Biogas Production from Domestic Waste and its Purification with Charcoal.

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ABSTRACT

The production of biogas from domestic wastes was achieved by anaerobic digestion. The rate of production was measured using displacement method over a retention period of 30 days. The efficacy of charcoal as a purifying agent of biogas was determined by passing the gas through a charcoal medium and its components and quantity were analyzed using gas chromatography. Result shows that 0.50m^3 of biogas was produced on Day 1. The gas became flammable from Day 12, with a production of 1.10m^3 biogas. The flammability improved with time.

The gas chromatogram of the biogas conducted on Day 10 of digestion when carbon dioxide (CO_2) (a component of biogas, but does not contribute to its flammability) production was expected to be high revealed that the quantity of carbon dioxide reduced from 53.94% to 12.00% after passing it through a charcoal medium and leads to the enhancement of the methane (the flammable component of biogas) content from 0.03% to 0.05%. This indicates that charcoal can enhance the quality of biogas by adsorbing and reducing its carbon dioxide component.

(Keywords: biogas production, domestic wastes, anaerobic digestion, charcoal, carbon dioxide, methane, gas chromatography)

INTRODUCTION

The rate of energy consumption and over-dependence on depleting and environmentally unfriendly fossil fuels has become a global issue. Oil-based fuels such as kerosene and natural gas contribute to World' current challenge - climate change, as a result of increase in CO_2 levels due to emissions from their combustion (Steinfed, *et al*., 2006). Their combustion also generates sulfuric, carbonic and nitric acid which fall to earth as acid rain, impacting both natural built environment. Fossil fuels contain radioactive materials, mainly uranium and thorium, which are released into the atmosphere (O'Driscoll and Vergano, 2007). Many rural dwellers rely on tree cutting, an act that leads to deforestation, ozone layer depletion and consequent rapid increase in global average temperature, and contributes to climate change (Hall and Ravindranath, 1994; Steinfed, *et al*., 2006).

Biogas technology is the option of choice in the search for alternative, renewable, affordable and environmentally friendly energy source. Biogas refers to a gas produced by anaerobic digestion of biodegradable materials. It is one of the products of anaerobic degradation, which is one of the oldest processes used for the treatment of industrial wastes and stabilization of sludge (Luste *et al.,* 2009; Bolarinwa and Ugoji, 2010 and Wei *et al.,* 2011). Biogas is mainly composed of Methane (CH_4), Carbon dioxide (CO_2) and other trace gases (Yadava and Hesse, 1981; Hagen *et al.,* 2001).

Identified substrates for an economically feasible biogas production in Nigeria includes water lettuce, water hyacinth, dung, cassava leaves and processing waste, urban refuse, solid (including industrial) waste, agricultural residues and sewage (Akinbami *et al.,* 2001; Ubalua, 2008; Potivichayanon *et al.,* 2011;). Pre-treatment of substrate before anaerobic digestion increases biogas production and volatile solid reduction due to increased solubilization (Katima, 2001; Mshandete *et al*., 2006).

The usefulness of biogas can be better appreciated when it is cleaned and upgraded. The purification mainly consists of separation of water and hydrogen sulphide and the upgrade consists of separation of carbon dioxide to raise the gas caloric value (Hagen *et al.,* 2001; Dahl, 2003). The upgrading of biogas has been reported using pressure swing adsorption (PSA), adsorption with selexol, adsorption with chemical reaction, membrane separation and cryogenic process (Lindberg, 1998; Hagen *et al.,* 2001; Dahl, 2003), no information on the upgrading of biogas with local materials that can be easily accessed by the rural dwellers. Hence, this research work is aimed at adding to knowledge, the possibility of upgrading biogas using charcoal which is abundant in local communities.

MATERIALS AND METHODS

Sample Collection

Five different samples of domestic wastes (food waste, vegetable waste, plantain peels, yam peels, and cow dung) were used as the substrate. They were collected from households and markets within Cross River University of Technology, Calabar, Nigeria. The cow dung was collected from an abattoir at Akim, Calabar. They were properly contained and transported to the Microbiology laboratory for preparation.

