternative energy resource for domestic heating in the rural areas.

1.3 Biomass Conversion Processes

Biomass resources can be converted into chemical, electrical or mechanical energy in order to have widespread use. Biomass conversion into heat energy is still the most efficient process, but not all of energy requirement is in the form of heat. It can be converted to solid fuel like charcoal, liquid fuel, ethanol or gaseous fuel like methane. The fuel can be used in a wide range of energy conversion devices to satisfy the diverse energy needs. The conversion technologies for biomass utilization may either be based on bio-chemical or thermo-chemical conversion processes. Figure 2.4 shows biomass conversion processes and utilization.

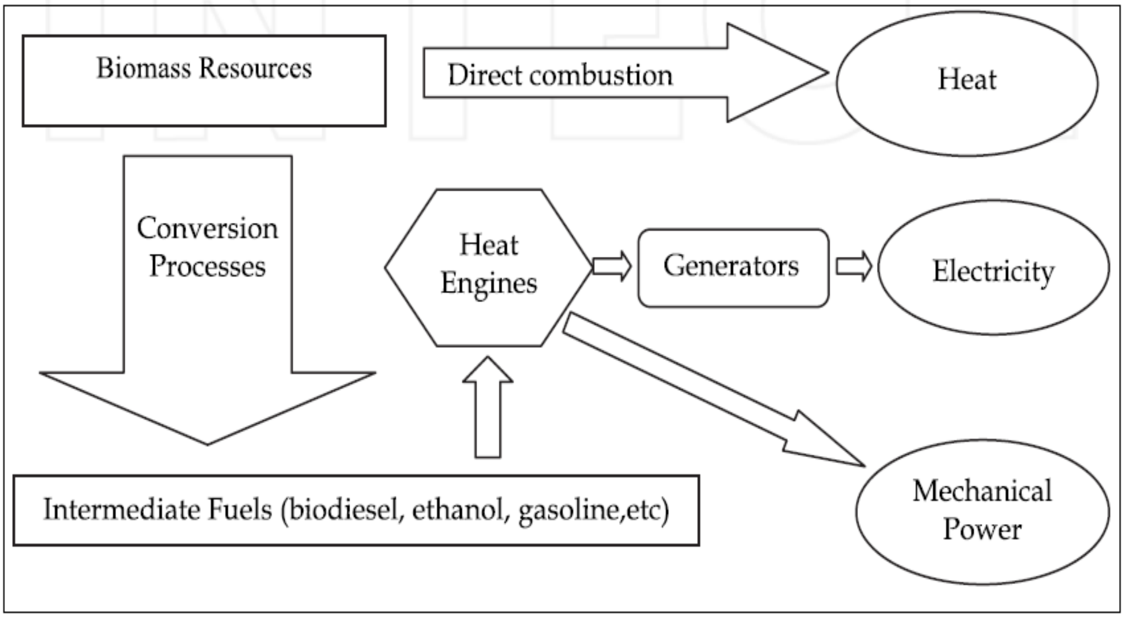

Figure 1.1 Biomass energy conversion and utilization

Source: [10].

1.5.1Bio-chemical conversion processes

A bio-chemical conversion process of Biomass involves bacteria, microorganisms and enzymes to breakdown biomass into gaseous or liquid fuels, such as biogas or bio ethanol. The two most important biochemical conversion processes are the anaerobic digestion and fermentation processes.

1.5.2 Anaerobic digestion

Anaerobic digestion is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen, the overall anaerobic organic solid digestion stages can be classified into hydrolysis, acidogenesis and methanogenesis processes, [11]. The processes take place in the presence of these bacteria:

i Hydrolysing bacteria
ii Acidogenic bacteria
iii Methaneogenic bacteria

(i) **Hydrolysing Process**

Hydrolysing bacteria transform the compound into soluble and the heavy particles into sample ones so that these particles can be attached by other bacteria and in the presence water. [12].

$$(C_6H_{10}O_6)n + nH_2O \longrightarrow n(C_6H_{12}O_6)$$

Hydrolysis process

(ii) Acidogenic Process

Acidogenic bacteria convert the broken-down organic matter into organic acids, principally acetic acid.

