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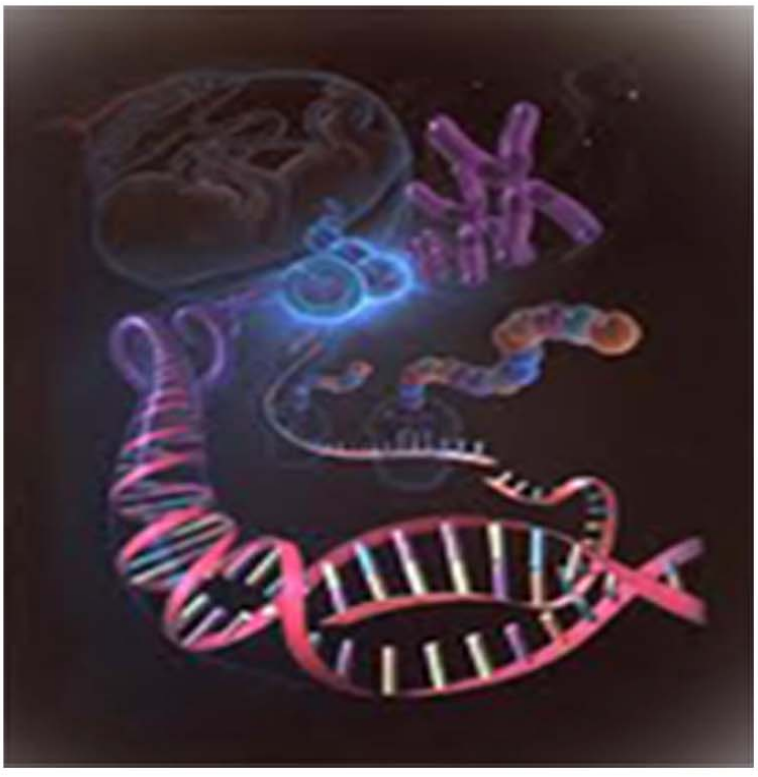

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Research Paper

PRODUCTION OF BIOGAS FROM CASSAVA AND PLANTAIN PEELS BLENDED WITH COWDUNG

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This research work centers on biogas production from cassava and plantain peels blended with cow dung. Two digesters were charged with cassava peels alone and plantain peels blended with cow dung respectively. This was done in metal prototype digesters of 5 L capacity in the ratio of 2:1 of water to waste for both. The anaerobic digestion process was batch, operated for 35 days under temperature condition of 27^0C-32^0C for ambient temperature and 32^0C-43^0C for slurry temperature were recorded daily for a period of 35 days. The cumulative gas production yield of cassava peels were 48.0 dm^3 and 72.0 dm^3 for plantain peels blended with cow dung. The mean volume of gas per day for the two set ups were 1.3 dm^3 and 2.05 dm^3 respectively while the lag day period of 21st day and 10th day was obtained respectively. The result revealed that plantain peels blended with cow dung gave the highest yield of biogas and flames easily when compared with cassava peels alone. Care should be taken when handling biogas production because from the microbial analysis alone, it contains pathogenic organisms like *Staphylococcus aureus* and *candida albicans*. Other organisms identified includes*: Escherichia coli, Streptococcus spp., Penicillum* spp*., Aspergillus* spp. *and Saccharomyces* spp.

Keywords: Biogas, Cassava, Plantain, Cowdung and digesters

INTRODUCTION

In the USA, the average consumption of oil equates to three gallons per day (Hashimoto *et al.,* 2004; Adeyanjo, 2006; Akinbami *et al.,* 1996). That is for every man, woman and children of the population. This makes an annual consumption of over two billion gallons. This is probably the most wasteful of the developed nations but not extremely far ahead of the others. This practice will necessarily have to come to a halt at some point in the near future, since the present rate of consumption should exhaust the known reserves of refinable crude oil in about 30 years. The constant effort of our oil companies to sell more and more of the blackgold make it unlikely that today's consumption will not increase in the future (Adeyanjo, 2006; Akinbami *et al.,* 1996; Brown and Tata, 1985; Byrant, 1984; Casebow, 1997).

