
EXTRACTION AND SYNTHESIS OF ENVIRONMENTAL RESOURCES FOR BIOGAS PRODUCTION

By

Okwara, O. Kalu,

Department of Science Education,
Federal University of Agriculture, Makurdi.

Email: okwarakalu@gmail.com

ABSTRACT

The paper investigates the use of environmental waste resources as potential for biogas production. With the rising cost of petroleum products, the non-sustainability of fossil fuel and increasing environmental wastes, it has become imperative to seek alternative resources for sustainable development. Biomass resources are essential ingredients for sustainable development. Some common waste materials such as tree litters, weeds, animal dungs and agricultural wastes were used to produce biogas. The yield of biogas was in various quantities and the highest was from animal waste, followed by weeds and mixtures of waste materials. Production of biogas in the laboratory is supposed to be practicalized theoretically, to make lessons easier and more comprehensible, for our development and utilization.

Keywords: Extraction, Synthesis, Biomass, Biogas, Digesters, Biotechnology Students.

INTRODUCTION

Biogas is a form of biomass which is energy from biological resources such as wood and organic wastes. Biomass is regarded as an indirect form of solar energy because it arises from photosynthesis (Olawaju, Agusiobo & Vowa, 2006). Biomass resources in Nigeria include wood, forages, grasses, shrubs, residues and wastes (forestry, agricultural, municipal and industrial) as well as aquatic biomass. There is a need to harness cheap, reliable and environmentally friendly alternative sources of energy in the poor countries because of the almost inexhaustible biomass resources, and this could be a panacea to energy and environmental problems in these countries (Akpabio, Sambo & Fai, 2002; Madumere, 2008). Biogas technology is free from pollution, provides efficient utilization of renewable energy resources, promotes profits from farming or it will also accelerate innovation in design and fabrication of biogas digesters to conform to our

local environmental conditions and needs (Akpabio, Sambo & Fai, 2002).

However, biomass fuels (biogas) share a major disadvantage. Nzewi and Nwagu (2004), Nwafor (2006) reported that without effective land use controls and replanting, wide spread removal of trees and plants can deplete soil nutrients, and cause excessive soil erosion, water pollution, flooding and loss of wildlife habitat.

Estimated crop residues and wastes produced annually in Nigeria is put at 6.1 million tons of dry biomass (Usman, Olanipekun & Kareem, 2012). A major crop residue especially in the North-Eastern part of Nigeria is rice straw, which is regarded as waste and is usually burnt (Xiguang, Rowena & Ruihong, 2010) or abandoned on the farms to decompose freely thereby imposing some environmental problems (Usman, Olanipekun & Kareem, 2012). In China, bacteria in an estimated 7 million biogas digesters convert plant and animal wastes into methane for heating and cooking

(Forhard, Khan, Sarkar & Ali, 2013). India has about 750,000 biogas digesters in operation, half of them built before 1990 (Forhard, Khan, Sarkar & Ali, 2013).

Also, methane is produced by underground decomposition of organic matter in the absence of air (anaerobic digestion) in active and closed landfills (Usman, Olanipekun & Kareem, 2012). The gas is collected by pipes inserted into landfills, purified and used as fuel because methane is a greenhouse gas. This recovery also helps to slow down global warming (Olawajuyi, Agusiobo & Vowa, 2006). Anaerobic methane fermentation is one of the earliest biological processes to evolve in nature, in which anaerobic bacteria break down complex organic compounds to methane (CH₄) and carbon dioxide (CO₂). The process is certainly complicated and requires sophisticated equipment, however it can be very easily studied in any school laboratory or at home.

Laboratory work is supposed to illustrate theory and to make lessons easier and more comprehensible (Olawajuyi, Agusiobo & Vowa, 2006). Biology practicals, however, tend to be compartmentalized to classroom-based and restricted aspects of a particular lesson. This practice has over the years transformed biology practicals from a training for keen observation to ritualistic look and draw activities. Whether it is a bone, leaf, flower or slide drawing has come to mean the basic requirement in most biology practicals. As a result, learning has also become more and more descriptive and recitative (Kola-Olusanya, 2005).