$$n(C_6H_{12}O_6)nCH_3COOH \longrightarrow$$

Acidogenic proces

(iii) Methaneogenic Process

The methaneogenic bacteria takes up the acetic acid and convert it into methane and carbon dioxide, e.t.c

$CH_3COOH \longrightarrow CH_4 + CO_2$ Methaneogenic Process

1.6 Factors Affecting the Rate of Biogas Production via Anaerobic Digestion

1.6.1Nature of feedstock

The Feedstock or substrate should be organic matter that is easily degradable within two to ten days and the size should be reduced to increase the surface area. The onset of biogas generation and cumulative product depend on the type of waste or feedstock. In many cases, various substrates should be mixed together in order ensure substantial gas yield and stabilizing the digestion process and promoting gas production, when two or more different type of feed stock or organic matter are mixed together, the process is term co-digestion process [13].

1.6.2 $_P$H value

$_P$H Value is a measure or degree of the acidic or basic nature of the slurry. The optimum Biogas production is achieved when the $_P$H value of the mixture in the digester is between 6.0 to8.0, [14]. Most microorganisms activities are of $_P$H dependant, as decrease or increase in $_P$H alters the chemical equilibrium of enzyme reactions or destroy the enzymes. $_P$H of less than 6.0 and $_P$H greater than 8.0 can cause the biological reaction in digester to cease [15]. The $_P$H of 8.5 is tolerable with cattle dung input, whose potential ammonia production is low. Significant deviations from the above stated range will mean poor biogas yield and digester failure. Low $_P$H will mean acid toxicity and high $_P$H will mean ammonia toxicity to methane producing bacteria

1.6.3 Temperature

Temperature is a vital or important factor for optimum Biogas production. The methanogens are inactive in extreme high and low temperatures; the optimum temperature is around 35^0C for mesophilic Bacteria or around 50^0C for thermophilic Bacteria, [16]. The mesophilic range (30^OC -40^OC) is known for providing a more stable biogas production as the micro organism that thrive in that range are less upset by temperature fluctuation, Mesophilic methanogenic group of bacteria which functions at 30-40^oC range, is more suitable for family size or community biogas plants . A constant range of temperature is important and sudden rise or fall by even 2-3^oC affects the methane forming bacteria. It is generally accepted that in Biogas plant with night soil (human excreta) as feedstock, the level of temperature decides not only the killing rate of pathogens but also which group of methaneogenic bacteria will function in the digester.

1.6.4 Carbon nitrogen ratio

For anaerobic biogasification or production, the necessary nutrients are carbon, nitrogen, phosphorous, of these, the ratio between C and N is vital because it is the carbonaceous matter that is converted to gas and humus-building materials, and any nitrogen apart from what is needed by bacteria will end up as ammonia which, when excessive, will be toxic to the bacteria [16]. Organic matter with a C:N ratio higher than 30:1, will produced a biogas with less methane [16] and more carbondioxide while a C:N ratio substantially lower than 30:1 will produced excessive ammonia and suppress the methanogenic bacteria. A carbon/Nitrogen ratio of 30:1 is critical for an optimum rate of digestion and gas production, if other conditions are favorable. Night soil (human excrete) being low in C:N ratio between 5:1 and 7:1, needs to be supplemented by other materials which have high cellulosic content and low in nitrogen, such as excrement of herbivorous animal, fallen leaves, vegetable stalks, fresh grass and garbage, e.t.c, which can be easily found in rural areas to bring the mixture in the digester to a optimal C:N ratio.

