Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **4(11),** 76-79, November **(2014)** *Res. J. Chem. Sci.*

Review Paper

Use of Polyethylene Tube Biodigester for fish production and Processing – A Review

***Nnaji, J. C.[1] and Ugwu, B. I.[2]**
[1]Department of Chemistry, Michael University of Agriculture, Umudike, P. M. B. 7267, Umuahia, Abia State, NIGERIA
[2]Department of Chemical Engineering, Michael University of Agriculture, Umudike, P.M.B. 7267, Umuahia, Abia State, NIGERIA

Available online at: www.isca.in, www.isca.me
Received 7th November 2014, revised 16th November 2014, accepted 18th November 2014

Abstract

The paper reviews the potential of renewable energy sources specifically, biogas produced in a polyethylene tube biodigester, as an alternative for the supplementation of energy requirements especially in the rural areas. A biodigester is a container which processes the organic material via anaerobic decomposition and produces biogas with methane and carbon dioxide being the major constituents. The chemical composition and properties of biogas, effluents and sludge are discussed and the use of biomass for biogas production is analyzed with reference to the utilization of biodigester effluent for fish farming and biogas for fish smoking. Comparison is made between direct fertilization of fish ponds with animal manure and with biodigester effluent in terms of public health risks. The polyethylene tube biodigester-fish system (PBFS) is recommended for use by fish farmers and fish processors and benefits of the system are outlined.

Keywords: Polyethylene**,** Biodigester, fertilization, pond, fish, smoking.

Introduction

Production of energy (biogas) from renewable sources like biomass is one of the potential solutions to the energy problems in energy deficient countries like Nigeria. Renewable energy is derived from natural (renewable) resources like as sunlight, biomass, wind, rain, tides and geothermal heat, which may be naturally replenished[1]. Significant investment in research and development of renewable energy sources is needed to aid the socio-economic development of Nigeria especially in the rural areas. Renewable sources of energy are of increasing importance due to negative issues like deforestation and global warming connected with the use of traditional energy sources like fuel wood and fossil energy sources like petroleum[2,3]. In addition, the large amount of solid organic wastes produced by urban dwellers can be utilized by biodigesters for the production of useful biogas and it will also facilitate solid waste disposal. For instance, it is estimated that 6.8 million litres of biogas equivalent to 3.9 million litres of petroleum in energy terms can be produced in Nigeria daily[4,5].

Biogas is produced from the anaerobic digestion (fermentation) or bacterial degradation of organic matter (sewage, manure, plants etc.) in a biodigester[6]. Ordinarily, the decomposition of manure produces NO_2 and CH_4 which warms the atmosphere 310 and 21 times, respectively, more than CO_2. Converting manure into biogas which is used as energy source, reduces global warming and is a means of reducing energy poverty which hinders economic development in Africa[7]. Production of biogas in a biodigester enables the controlled management of large quantities of animal dung and plant wastes, makes gas available for cooking, lighting or power generation and it can be done at the household, commercial, or village scale[8]. Biogas technology has supplemented a substantial part of the rural energy requirements in countries like China, India and Taiwan.

One of the constraints to fish farming is the high cost of fish feed and development of low cost systems of fish production is desirable for the small-scale fish farmer. Direct fertilization of fish ponds with animal manure in an integrated system is used in some countries as a low input system of fish production. However, this practice raises public health issues like the risk of pathogen and heavy metal contamination of fish and the transfer of these to human and animal consumers of fish and fish products[9,10]. The use of biodigester effluents/sludge for fish farming becomes pertinent since pathogen load and heavy metal content are substantially reduced in the biodigester effluent which can be used as a source of fish pond fertilization thereby reducing the risk of transfer of contaminants from fish to consumers[11]. The biogas produced can also be used to power a gas smoking kiln for the smoking of fish. In addition, the use of biogas for fish smoking will reduce the pressure on Nigeria's forest resources. It is also a better alternative to the use of fuel wood which deposits a lot of unwanted and potentially hazardous substances on smoked fish. Effluent from a biodigester utilizing chicken manure is a better fertilizer than dried chicken manure[12]. Widespread dissemination of information on biodigester-fish system is a potential source of wealth creation for farmers and employment generation for unemployed youths in energy deficient countries.

