Nigerian Journal of Engineering Science Research (NIJESR).
Vol. 6, Issue 1, pp.01-10, March, 2023

ISSN: 2636-7114
Journal Homepage: https://www.iuokada.edu.ng/journals/nijesr/

Comparative Analysis of Biogas Yield from Kitchen Waste

[1a]*Oyiboruona E.P., [1b]Atumah E.V., and [2]Tamuno R.I.

[1]Department of Mechanical Engineering, Delta State Polytechnics, Otefe-Oghara, Delta State, Nigeria
[a]paul.oyiboruona@gmail.com; [b]victoratumah@gmail.com
[2] Department of Technical Services, Power Equipment and Electrical Machinery Development Institute, National Agency for Science and Engineering Infrastructure (NASENI), Okene, Kogi State, Nigeria
rogerstamuno@gmail.com

**Corresponding Author: Oyiboruona E.P. paul.oyiboruona@gmail.com (+23407034430738)*

Manuscript History
Received: 21/01/2023
Revised: 20/03/2023
Accepted: 29/03/2023
Published: 30/03/2023

Abstract: *In this study, Kitchen waste (KW) was obtained from household in Oghara, Delta State, Nigeria. The collected KW was sorted and impurities such broken bottles, plastics, metals, ashes, textiles, etc., were removed. Thereafter, KW was grinded with a grinding machine to achieve a homogeneous composition and also to improved microbial hydrolysis when fed into the anaerobic digester. The anaerobic digester was seeded with 100 liters of anaerobic sludge obtained from three (3) stage continuous anaerobic digester plant installed at the University of Benin. The results of physiochemical properties of the KW that the pH value in this study ranges from 4.95-7.08 m within the retention time of 45 days. Also, the moisture content was as a function of total solid (TS), therefore, the effect of moisture content on biogas generation is uniform. The value of the volatile solid obtained was 88.87% and an average per day biogas yield of 0.0065 m^3 was obtained. More so, an increased cumulative biogas yield was obtained throughout the retention time of 45 days.*

Keywords: *Kitchen Waste, Biogas, pH, Total Solids, Cumulative Biogas Yield*

INTRODUCTION

According to the United Nations, the world population is expected to rise from the current 7.3 to 8.5 billion by 2030, and increasing to 9.7 billion by 2050 if no specific control measures are properly adopted (Mavropoulos, 2010) with developing countries, the most unprepared, having the highest share. About 97% of this growth is expected to take place in Asia and Africa due to their increase in population and industrialization (UNEP, 2009). According to the United Nations habitat watch, African city populations will triple over the next 40 years (UNEP, 2009). African cities are already inundated with slums; a phenomenon that could triple urban populations and spell disaster, unless urgent actions are initiated. Unfortunately, Africa and Asia countries have the least capability to absorb the associated waste increase. Nigeria 's population is already in excess of 190million (Worldometer, 2017) and is not reducing with its attendant soaring energy needs while the consequent huge wastes generated constitute health and environmental hazards due to improper management. Nigeria accounts for nearly half the total population of West Africa, and more than 15% of the total population of African.

She is ranks number seven in the list of countries after China, India, US, Indonesia, Brazil, Pakistan. The population density in Nigeria is 205 per Km^2, and the total land area is 910,802 Km^2. Estimated 48.1 % of the population live in urban (91,668,667) while the rest based in the rural area with farming as their major occupation (Wordometer, 2016).