The anaerobic digester was fabricated using a steel cylinder. The digester was designed to carry inlet, outlet and gas collection facilities. A laboratory Bunsen burner was used to demonstrate the usability of the biogas for laboratory purposes. The charcoal used to purify the biogas was collected from Royal bakery in Calabar while the Gas chromatography analysis was done at Laser Engineering and Resources Consultants Limited, Port Harcourt, Rivers State, Nigeria.

Sample Preparation

The samples were shredded separately using knifes and mutter in order to improve system performance and enhance biogas production. Two hundred grams (200g) each of the treated samples were shuffled, mixed with water to the ratio of 1:3 and introduced into the anaerobic digester.

Fabrication of Anaerobic Digester

An anaerobic digester of 12L size was fabricated using a metallic cylinder. It was designed to accommodate the inlet, digester chamber, outlet, gas valve and the gas collection system. It was properly sealed by welding to avoid leakage.

Experimental Design

The digester containing the prepared domestic wastes was connected with a gas collection tube through a gas valve. The tube was made to pass under an inverted 500ml glass cylinder was mounted over water as shown in Figure 1.

Figure 1: Experimental Setup.

Determination of Biogas Production

The production of biogas was determined by displacement method. The production is indicated by the presence of gas bubbles and displacement of water in the inverted cylinder. The volume of water displaced is equivalent to the biogas produced. The readings are taken daily for a retention time of 30 days. The experiment was conducted at ambient temperature.

Flammability Testing

The anaerobic digester was connected to a laboratory Bunsen burner. The flammability was then tested by lighting the burner after switching on the gas valve

Examining the Effect of Charcoal Purification on Biogas Using Gas Chromatography

The biogas was analyzed before and after passing it through a granulated charcoal using a Gas chromatography. The gas chromatography carries the gas source, inlet, oven, detector (flame ionization detector and thermal conductivity detector) and the data recorder (computer). The adsorbing effect of charcoal was exploited with the intention to reduce the quantity of carbon dioxide thereby enhancing the quality of the biogas. The various compositions of the biogas and their quantities were recorded.

RESULTS

Biogas production which was determined by water displacement method shows production of 0.05m^3 biogas on Day 1. The daily biogas production over a 30 day period is shown on Table 1.

Result shows that the gas was flammable in a Bunsen burner from the Day 12 of anaerobic digestion of the substrate, with a biogas production of 1.10m^3.

The result of the effect of charcoal on biogas using Gas chromatography is presented on Figures 2 and 3. The values of the different components of the biogas are displayed on Tables 2 and 3.

The analysis was carried out after 10 days when CO_2 production was expected to be high. Result shows that 53.94% of CO_2 that was generated reduced to 12.00% after it was passed through a charcoal medium. Though methane production was still minimal as the digester was not yet fully anaerobic - a condition that favors the growth of methane-producing methanogenic bacteria, but the process improved the quantity of produced methane from 0.03% to 0.05% (Tables 2 and 3).

Table 1: Rate of Daily Biogas Production over a period of 30 Days.

Days	Biogas Production (m^3)
1	0.05
2	0.12
3	0.20
4	0.27
5	0.40
6	0.48
7	0.61
8	0.80
9	0.71
10	0.86
11	0.90
12	1.10
13	1.00
14	1.05
15	1.12
16	1.00
17	0.90
18	0.95
19	0.80
20	0.86
21	0.70
22	0.67
23	0.60
24	0.70
25	0.65
26	0.50
27	0.60
28	0.60
29	0.50
30	0.50

DISCUSSION AND CONCLUSIONS

Biogas production (0.05m^3) was observed on Day 1. This indicates that the slurry contained microorganisms that have the enzymatic capacity to initiate fermentation. The presence of these organisms could be attributed to the introduction of digested slurry from spent anaerobic digester, which introduced additional and the necessary bacteria required for biogas production.

Research has shown that recycling digested slurry along with filtrate helps to conserve water and increase biogas production (Malik and Dehiya, 1990; Santosh *et al*., 1999). This corroborates that finding of Kanwar and Guleri (1994), who reported that about 60 – 65% more biogas production can be obtained by simply recycling the digested slurry in 1m^3 plug flow type pilot plants.

