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Thermal Effects on Anaerobic Digestion Efficiency of Discarded Cassava for Biogas Production

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Abstract

Anaerobic digestion is an established technology to treat diferent kinds of wastes and simultaneously produce biogas, a mixture of methane and carbon dioxide, which is a useful and renewable energy source. In this work, the influence of temperature on the biogas production from cassava peels is studied

in batch-type anaerobic digesters of volume 500 ml at digestion temperatures of 35±50C, 45±50 C and 55±50C for a retention period of 30 days. Biogas produced was measured following the manometric method with a pressure gauge twice a day for the first 7 days and then once a day for the remaining 23 and converted to volumetric gas production. It was observed that the cumulative biogas production increased by 25 % when the digestion temperature was increased from the mesophilic temperature range to thermophilic temperature range. The highest cumulative biogas yield of 289.3 3 X 10-5 m3/kg-TS was obtained with the highest digestion temperature of 55±50C. It is therefore concluded that biogas production increases with the increase in digestion temperature and it is recommended that anaerobic digestion should be carried out at the thermophilic temperature range for better gas yield.

Keywords: Thermal, Efficiency, Wastes, Anaerobic, Cassava, Biogas.

Introduction

Cassava is one of the most important agricultural food crops in Southern and Western Nigeria. Several varieties of products such as starch, gari, cassava flour, and fufu are among the staple foods of the people of southern, western and some parts of northern Nigeria which are the products of cassava (Lebot, 2009 and Odediran *et al.,* 2015).

During the conversion of cassava into these products large quantities of waste such as cassava peels, slurry etcetera are generated which are mostly dumped within the community constituting a major problem for the inhabitants of those communities (Ubalua, 2007 and David and Tope, 2018).

Macias-Corral *et al.* (2008) and Olaniyan *et al.* (2017) reported that agricultural wastes such as cassava peels are among the major environmental challenges in both developed and underdeveloped nations. The effect of such wastes on natural resources such as surface and ground waters, soil and crops, as well as human health is enormous as they constitute environmental hazards, leading to global warming and causing environmental diseases thereby resulting in high mortality rate among the populace

(Sarmah, 2009 and Olaniyan *et al.* 2017). However, agricultural wastes such as cassava peels and other waste have been reported to possess huge potential for alternative energy sources from firewood and fossil fuels during anaerobic fermentation (Sammy *et al.,* 2018).

Anaerobic fermentation significantly reduces the total mass of wastes generated into liquid fertilizers and produces energy (Vindis and Mursec, 2009, Navickas and Venslauskas, 2012).

The anaerobic fermentation can take place under psychrophilic conditions (16 ºC – 25 ºC, e.g. in landfills, swamps, or sediments), mesophilic conditions (35 ºC – 40ºC, e.g. in the rumen and anaerobic digesters) or thermophilic condition (52 ºC – 60 ºC, e.g. in anaerobic digesters or geothermally heated ecosystems). The optimum digester temperature setting, considering both the potential biogas yield and energy value, is one of the most critical factors for the economically viable digester operation (Kestutis *et al.,* 2013).

Digestion temperature has been reported to have a direct effect on the physicochemical properties of all the components in the digester and affects the thermodynamics and the kinetics of the biological processes. The temperature determines if a specific reaction is favourable (Kestutis *et al.,* 2013). According to Hansson *et al.,* (2002), the increase in temperature has

Increase the solubility of the organic compounds which makes them more accessible to the micro-organisms., Increase the chemical and Biological reaction rates and hence accelerate the conversion process, therefore the reactor can be smaller and can operate with a shorter hydraulic retention time (HRT). Improve several physicochemical properties like diffusivity of the soluble substrate, the increase in the rate of transfer of liquid towards gas due to the low solubility of the gas, reduction in the liquid viscosity which makes decreased the energy of agitation necessary and also improves separation, liquid-solid separation of the biomass. Particularly increases the death rate of the pathogenic bacteria, which decreases the necessary time for the reduction of pathogenic bacteria. Moreover, the reactions of oxidations of organic acid become more energetic at high temperatures, which is advantageous for the degradation of fatty acid to long-chain fatty acid, and other intermediaries (Chynoweth *et. al,* 1993 and 1994). Temperature is a very important factor in anaerobic digestion (AD) as it affects the rate of reaction. Prakasha *et al.* (2015) reported that digestion temperature has a strong influence on the quality and quantity of biogas produced.

Mackie and Bryant, (1995) found that thermophilic (60°C) anaerobic digestion of cattle waste is more stable as compared to mesophilic (40°C) and reported that thermophilic digestion is 4 (Four) times more intense and can yield more biogas.