Types of Biodigesters

Biodigesters can be described according to location, construction material, shapes, input process etc. and they include: Surface and underground digesters, Fixed-dome and floating drum digesters, Metal, plastic, cement block, concrete, clay, ferrocement and stonework digesters, Circular and cylindrical (tubular) digesters, Vertical and horizontal digesters, Batch, semi-batch and continuous digesters

Anaerobic Digestion Process

Anaerobic digestion is actually a collection of several processes but may be regarded as four stage biochemical transformations engineered by different groups of bacteria as follows[13,14]: Stage 1: Breakdown of organic materials like cellulose, hemi-cellulose, fats and protein, Stage 2: Acidogenesis or conversion of products of stage 1 to organic acids, alchohols, hydrogen, ammonia and CO_2 by acidogenic or fermentative bacteria, Stage 3: Acetogenesis or conversion of products of stage 2 by acetogenic bacteria to mainly acetic acid, carbon dioxide and hydrogen, Stage 4: Methanogenesis or conversion of products of stage 3 to methane, CO_2 and other products by methanogenic bacteria. The overall processes for carbohydrates can be represented by the chemical equation:

$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$

These processes are illustrated in figure-1.

Chemical Composition and Properties of Biogas

Biomass (materials derived from living or dead organisms) is regarded as renewable energy sources because they are naturally occurring and can be harvested without significant depletion if managed properly[3,15]. Biogas produced from biodigesters utilizing organic feedstocks is a mixture of different gases but it mainly consists of methane and carbon dioxide. The composition of biogas depends on the feedstock used, organic load applied time and temperature[11]. Different authors give slightly different composition of biogas. Biogas is a mixture of methane (55 - 70%), carbon dioxide (30 - 45%) and traces of nitrogen, hydrogen, carbon monoxide, water vapour, ammonia and hydrogen sulphide[16]. It may also contain about 55-65% methane (CH_4), 35-45% carbon dioxide (CO_2), 0-3% nitrogen (N_2), 0-1% hydrogen (H_2) and 0-1% hydrogen sulphide (H_2S)[12]. Clean biogas burns with a blue flame like liquefied petroleum gas (LPG)[17]. It is odourless and colourless; is about 20 percent less dense than air and has an ignition temperature range of 650 – 750 ºC. The calorific value of biogas ranges from 4800-4900 Kcal/m^3 while pure methane has a calorific value of 9100 Kcal/m^3 at 15.5^{o}C and 1 atmosphere[8]. In energy equivalent terms, 1.33-1.87 m^3 and 1.5-2.1 m^3 of biogas are respectively equivalent to 1 liter of gasoline and 1 liter of diesel[18]. Biogas production depends on temperature of operation, feedstock used (nature of organic matter), concentration of solids in the feedstock, loading rate, retention time, pH and microorganisms present. There are two temperature ranges that affect biogas production – mesophyllic ((30 – 40^{o}C) and thermophyllic (50 – 60^{o}C) ranges. Optimum biogas production can be obtained while using both processes but the mesophyllic process is preferred for feedstocks that are not lignified[19]. Optimum pH for action of anaerobic bacteria is neutral and it needs to be controlled in order not to inhibit bacterial action. Bacterial action will also be inhibited by high accumulation of salts, insufficient alkalinity (acids are produced as intermediates during the digestion process), presence of heavy metals and high ammonia production.

Production of Effluents/Sludge

The effluent from the digester has 60 – 80% less BOD (Biological Oxygen Demand) compared with the input material[20]. It has been shown to be a high quality fertilizer[21,22]. Biodigester effluent quality depends on the nature and composition of feedstock used; loading rate and retention time[23]. Research has shown that higher productivity may be obtained in fish ponds when biodigester effluent is used in comparison with direct fertilization of ponds with raw animal manure. Pathogen load in animal manure is also significantly reduced in a biodigester because the anaerobic fermentation process kills pathogens (bacteria, intestinal parasites etc.) making the effluent chemically and biologically improved. In the past, biodigesters were used mainly for the production of combustible gas from waste organic matter but due to increased emphasis on the sustainable use of natural resources in farming systems, biodigesters are now being used for the recycling of nutrients from plant and animal wastes for use as fertilizers for crops, aquatic plants and fish ponds[24]. This helps in reducing dependency on inorganic fertilizers.

