Converting Cassava (*Manihot spp)* Waste from Gari Processing Industry to Energy and Bio-Fertilizer

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Abstract: **The high COD values associated with indiscriminate discharging of cassava peels and effluents during cassava processing to gari was studied. To challenge this problem, a 500-litre capacity batch-operated metal biogas digester was designed and constructed. Cassava roots were harvested, peeled and the pulp fermented for 4 days at ambient conditions. The resultant unwanted liquid and cassava peels were used to charge the biogas digester at a ratio of 3:1 (i.e. liquid waste to cassava peels) and allowed to ferment for 21 days. During the fermentation period, rate of biogas generation, pH of the digesting medium, both total and volatile solids were monitored using appropriate standard laboratory methods while the odour levels of the garri processing site was by sensory evaluation and stastical analyses. The fertility status of the biogas slurry was assessed by evaluating the percentage of the ammonium-nitrogen, potassium, and phosphorous contents both before and after fermentation. Results obtained show generation of a combustible gas (biogas) after 3 days of charging. A rich bio-fertilizer and a significant reduction of odour level within the gari processing vicinity (P<0.05) were also recorded.**

Keywords: Biogas, gari, acidogenes, methanogenes and cyanogenic glucoside

I. Introduction

Cassava (manihot spp) is one of the most staple roots that is being consumed in the different forms in Nigeria and other African countries. In Nigeria it is consumed either as foo foo or processed into garri. The technology of processing cassava roots into gari involves essentially, peeling, grating, fermenting, de-watering and frying. Basic processes such as soaking, grating and fermatation, increase qualities of cyanogenic glycosides and cassava waste products lost into the wash water used. This wash water that that has been reported to contain high BOD oncentration, can not be discharged directly into the environment; they need to be treated biologically before discharging (Chittendum, et. all, 1980).

Anaerobic digestion of the cassava waste water is an eco-friendly technology that can not only stabilize the cassava waste water but also produces biogas as an alternative to fuel wood needed for the light roasting of the mashed pulp in shallow metal vats placed on fire.

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The detoxified cassava waste water can also be used to supplement other local feed ingredients for animal production (Tewe, 2008). Besides the energy value of this conversion the pollution potential of the cassava waste water is also minimized within the environment this research was therefore, undertaken to scientifically explore the possible application of biological degradation of gari processing wastes in solving the energy and environmental pollution of garri processing sites in Nsukka, Nigeria. However, the specific objectives of this research include:

To assess odour level of the environment where garri is being processed and produced, before and after a production batch.

To assess the impart of cyanogenic glucoside in biogas generation from cassava-based wastes.

To evaluate the fertilizing value of the cassava digested slurry.

II. Literature Review

Reported study by Okoro (1986) and Okafor (1994) confirmed that in Nigeria, more than 60% of the rural population is engaged in cassava-based cottage industries. Millions of tons of this waste water from such industries cause environmental pollution. These wastes need to be managed and utilized in environmentally before final disposal. Anaerobic degradation of these complex materials to biogas and other by products of low molecular weight is eco-friendly technology. In the process, these complex wastes are degraded in the first instance, by the acid-forming bacteria that convert the waste to compounds of low molecular weight fatty acids. These are later converted in the second stage by methane-forming bacteria to biogas (methane), carbon dioxide and other products.

The biogas produced has wide range of applications including its use for lighting, driving automobiles, powering farm machinery heating, cooking. The successful operation of a digester relies on the correct balance between the acidogenic and methanogenic bacteria in the system and this occurs within a pH range of 6.5-7.6 ().The p.H is considered by the carbon dioxide/ bicarbonate buffer system; the bicarbonate being in equilibrium with ammonia generated from nitrogenous materials present in the waste.