Ironically, in most African countries, fire wood is commonly used as a source of fuel whereas

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huge wastes in the form of crop wastes, human and animal wastes are either burnt or left to rot in the farms and factory dumps and also is the rising cost of petroleum products (Dioha *et al.,* 2003; Ezeonou, 2002; FAO, 2000).

There is need to find alternative, renewable and ecologically sound source of power for the future, unless we want to face rocketing power prices and possible rationing in our in future.

Biogas technology in which biogas is derived through anaerobic digestion of biomass such as agricultural wastes, municipal and industrial waste is one of such alternative way and technology the world should adopt to easy it's energy and environmental problems (Ilori *et al.,* 2007; Marchain, 1992; Mathew, 1982; Mclaerney, 1984). Biogas production is a complex biochemical process that takes place in the absence of oxygen and in the presence of highly sensitive micro organisms that are mainly bacteria (Meher, 2000; Nagamani, 1997; Nagamani *et al.,* 1994).

The predominant component of flammable biogas is methane (CH_4) and CO_2 with traces of other gases like H_2S, NH_3, CO, H_2, N_2 and water vapor. It has a heating value of 22 mj/m^3 (156 mj/kg) (Odeyeme, 1981). Consequently, biogas can be utilized in all energy consuming applications designed for natural gas (Ezeonu, 2002; Sahota, 1999; Smith *etal.,* 1980). Anaerobic digestion which is employed in the production of biogas consists of several interdependent, complex, sequential and parallel biological reactions in the absence of oxygen, during which the products from one group of micro-organisms serve as the next, resulting in transformation of organic matter (biomass) into a mixture of methane and carbon dioxide (Adeyanju, 2006; Brown and Tata, 1985; Yeole, 2003).

Scientific interest in the manufacturing of gas produced by the natural decomposition of organic matter was reported in the seventeenth century by Robert Boyle and Stephen Hale, who noted that flammable gas was released by disturbing the sediments of streams and lakes in 1808, Sir Humphrey Davy determined that methane was present in the gas produced by cattle manure (Marchain, 1992; Nagamani *et al.,* 1994). The first anaerobic digester was built by a leper colony in Bombay, India in 1859. In 1859, the technology was developed in Exeter, England where a septic tank was used to generate gas, for the sewer gas destructor lamp, a type of gas lightening. In 1904, the first dual purpose tank for both sedimentation and sludge treatment was installed in Hampton. Through scientific research, anaerobic digestion gained academic recognition in the 1930s.

This research led to the discovery of anaerobic bacteria, the micro organisms that facilitate the process. Further research was carried out to investigate the conditions under which methanogenic bacteria grow and reproduce (Ilori, 2007; Marchain, 1992). The chemical composition of methane was established by Henry and Davy Dalton in 1810 via methane from coal mines. This was soon linked to the biogas involved in volta's scientific discussion. By 1884, a student of pasteur in France named Gayon had anaerobically produced biogas of suspending cattle manure in a water solution at 35 Celsius. At that time, he was able to obtain 100 L of biogas per meter cubed of manure (Casebow, 1997; Dioha, 2003). The discovery and separation of certain kinds of bacteria involved in the digestion

process begun as early as 1906 by Sohugen. By the 1920's Buswell was able to track and record the movement and uses of nutrients such as nitrogen through the digestion process. Bakers in the mid 20th century were able to isolate and perform biochemical studies on a large number of bacteria involved in anaerobic digestion. Utilizing anaerobic digestion technologies can help reduce the emission of green house gas in a number of key ways.