Hassib *et al.* (2004) compared the performance of the anaerobic digestion of fruits and vegetable wastes in thermophilic (55^0C) digesters with those in psychrophilic (20^0C) and mesophilic (35^0C) digesters. The study showed that biogas production in thermophilic digesters was higher than that in psychrophilic and mesophilic digesters by 144 and 41% respectively. During the co-digestion of waste-activated sludge Gou *et al,* (2014) found that the average gas production rate of the thermophilic (55^0C) process was 1.6 times higher than that of the mesophilic (35^0C) process. During the co-digestion of Lignocellulosic Biomasses with cattle dung at various temperature ranges, Manjula and Mahanti (2014) observed that biogas production increases with temperature. The objective of this study is to investigate the effect of temperature on the biogas production rate of Cassava peels mixed with cattle dung.

Materials and Method

The substrate (Discarded cassava peels) was obtained from cassava processing companies available from three local government areas (Wukari, Ussa and Donga) of Taraba State, which are the major cassava producers in Southern Taraba. Parts of the collected cassava peels were cleaned and sun-dried in the area and later ground into smaller pieces using mortar and pestle and kept for the experiment, while the other parts were oven-dried and pounded for proximate analysis. Fresh cow dung was obtained at the Teaching and Research Farm, Federal University Wukari, Taraba State Nigeria.

The Physico-chemical analysis of the Cassava Peels was carried out at the National Research Institute for Chemical Technology Zaria (NARICT), Kaduna State Nigeria to determine the following: Moisture Content, Total Solid, Volatile Solid, biochemical oxygen demand (BOD), Crude Lipid, Crude Fibre, Nitrogen content, Crude Protein, total solid concentration, ion content, mineral content and volatile fatty acid content. They were all determined using standard methods as described by (AOAC (1990), Onyeike and Osuji (2003), Asam *et al.* (2011) and Jagadish, *et al.* (2012).

AAS MACHINE (Atomic Absorption Spectrophotometer) was used to determine the ion and mineral contents while volatile fatty acid contents were determined using a Gas chromatography-mass spectrometry (GC-MS) machine. The result of the Physico-chemical analysis of the Cassava Peels as presented in Table (1) shows that the average total solid and carbon-nitrogen (C: N) content of the cassava peels are 9% and 34.7 which is a favourable condition for good biogas production as reported by Manjula and Mahanti (2014).

Experimental setup and procedure

In this experiment, rani bottles of 500 ml capacities were used as bio-digesters or reactors which were set up for the experiment as shown on Plate 1. The rani bottles used have a volume of 500 ml; the effective working volume is maintained at 200 ml and 300 ml is left for the biogas.

A weighing balance was used to measure the required mass of cattle dung and biomass which were mixed in the ratio of 1:3 and water was added to the mixture in the ratio of 1:3, 200ml of the mixture was then put into each of the 9 digesters, on the cover of each bottle a small hole is provided to which flexible connecting tube were attached. On the other end of the flexible tube, a rubber stopper is attached to ensure a complete seal digestion chamber is obtained. When measuring the gas production, a pressure gauge will be attached to the rubber stopper and then the valve of the stopper will be opened to measure the pressure of the digestion chamber.

Plate 1: Batch Digester

To obtain replications for statistical purposes, 3 bottles were placed into each of the 3 water baths and hot water was added into the water bath until the temperature of each gets to the required level as indicated by the thermometer inserted into the water baths.

To maintain uniform temperature i.e. (3 5±50C, 45±50C, and 55±50C) during the 30 days retention period of the experiment for each water bath, the water baths are closed with a cover and mercury in a glass thermometer is passed through it into the digestion unit for temperature measurement as well a hole is provided on the water bath cover for addition of hot water when the temperature within the water bath goes down to rise the temperature.

After every measurement of biogas accumulation over time, the gas was allowed to escape in order to avoid pressure build-up that would exceed pressure gauge capacity. The average was recorded and reported as biogas production.

Results and Discussion

A. Physico-Chemical of the Cassava Peels

The Chemical properties of the discarded cassava peels as shown in Table 1 indicate that the cassava peels contain (9.01 .0%) total solid, the volatile solids contained in the cassava peels were found to be (2.470.05%), the carbon contains the peels were found to be (13.11.25%), the Nitrogen content was (0.40. 1%), the ratio of carbon to nitrogen was found to be (34.711.1%), while the pH of the peels was found to be around the neutral level i.e. between 6.8 % to 7.7% which is within the optimum range for anaerobic digestion. Other chemical elements found in the peels include the electronic conductivity (EC) which was found to be (1 2.60.8Ms/Cm), Bio-oxygen demand which was found to be (11.30.9mg/l), Carbon-Oxygen demand of the peels was found to be (20.6 1.0%), the Hemicellulose contain of the peels was found to be (1.50.2%) and the moisture content of the cassava peels was found to be (6.250.02%).