The anaerobic digester effluent from the biomethanization process is commonly used as a liquid fertilizer. However, land applying anaerobic digester effluents often creates serious environmental problems. For instance, limitation of farm lands can cause excessive accumulation of nutrients and the odour often bothers neighbouring residents as people expending into rural areas from crowded cities. Additionally, runoff after heavy rainfalls or storms can cause entrophication and pollution when these nutrients are carried to the run place or ground water (Filmax 2009).

III. Materials and Methods

A 500litre (0.5m3) capacity batch-operated metal biogas digester was designed and constructed at our mechanical workshop using a 2mm thick mild stainless steel metal. The inlet and outlet pipes are all made of metal. A 1mm rubber hose served as the biogas conveying system from the digester of the biogas burner or gas cylinder depending on the need. A 3/8 rod was used to construct the stirrer (Fig.1). Special rubber flanges were used to ensure leak-free joints during the coupling of the various digester components. There are two control values to regulate the flow of gas to the burner; one is located at the beginning of the joint between the top of the digester and the gas conveying-hose while the other valve is connected to the biogas burner. At the lower part of the digester, a circular slurry outlet that is closed with a thread plug for discharging off the slurry, is incorporated. This slurry outlet also serves as the sampling port for the collection of the digesting waste for intermittent analysis.

The wastes for charging the digester were cassava peels. The cassava roots were manually peeled with a knife to expose the pulp, washed in clean water and they were grated in a lister (6 AP) engine-powered grating machine made for that purpose. It was packed in jute bags and de-watered using local fabricating mechanical press. Pressure was applied to express the unwanted liquid from the mashed cassava pulp by tightening two big nuts fitted to the pressing machine. The cassava pulp was then left to ferment for four days at ambient conditions with occasional application of pressure to squeeze out unwanted fluid. It was this fluid (effluent) which has earlier been reported to contain high strength process effluent, with various COD values that was mixed with the cassava peels at a ratio of 2:1 (effluent to cassava peels) and used to charge the digester. The charged digester was monitored on daily basis with the following parameters:

1) Gas production rate was assessed by downward displacement of water using a 25l transparent and calibrated plastic gallon
2) The temperature of the experimental location was monitored with a thermometer while that of the digester slurry was recorded with a thermocouple.
3) The pH of the slurry was monitored with a Jeanway3020 pH meter and pressure was with a manometer.

The total solid and volatile acid contents were determined in the laboratory by standard methods as recorded by (Maynell, 1982).

1) Presence of hydrogen cyanide in biogas was determined by using draeger tubes sensitive in the range of 0-30ppm.
2) The fertilizing value of biogas slurry was through appropriate chemical analyses of the percentage of potassium (K), phosphorus (P) and nitrogen (N) of the wastes before and after fermentation, as recorded in AOAC (1990).
3) The odour level in the gari processing site was evaluated through interviews of some neighbours living at least 50meters away from the gari processing vicinity. A 7-point Hedonic scale sensory (odour/flavour) was also used to assess this parameter.

Plate 1: The Biogas Digester used For Experiment

IV. Results and Discussion

The results of some of the parameters such as Total solids and pressure measured during the period are presented in Table 1 while that of the digester and ambient temperatures are presented in Fig 2 respectively.. The maximum and minimum daily temperatures recorded were 36^{0}C and 26^{0}C respectively (Fig. 2). The optimum operating temperature range was 30 – 35^{0}C. Below 30^{0}C, digestion proceeded more slowly. Lower temperatures appeared to favour acid-forming bacteria and the system became more susceptible to a reduction in pH (Fig 4). There was no defined pattern of pressure change during the period. The internal pressure reached a maximum of 55 cm SWG*. This was evident when gas evolution was rapid and the internal pressure exceeded 50 cm SWG; causing effluent overflow and a great leak of biogas from an air-tight gas tank of the digester.

Gas production rate with daily temperature cycling of the system was observed to vary linearly with temperature (Fig. 3). This could be as a result of a combination of factors, improved mixing by convection, increased bacterial activity and degassing. The temperature differential between the ambient and digester temperatures was about ±2^{0}C and both were also observed to be linearly related.