Nigeria increasing population generated municipal solid waste (MSW) daily and generated MSW is dump indiscriminately (Orhorhoro and Oghoghorie, 2019). Solid wastes are generated and dump indiscriminately in Nigeria due to poor implementation of standards, thus causing environmental and public health hazards (Igbinomwanhia *et al.,* 2012; Orhorhoro *et al.,* 2017b; Orhorhoro *et al.,* 2019). Nigeria generates more than 32 million tons of solid waste annually, out of which only 20-30% is collected and disposed in an open dump site (Owamah *et al.,* 2015). Different researchers have reported that organic waste fraction of solid waste generated in Nigeria has the highest percentage which is over fifty percent (Igbinomwanhia *et al.,* 2017; Owamah, et al., 2015; Orhorhoro *et al.,* 2017). Unfortunately, this portion of generated solid waste has not been properly enhanced for biogas production (Ebunilo *et al.,* 2015a; Orhorhoro *et al.,* 2022). Besides, reckless disposal of solid waste has led to blockage of sewers and drainage networks, and choking of water bodies. Most of the wastes are generated by households and in some cases, by local industries, artisans and traders which litter the immediate surroundings. Improper collection and disposal of solid wastes is leading to an environmental catastrophe as the country currently lack adequate budgetary provisions for the implementation of integrated waste management programs across the states (Owamah *et al.,* 2015). Kitchen waste (KW) represents nowadays a major contributor to environmental pollution, which causes also severe economic and ethical reputation losses in sub-Sahara Africa countries. The Food and Agriculture Organization estimated that one third of the food produced annually in the World is lost or wasted. In this context, KW valorization into bioenergy and biofertilizers represents a promising strategy to mitigate both the environmental and economic issues caused by uncontrolled KW disposal.

The anaerobic digestion (AD) process is a green technology involving the generation of methane rich biogas via the biological degradation of available biomass from organic waste such as cow dung, water hyacinth, and food waste. It is an efficient process for treatment and utilization of organic waste because it has proven to be a promising method for waste reduction and energy recycling (Adeoti, 1998; Adekunle *et al.,* 2011; Park and Ahn, 2011; Zhang *et al.,* 2013; Orhorhoro, et al., 2017a). It is extensively acceptable as an efficient process for treatment and utilization of KW because it has proven to be promising method for waste reduction and energy recycling (Zhou *et al.,* 2014). According to other researchers, AD system can be used in treatment of agricultural waste, sanitize sewage sludge waste from aerobic wastewater by reducing its odour and volume (Mihelcic *et al.,* 2009; WHO, 2011). Generally, biogas is produced from biodegradable organic waste and sewage sludge. However, the quantity and production rate of biogas depends on the sources of feedstock used. One of the major sources of feedstock for an AD process is food waste (FW) which is gotten from household solid wastes generation (HSWG) (Orhorhoro *et al.,* 2017b). The anaerobic digestion process is a technology that recovers energy and nutrients from organic waste streams in useable forms in the absence of oxygen (Ge *et al.*, 2014). It is sustainable, renewable and a zero-carbon form of energy supply. The anaerobic digestion process can be used to recover some of these energy in the form of biogas typically as a mixture of methane (CH_4), carbon (IV) oxide (CO_2), hydrogen sulphide (H_2S), hydrogen gas (H_2), water vapour (H_2O), nitrogen gas (N_2) and siloxane (Ebunilo *et al,* 2016b). In the absence of the process, there is an uncontrolled released of methane to the atmosphere due to biodegradation of organic matter from open waste dump sites. Annually, natural biodegradation of organic matters is estimated to release Yearly, 590-880 million tons of methane gas into the atmosphere (Reza *et al.,* 2016).

AD system is widely adopted by Germany, Sweden, China, USA, and Denmark, which have implemented rigorous waste disposal legislation (Bhattacharya et al., 2005).

Since 2000, annual power generation from digester projects in USA has increased almost 25- fold from 14 million kilowatt-hours (KWh) to an estimated 331 million kWh per year. The technology is yet to achieve reasonable results in Nigeria despite her huge biogas potential that is estimated at 25.53 billion m^3 per year (Chima et al., 2013; Hamawand et al., 2014; Orhorhoro *et al.,* 2022). Biogas technology is still at the elementary stage in Nigeria as major breakthrough has not be achieved in terms of production, commercialization and availability in comparison to Germany, USA, Sweden etc. that depend on renewable energy from biogas (Eurostat, 2013; IEA, WBA 2015). However, various research works on the technology and policy aspects of biogas production has been carried by various researchers in Nigeria (Odeyemi, 1981; Omer, and Fadalla,2003; Itodo et al., 2005; Ojolo *et al.,* 2007; Elijah *et al.,* 2009; Ofuefule et al., 2011; Uzodinma *et al.,* 2011; Adeyosoye, 2010; Akinbami, 2011; Chima et al., 2013; Ebunilo *et al.,* 2016a; Orhorhoro *et al.,* 2016; Orhorhoro *et al.,* 2019)