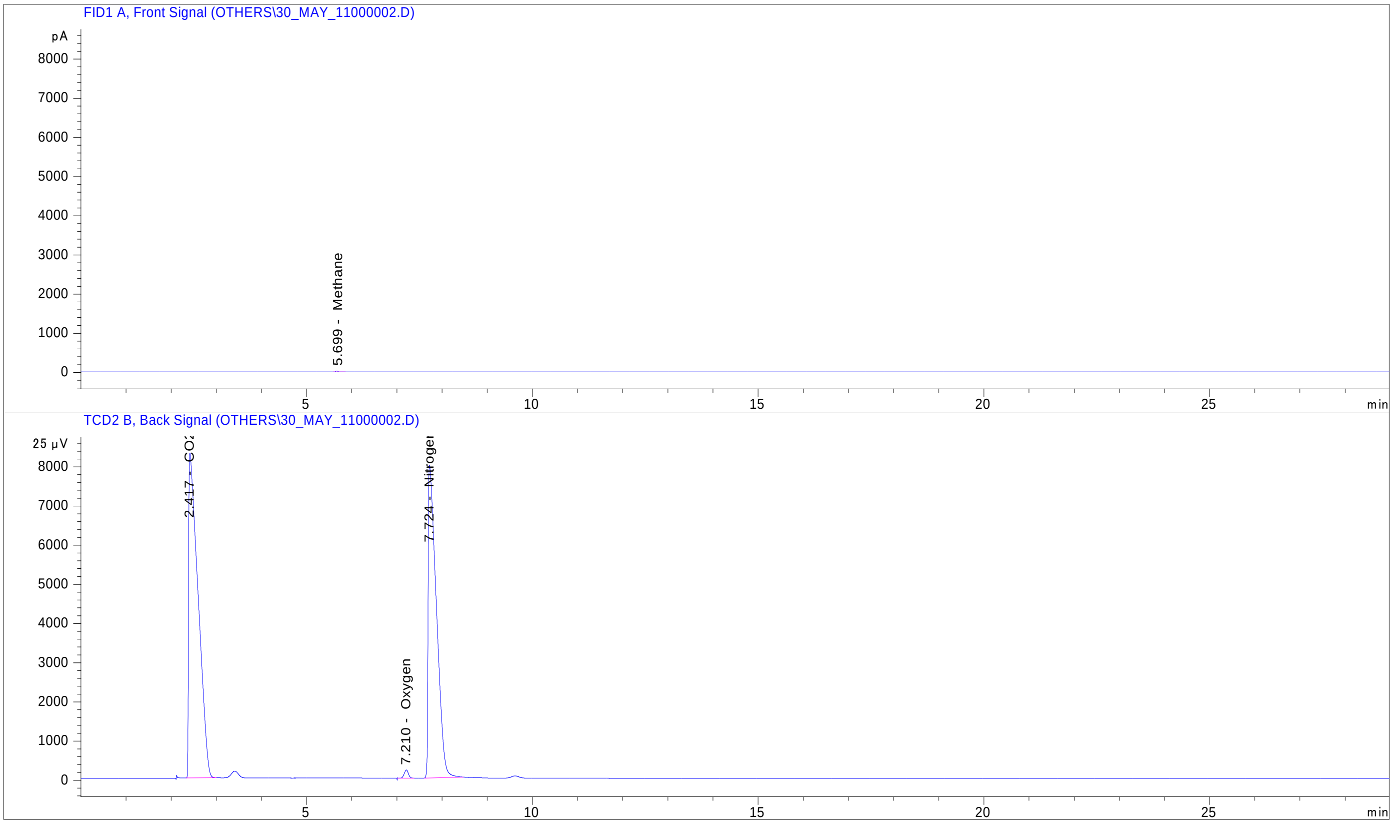

Figure 2: Gas Chromatographic Chart of Biogas before passage through Charcoal Medium.