The researcher through interaction with biology teachers found out that the teachers hardly carry out laboratory practical demonstrating biogas production. There is therefore need for the biology teacher to devise more comprehensive, do-it-yourself practicals using the simplest equipment and materials that can instill confidence in students and gain impressions through keen observations of biology as an

integrated process combining all branches of science. Apart from using the simplest equipment and materials, simultaneous comparison of gas production by different waste materials or mixtures of materials can also be studied.

MATERIALS AND METHODS

Environmental wastes utilized for the purpose of this study included tree litters such as *Albizia* flowers; *Azadirachta indica* leaves and *isoberlinia* leaves. Weeds were *Eragrostis sp.*, *Pistia sp.*, *Striga sp.*, and *Tridax sp.*; all obtained from bushes, farms and gardens. While animal wastes such as cattle dungs and chicken droppings were from farms and poultry houses. Agricultural wastes of banana leaf stalk, groundnut stalk and guinea corn stalk were collected from farms. Mixtures (Guinea corn + cow dung; Guinea corn + cow dung + ash; Guinea corn + Groundnut plants; Banana Stalk + Chicken droppings) were obtained from collections. These wastes were readily available to explore their potentials and utilization in biogas production.

Other requirements were dilute slurry of waste organic matter chopped grass, algal soups from ponds or drainage ditches, agricultural or kitchen waste, animal dungs, sewage and sludge containing anaerobic bacteria from various sources such as sewage tanks, congested drains and ponds, gut contents of animals from abattoirs. Finally, digesters (tightly sealed containers) without oxygen were provided.

Experimental set up

A set of sixteen (16) one-litre Erlenmeyer flasks were used as digesters. About 200mls of the bacterial sludge was added to a mixture (5%) of the organic waste in each Erlenmeyer flask and sealed with a rubber stopper with a thermometer inserted through to an exit glass tubing. Tap water was added to each of the digesters and the contents well shaken. Gas was released through the system of glass and rubber tubes

and collected in a second jar by water displacement. The amount of gas evolved over the period of time (six weeks) was measured by the volume of water displaced into a measuring cylinder. The digesters were closely monitored four times daily. Initially, the gas was mainly carbon dioxide but gradually the methane content increased by which time the gas ignited when passed into a Bunsen burner. When the gas collector is full the water outlet tubing to the measuring cylinder is then

connected to an overhead aspirator and the gas tap on the collector opened so that water will flow into the collector and force the gas to a burner. Gas production continued for six weeks and completely stopped when all the digestible materials were exhausted.

Fluid samples were withdrawn from the digesters through the side taps and tested for pH. The process worked best at pH 7 – 8. A small amount of wood ash was added to the slurry, if too acidic.

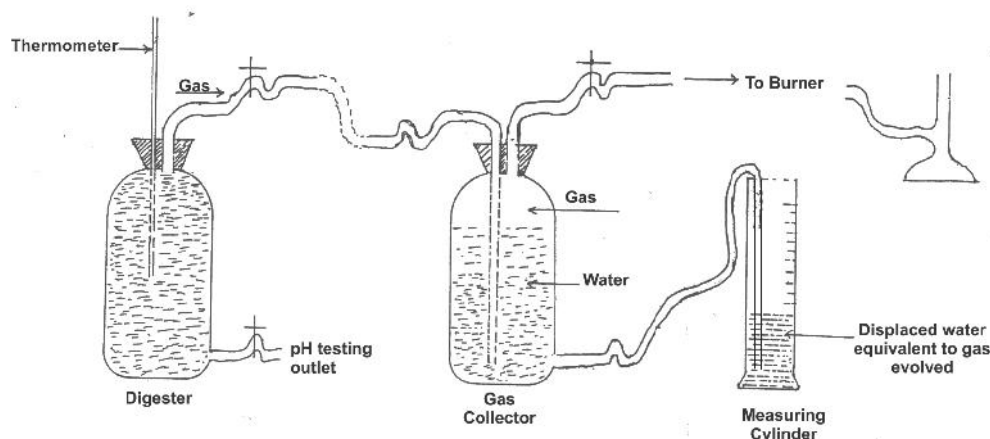


Figure 1: A Simple Batch Digester Set Up

Gas analysis

Using sodium hydroxide as described by Zeman and Lackner (2004), Sang Jun, Miram, Dong-woo, and Jung-Ho (2011), the quantity of carbon dioxide in the biogas was determined and the presence of hydrogen sulphide was determined qualitatively with lead acetate paper and potassium permanganate solution.