MATERIALS AND METHODS

Kitchen waste (KW) was obtained from household in Oghara, Delta State, Nigeria. This was followed by sorting of collected kitchen waste. Impurities and non-biodegradable municipal solid wastes (MSW) such broken bottles, plastics, metals, ashes, textiles, etc., were removed, and the KW was grinded with a grinding machine to achieve a homogeneous composition and also to improved microbial hydrolysis when fed into the anaerobic digester. The digester was made from mild carbon steel and it has a capacity of 300 liters. The anaerobic digester was seeded with 100 liters of anaerobic sludge obtained from three (3) stage continuous anaerobic digester plant installed at the University of Benin. The grinded KW was diluted by mixing it with water in a ratio of 1: 2. Dilution of KW was carried out prior charging to the digester to maintain a constant volatile solid (VS) concentration. The diluted KW was charged into the digester and made air tight. The digester content was stirred several times per day with the aim of mixing the slurry inside the digester for efficient biogas yield. Stirring prevents formation of swimming layers and of sediments; it also brings the micro-organisms (MOs) in contact with the feedstock particles, facilitates the up-flow of gas bubbles and homogenizes distribution of heat and nutrients through the whole mass of substrates (Orhorhoro *et al.,* 2017c). Furthermore, the moisture content of the KW was determined by water to waste ratios used for digester charging. The experimental slurry taken with total solid concentration by mixing fermented biodegradable waste to initiate anaerobic fermentation process. The cumulative biogas yield was collected in liters. The volume of biogas and digestate produced in the anaerobic digester were measured daily. The digester was insulated, and the walls heated with an electric resistance to maintain an optimum mesophilic temperature range (Ebunilo *et al.* 2016a). The slurry temperatures were monitored throughout the period of gas production using thermometer. It was necessary to keep the digester at the ideal temperature, as a result the digesters was properly insulated.

RESULTS AND DISCUSSION

The results of physiochemical properties of the KW is shown in Table-1. The results revealed that the pH value in this study ranges from 4.95-7.08 m within the retention time of 45 days. The pH values obtained was in the same range with the values obtained for the research work of (Ofuefule *et al.,* 2009; Uzodinmah *et al.,* 2011; Paramagurua *et al.,* 2017b; Orhorhoro and Erameh, 2019) and is found to be within the pH range that favor biogas production. Besides, it was observed that the moisture content is a function of total solid (TS), therefore, the effect of moisture content on biogas generation is uniform. The value of moisture content for this study was 12.85% and this value is close to the one obtained by (Uzodinmah *et al.,* 2011). The value of the volatile solid obtained was 88.87% and this value was close to the value obtained by (Sajeena *et al.,* 2013; Orhorhoro *et al.,* 2017d). A higher percentage volatile solid is an indication of an improve biogas yields because the volatile solids is the biodegradable portion of the waste.

Table-1 Physiochemical properties of kitchen waste

S/N	Parameter	Kitchen Waste
1	pH (m)	4.95-7.08
2	Moisture content (%)	12.85
3	Total solids (%)	10.09
4	Volatile solids (%)	88.87

The 300 liters fully charged anaerobic digesters was run to a complete retention time of 45 days while monitoring the evaluated operation parameters (temperature, pH, and pressure). The pressure gauge was continuously monitored for biogas. Flame test was used for confirmation of useful bio-methane production. It was observed that biogas production started in the second week and this agreed with the research work of Ebunilo *et al.,* (2015a). However, at this stage, the biogas could not combust and this can be attributed to the large percentage of carbon (IV) oxide and hydrogen sulphide as reported by Ebunilo et al., (2016b) and Adegbayi, (2016). Nevertheless, on the 14th day and 16th day, the biogas burnt with yellow and blue flame respectively. Also, results revealed an average per day biogas yield of 0.0065 m^3 as shown in Fig. 1.

