International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Bioconversion of Cassava Peels Via Anaerobic Digestion for Biogas Production.

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ABSTRACT

The all-year round cassava processing in Nigeria has led to high generation of cassava peels. These peels which contain hydrogen cyanide are left to rotten or burnt at dumpsites causing environmental hazards. This led to the investigation of bioconversion of cassava peels via anaerobic digestion for biogas production. Fresh cassava peels were collected and pretreated. The slurry was loaded in a locally constructed digester with a gas collection system. Cattle rumen contents were applied as the inoculum using an inoculum to substrate ratio (ISR) of 2:1. The batch-feed system was employed at a hydraulic retention time of 45 days. The proximate composition and physicochemical analyses were evaluated using standard methods. The results of the proximate composition analysis showed that the substrate was good for biogas production. The physicochemical analysis results throughout the digestion period, revealed a pH range of 4.5 to 7.5 and a temperature range of 30^0C to 35^0C. The Total Solids (TS) contents showed a decrease from 87.64% to 61.00% while Volatile Solids (VS) contents decreased from 82.48% to 55%. The cumulative mean biogas yield was 1203.37 mL. Gas chromatographic analysis of the biogas composition showed that the methane content was the highest (52.35%) amongst other gases present. One-way ANOVA for the physicochemical parameters indicated a significant difference ($P \leq 0.05$) in all the treatments. The results proved that the anaerobic digestion of cassava peels can be used to produce biogas.

Key words: Anaerobic digestion, Biogas production, Bioconversion, Cassava peels, Rumen content.

1. INTRODUCTION

Cassava peels are among the most common wastes generated in Nigeria and are carelessly disposed into the environment, thus constituting public health risks. Nigeria is the world's largest producer of cassava, producing 57,134,478 tons of cassava per year (FAOSTAT, 2016). In 2020, however, the production of cassava in Nigeria reached 60 million tons (FAO, 2022). It has been reported by FAOSTAT, (2016) that 450,000 tons of cassava peel waste is generated annually with an increasing trend as statistics reveal.

Nigeria relies heavily on fossil fuels to cook, generate electricity and drive vehicles (Akinbomi *et al.,* 2014). The removal of fuel subsidy in Nigeria has caused untold hardship to the masses. The lack of sustainable waste management practices has made environmental pollution severe (Forbis-Stokes *et al.,* 2016). Therefore, there is a high quest for measures to convert these organic wastes to resources and find alternative, renewable and sustainable energy sources (Seruga *et al.,* 2018).

A sustainable system capable of addressing these energy challenges while at the same time offering a recycling option for organic waste will be most welcomed. Anaerobic digestion, however, can proffer solutions to these crucial issues. This can be realized by enhancing the energy production; as well as reducing the volume and weight of organic solid waste (Vasco-Correa *et al.,* 2018).

Production of biogas and its increase not only supports the Global Climate Action Plan goal of cutting methane emissions, but it also increases energy independence and security, improve water quality, limit odours and produce biofertilizer (USDA, 2014).

Anaerobic digestion (AD) is a viable and cost-effective technology for waste management (Al-Addous *et al.,* 2019). It is a process of biologically breaking down organic wastes in absence of oxygen. The main and final products of anaerobic digestion are biogas (Tasnim *et al.,* 2017) and a nutrient-rich effluent used as a fertilizer (Forbis-Stokes *et al.,* 2016).

This research investigated the biogas production from digestion of cassava peels using the cattle rumen fluid as inoculum.

2. MATERIALS AND METHODS

2.0 Sample Collection

Samples used were Cassava peels (CP), collected from the cassava processing unit at National Roots Crop Research NRCRI farm, Umudike, Abia State. Twenty-four hour-old Poultry droppings (PD) were collected from a poultry farm at Ahiaeke in a sterile container. Rumen content (RC) which served as the inoculum was collected from freshly killed adult cattle at Ubakala abattoir, Abia state into a sterile container. All samples were taken immediately after collection to the Microbiology laboratory of Michael Okpara University of Agriculture, Umudike, Abia State for further analyses.