1.6.5 Stirring/Mixing

Biological activities are increased when digester fluid are properly mixed to provide homogenous temperature and nutrient condition throughout the digester. When solid material are not well shredded are present in the digester, gas generation may be impeded, Stirring ensures exposure of new surface to bacterial action, prevent separation or stratification of the feedstock into layers and formation of surface crust and ensures that solids remains in suspension [17]. Proper mixing can increase or enhance biogas production due to the distribution of substrates, enzymes and microorganisms throughout the digester [18]. Mixing also promotes heat transfer, particle size reduction as digestion progresses and release of produced gas from the digester contents [19]. According [20], various mixing methods such as mechanical agitation, recirculation of biogas digester through the bottom of the digester, or hydraulic mixing by recirculation of the fermented liquid with a pump for efficient mixing of the digester content can be employed, thus enhancing methane (biogas) production. , Proper mixing of the feedstock in the digester also help to release the gas bubbles trapped in the medium and helps avoid sedimentation of denser particulate matter in the digester

1.6.6 Retention time

Retention time is one of the factors that affects the efficiency and performance of anaerobic digestion systems. The retention time vary depending on the chemical properties or organic waste characteristics in digester such as volatile solid, design of digester, environmental conditions within and around the digester, microorganisms and additives involved in the anaerobic process. Total or Cumulative gas yield increases with retention time. Other factors such as water present, loading rate, e.t.c influence retention time. At high temperature, bio-digestion occurs faster, reducing the time requirement. Seeding lowers retention time due to high amount of acetogenic and methanogenic bacteria [3].

1.7 Digestible Properties of Organic Matter

When raw materials are digested in a container, only part of the waste is actually converted into methane and sludge. Some of it is indigestible to varying degrees and accumulates in the digester and past out with the effluent and scum. The digestibility and biogas yield of any organic matter can be influence by following:

(i) Total solid (TS) of the organic matter: The weight of dry material remaining after drying the organic matter in the sun. TS weight is usually equivalent to "dry weight". TS is composed of digestible organic matter or Volatile Solids (VS) and indigestible residues or " Fixed Solids"

(ii) Volatile Solids (VS): The weight of organic solids burned off when dry material is ignited. This is a handy property of organic matter to know, VS present in organic matter is the measure of the solids actually converted by the bacteria.

(iii) Fixed Solids (FS): Weight remaining after ignition, this is biologically inert material.

II. MATERIALS AND METHODOLOGY

2.1Materials

The materials used in this research work are;

2.1.1Biodegradable Materials

The organic matters used for this work is as follows-

(i) 3kg of Cassava Peels (ii) 4.5kg of Pig Dung (iii) And 15kg (15 litres) of tap water

The above organic matter was chosen on the basis of it availability in abundance and at no cost in almost every rural area.

2.1.2 Verification of C/N ratio of The Blended Cassava Peels with Pig dung in The Digester

According to Karki and Dixit 1984 that undigested cassava peel and pig dung has a carbon/nitrogen 48.7 and 18 respectively

Percentage of organic Carbon in Pig dung 18

Percentage of organic Nitrogen in Pig dung 1

C/N ratio of Pig dung 18/1= 18

Percentage of organic Carbon in Cassava Peels 48.7

Percentage of organic Nitrogen in Cassava Peels 1

C/N ratio of Cassava Peels 48.7/1 = 48.7

Nitrogen in 3kg Cassava Peels = 1% x 3 = 0.03

Carbon in 3kg Cassava Peels = 48.7 times more than Nitrogen = 48.7 x 0.03 = 1.461

Nitrogen in 4.5kg Pig dung 1% x 4,5 = 0.045

Carbon in 4.5kg Pig dung = 18 times more than Nitrogen = 18 x 0.045 = 0.81

Result from the above calculations

	Carbon	Nitrogen
Cassava	1.461	0.03
Pig Dung	0.81	0.045
Total	**2.271kg**	**0.075kg**

C/N ratio for the mixed organic matter (Cassava peel and Pig dung) used = 2.271/0.075 = 30.28 = 30:1 C:N of 30:1, satisfactory ratio for anaerobic digestion purposes as stipulated by Mechaim (1992)

2.2 Non Biodegradable Materials

The following items started in Table 3.1 below are Non Biodegradable Materials used:

S/N	Item description	Quantity
1	Metal clip	4
2	Wooden stirrer (2x3x1.5m)	1
3	Quarter inch metal nozzle	1
4	Black RTV Silicon gum	1
5	500cm measuring cylinder	1
6	Glass delivery tube	1
7	glass beaker	1
8	Silica gel	50g
9	10mm bolt	16
10	10mm nut	16
11	metal washer	16
12	Gas host	1.5m
13	Black paint	500g