Table 2: Composition of Biogas before passing it through a Charcoal Medium.

Composition	Quantity	% Content
Methane	66.7680	0.03
Nitrogen	101412.0000	45.43
Oxygen	1335.9858	0.60
Carbon dioxide	120425.3672	53.94
Total	**223249.7538**	**100**

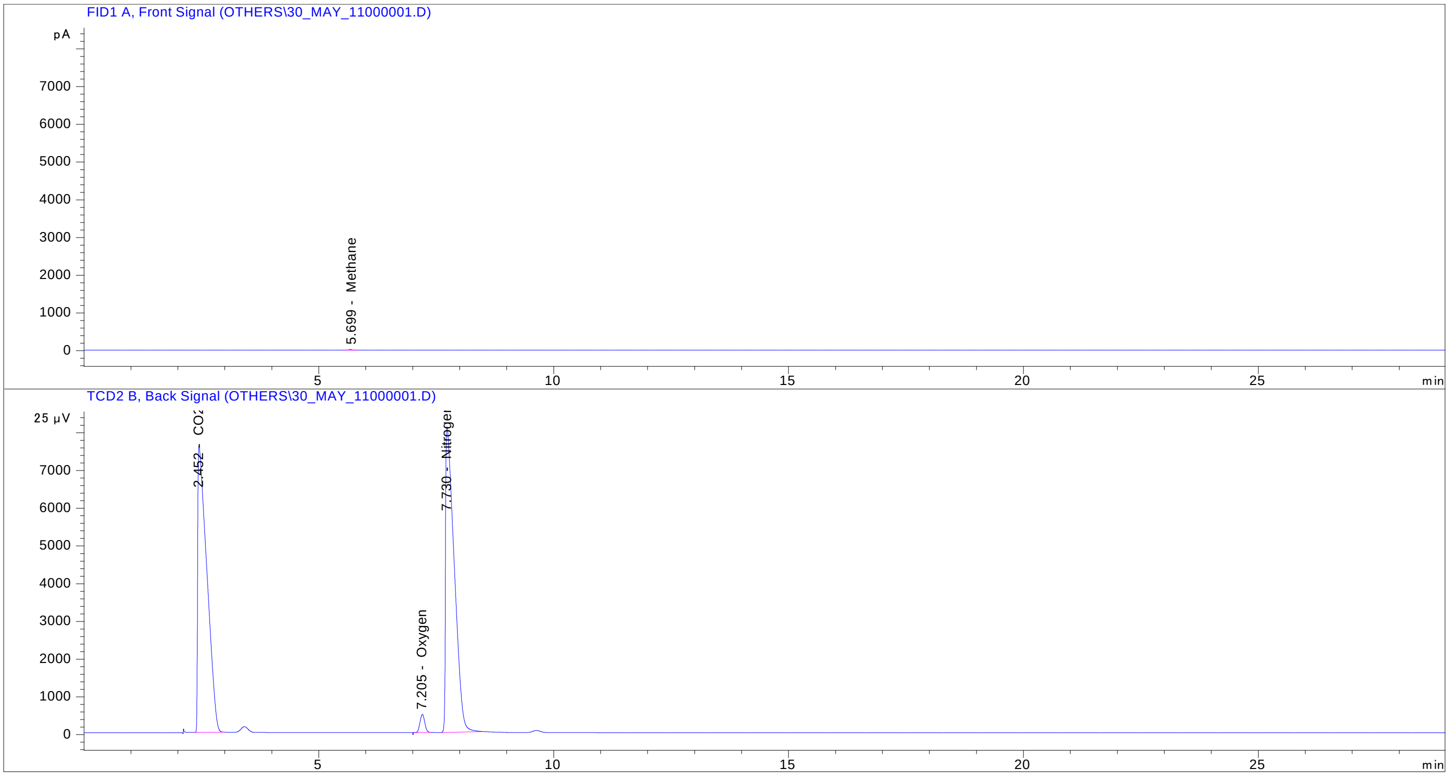

Figure 3: Gas Chromatographic Chart of Biogas after passage through Charcoal Medium

Table 3: Composition of Biogas after passing it through a Charcoal Medium.