- Replacement of fossil fuels.
- Reduce the energy footprint of waste treatment plants.
- Reducing methane emission from landfills.
- Displacing industrially used chemical fertilizer.
- Reducing vehicle movements.
- Reducing electrical grid transportation losses (Adeyanju, 2003; Akinbami *et al.,* 1996).

Methane and power produced in anaerobic digestion facilities can be utilized to replace energy derived from fossil fuels and hence reduce emission of green house gases.

MATERIALS AND METHODS

The cassava peels used for this study were obtained from the local processors of Garri, while plantain peels were obtained from New Market Enugu State, Nigeria. The study commenced on the 1st day of March and ended on May 6, 2011. The soaking of substrates in water started on 1st March and ended on 6th April and was charged on the 6th of April, 2011. The experiment ended on 6th May, making it a total of thirty five days retention time. Nutrient agar, MacConkey agar, Saboraud dextrose agar and other reagents for biochemical tests were procured from the market. Other materials used were weighing balance, five liters prototype digesters, graduated transparent bucket, thermometer, pH paper, hose pipes, biogas burner fabricated for checking gas flammability, distilled water, conical flask, sterile tubes, petridishes, agar (MacConkey, Nutrient and Saboraud dextrose agar plus chloramphenicol).

Soaking

Plantain peels were chopped into smaller units and about seven kilograms of it was soaked in water. Fifteen kilograms of cassava peels were separately soaked in water also but was not chopped because it was already in small pieces. It lasted in water from 1st March to 6th April and the aim was to soften the substrates so that the micro-organisms involved during the anaerobic digestion will have access to them easily for quick production of biogas.

CHARGING OF WASTES

Cassava Peels Alone

Fifteen kilograms of cassava peels was charged with thirty kilograms of water in the ratio of 2:1 of water to waste in a metal prototype digesters of five liters capacity. Biogas in small quantity was produced the next day. The anaerobic digestion process was batch operated for thirty days under mesophilic temperature conditions of 27^0C-32^0C for ambient temperature and 32^0C-43^0C for slurry temperatures. Daily biogas production, ambient and slurry temperatures and pH were recorded throughout the 35 days period. Gas production measured in liters/total mass of the slurry was obtained by the displacement of water by gas using a transparent graduated cover bucket inserted with a hose.

Plantain Peels and Cow Dung

About 7 kg of plantain peels blended with seven kilograms of cow dung making it a total of 15 kg of waste was charged with 30 kg of water in a ratio of 2:1 of water to waste. Biogas production commenced within twenty four hours and it started flamming on the 11th day post charging period. The anaerobic digestion process was batch operated for thirty five days under mesophilic temperature conditions of 27^0C-32^0C for ambient temperatures and 32^0C-43^0C for slurry temperatures. pH recorded falls between 7.0-8.0 throughout the whole period. All other parameters were recorded. The digester containing cassava peels which serves as the control was recorded together with the digester containing plantain peels and cow dung. Gas flammability was checked in both digesters using a fabricated biogas burner.

Isolation and Identification of Micro-Organisms Presenting the Slurry

Sample Collection

The substrates charged inside the digesters were collected separately through the arm of the digester using a sterile bottle. Immediately after the sample collection, it was delivered to the laboratory for analysis within two hours to minimize biological changes that occur between the time of collection and the actual testing procedure.

Procurement of Reagents, Equipment and Media

All the equipment, reagent and media used in this analysis was procured from the market and sterilized to avoid contamination. All the glass wares were washed with detergent, rinsed and sterilized in hot air oven at 180^0C for one hour and stored at 40^0C.

Media Preparation

Three different media were used, they are:

- Nutrient Agar
- MacConkey Agar
- Saboraud Dextrose Agar

Nutrient/MacConkey Agar

Six Nutrient and MacConkey agar were weighed separately in 100 mL of distilled water in a conical flask, it was covered with aluminium foil and cotton wool, was autoclaved at 121^0C for 10 min and poured in a sterile Petri dish respectively.