2.1 Pretreatment of Cassava peels

Cassava peels were pretreated by sun drying as described by Yaru *et al*. (2020). This is to remove the hydrogen cyanide contained in the peels. The peels were milled into very small particles as described by Sawyerr *et al.* (2019).

2.2 Preparation of substrate

Two kilograms (2kg) of milled cassava peels and 4kg rumen content were mixed using an inoculum to substrate ratio (ISR) of 2:1 as described by Achi *et al*. (2020). This was mixed with equal weight of water. Ten grams (10g) of lime (Ca (OH_2) were added to the slurry to raise the pH to a neutral level as described by Georgiou *et al.* (2019).

2.3 Loading of biodigester

Substrates were loaded up to three-quarter volume of the digester as described by Poudel *et al.* (2010). They were operated under the batch-feed system at hydraulic retention time (HRT) of 45 days. The digester was stirred twice daily as described by Nkodi *et al.* (2016).

2.4 Proximate composition analysis

The following parameters Moisture, Ash content, Crude Protein, Crude Fibre, Fat and Carbohydrate were determined according to the methods of A.O.A.C. (2000).

2.5 Physicochemical parameter analysis

Temperature was determined using a thermometer. pH was read using a digital pH meter. Carbon content, nitrogen content, C: N ratio, Total Solids (TS) and Volatile Solids (VS) were determined according to *The Standard Methods for the Examination of Water and Wastewater* (APHA, 2012). Samples were collected on weekly basis.

2.6 Quantitative and Qualitative analysis of biogas produced

These were determined using the water displacement method as described by Olaniyi *et al*., (2018) and the gas chromatography (GC-MS) as described by Li *et al*. (2017) respectively.

2.7 Statistical Analysis

The SPSS (version 26) was used to run the One-way ANOVA test to observe any significant relationships among the physicochemical parameters and 95% confidence interval was considered significant.

3.0 RESULTS AND DISCUSSION

Table 1 shows the result of the proximate composition analysis of cassava peels inoculated with rumen content.

Table 1. Proximate composition analysis of cassava peels and cassava peels blend with rumen content.

Parameters (%)	**CP**	**CP:RC**
Carbohydrates	40.00 ±0.03	28.34±0.84
Protein	2.10 ±0.17	4.50±0.13
Fat	2.02 ±0.15	2.11±0.51
Ash	4.16 ±1.9	5.00±1.15
Moisture	45.64 ±0.06	55.00±0.47
Fibre	6.08 ±0.21	15.05±0.71

Key: **CP** = cassava peels. **CP: RC** = substrate blend of cassava peels **+** rumen content.

*Values are mean ± standard deviation.

The results of the proximate composition analysis highlighted that cassava peels inoculated with cattle rumen content served as good source of feedstock for biogas generation. This can be as a result of the macromolecules they contain that are required for microbial growth and multiplication which conformed to the studies of Oparaku *et al.* (2013).