Figure 1 diagrammatically, illustrates the methodology and uses of biogas production in the laboratory. This process in some detail has illustrated the concept of a comprehensive, project-type laboratory work.

RESULTS AND DISCUSSIONS

The following observations were made during the process as biogas production increased from week one to week six. This implied that digestion of materials

became more efficient with time. Animal wastes yielded the highest biogas of 20.66/15.94 litres followed by biogas from weed/forage (Appendix I). The digesters started releasing biogas after one day (lag time) (Appendix II). Several studies have shown conclusively that biogas yield from animal droppings is higher than yield from organic plants or mixtures of materials (Akpabio *et al.*, 2002; Xiguang, Rowena & Ruihong, 2010; and Forhad *et al.*, 2013). However, the absence of hydrogen sulphide (H_2S) in the biogas produced from rice straw indicates a better quality of biogas as compared to biogas obtained from animal wastes (Roati, Fiore, Ruffino, Maschese, Novarino & Zanetti, 2012).

Qualitative and quantitative analysis of the biogas obtained revealed it contained 34-47% of carbon dioxide and 5-10% of hydrogen sulphide. The amount of H_2S is still much lower compared with amounts

contained in some fossil fuels (Akpabio, *et al.*, 2002; Sunarso, Budiyo & Sumardiono, 2010).

Substrate analysis (Akpabio, *et al.*, 2002) also revealed that almost 70% of the biomass was expected to be converted to biogas while about 19% was expected to remain in the sludge, but the expectation of 100% yield is rare (Roati, Fiore, Ruffino, Maschese, Novarino & Zanetti, 2012). This is because, lignin which is included in the percentage of organic material content cannot be digested by anaerobic bacteria, and as much tends to block other digestible organic materials from being reached by digestive bacteria or enzymes from these bacteria (Usman *et al.*, 2012).

After 21 days' retention period, the gas production in the digesters became sporadic and seem to be related to fluctuating daily temperatures. This agrees with the findings that temperature affects the rate, quality and quantity of biogas production (Forhad, Khan, Sarkar & Ali, 2013; and Ayhan, Qingyu, Alibas & Unal, 2013). This is because the effect of temperature is most important in biogas production (Ayhan, Qingyu, Alibas & Unal, 2013). One of the important problems associated with anaerobic digestion of waste, particularly in developed countries has been the cost of maintaining the digester temperature within the mesophilic range (20°C → 40°C) or the thermophilic range (40°C → 60°C) in environments with temperatures of less than 15°C (Roati, Fiore, Ruffino, Maschese, Novarino & Zanetti, 2012). However, the high tropical temperature of Nigeria is considered as an advantage to eliminate the use of fuel for heating the system. The operating ambient temperatures ranged between 23°C and 31°C, which showed a wide range of temperature variation, although still within the mesophilic temperature range. Digesters are slow and unpredictable at low temperature or when contaminated by acids, heavy metals, synthetic detergents, and other industrial effluents. Development of new, more reliable

models could change this (Lungkhimba, Karki & Shrestha, 2010).

The sludge after fermentation is an excellent organic fertilizer (biofertiliser) in which nitrogen; potassium, phosphorus and other mineral salts are concentrated. They provide good manure for farming and fishponds (Wan Ab Karim, Ghani & Idris, 2009; Usman, Olanipekun, & Kareem, 2012; Ayahan, Qingyu, Alibas & Unal, 2013).