Saboraud Dextrose Agar Plus Chloramphenicol

The same method used for MacConkey and NA preparation was used in SDA + C preparation but chloramphenicol which serves as inhibitor to other organisms and encourage only the growth of fungi was added.

Inoculation and Incubation of the Samples

For sample inoculation, the spread plate method was used 0.1 mL of the sample was streaked on the already prepared media using a wire loop. The plates were incubated at inverted position for 24-48 h at 35-37^0C for bacteria and then 3-7 days for fungal growth. After the period of incubation, microscopy was done to identify the moulds/fungi present while biochemical tests were done to identify the specie of bacteria present.

Subculturing

After the incubation of the culture, sterilized inoculating wire loop was used to subculture a well discrete colony into a well freshly prepared nutrient agar and then incubated at 37^0C for 24 h. The purpose of this was to get a pure culture of the suspected bacteria organism for biochemical test.

Gram Staining

Gram staining for bacteria was done to differentiate the gram positive bacteria from gram negative ones. This was done by emulsifying a colony from bacteria culture in a drop of sterile distilled water, from this a thin film preparation was made on a clean grease slide, the smear was allowed to air dry completely and was heat fixed and allowed to cool before staining and was stained first with a primary stain (crystal violet) for 30-60 s. It was washed off with clean water. The smear was also raised briefly with 95% acetone and washed off with clean water. The smear was counter stained with neutral red stain for 1 min and was washed off with water and placed in a draining rack for the smear to air dry a drop of oil immersion was made on the slide and was examined under the microscope x 100.

Wet Mount for Yeast and Mould Identification

A drop of normal saline was placed on a clean slide and a loopful of the organism from the culture colony was removed and put in slide with an inoculating wire loop and stirred. A cover slip was placed over it and was examined under the microscope.

Motility Test

Sterilized wire loop was used to make a drop of the test organism on a clean slide and three drops of peptone water was added, this was covered with a cover slip and examined microscopically.

Biochemical Tests

a. Catalase Test: This test was used to differentiate bacteria that produce the enzyme catalase, such as *Staphylococci* from non-catalase producing bacteria such as *Streptococci*. A 2.3 mL of the 3% hydrogen peroxide (H_2O_2) was poured into a test tube, glass rod was used to remove several colonies of the test organism and was immersed in hydrogen peroxide solution, this was observed immediately for bubbling of gas. Active bubbling shows positive catalase test and no bubbles shows negative catalase test.

b. Indole Test: This is important in the identification of *Enterobacteria*. It shows that the ability of micro-organisms to produce indole from amino trypotophan. The reagent (Kovac's reagent) was prepared according to the manufactures instruction to a peptone water culture. A loopful of the test organisms was cultured into a peptone water and after 48 hours incubation, 0.5 mL of kovac's reagent was added, shaked gently and was examined for a red color in the surface layer within 10 min. Red surface layer indicates positive indole test and no red surface layer indicates indole negative test.

c. Coagulase Test: This test is used to differentiate *Staphylococcus aureus* which produce the enzyme coagulase from *S.epidemis* and *S.saprophyticus* which do not produce coagulase. A drop of distilled water was placed on two separate slides, a colony of the test organism was emulsified in each of the drops to make two thick suspension. A loopful of plasma was added to one of the suspensions and mixed gently. This was observed for clumping of the organisms within 10 s. No plasma was added to the second suspension, this was used to differentiate any granular appearance of the organism for true coagulase. Clumping of the organism within 10 s was an indication of a positive reaction.

d. Oxidase Test: The oxidase test is used to assist in the identification of pseudomonas, *Neisseria, Vibro* and *Brucella.* All of this produces the enzyme cytochrome oxidase. A piece of fitter paper was placed on a clean Petri dish and 2 drops of oxidase reagent was added, a sterile wire loop was used to remove a colony of the test organism and was smeared on the filter paper. Blue purple color within 10 s showed positive oxidase test while no blue purple color within 10 s showed negative oxidase test.