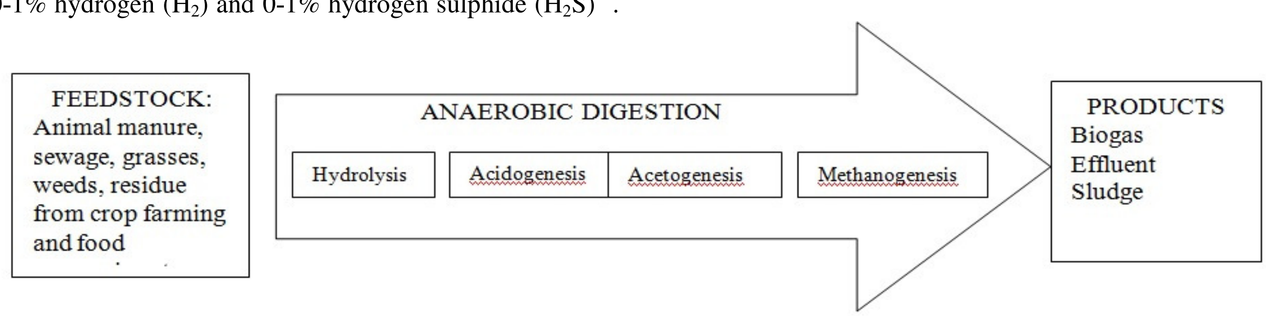

Figure-1
The Anaerobic Digestion Process

The Polyethylene Tube Biodigester-Fish System: For the small-scale fish farmer and processors, the polyethylene tube biodigester-fish system (PBFS) is recommended. It is relatively simple, cheap and easy to adopt. A typical PBFS (figure-2) will consist of an excavated pit which may be earthen or lined with cement blocks. A roof may be constructed to prevent atmospheric damage to the digester. The tube-shaped (tubular) biodigester is made with plastic material like 1.5mm high density polyethylene (HDPE) and placed in the pit. A stirrer is also constructed to stir the feedstock. The exit and entrance tubes for addition of feedstock and exit of effluent respectively, are made with PVC pipes while a hole is made at the top of the digester with PVC pipe to channel the biogas produced from the biodigester. The pipe is made to pass through a chamber for the removal of carbon dioxide, water vapour and other gases. After construction, the biodigester is charged with feedstock/water slurry and this is added daily until the biodigester plastic inflates. Effluent from the biodigester is channeled into a nearby earthen fish pond and fish growth and water quality parameters are monitored in the ponds. The biogas produced can be used to power a gas smoking kiln for the smoking of fish. The solid effluent (sludge) can also be dried, ground and packaged for sale as organic fertilizer for the farming of vegetables and other crops. Potential Benefits of Benefits of the PBFS include: i. Reduction of greenhouse gas emissions and deforestation. ii. Preservation of threatened forest resources. iii. Production of more health friendly smoked fish. iv. Increase in personal income through savings on energy. v. Source of fertilizer for crop production, fishpond fertilization etc. vi. Increased food production, poverty alleviation and employment generation. vii. Facilitation of animal and plant waste disposal leading to the reduction of surface water pollution

Conclusion

Energy constraint is a factor militating against the economic and social development of energy deficient countries of the world. The use of renewable and relatively cheaper energy sources is an important avenue for ameliorating this scenario and the feasibility of such energy supplementation has been demonstrated in countries like China and India. It then important that governments, research organizations, communities and entrepreneurs should engage in research and design of renewable energy based power systems such as the Polyethylene Tube Biodigester-fish System which has the potential of providing energy in form of biogas, enhance fish preservation/processing and lead to reduction in deforestation.