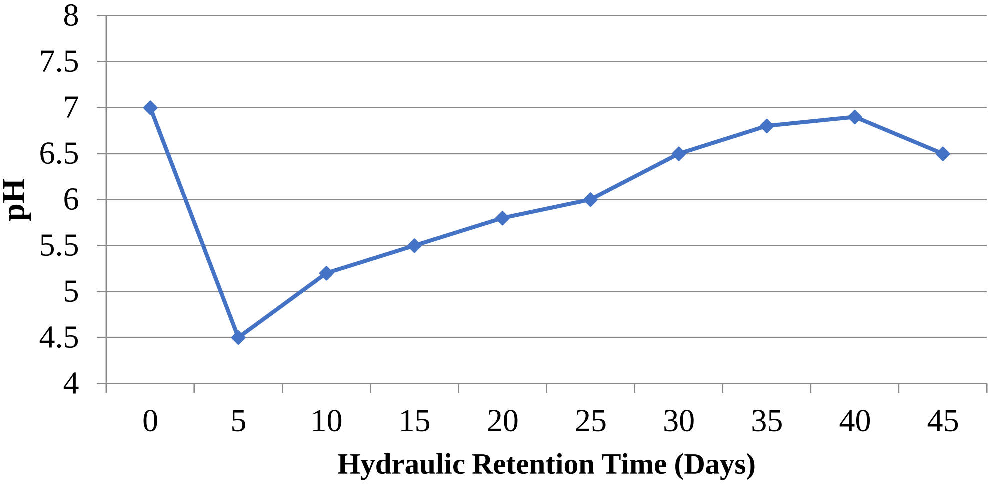

Figure 1: pH variations during anaerobic digestion of cassava peels

The results of the pH during the anaerobic digestion are shown in Figure 1. The pH fluctuated throughout the digestion period. At the start-up digestion time, Day 0, the pH of cassava peels and rumen content (CP: RC) was raised from 6.1 to 7.0 after addition of (Ca (OH)) lime. The pH at start-up digestion (day 0) was at neutral due to adding of lime. This is similar to the reports of Cuzin *et al*. (1992) who raised the pH at start –up fermentation by the addition of Na_2CO_3.

The pH value dropped on day 5 to 4.5. This could be as a result of the action of hydrolytic and acidogenic bacteria that breakdown polymers to monomers and to volatile fatty acids which result in a drop in the pH. This could be as a result of some cyanide content remaining in the peels of cassava. This lent weight to previous studies of Aisien and Aisien (2020) who reported that excess acid production due to the presence of cyanogenic glucosides in cassava peels which cause low pH. This decrease in pH could also be attributed to the process of hydrolysis as reported by the previous studies of Oparaku *et al.* (2013) and Ukpabi *et al.* (2017). They observed an initial acid condition with low pH which neutralized as the reactions progressed.

At day 10, a gradual increase was noticed from 4.5 to 5.2. The pH value on day 15 was 5.5. The pH readings increased as retention time progressed. A pH value of 6.5 was observed on day 30. The increase in pH was observed to continue; on day 35 the pH increased to 6.8. At day 40, a pH value of 6.9 was observed. On the day 45 pH value of 6.5 was recorded. This gradual increase in pH observed corroborated the studies of Ukpabi *et al.* (2017) who reported the sequential rise of pH after the initial dropping during hydrolysis. The pH was observed to stabilize as the digestion process progressed and this also favoured methanogenesis.

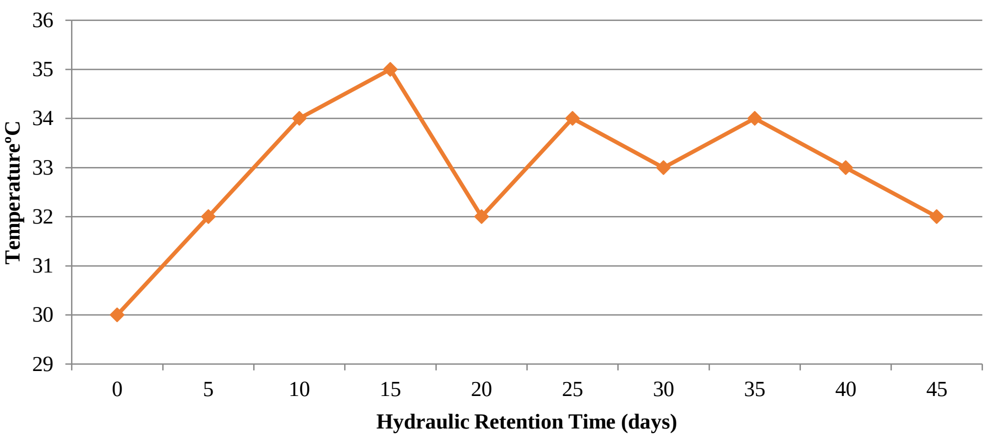

Figure 2: Temperature dynamics during AD of cassava peels

The temperature varied between 30^{0}C and 35^{0}C degrees throughout the anaerobic digestion period as shown in Figure 2. This temperature range falls within the mesophilic range. Similar temperature range has been reported by previous studies of Oparaku *et al.* (2013) which enabled the microbes present to thrive favourably in the anaerobic digestion system for maximum performance.