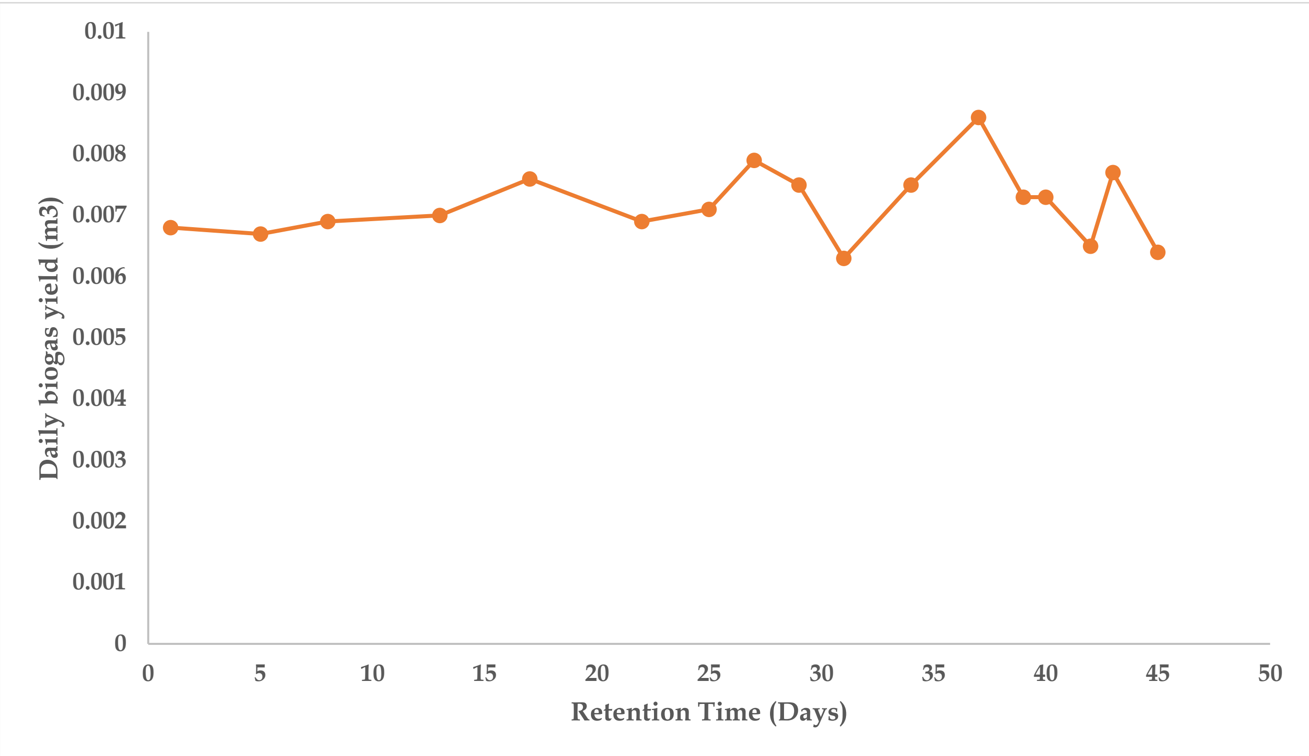

Fig. 1 Results of daily biogas yield

The results of cumulative biogas yield are shown in Fig. 2. An increased cumulative biogas yield was obtained throughout the retention time of 45 days.