References

1. Rabah A.B., Baki A.S., Hassan L.G., Musa M.I. and Ibrahim A.D., Production of Biogas using Abattoir Waste at different Retention Time, *Sci. World J.*, **5** (**4**), 23-26 (**2010**)

2. Uzoma C.C., Nnaji C.E., Ibeto C.N., Okpara C.G., Nwoke O.O., Obi I.O., Unachukwu G.O. and Oparaku O.U., Renewable Energy Penetration in Nigeria: A Study of the South-East Zone, *Continental J. Environ. Sci.*, **5** (**1**), 1 – 5 (**2011**)

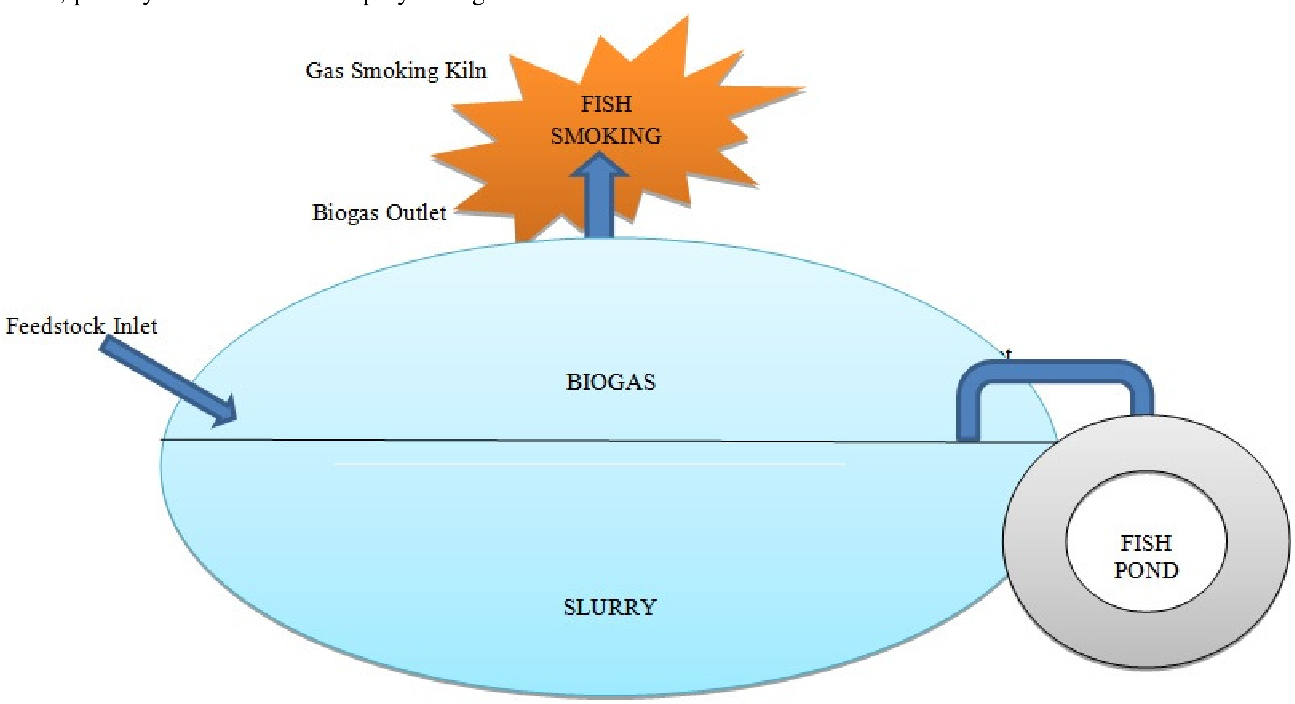

Figure-2
Schematic Diagram of a Biodigester-Fish System

3. Abdullahi I., Musa A.O., Isma'ila A. and Mika'ilu A., Design and Construction of a Biodigester, *Europ. J. Sci. Res.,* **71 (3)**, 452-460, **(2012)**

4. Faniran A., Solid wastes management, In: A preliminary survey of environmental pollution in Ibadan Region, 186-205 **(1982)**

5. Matthew P., Gas production from animal wastes and its prospects in Nigeria, *Nig. J. Solar En.*, **2(98)**, 103 **(1982)**

6. Akinbami J.F.K., Ilori M.O., Oyebisi T.O., Akinwuni I.O. and Adeoti O., Biogas energy use in Nigeria: current status, future prospects and policy implications, *Renew. Sustain. Energ. Rev.,* **5**, 97-112 **(2001)**

7. Mshandete A.M. and Parawira W., Biogas technology research in selected sub-Saharan African countries – A review, *Afr. J. Biotech.*, **8(2)**, 116-125 **(2009)**