Implications of Biogas Production

Apart from the intellectual satisfaction arising from keen observation, evaluation and improvisation (e.g. innovation in design and construction of biogas digesters), there are several other benefits such as:

- i. The products of the process – gas and manure can be utilized in the laboratory and school garden; from suitable sizes of digesters enough gas can be generated for use in laboratory burners. Gas from a large central digester can be used to generate electricity.
- ii. Whatever the young biologist specializes in later – teaching, research, agriculture, forestry, medicine, veterinary medicine, administration, will realize the importance of the modest but comprehensive study of bacterial fermentation to wider life situations.
- iii. Environmental cleanliness – our garbage can be used; sanitation and sewage disposal – the fermentation kills most pathogens; and alternative energy source and save the woods for timber.
- iv. Burning of biomass fuels such as biogas adds much less sulfur dioxide and nitric oxide to the atmosphere per unit of energy produced than the uncontrolled burning of coal and thus requires fewer pollution control measures.

CONCLUSION

Reliance on the fossil fuel to meet energy requirement of the 21st century and protecting the environment may not be sustainable as it requires increase in the efficient use of the energy generation and increase in the use of renewable energy resources. In this regard, biomass resources will play an immense role. Bio-resources can be utilized in cooking, heating, manure and feeds. It is therefore important to convert the abundant unused bio-resources into other beneficial uses. Biomass will continue to be the dominant energy resource for cooking and heating in the rural areas in the foreseeable future. For improvement of biomass energy use, there should be introduction of improved wood/biomass burning stoves to enhance conversion efficiency and reduce the time required for cooking. The use of more efficient biomass fuels that can be processed and preserved such as charcoal and briquettes of agricultural residues and flora especially weeds should be emphasized. Planting and nursing of vegetation to assure future availability is necessary.

REFERENCES

- Akpaibio, I.O., Sambo, A.S., and Fai, F. (2002). A Study of biogas production from rice straw in an underground digester. *Proceedings of the Nat. Con. on Energy Res. and dev. Centre for Energy Res: A.T.B.U. Bauchi Feb., 2002.* 92-96.
- Ayhan, A; Qingyu, L; Alibas, K. & Unal, H. (2013). Biogas production from maize silage and dairy cattle manure. *Journal of Animal and Veterinary Advances*, 2(5):553-556.
- Forhad Ibne Allman, M.Z.H. Khan, M.A.R. Sarkar, S.M. Ali. (2013). Development of biogas processing from cow dung, poultry waste, and water hyacinth. *International Journal of Natural and Applied Science (IJNAS)* 2(1):13-17.
- Kola-Olusanya, A. (2005). Free-choice environmental education: Understanding why children learn outside of school. *Environmental Education Research* 11(3):297-307.
- Lungkhimba, H.M; Karki, A.B & Shrestha, J.N. (2010). Biogas production from digestion of biodegradable household wastes. *Nepal Journal of Science and Technology*, 11:167-172.
- Madumere, A. J. (2008). Problems and prospects of environmental education curriculum delivery in Nigeria. In Olarewaju, A. O. (ed). *In STAN 46th Annual Conference Proceedings*. Ibadan: Heinemann Educational Books, 181 – 185.
- Nwafor, J.C. (2006). *Environmental Impact Assessment for Sustainable Development*. Enugu: EL-DEMAK Press.
- Nzewi, U.M. & Nwagu, E.K.N. (2004). Strategies for teaching rain forests to pre-primary and primary pupils. In P. Okebukola and B. Akpan (eds.) *STAN EE. Project Series. No. 8: Focus on Rain Forest*, Ibadan: STAN 61-71.
- Olarewaju, A.O; Agusiobo, B.C. & Vowa, C.A. (2006). *Science is Discovering*, Ibadan: Alfas Nigeria Company.
- Roati, C; Fiore, S; Ruffion, B; Marchese, F; Novarino, D & Zanetti, M.C. (2012). Preliminary evaluation of the potential biogas production of food-processing industrial wastes. *American Journal of Environmental Science*, 8(3): 291 – 296.
- Sang Jun, H; Miram, Y; Dong-woo, K & Jung-Ho, W. (2011). Carbon dioxide capture using calcium hydroxide aqueous solution as the absorbent. *Energy and Fuels* 25:3825-3834.
- Sunarso, S; Budiyo, B; & Sumardiono, S. (2010). Production using anaerobic biodigester from cassava effluent. *IJSEI*(2): 33-37.
- Usman, M.A., Olanipekun O.O., Kareem, O.M. (2012). Biogas generation from domestic solid waste in mesophilic anaerobic digestion. *International Journal of Research in Chemistry and Environment*; 2(1), 200 – 205.