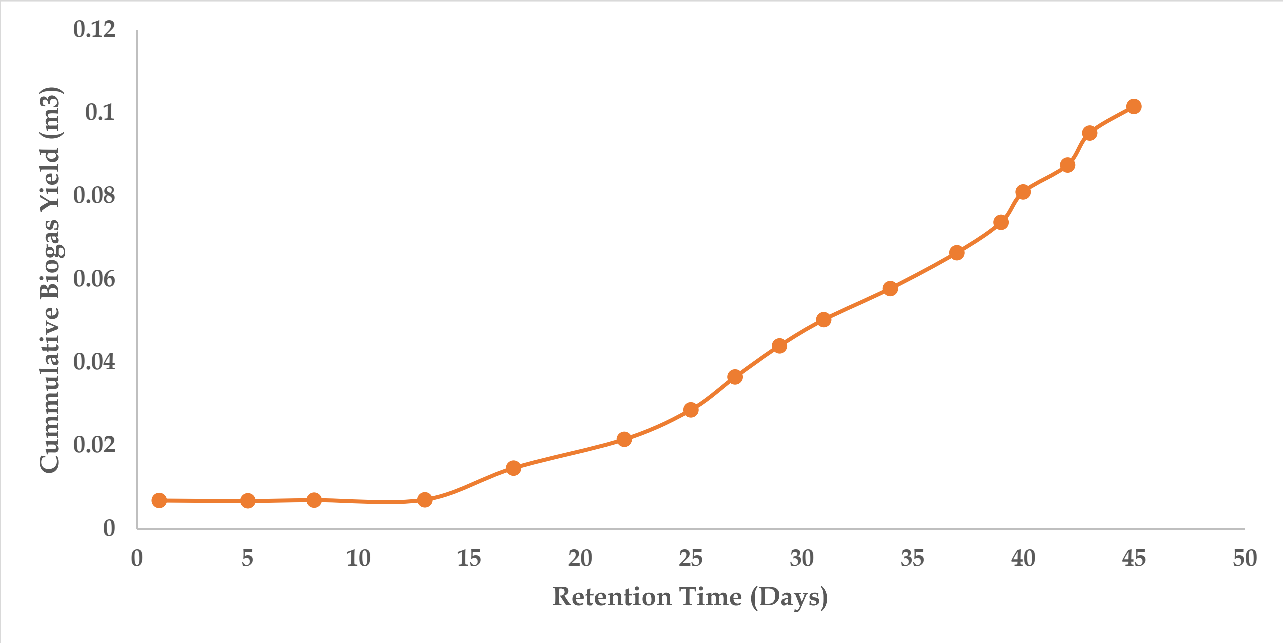

Fig. 2 Results of cumulative biogas yield

It was observed that a good mesophilic temperature enhances biogas yield as shown in Fig. 3. According to Ebunilo *et al.,* (2016a), optimum biogas yields are obtained within mesophilic temperature range of 36^0C-37^0C. A good look at Fig. 3 showed that better and improved biogas yields were obtained at an optimum mesophilic temperature range of 36^0C-37^0C. Therefore, the research work agrees with the work of Ebunilo *et al.,* (2016a).