2.3 Equipment/Apparatus

The Equipment/Apparatus use in this work includes:-

(i) pen-type Digital $P^{.H}$ Meter , manufactured by Excelvan in China, the $P^{.H}$ Meter was used to measure the degree of acidity or alkalinity of the slurry to ensure a $P^{.H}$ value of 6.5 - 8 is obtain for optimal biogas yield. Pen-type Digital $P^{.H}$ Meter measures and displace the P^{H} value in numbers. The meter has a very accurate and durable specification measuring range: 0.0 to 14.0 pH Resolution, $0.1p^{H}$ Accuracy, +/- 0.2 pH temperature, auto-off function after three minutes of non-use to conserve battery with a weight of 0.5kg when package.

(ii) Indoor outdoor digital LCD Thermometer: manufactured by Fuzhou Action Electronic Co., Ltd, Fujian, China. It was use to measure temperature of the digester. The thermometer has an accuracy of +/-2, with approximate size of 3cmx15.5cmx1.4cm, and measures temperature of 0.1 to 80^{o}c (Fahrenheit 32.0 to 176.0^{o}F) and weighing about 60g.

(iii) Camry Godmarc Weighing Balance: manufactured by Zhongshan Camry Electronic Co., Ltd, Baishawan Industrial park, China. It was use to measure the amount of organic matter put into the digester, which serves as a guide to calculate the Carbon Nitrogen ratio. The weighing is compactly design, easy to carry, weighing range of 3 to 150kg, with minimum precision of 0,1 to 0.3, weighing 1.52kg, square shape, 26cmx26cmx2.6cm in dimension and electronically driven.

2.4 METHODOLOGY

The study was carried out between November 7th and December 19th 2023 at Karu, Federal Capital Territory Abuja. A digester used for this work is a 34 litres capacity, a Single loading method was used, and thus, the digester was loaded once for the whole retention period. Cassava peels were collected from one of the local garri processors at Mararaba, Nasarawa State. The cassava peels were immediately rinsed with clean water to remove sand, small sticks and other unwanted particles and further chopped to smaller sizes and socked in clean in water for ten days in a container while the water used was repeatedly changed every day so as to reduced its toxicity and the cassava peels were later subjected to mechanical pounding using mortar and mortar pestle so as to increase the surface area of the Cassava peel for faster digestion. Then, a known mass (4.5kg) of fresh pig dung collected into plastic container from a farm at Masaka, Nasarawa State was mixed with a known mass (3kg) of the pounded Cassava peels with water into the digester, adequate water content in the substrates is essential for the activities of the anaerobes because the methanogenic activity would decrease with a decrease in the moisture content, thus lower biogas production (Lay et al., 1997). The slurry was stirred for twenty minutes with a stirrer to ensure uniform mixture in digester. A digital pen type pH Meter was then used to measure the pHvalue of the slurry by dipping the bulb inside the slurry, finally, the digester inlet and outlet was then covered sealed with a Black RTV Silicone gum, gasket, bolt and nut to ensure air tightness of the digester and avoid

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biogas leakage and generate anaerobic condition of the digester. A digital hand thermometer was brought in contact with the body of the digester to determine its maximum daily temperatures and the temperature of the experimental environment was obtained from Federal Capital Development Authority, Abuja. Biogas production were measure by downward displacement of acidicfied water as shown in experimental set-up in Figure 2.1 and volume of gas generated equal to volume of water displaced downwards in a inverted measuring cylinder which was recorded at every one day interval at 12 noon for the duration of thirty (30) days. The digester was shaken at the beginning every day (remaining twenty-nine days) to ensure that the biogas was not trap in slurry or scum layer. Experimental Set-up for the Measurement of Biogas Volume

Figure 2.1 Shows Experimental set up and biogas collection

III. RESULTS AND DISCUSSION

3.1 Results

The results for the anaerobic digestion of 3kg of cassava peels and 4.5kg pig dung for production of Biogas is shown in the table 2.1 for hydraulic retention period of thirty (30) days , Highest Ambient Temperature, Digester highest Temperature and biogas per day