e. Germ Tube Test: 5 mL of human serum was pipetted into a small test tube yeast colony from the culture plate was inoculate with the serum using a sterilized wire loop. The tubes were incubated at 37^0C for 3 h, after which a drop of the serum yeast culture were transferred to a glass slide using a Pasteur pipette and covered with a cover glass. It was examined on a microscope using with a cover lass. It was examined on a microscope using 10x and 40x objectives. Sporulating yeast cells that is tube like out growths fro the cells indicate positive result.

f. DNASE Test: Dnase agar plates were divided into 3 strips by marking the underside of the plate. The test and control organisms were spot inoculated using a sterile swab making sure that the test areas were labelled clearly. After that, the plate was incubated overnight at 37^0C. The surface of the plate was covered with 1 mL of hydrochloric acid solution. The excess acid was tipped off. Clearing around the colonies indicates DNASE positive within 5 min of adding acid.

g. Novobiocin Test: A loopful of the test organisms was cultured in an agar plate. After 24 h of incubation, sensitivity disc containing Novobiocin was placed on the organism. The presence of inhibition area of within 17 min showed positive reaction.

RESULTS

Table 1 below indicates the lag period, the cumulative gas yield and the mean volume of the gas produced by the two digesters containing cassava peels alone and plantain peels blended with cow dung. The lag period is the number of days taken for the wastes to produce flammable gas ie from the day of charging to the day of producing flammable biogas. The cumulative gas yield is the sum of the daily gas production up to the retention period of 35 days while the mean volume of gas is the cumulative gas yield divided by the total retention period of 35 days while the mean volume of gas is the cumulative gas yield divided by the total retention period of 35 days.

Table 1: LAG Period, Cumulative Gas Production and Mean Volume

Parmeters	Cassava peels alone	Plantain peels blended with cow dung
Lag period	21st day	11th day
Cumulative gas yield (liters)	48.0	72.0
Mean volume of gas production (liters)	1.3	2.05

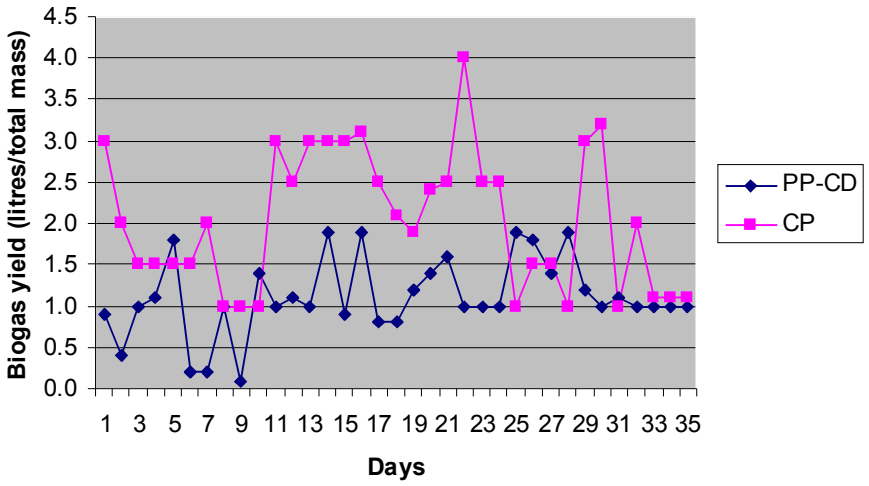
Daily Biogas Production

Table 2 shows the daily volume of biogas produced from cassava peels alone which serves as the control experiment. The volume of the gas was recorded together with ambient temperatures, slurry temperatures and pH. The experiment was carried out during the rainy