The Ash contained, Crude lipid, Crude protein, and Crude fiber contained in the peels were found to be (1 1.510.02%), (0.970.01%), (3.1 10.02%) and (16.20.2%)

respectively. The carbohydrates contained in cassava peels were found to be very high (61.920.02%) making it a suitable substrate for the Anaerobic Digestion (AD) process (Fan, *et. al.,* 2008)

Table 1: Chemical composition of discarded cassava peels

Characteristic	1st Rep.	2nd Rep.	3rd Rep.	Mean
Total solid (TS) (%)	9.0	10.0	8.0	9.0
Volatile solids (VS) %	2.50	2.50	2.40	2.47
Carbon (C) (%)	13.2	11.8	14.3	13.1
Nitrogen (N) (%)	0.4	0.5	0.3	0.4
C: N Ratio	33	23.6	47.7	34.7
PH	7.7	7.5	6.8	7.3
EC (Ms/Cm)	12.7	11.8	13.2	12.6
B. O. D (mg/l)	11.2	10.5	12.2	11.3
C.O.D (mg/l)	21.6	20.5	19.8	20.6
Hemicellulose (%)	1.5	1.3	1.6	1.5
Moisture Content (%)	6.24	6.25	6.26	6.25
Ash (%)	11.50	11.51	11.53	11.51
Crude Lipid (%)	0.96	0.98	0.99	0.97
Crude protein (%)	3.10	3.12	3.13	3.11
Crude fibre (%)	16.0	16.2	16.4	16.2
Carbohydrate (%)	61.91	61.94	61.93	61.92

(NARICT, Zaria 2018)

B. Chemical Composition of Biogas from Cassava peels

The chemical composition of the 67.0%, with 3 8.7% of Carbon dioxide.It is biogas produced from cassava peels is found to also contain a minute quantity of presented in Table 2. The gas contains a Hydrogen Sulphaide, Nitrogen and large quantity of Methane (CH4) of about Hydrogen.

Table 2: Chemical composition of Biogas Composition (%)

Constituents	Average
Methane (Ch4)	67.0
Carbon Dioxide (Co2)	38.7
Hydrogen Sulphaide (H2s)	1.1
Nitrogen (N2)	0.4
Hydrogen (H2)	0.4

C. Biogas daily and cumulative production of biogas during the digestion of cassava peels at the digestion temperatures of 3 5±50C, 45±50C and 55±50C are presented in Figures 1 and 2.

From Figure 1, it can be noted that gas production begins on day 2 of the digestion for all the three digestion temperatures with gas production of 1.94 X 10-5, 1.64 X 10-5 and 2.27 X 10-5 m3/kg-TS respectively. The highest level of gas production for the three digestion temperature were on days 15 for the digestion temperature of 3 5±50C and 45±50C with a production of 14.34 X 10-5 and 13.32 X 10-5 m3/kg-TS and day 10 for 55±50C with the production of 15.69 X 10-5 m3/kg-TS, after the peak production days the gas production begins to decline to 0.23 X 10-5, 0.03 X 10-5 and 0.07 X 10-5 m3/kg-TS for the digestion temperatures of 35±50C, 45±50C and 55±50C respectively.

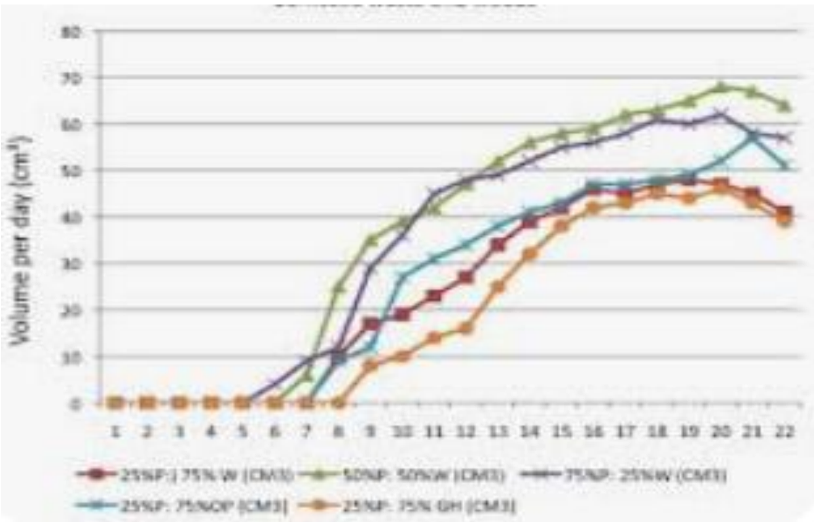

Figure 1: Daily Biogas Production at different digestion temperature.