Number of Days	Ambient Temp (o_C)	Digester Temp (o_C)	Biogas Produced (cm^3)
1	30	34.8	0
2	31	34.6	15
3	30	35.0	45
4	31	35.7	40
5	31	36.1	85
6	31	36.0	90
7	32	36.3	120
8	32	37.1	130
9	32	36.9	150
10	30	35.2	150
11	31	36.0	130
12	31	35.7	150
13	31	35.4	130
14	31	36.0	160
15	32	36.5	190
16	31	34.9	175
17	31	35.1	235
18	31	35.6	275

19	31	34.9	415
20	30	34.8	400
21	31	36.5	365
22	31	37.0	360
23	31	38.1	315
24	32	39.0	280
25	32	38.0	230
26	33	38.9	140
27	31	35.2	60
28	31	36.0	20
29	31	35.4	0
30	32	37.6	0

Total biogas volume $4775cm^3$
Expressing the total biogas production in cubic meter= $\frac{4775}{1000000} = 0.04775m^3$
Mass of biogas $1.15 \times 0.04775 = 0.05491kg$

Table 2.2 shows the Highest Ambient Temperature from November 7th to December 19th 2024 for which the Experiment was carried out in Federal Capital Territory

Table 2.2 Daily ambient temperatures for experimental environment

No of days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ambient Temp	30	31	30	31	31	31	32	32	32	30	31	31	31	31	32	31	31	31	31	30

No of days	21	22	23	24	25	26	27	28	29	30
Ambient Temp	31	31	31	32	32	33	32	31	31	32

Source: Federal Capital Development Authority/Accu Weather.com

3.2 Discussion of Results

A graph of ambient temperature and digester temperatures against the hydraulic retention period is as shown