8. Eze J.I. and Uzodinma E.O., Generation of Methane Gas from Poultry Brooding House, *Pacific J. Sci. Technol.,* **10(2)**, 942-948 **(2009)**

9. Blumenthal U.J., Mara D.D., Peasey A., Ruiz-Palacios G. and Stott R., Guidelines for the microbiological quality of treated wastewater used in agriculture: recommendations for revising WHO guidelines, *WHO Bulletin*, **78(9)**, 1104–16 **(2000)**

10. Nnaji J.C., Uzairu A., Gimba C. and Kagbu J.A., Heavy Metal Accumulation in *Oreochromis niloticus* and *Clarias gariepinus* from an Integrated Chicken-fish System, *Afr. J. Pure Appl. Chem.*, **6(7)**, 86-99 **(2012)**

11. Thy S., 2004. *Management and Utilization of Biodigesters in Integrated Farming Systems*. http:// www.mekarn.org / msc2001-03/theses03/ santhlitrevapr 27.htm. Retrieved 14 May **(2013)**

12. Oyewole O.A., Biogas Production from Chicken Droppings. *Sci. World J.*, **5 (4)**, 11-14 **(2010)**

13. Lawal A.K., Ajuebor F.N. and Olatunji O., Preliminary Investigations into the Operating Parameters for the Generation of Quality Biogas from Piggery Waste, *J. Ind. Res. Technol*., **2(1)**, 1-5 **(2008)**

14. Tabatabaei M., Rahim R.A., Wright A.G., Shirai Y., Abdullah N., Sulaiman A., Sakai K. and Hassan M.A., Importance of the Methanogenic Archaea Populations in Anaerobic Wastewater Treatments, *Process Biochem.*, **45(8)**, 1214-1225 **(2010)**

15. Sambo A.S., Strategic Development in Renewable Energy in Nigeria. In: *International Association for Energy Economics*, *Third Quarter*, 15-19 **(2009)** www.iaee.org/en/publications/newsletterdl.aspx?id=75 Retrieved 20 Feb 2011, **(2011)**

16. Dangoggo S.M., Aliyu M. and Atiku A.T., The effect of seeding with Bacteria on Biogas production, WREC, 1045-1048 **(1996)**

17. Sathianathan M.A., *Biogas Achievements and Challenges*. Association of Voluntary Agencies for Rural Development, New Delhi, India, 20-32 **(1975)**

18. Barker J.C., Methane Fuel gas from Livestock Waste; A Summary, *North Carolina Cooperation Extension Service Publication* No. EBAE, **071-80**, 20–27, **(2001)**

19. Eyo A.A., Review and Possibilities of Water Hyacinth (Eich/wrnia crassipes) Utilization for Biogas Production by Rural Communities in Kainji Lake Basin, **(2008)** http:// aquaticcommons.org / 955/1/ WH_052-064 . pdf Retrieved 20 January, 2013, **(2013)**

20. Arthur W., Process design of Agricultural digesters, In: O. Henrik (Ed.), Anaerobic digestion: Making energy and solving modern waste problems, *Network on Anaerobic digestion of Agro- industrial wastes (AD-NETT- A)*, Herning Municipal utilities, Denmark, 8-21 **(2000)**

21. Preston T.R. and Rodríguez L., Low-cost biodigester as the epicenter of ecological farming systems, *Proceedings of the biodigester workshop,* **(2002)**

22. Chau L.E., Biodigester effluent versus manure from pigs or cattle as fertilizer for production of cassava foliage (Manihot esculenta), *Livestock Research for Rural Development* **10(3)**, **(1998)**. http://cipav.org.co/lrrd/ lrrd10/3/chau1.htm. Retrieved 15 May 2013, **(2013)**

23. Henrik O., *The use of digested slurry within Agriculture*. Network on Anaerobic digestion of Agro- industrial wastes (AD-NETT- A), Herning Municipal utilities, Denmark, 53-65 **(2000)**

24. Preston T.R., Biodigesters in ecological farming systems, *LEISA Magazine*, 8-12 **(March 2005)**

25. http://www.mekarn.org/probiod/pres.htm Retrieved 15 May 2013, **(2013)**