Table 2: Daily Volume of Biogas Produced from Cassava Peels Alone

Day (s)	Volume of gas (litre)	Ambient Temp (0^0c)	Slurry Temp (0^0c)	pH
1	0.9	28	39	5.0
2	0.4	28	40	5.0
3	1.0	30	39	6.0
4	1.1	30	38	5.0
5	1.8	30	41	6.0
6	0.2	30	38	6.0
7	0.2	30	39	5.0
8	1.0	30	38	5.0
9	0.1	30	34	6.0
10	1.4	28	32	5.0
11	1.0	28	34	5.0
12	1.1	30	41	6.0
13	1.0	32	42	6.0
14	1.9	32	40	5.0
15	0.9	32	41	5.0
16	1.9	29	40	6.0
17	0.8	30	41	6.0
18	0.8	29	40	5.0
19	1.2	29	42	6.0
20	1.4	28	37	5.0
21	1.6	28	36	5.0
22	1.0	29	34	6.0
23	1.0	30	33	5.0
24	1.0	29	38	6.0
25	1.9	29	41	5.0
26	1.8	29	43	6.0
27	1.4	30	40	5.0
28	1.9	30	41	5.0
29	1.2	32	39	6.0
30	1.0	32	41	5.0
31	1.1	32	40	6.0
32	1.0	28	41	6.0
33	1.0	28	41	5.0
34	1.0	28	42	6.0
35	1.0	30	39	6.0

Figure 2: Daily Biogas Production Graph



season and increase in temperature is beneficial to biogas production. Therefore, biogas production is best done during the dry/hot seasons.

DISCUSSION

This research work was done during the rainy season with an ambient temperature range of 270^{0}C-320^{0}C and slurry temperature range of 320^{0}C-430^{0}C during a 35 day retention time. It started on the 1st day of March and ended on the 6th day of April, 2011. When the two digesters were charged with their respective substrates, it commenced biogas production within 24 h, but the flammability varies. From the results does it show that rainy season with low atmospheric temperature is good for biogas production?, plantain peels which is fairly adequate for biogas production and cow dung which has been acknowledged as the best biogas producer amongst animal wastes, when blended together were adequate substrate for biogas production?, produce enough biogas?, and flame early when compared with their separate use for biogas production?. This were the questions that led to this research work and the use of cassava peels alone, which served as the control experiment and plantain peels blended with cow dung which serves as the main experiment. From the experiment conducted, it tallies with the fact that cassava peels are the worst substrate for biogas production in the sense that the volume of the gas produced daily and the cumulative gas yield does not tally with that of plantain peels and cow dung blended together. The results of this research also showed that flammability was hard to commence and occurs towards the end of the experiment. It was also noticed that the pH recorded is not the ideal pH that is required for effective biogas production. This could arise from the fact that cassava peels contains toxic glycosides (Smith *et al.,* 1980). Another actor is acidification, it was observed that the thin brownish outer membrane of cassava roots consists of lignified cellulosic material while the inner portion comprises of parenchymateous material known to contain most of the toxic cyanogenic glycosides and linamarin, in the entire

Table 3: Daily Volume of Biogas Produced from Peels Blended with Cow Dung

Day (s)	Volume of gas (litre)	Ambient Temp (0^0c)	Slurry Temp (0^0c)	pH
1	3.0	28	38	7.0
2	2.0	28	39	7.0
3	1.5	30	39	8.0
4	1.5	30	37	8.0
5	1.5	30	40	7.0
6	1.5	30	39	8.0
7	2.0	30	38	7.0
8	1.0	30	37	7.0
9	1.0	30	32	8.0
10	1.0	28	32	7.0
11	3.0	28	32	8.0
12	2.5	30	40	8.0
13	3.0	32	43	7.0
14	3.0	32	41	7.0
15	3.0	32	40	8.0
16	3.1	29	41	8.0
17	2.5	30	42	8.0
18	2.5	29	40	7.0
19	1.9	29	40	7.0
20	2.4	28	39	7.0
21	2.5	28	40	7.0
22	4.0	29	40	8.0
23	2.5	30	40	7.0
24	2.5	29	41	7.0
25	1.0	29	32	7.0
26	1.5	29	37	8.0
27	1.5	30	35	8.0
28	1.0	30	38	7.0
29	3.0	32	40	7.0
30	3.2	32	40	8.0
31	1.0	32	41	8.0
32	2.0	28	42	8.0
33	1.1	28	45	7.0
34	1.1	28	44	8.0
35	1.1	30	41	7.0