- Wan Ab Karim, W.A; Ghani, A; & Idris, A. (2009). Preliminary study on biogas production from municipal solid waste (MSW) leachate. *Journal of Engineering Science and Technology*, 4(4):374-380.
- Xiguang, C; Rowena, T. R. & Ruihong, Z. (2010). Anaerobic digestion of food wastes for biogas production. *IJABE (International Journal of Agricultural and Biological Engineering)*. 3. (4) 214-220.
- Zeman, F.S. & Lackner, K.S. (2004). Capturing directly from the atmosphere. *World Resource Review*, 16(2):157-172.

Appendix I: Cumulative biogas production in litres, from litre size batch digesters of 5% solid wastes

MATERIAL	WEEK						
	1	2	3	4	5	6	
Tree Litters							
(a) <i>Albizia flowers</i>	(D1)	0.20	0.22	0.70	1.06	1.79	1.97
(b) <i>Azadirachta indica</i> leaves	(D2)	0.32	0.51	0.51	0.77	1.40	2.05
(c) <i>Isobertinia</i> leaves.	(D3)	0.19	0.21	0.21	0.21	0.21	0.21
Weeds							
(a) <i>Eragrostis Sp</i>	(D4)	1.32	2.46	10.13	13.67	14.90	15.38
(b) <i>Pistia Sp</i>	(D5)	0.54	1.30	6.33	9.92	12.16	12.91
(c) <i>Striga Sp</i>	(D6)	0.63	0.99	1.27	2.05	4.16	5.30
(d) <i>Tridax Sp</i>	(D7)	0.38	0.55	0.69	0.90	1.06	1.06
Animal Wastes							
(a) Cattle dung	(D8)	2.03	5.43	8.96	10.30	12.45	20.66
(b) Chicken droppings	(D9)	1.09	3.40	5.93	9.24	10.72	15.94
Agricultural Wastes							
(a) Banana leaf stalk	(D10)	0.43	0.70	3.01	5.04	6.34	7.34
(b) Groundnut stalk	(D11)	0.47	0.84	0.94	1.10	1.25	1.33
(c) Guinea corn stalk	(D12)	0.47	1.11	2.11	3.45	4.03	5.01
Mixtures							
(a) G/Corn + Cow Dung	(D13)	0.13	0.47	3.93	8.08	9.10	9.50
(b) G/corn + Cow dung + ash	(D14)	0.10	1.58	8.49	10.18	11.56	12.00
(c) G/corn + G/nut plants	(D15)	0.65	1.04	1.23	1.41	1.54	1.54
(d) Banana Stalk + Chicken droppings	(D16)	0.07	0.56	3.89	5.09	5.67	5.87

Appendix II: Summary of results of biogas production

Digester	Lag Time (days)	Retention Time (Weeks)	Cumulative gas production (litre)	Average weekly production (litre)	Type of material
D1	1	6	1.97	0.33	Tree litter
D2	1	6	2.05	0.34	Tree litter
D3	1	6	0.21	0.03	Tree litter
D4	1	6	15.38	2.56	Weed
D5	1	6	12.91	2.15	Weed
D6	1	6	5.30	0.88	Weed
D7	1	6	1.06	0.18	Weed
D8	1	6	20.66	3.44	Animal Waste
D9	1	6	15.94	2.65	Animal Waste
D10	1	6	7.34	1.22	Agric waste
D11	1	6	1.33	0.22	Agric. Waste
D12	1	6	5.01	0.83	Agric waste
D13	1	6	9.50	1.58	Mixture
D14	1	6	12.00	2.00	Mixture
D15	1	6	1.54	0.25	Mixture
D16	1	6	5.87	0.97	Mixture