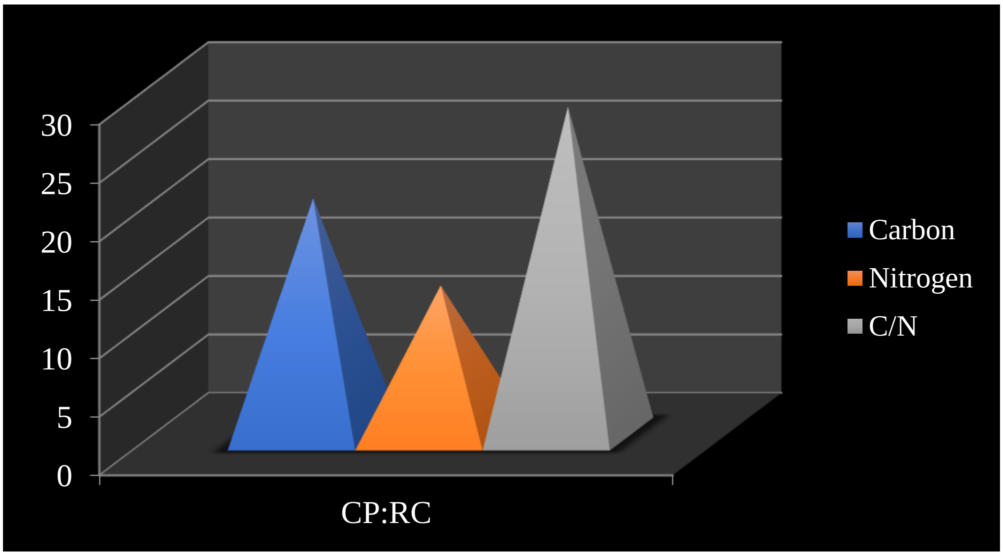

Figure 3. Carbon, Nitrogen and C/N ratio of cassava peels

Figure 3 showed the Carbon and Nitrogen contents and the Carbon-Nitrogen (C/N) ratio of the cassava peels. The Carbon content recorded was 20.18 while the Nitrogen content was 12.72. The C/N ratio of 28.02. The C/N ratio within the range of 20 and 30 has been reported to be ideal for anaerobic digestion. The C/N ratio of cassava peels inoculated with rumen content falls within the C/N optimum range. On the contrary, Lin *et al.* (2017) reported also that the C/N ratio of cassava residue combined with swine manure gave 15.1 which is lower than the optimum range of 20 to 30. A high C/N ratio leads to rapid consumption of nitrogen by methanogens.