The cumulative gas production for the period of 30 days of the test is presented of figure 2, a total of 289.33 X 10-5 m3/kg-TS was produced when the digestion temperature was 55±50C, while 253.90 X 10-5 and 231.83 X 10-5 m3/kg-TS were produced when the digestion temperature were 3 5±50C and 45±50C respectively.

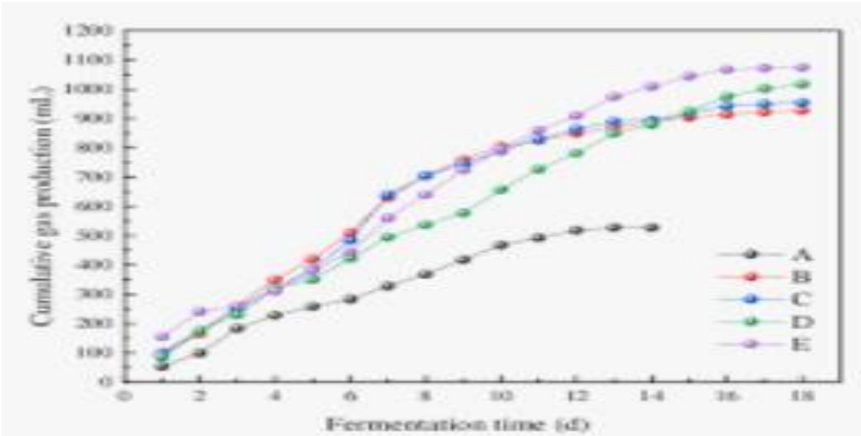

Figure2: Cumulative Biogas Production at different digestion Temperatures

Conclusion

From this study, it can be concluded that biogas production from cassava peels mixed with cattle dung can be improved by increasing the digestion temperature as the 30 days cumulative biogas production increases from 231.83 X 10-5 m3/kg-TS when the mixture was digested at mesophilic temperature range (3 5±50C) to 289.33 X 10-5 m3/kg-TS when digested at thermophilic temperature range (55±50C), representing 25% increase in gas production. So if we can provide extra energy to increase the digestion temperature, better and faster gas production can be achieved from cassava peels. The only disadvantage of thermophilic anaerobic digestion is that more energy is needed to raise and maintain the temperature.

REFERENCES

AOAC, (1990). Official Methods of Analysis. 15th Edition, Association of Official Analytical Chemistry. Washington D.C., USA. Asam, Z.Z., Paulsen, T.G. and

Nizami, A.S. (2011) How can we improve biomethane Production per unit feedstock in biogas plan? *Applied Eng.* Vol. 88 pp 2013-2018

Chynoweth, D. P., Turick, C. E., Owens, J. M., Jerger, D. E. and Peck, M. W. (1993) Biochemical methane potential of biomass and waste feedstocks. *Biomass Bioenerg,* Vol 5. Pp 95–111.

Chynoweth, D. P., Svoronos, S. A., Lyberatos, G., Harman, J. L., Pullammanappallil, P., Owens, J.
M. and Peck, M. J. (1994). Real-time expert system control of anaerobic digestion, *Water Science and Technology,* 30, (12), 2 1-29.

David, O. O. and Tope, O. O. (2018). Cassava Waste Management and Biogas Generation Potential in Selected Local Government Areas in Ogun State, Nigeria. *Recycling,* Vol. 3(5 8) available at www.mdpi.com/journal/recycling

Fan, Y. T., Xing, Y., Ma, H. C., Pan, C. M., & Hou, H. W. (2008). Enhanced cellulose-hydrogen production from corn stalk by lesser panda manure. *International Journal of Hydrogen Energy,* 33(21), 6058-6065.

Gou, C. Yang, Z. and Huang, J. (2014). Chemosphere effect of temperature and organicloading rate on the performance and microbial community of anaerobic co-digestion of waste-activated sludge and food waste.

Hansson, M., Nordberg, Å., Sundh, I. and Mathisen, B. (2002). Early warning of disturbances in a laboratory-scale MSW biogas process. *Water Science and Technology,* 45 (10), 255-260.