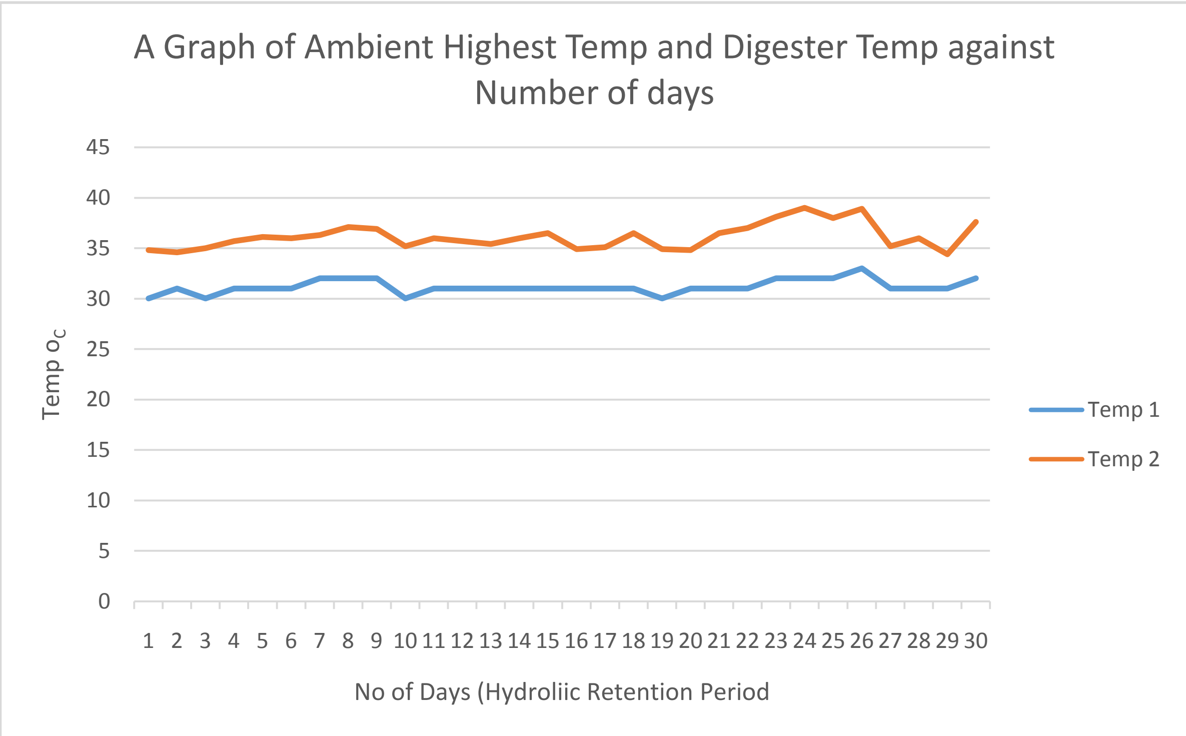

Figure 3.1 Temp 1 for Ambient Temp., Temp 2 for Digester Temp

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Figure 3.1A Graph of Ambient Highest Temp and Digester Temp against Number of days

It can be seen from figure 3.1 a temperature range of 3o$_C$(33 – 30) and 4.4o$_C$)(39 – 34.6) were observed for the ambient temperature and digester temperature for the hydraulic retention period respectively for the anaerobic digestion of the cassava peels blend (mixture of cassava peels and pig dung). It was also observed that a mesophilic temperature range of 39o$_C$ – 30o$_C$ was maintained thorough out the hydraulic retention period which favours methane forming bacteria (methanogenesis), since this temperature range gives better biogas production which agreed with the result of [21] and as reported by [16]. There were positive temperature difference between daily maximum digester temperatures and daily maximum ambient temperatures due the black coloration of the digester as black surfaces are good heat absorbers and thus, help to keep the digester above 10o$_C$ at night for psychrophilic bacteria. An average digester temperature of about 35o$_C$was attended and maximum temperature of less than 50o$_C$ was kept which supported [16] that average ideal temperature of 35o$_C$ is needful for good gas yield and temperature above 50o$_C$ kill bacteria and declined biogas production.

The biogas volume produced from the mixture of the cassava peels and pig dung in the anaerobic digester within the hydraulic retention period is as shown in Figure 3.2