Figure 3: Daily pH Changes for the First Two Weeks

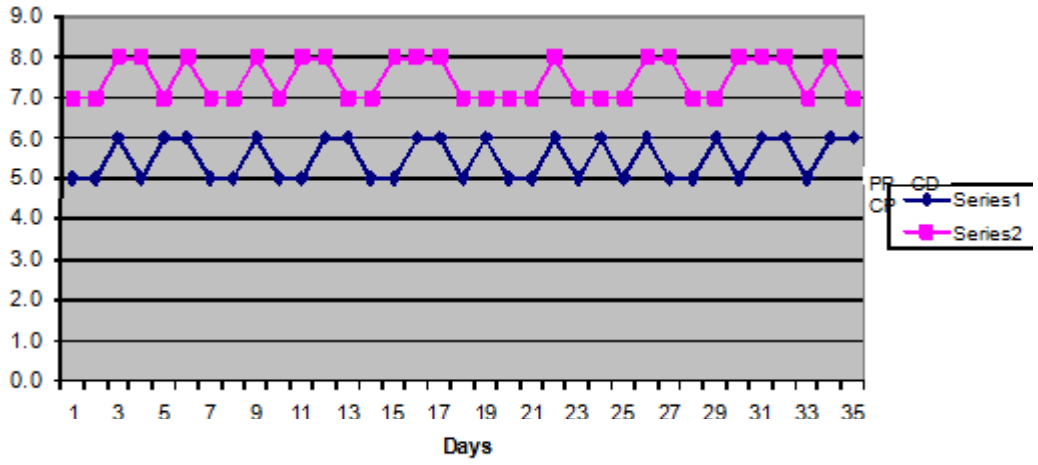


Table 4: Yeast Identified Scheme for the Recovered Isolates

S. No.	Sample	Gram Reaction	Germ Tube	Organism Isolated
1.	Cassava peels alone	Gram +ve cocci (bud)	-ve	*Saccharomyces spp*
2.	Plantain peels and cow dung	Gram +ve cocci (unbud)	+ve	*Candida albicans*

Table 5: Fungi Identification Scheme for Recovered Isolates

S. No.	Sample	Colonial Appearance on SOA + C	Lactophenol Cotton Blue Microscopy Appearance	Organism Isolated
1.	Cassava peels alone	Greyish colouration with which boarders	Septate hyphae, conidia borne on the conidiophores in multilink chains like a paint	*Penicillium specie*
		Blackish colouration	Septae hyphae, condiophores born laterally on the hyphae, non septate, numerous sterigmata proceed from the apical club shaped swellings; conidia born in chains of the sterigmata	*Aspergillus niger*
2.	Plantain peels and cow dung	Greyish colouration with boarders	Septate hyphae, conidia borne on conidiophores in multilink chains like a paint brush	*Penicillum specie*
		Blackish colouration	Septate hyphae, conidiophores borne laterally on the hyphae, non septate, numerous sterigmata proceed from the apical club shaped swellings; conidia born in chains of the sterigmata	*Aspergillus niger*
		Greenish colouration	Septate hyphae, conidiophores born laterally on the hyphae non septate, numerous sterigmata proceed from the apical club-shape swelling.	*Aspergillus fumigatus*

cassava root (Akinbami *et al*., 1996). The second digester which contains plantain peels and cow dung seems to reach the height of what is expected of it but the flammability which was a bit delayed seems to point that the synergy in existence between cow dung and plantain peels is low when compared with other wastes because it is a fact proven that cow dung have been acknowledged as the best biogas producer amongst other animal wastes and flames early during digestion.