Hassib, __ B., Haouari, O., Youssef, ____ T., Ridha, B. C., Marouani, L. and Moktar, H. (2004). Effect of temperature on the performance of an anaerobic tubular reactor treating fruit and vegetable waste. *Process Biochemistry,* Vol. 39(12) Pp. 2143-2148

Jagadish, H., Malourdu, A.R. and Muralidhara, P.L. (2012). Kinetic of anaerobic anaerobic Digestion of water Hyacinth using poultry liter as inoculums. *International Journal of Environmental Science and Development,* No.3 pp2

Kestutis, N., Kestutis, V., Arnas, P. and Vidmantas, Z. (2013). Influence of Temperature Variation on Biogas Yield From Industrial Wastes and Energy Plants. *Engineering for Rural Development.* Vol. 23 Pp. 405 – 410.

Lebot, V. (2009). Tropical Root and Tuber Crops: Cassava, Sweet Potato, Yams And Aroids. Crop Production Science in Horticulture, 17.

Macias-Corral, M., Samani, Z., Hanson, A., Smith, G., Funk, P. and Longworth, J. (2008). Anaerobic Digestion of Municipal Solid Waste and Agricultural Waste and the Effect of C-digestion with Dairy Cow Manure. *Bioresource Technology,* Vol. 99, no. 17. pp 8288-8293

Mackie, R.I and Bryant, M.P. (1995). "Anaerobic Digestion of Cattle Waste at Mesophilic and
Thermophilic Temperature. *Applied Microbiology and Biotechnology.* 43: 346-350.

Manjula, Das and Mahanti Pinakeswar (2014). Effect of Temperature on Anaerobic Co-digestion of Cattle dung with Lignocellulosic Biomass. *Journal of Advanced Engineering Research.* Volume 1, Issue 1, Pp.1-7

Navickas, K. and Venslauskas, K. (2012). Energy balance of biogas production from perennial grasses. Engineering for rural development: 10th international scientific conference: proceedings, Vol. 11, Pp. 382-387.

Odediran, O. F., Ashimolowo, O. R., Sodiya, C. I., Sanni, L. O., Adebayo, K., Ojebiyi, W. G. and Adeoye, A. S. (2015). Awareness of Cassava Peel Utilization Forms among Cassava Processors in Rural Communities of Southwest, Nigeria. *International Journal of Applied Agricultural and Apicultural Research (IJAAAR)* Vol. 11 (1and2) Pp. 93-102

Olaniyan, A. M., Olawale, T. T., Alabi, K. P., Adeleke, A. E. and Oyeniyi, S. K. (2017). Design, Construction and Testing of a Biogas Reactor for the Production of Biogas Using Cassava Peel and Cow Dung as Biomass. *Arid Zone Journal of Engineering, Technology and Environment,* Vol. 13(4) Pp. 478-488

Onyeike, E.N. and Osuji, J.O. (2003). Research Techniques in Biological and Chemical Sciences. Springfield Publishers Ltd., Owerri, Nigeria. pp: 403.

Prakasha, O., Kumarb, A., Pandeyc, A., Kumara, A. and Laguria, V. 2015. A Review on Biogas Plant. *International Journal of New Technologies in Science and Engineering,* 2 (4)

Sammy, N. A., Arthur A. T. and Simeon C. A. (2018). Cassava Residues Could Provide Sustainable Bioenergy for Cassava Producing Nations. IntechOpen. Available at http://dx.doi.org/10.5772/intechope n.72166

Sarmah, A. K. (2009). Potential Risk and Environmental Benefits of Waste Derived from Animal Agriculture. Soil Chemical and Biological Interactions, Soils and Landscape Team, Landcare Research, New Zealand, pp 1-17

Sofiane, M., Eric L., Daniel J., Damien C., Jean-Philippe S. (2013). A manometric method for monitoring biogas production in anaerobic bioreactors. Conference proceedings of the 11th IWA Conference on Instrumentation Control and Automationat Narbonne - France. Available at"https://www.researchgate.net/pu blication/270875 875_A_manometric method_for_monitoring_biogas production_in_anaerobic_bioreacto rs´. Retrieved on 2nd February, 20120

Ubalua, A. O. (2007). Cassava wastes: treatment options and value addition alternatives. African *Journal of Biotechnology,* Vol. 6 (18), pp. 2065-2073,

Vindis, P. and Mursec, B. (2009). The impact of mesophilic and thermophilic anaerobic digestion on biogasproduction. *Journal of achievements in materials and manufacturing engineering,* Vol. 36 (2) Pp. 192-198.