Composition	Quantity	% Content
Methane	65.5387	0.05
Nitrogen	103958	85.16
Oxygen	3402.58	2.79
Carbon dioxide	14646.9	12.00
Total	**122073.0259**	**100**

It also agrees with the study of Malik and Tauro (1995), who observed an increase of up to 18.8% in gas production (CH_4 = 80%) when predigested slurry was used along with 10% effluent slurry recycling in a $1m^3$ daily fed floating drum biogas digester. A ten-fold and three-fold increase in the degradation rate of mannitol and lactic acid respectively was observed when liquid recirculation was initiated in a silage-fed two-phase biogas plant (Jarvis *et al.,* 1995). The number of hydrogenotrophic methanogens increased ten-fold while there was an increase in nine-fold in activities.

The quick production of biogas could also be related to the pre-treatment (shredding) of the substrate before digestion. Large particles results in the clogging of the digester, making it difficult for microbes to carry out digestive functions. Smaller particles on the hand would provide large surface area for adsorbing the substrate that would result in increased microbial activities and consequent gas production. The positive effect of pre-treatment in biogas production has been reported by researchers (Luste *et al.,* 2009; Mendes *et al.,* 2006). Sharma *et al.* (1988) found that out of five particle sizes (0.088, 0.40, 1.0, 6.0 and 30.0mm), maximum quantity of biogas was produced from raw material of 0.088 and 0.40mm particle sizes.

Though biogas was produced on Day 1, but it did not flame. The inability of the gas to flame may be attributed to high concentration of CO_2. Biogas becomes flammable when its methane content is at least 45% (Http:file://A:/Design-Tutor.htm, 2003). Result shows that the gas was flammable from Day 12 in a Bunsen burner which indicates that the gas could be used for laboratory purposes. The flammability may also be as a result of high volatile solids (the biodegradable portion of the waste) in the substrate. The early onset of flammability may be traced to the presence of cow dung. This agrees the finding of Uzodinma and Ofoefule (2009) that addition of rabbit or cow dung enhances the onset of flammability. Sharma (2002) reported that cow dung acts as a buffer and takes care of acid accumulation during anaerobic digestion, thereby enhancing biogas production.

The reduction in the quantity of CO_4 from 53.94% - 12.00% after passing it through a charcoal medium as revealed in the gas chromatogram (Figures 2 and 3) shows that the CO_4 content of biogas can be reduced using charcoal. The reduction in CO_4 improves the quality of the biogas by increasing the content of methane, thereby making the biogas more flammable. This research indicates that charcoal can be used to upgrade biogas by reducing the CO_4 content and increasing the quantity of CO_4 thereby enhancing the caloric value of gas.

REFERENCES

1. Akinbami, J.F.K., M.O. Ilori, T.O. Oyebisi, I.O. Akinwuni, and O. Adeoti. 2001. "Biogas Energy use in Nigeria: Current Status, Future Prospects and Policy Implications". *Renew. Sustain. Energ. Rev*. 5:97-112.

2. Bolarinwa, O.A. and E.O. Ugoji. 2010. "Production of Biogas from Starchy Wastes". *J. Sci. Res Dev.* 12: 34-45.

3. Dahl, A. 1999. "Uppflöljning av kvalitetsspecifikation för uppgraderad biogas som fordonsbränsle". Swedish Gas Center AB, Report SGC 103, Malmö, Sweden

4. Hagen, M., E. Polman, K. Jensen, M. Jan, J.O. Asger, and D. Anders. 2001. "Adding Gas from Biomass to Gasgrid". Swedish Gas Centre, Report SGC 118, Malmö, Sweden.

5. Hall, D.O. and N.H. Ravindranath. 1994. "Indian Forest Conservation and Tropical Deforestation". *Ambio*. 23 (8): 521-523.

6. Http:file://A:/Design-Tutor.htm, 2003. "Waste Digester Design". University of Florida Civil Engineering. p. 3.

7. Jarvis, A., A. Nordberg, B. Mathisen, and B.H. Svensson. 1995. "Stimulation of Conversion Rates and Bacterial Activity in a Silage Fed-Two-Phase Biogas Process by Initiating Liquid Circulation". *Antonie-Leeuwenhoek-J. Microbiol*. 68(4):317 – 327.