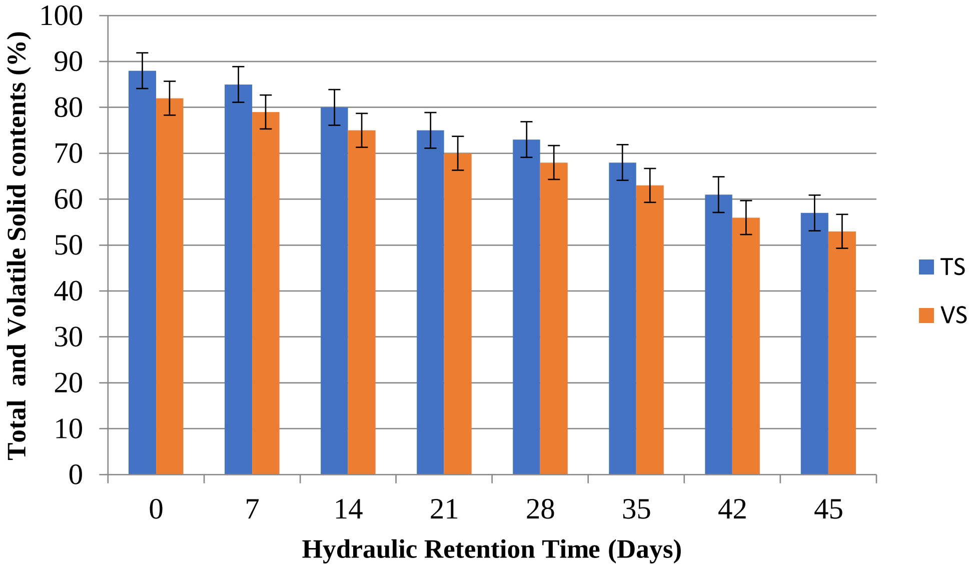

Figure 4: Total and Volatile solid contents during AD of cassava peels

The Total and Volatile solid contents during the anaerobic digestion of cassava peels are as shown in Figure 4. The total and volatile solid contents decreased throughout the anaerobic digestion period. The Total solids (TS) and Volatile solids (VS) contents were observed to decrease significantly in all digesters during the anaerobic digestion process in this study. This is in line with Aisien and Aisien, (2020) who submitted that there was 54.02% and 80.95% decrease in total solids and volatile acids during the anaerobic digestion of fresh and stale cassava peels. In the same vein, Ezeokoye *et al.* (2011) reported a decrease in TS of cassava peels and poultry droppings from 96.32% to 76.30%. This showed that the microorganisms utilised the organic matter for the production of biogas (Nkodi *et al*., 2016).

The results of the physicochemical analysis of this study in summary showed that the AD process was unperturbed and stable. The system process occurred under optimum conditions which favoured the anaerobic digestion hence enabled biogas production.