* = Standard Water Gauge

Table 1: Changes in the digester pressure and total solids during fermentation

Times(days)	Pressure	TS(%)	Times(days)	Pressure	TS(%)
1	0.0	4.20	11	40.10	2.61
2	28.4	4.05	12	48.60	2.51
3	32.3	3.72	13	54.20	2.22
4	30.0	3.88	14	30.30	1.90
5	28.3	3.81	15	35.40	1.61
6	34.4	3.77	16	40.60	1.46
7	45.2	3.77	17	49.50	1.39
8	50.3	3.74	18	48.00	1.30
9	55.0	3.70	19	43.2	1.28
10	53.8	2.65	20	36.2	1.2
			21	20.2	1.19

T dig- Temperature of Digester, T amb- Ambient Temperature

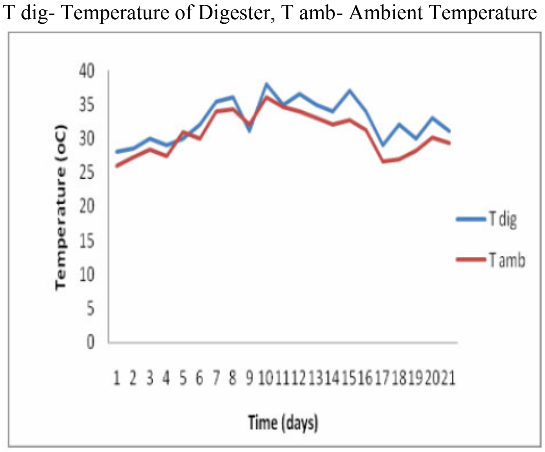

Fig. 2 Temperature Variations During Fermentation

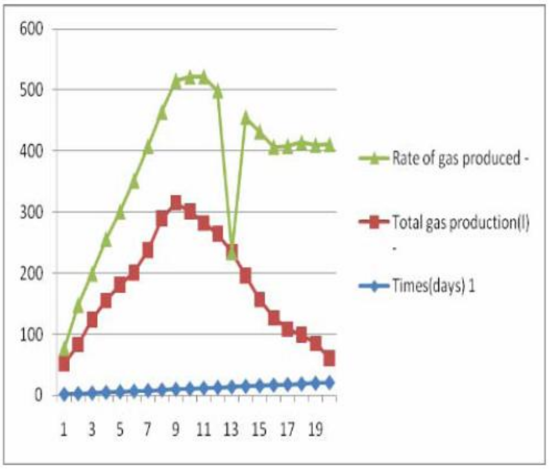

Fig.3 Gas Production during the study

Result of the pH of the digesting slurry shows an initial acidic medium which decreased linearly as the hydraulic retention time increased (Fig. 3). This was attributed to the activities of acidogenes that were initially concerned with the polymerization of organic substrates in the digester; hence, there was no biogas cassava contains cyanogenic glucosides which liberate cyanide under the influence of endogenous enzymes with the concentration of these glucosides in the peelings, test results for possible presence of hydrogen cyanide in the biogas from cassava peelings indicated that there was no cyanide in it. This result supports earlier claim by (Chittenden *et*. al.,1980) that hydrogen cyanide, if present, in biogas, was at a concentration of less than 1 ppm. The total solids of the fermenting medium diminished as hydraulic retention time increased. This is as a result of the conversion of the production in the initial stage of production. As the hydraulic retention time advanced, the acidogenes were displaced by the methanogenes, thereby increasing biogas production rate and yields. Decline in gas production was noted on the 11th day when the operational factors and conditions in the biogas digester changed against methanogenesis. Though polymers to monosaccharides and amino acids. These compounds were later converted to methane and ammonium compounds which turned the pH towards neutral that favoured methanogenesis (Eze, *et. al.*, 2008).