8. Kanwar, S.S. and R.L. Guleri. 1994. "Effect of Recycling of Digested Slurry on Biogas Production". *Biogas Forum*. 1V. 59:12 – 13.

9. Katima, J.H.Y. 2001. "Production of Biogas from Water Hyacinth: Effect of Substrate Concentration, Particle Size and Incubation Period". *Tanz. J. Sci.* 27:107-119.

10. Kozo, I., Hisajima, S. and R.J. Darryl. 1996. "Utilization of Agricultural Wastes for Biogas Production in Indonesia". In: *Traditional Technology for Environmental Conservation and Sustainable Development in Asia Pacific Region*. 9th Ed. 137 – 138.

11. Luste, S., S. Luostarinen, and M. Sillanpaa. 2009. “Effect of Pre-Treatments on Hydrolysis and Methane Production Potentials of By-Products from Meat-Processing Industry”. *J. Hazard Mater*. 164: 247-255.

12. Malik, R.K. and D.S. Dahiya. 1990. “Biogas Production from Cattle Waste by Recycling of Filtered Liquid of Digested Slurry”. *Urja*. 28, 30.

13. Malik, R.K. and P. Tauro. 1995. “Effect of Predigestion and Effluent Digestion Slurry Recycling on Biogas Production”. *Indian J. Microbiol*. 35 (3): 205 – 209.

14. Mendes, A. A., E.B. Pereira, and H.F. de Castro. 2006. “Effect of the Enzymatic Hydrolysis Pretreatment of Lipids-Rich Wastewater on the Anaerobic Biodigestion”. *Biochem. Eng. J.* 32: 185-190.

15. Mshandete, A., L. Björnsson, A.K. Kivaisi, M.S.T. Rubindamayugi, and B. Mattiasson. 2006. “Effect of Particle Size on Biogas Yield from Sisal Fibre Waste”. *Renew. Energ*. 31: 2385-2392.

16. O'Driscoll, P. and D. Vergano. 2007. "Fossil Fuels are to Blame, World Scientists Conclude". *USA Today.* http://www.usatoday.com/tech/science/2007-01-30-ipcc-report_x.htm. Retrieved 2010-05-02

17. Santosh, T.R., P. Vasudevan, and S. Chanel. 1999. “Studies on Developing a Model for Water Conservation in Biogas System.” CRDT IIT: Delhi, India.

18. Sharma, D.K. 2002. “Studies on Availability and Utilization of Onion Storage Waste in a Rural Habitat”. Centre for Rural Development and Technology, Indian Institute of Technology: Delhi, India.

19. Sharma, S.K., I.M. Mishra, M.P. Sharma, and J.S. Saini. 1988. “Effect of Particle Size on Biogas Generation from Biomass Residues”. *Biomass*. 17: 251–263.

20. Ubalua, A.O. 2008. “Cassava Wastes: Treatment Options and Value Addition Alternatives”. *Afr. J. Biotechnol*. 6:2065-2073.

21. Wei, C., T. Zhang, C. Feng, H. Wu, Z. Deng, C. Wu, and B. Lu. 2011. “Treatment of Food Processing Wastewater in a Full-Scale Jet Biogas Internal Loop Anaerobic Fluidized Bed Reactor”. *Biodegradation*. 22:347-357.

22. Yadava, L.S. and P.R. Hesse. 1981. *The Development and Use of Biogas Technology in Rural Areas of Asia (A Status Report 1981)*. Improving Soil Fertility through Organic Recycling, FAO/UNDP Regional Project RAS/75/004, Project Field Document No. 10.

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SUGGESTED CITATION

Akubuenyi, F.C. and L.O. Odokuma. 2013. “Biogas Production from Domestic Waste and its Purification with Charcoal”. *Pacific Journal of Science and Technology*. 14(2):63-69.

Pacific Journal of Science and Technology