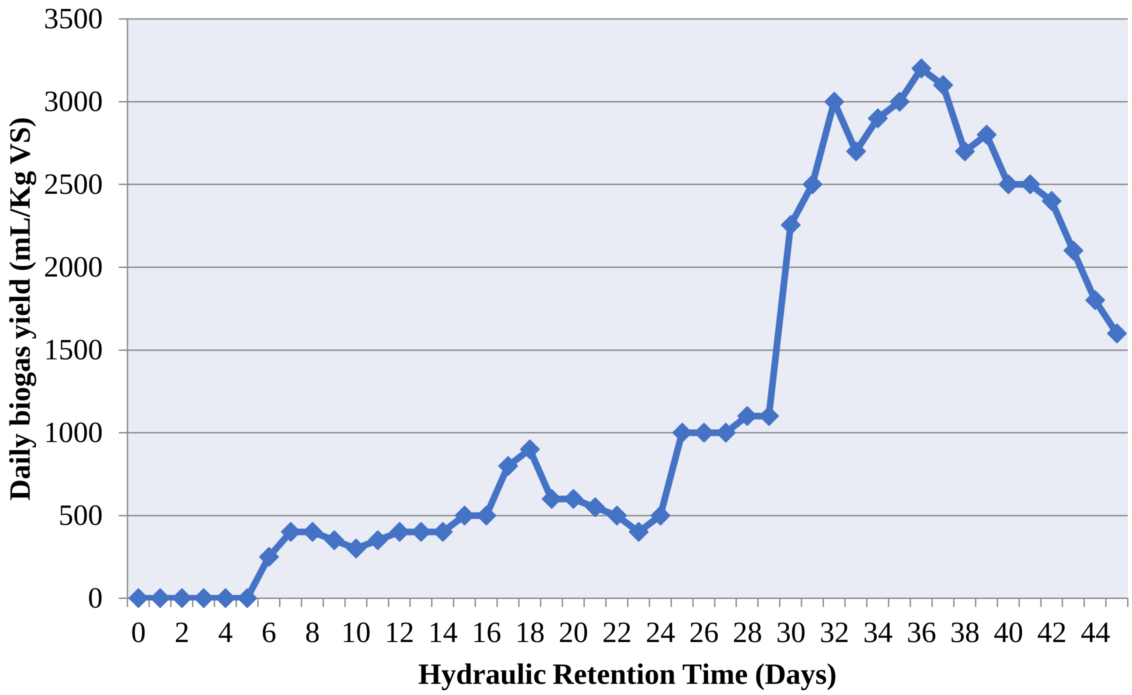

Figure 5: Daily biogas production during anaerobic digestion of cassava peels

The daily biogas yield of anaerobic digestion of cassava peels are presented in Figure 5. Gas production started on day 6. There were spikes in the daily biogas production at different days exhibiting fluctuations in biogas production during the digestion period as seen in Figure 5. The delay in biogas production observed in the anaerobic digestion of cassava peels, however, could be as a result of the microorganisms adjusting to the hydrogen cyanide content still present in the cassava peels. This conforms to the study of Adeyanju, (2008) who reported the production of biogas on day 6 of some of his digesters containing blends of cassava peels and pig dung seeded with ash. The findings of Ofoefule and Uzodinma, (2009) and Aisien and Aisien, (2020) however, had a contrary report. Their studies reported that for both fresh and stale cassava peels, the biogas production started after 24 hours. The biogas yield fluctuated during the AD process. This could be attributed to the variations in pH. It was deduced that pH stability correlated with stability in biogas production. A steady increase in biogas production was noticed when pH is near neutral. This agrees with Aragaw *et al.* (2013) who submitted that pH increase accompanies biogas yield increase. A mean cumulative gas of 1203.37 mL was obtained.

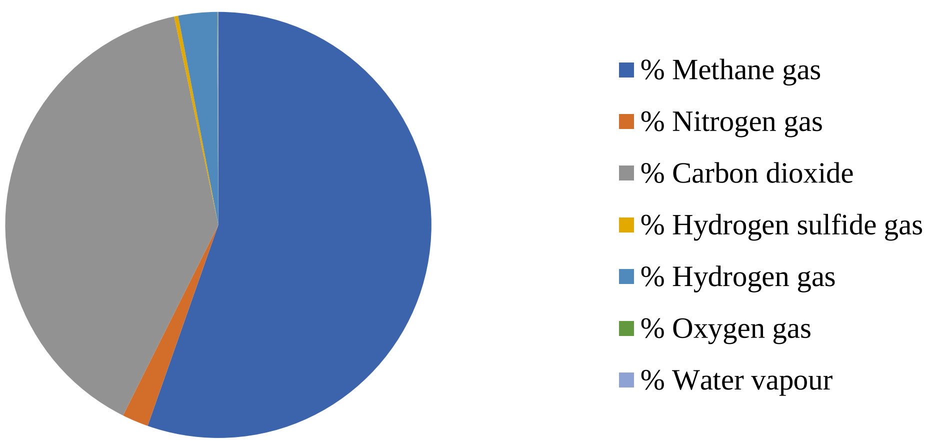

Figure 6: Compositions of biogas produced during the AD of cassava peels.

The compositions of the biogas produced during the AD of cassava peels are shown in Figure 6. The methane content of the biogas composition was 52.35%. This was followed by carbon dioxide gas content that gave 37.13%. Other biogas components were Nitrogen gas content of 1.80%, hydrogen sulphide gas content was 0.29%, and hydrogen gas content was 2.76%. Oxygen gas percentage content was 0.03% and water vapour percentage content was 0.06%. This is in agreement with previous reports of Onuorah *et al.* (2016) who opined that biogas comprises mainly of methane (50-75%), carbon dioxide (25-45%), nitrogen (<2), hydrogen sulphide (<1%), water (2-7%) and oxygen (<2%), the composition however can vary depending on the substrates types used for digestion.

CONCLUSION

The result of this study has shown that agro-waste materials such as cassava peels which constitute nuisance to lives and environment could be bio transformed by microorganisms using the process of anaerobic digestion to produce biogas production. Cassava peels because of hydrogen cyanide are poor producers of biogas, however, pretreatment and addition of rumen content as inoculum enhanced its biogas production. This therefore can be carried out at domestic level.

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