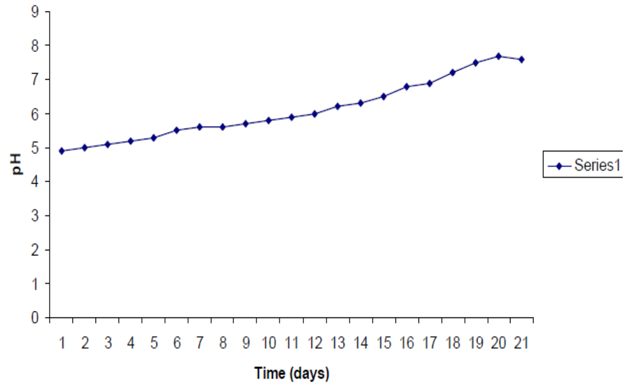

Fig. 4: Changes in pH During Fermentation

The chemical composition of the input materials loaded into the digester and the digested slurry output of the fermentation system as presented in Table 2 shows that organic matters are degraded during anaerobic fermentation to produce biogas, thereby making the percentage of Nitrogen in the slurry to rise compared with the solid content. The three fertilizer elements were therefore, conserved during anaerobic fermentation. This may crate an elusion of ―new" Nitrogen if only the Total Kledahl Nitrogen (TKN) is considered. Nitrogen can be lost only by reduction of nitrates to nitrogen gas and volatilization of ammonia into biogas.. Loss of nitrogen through volatilization of ammonia can occur from the slurry if not correctly handled. The volatile fatty acids which serve as primary sources of energy for the ruminants decrease during anaerobic digestion. This is because the process converts available energy into gas.

Table 2: Chemical composition of input materials and digested slurry

Parameters Determined	Input materials	Output materials
Total solid (%)	4.50+0.28	2.45+0.21
Volatile acids(acetic acid mg/l)	820+2.04	200+1.52
Nitrogen (%)	0.38+0.59	0.65+0.27
Phosphorus (%)	0.72+0.18	1.25+0.26
Potash (%)	0.55+0.13	0.97+0.28
Potassium (g/l)	4.94+0.23	5.80+0.28
Potassium (g/l)	4.94+0.23	5.80+0.28
Ammonia (g/l)	0.68+1.53	0.40+1.83
p.H	6.20+0.54	7.40+0.26

Table 3: Sensor Evaluation Result sheet for the Panels

Score	Odour	Sample A	Sample B
7	Extremely unobjectionable		
6	Moderately unobjectionable		
5	Slightly unobjectionable		
4	Neither objectionable or unobjectionable		
3	Slightly objectionable		
2	Moderately objectionable		
1	Extremely objectionable		

Sensory evaluation of the odour level of the gari processing site was carried out with sensory evaluation sheet as presented in Table 4. Results of the sensory panellists showed that 64 out of 81 residents within the gari processing site maintained that after anaerobic digestion of the gari processing wastes ,the prevailing odour level there was ―extremely unobjectionable" while 9 indicated that it was ―moderately unobjectionable" and the remaining 8 residents described the site as being ―slightly objectionable". Statisticaly, application of anaerobic fermentation in gari waste management has a significant impact in odour reduction ($P<0.05$) within the gari processing vicinity with a rich bio-fertilizer.

V. CONCLUSION

This research has demonstrated that anaerobic fermentation is an environmentally friendly technology that could be used to generate biogas. This biogas could be used as a reliable and an eco-friendly alternative energy to fuel wood needed for the various unit operations in gari processing industries in Nigeria. It was also noted that cyanide in cassava has no effect on biogas production from cassava wastes. Application of biogas technology as an alternative to fuel wood has the potential of addressing the pollution problems associated with the Nigerian gari processing industries. The associated slurry has been confirmed to conserve those fertilizer elements that have the potential to re-condition the soil and increase its fertility. The bio-fertilizer, i;e, the slurry, was observed to be relatively odourless; thereby enhancing the environmental sanitation of the gari processing vicinity. Besides, it is a home made technology.

VI. REFERENCES

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