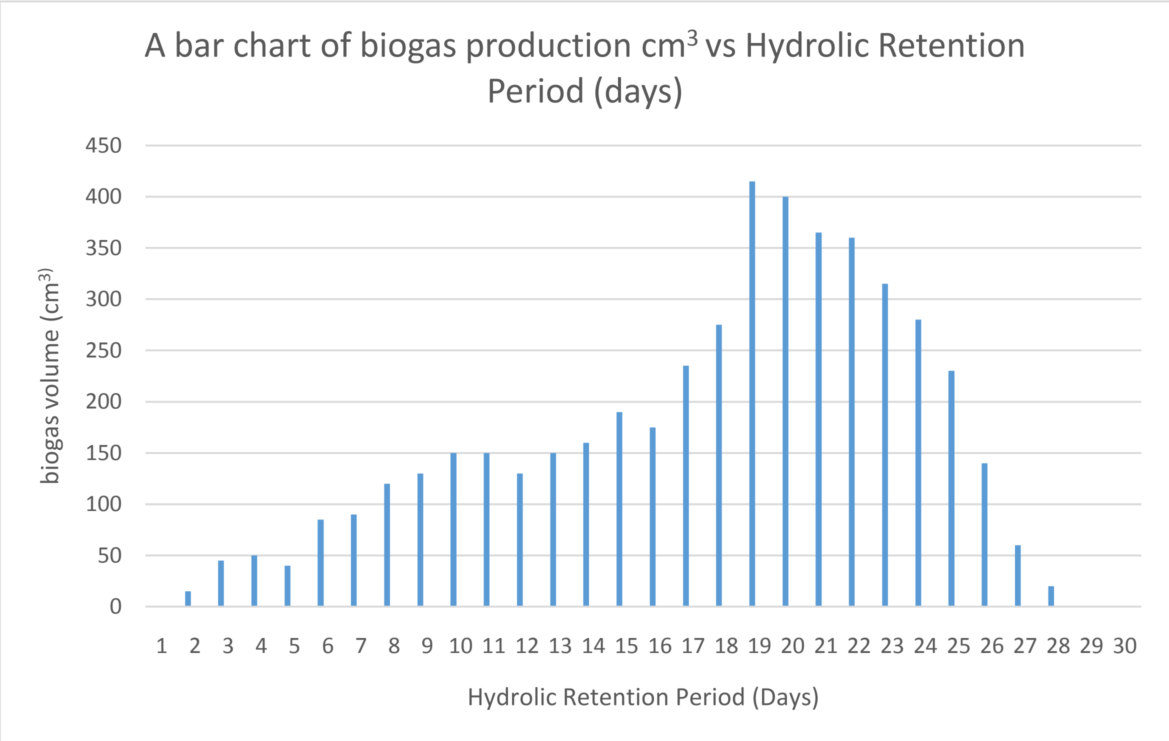

Figure 3.2 biogas production (cm^3) vs HRT

It can be seen from Fig. 3.2 indicated that there was no gas production on the first day of the hydraulic retention time as no methane forming bacteria has grown in the digester and with only 15cm^3 of gas on the second day signifying the commencement of growth of methane forming bacteria (methanogenesis). As the hydraulic retention period increases, fermentation or anaerobic digestion commences, operational factors and conditions in the biogas digester favouring methanogenic process resulting in gradual increase in biogas production as the retention increases as seen but with reoccurring drop on gas productionon 5th, 9th, and 12th day which could be due to adjustment of the pH in the digester tending towards acidity thus, disfavouring methane forming bacteria, the biogas digester content pH was later turned towards neutral that favoured methanogenesis, thus leading to better digestibility and further significant increase in biogas production over some more days before peak biogas production was observed on nineteenth day with a biogas production of 415cm^3, indicating more growth and increase in methane forming

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bacterial, the peak periods of biogas production were observed between day 17 – 21 with respective gas volumes of 235cm^3, 275cm^3, 415cm^3, 400cm^3, 365cm^3. This result closely agrees with the observation of [22] who observed a peak period of 15-25 days, Thereafter the peak gas yield, a decline in biogas production followed as the hydraulic retention time goes further, zero biogas production on the twenty eighty day was noticed. The zero biogas production from day twenty-eighty indicates that the all Volatile Solids (VS) in the feedstock have been completely converted by the bacteria. Total gas volume produce 4775cm^3 with a mean volume of 159.17cm^3. The C/N (30/1) of the blended cassava peels with pig dung makes the fermentation period to be moderate [16].

IV. CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

A research on generation of biogas from cassava peels/pig dung blend as an alternative source of fuel for heating in rural areas was carried out, the result obtained shows that anaerobic digestion of a mixture of cassava peels and pig dung in mass ratio of 3kg and 4.5kg yielded biogas which was burnt and observed to be flammable thus obtaining an alternative fuel for domestic heating and power generation. Anaerobic digestion is a secure and profit yielding way to dispose of these organic matters that were hitherto indiscriminately discharged as the methane content in it is directly tap or extracted and burnt as fuel thus mitigating the release of methane from landfill, open disposition of organic matters thus reducing the emission of greenhouse gas and its aftermath global warming. The biogas generated served as green alternative fuel and save money which would have been used for the purchase of conventional fuel for domestic heating in rural areas. Biogas production as fuel from non-wood biomass resources help to preserve our forest reserved resources and save man-hours used in cutting fuel wood for heating thus mitigating desert encroachment and soil vulnerability to erosion.

4.2 RECOMMENDATION

In view of the above research on generation of biogas from cassava peels and pig dung blend as an alternative source of fuel for heating in rural areas carried out, the following are hereby recommended;

(i) Further research work aim at purification of the biogas for higher percentage of methane for efficient combustion and high calorific value and on how to bottle the biogas so it can be taken from one place to another.
(ii) Anaerobic digestion should be adopted as it could help provide fuel for cooking, cheap fertilizer, mitigate or reduce environmental pollution and global warming.
(iii) Further research on cheap innocuous additive(s) that should be added to the cassava peels to neutralize the acidic content of the peel and ways of improving or enhancing biogas yield.
(iv) More efficient and hygienic way of collecting, handling and mixing of the pig dung and cassava peels to avoid inhalation of offensive odour emitted from the mixture and possible outbreak of epidemic.
(v) Any researcher intending to take further research on this subject should look at a way of purifying the biogas to get pure methane for better flammability.

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