Table 6: Bacterial Identification Scheme for the Recovered Isolates

S/N	Sample	Colonial appearance	Gram reaction	Catalase Test	Coagulase Test	Motivity Test	DNAS E Test	Noobcoin Test	Citrate Test	Indole Test	Oxidase Test	Germ Tube	Organism isolated
1.	Cassava peels alone	Medium size elevated creamy colonies on NA	Positive cocci in clusters	+ve	+ve	-ve	+ve	-ve	-ve	-ve	-ve	-ve	*Staphylococcus aureus*
		Circular convex smooth colonies with distinct edge on NA	Negative rod	-ve	-ve	+ve	-ve	-ve	-ve	+ve	+ve	-ve	*E.Coli*
		Chuters of medium size colonies on NA	Positive rod	+ve	-ve	-ve	-ve	+ve	-ve	-ve	-ve	-ve	*Microscoccus specie*
2.	Plantain peels and cow dung	Small flat pile colonies on NA	Positive cocci in chains	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	*Streptococcus specie*
		Clusters of medium size colonies on NA	Positive Rod	+ve	-ve	-ve	-ve	+ve	-ve	-ve	-ve	-ve	*Microscococis specie*
		Circular convex smooth colonies with distinct edge on NA	Negative Rod	-ve	-ve	+ve	-ve	-ve	-ve	+ve	-ve	-ve	*E.coli*
		Medium size elevated creamy colonies on NA	Positive cocci in clusters	+ve	+ve	-ve	+ve	-ve	-ve	-ve	-ve	-ve	*Staphylococcus aureus*

Generally, it seems that the draw back or the delayed flammability of both digesters may be as a result of plant wastes present in them because they are known to be difficult to biodegrade. This may be because of lignin, cellulose and hemicelluloses in the wastes which leads to an acidic condition. The microbes that convert wastes to biogas are sensitive to pH and survive optimally at pH range of 6.5 – 8.0. This may have contributed to the poor performance of the waste. However, it is thought that blending of the plantain peel and cow dung brought the C/N ratio within the optimum range needed for effective biogas production while improving other physical chemical properties like fats, proteins, etc., which might be lacking in the plantain peels (Mathew, 1982). From the microbial analysis done, biogas contains micro-organisms including the pathogenic ones that are dangerous to human. This means that biogas should be handled with care and kept in a somewhat isolated place. Most of the organism were isolated through a complex and highly cautions means. Series of biochemical tests were employed after culturing, subculturing, microscopy and gram reaction has been done.

CONCLUSION

The results of this research has shown that cassava peels are poor producers of biogas and will require pre-treatment to enhance its biogas yield. Also, any biogas work using cassava materials should be added inoculums and neutralizers to the slurry to bring the pH to neutrality or it should be blended with wastes like swine dung, cow dung, etc., so that there would be higher cumulative gas yield with reduced number of lag days and comparison with the cassava peels alone.

Secondly, cassava and plantain peels which are obtained after processing the valuables (inner contents) are consumed in reasonable large

quantities in homes can be used to generate biogas, if this is done, they will lose the name attached to them as being a nuisance that create environmental problems. This technology will help curtail the overdependence on oil which at the rate used today might dry up in future. This will help create different ways whereby power or energy can be generated and the most important significant of this is that the populace will no longer be buying energy at exorbitant prices.

RECOMMENDATIONS

The followings were recommended as a result of findings in this work:

- There should be further purification of biogas to enhance other applications of biogas flame.
- There should be cautious approach to be adhered to when handling the digesters as pathogenic organisms proliferate there.
- Constructing sophisticated equipment that will help store the biogas produced separately from the digester.
- Design and fabrication of biogas burners are necessary to facilitate development and dissemination of the stored biogas and thus encourage its wide utilization in this part of the world.

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