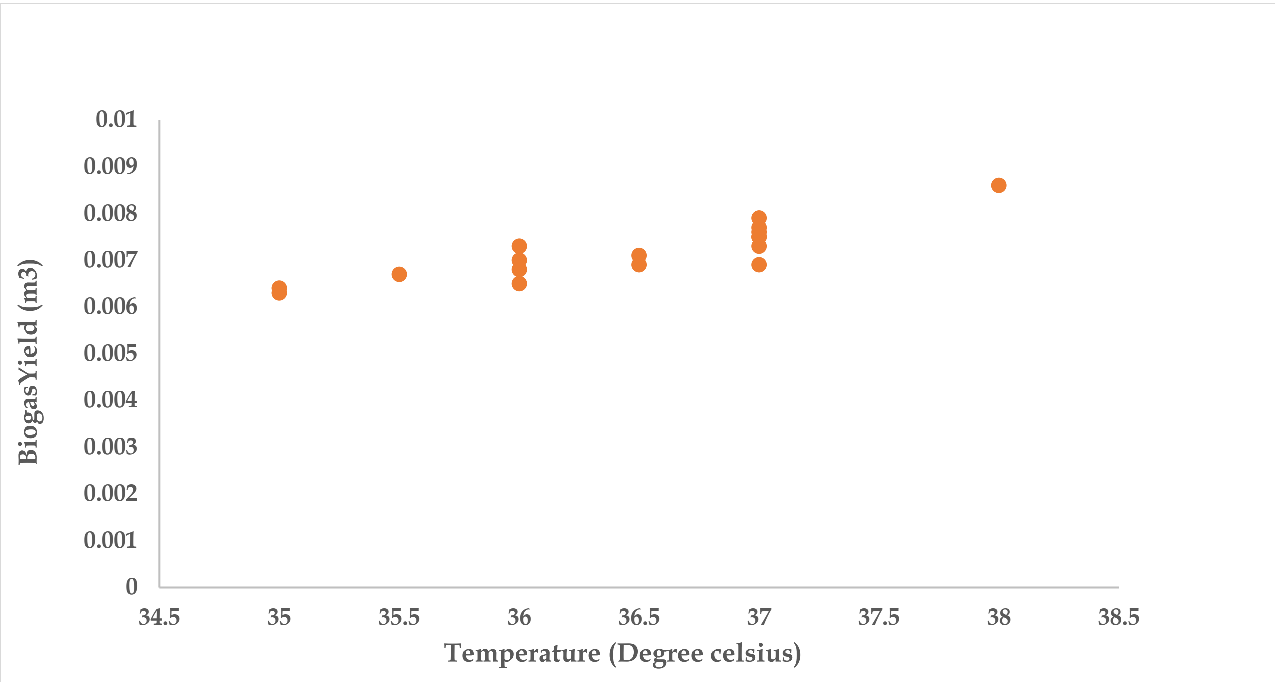

Fig. 3 Evaluation of effect of temperature on biogas yield

Moreover, it was observed that a neutral pH reading favor optimum biogas yield as shown in Fig. 4. Also, at the initial stage of the process, the pH reading indicated that the slurry in the digester is a weak acidic. Thus, the inactivity of the process at initial retention time is probably due to the methanogens undergoing a metamorphic growth process (Elijah *et al.,* 2009). It is generally agreed that at the initial stages of the overall process of biogas production, acid forming bacteria produces volatile fatty acids (VFA) resulting in declining pH and diminishing growth of methanogen bacteria (Zhang *et al.,* 2015; Paramagurua *et al.,* 2017a; Orhorhoro *et al.,* 2017d).

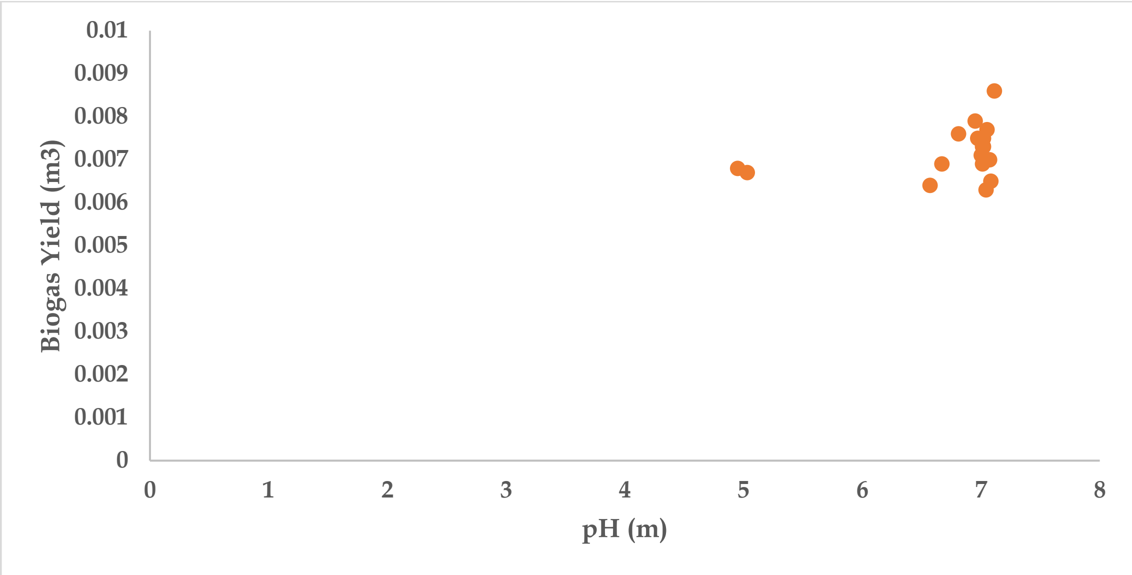

Fig. 4 Evaluation of effect of pH on biogas yield

CONTRIBUTION TO KNOWLEDGE

This study has shown that sufficient biogas can be generated from kitchen waste. Besides, operating parameters such as mesophilic temperature, pH, total solid, and moisture contents have effect on biogas yield.

CONCLUSION

Nigeria 's population is increasing tremendously and this will bring about increase in volume generated MSW. Also, the huge wastes generated constitute health and environmental hazards due to improper management. In this study, parts of the generated MSW was co-digested to produce biogas. It was observed from the results that a good mesophilic temperature enhances biogas yield. Also, on the 14th day and 16th day, the biogas burnt with yellow and blue flame respectively. The results similarly revealed an average per day biogas yield of 0.0065 m^3. More so, an increased cumulative biogas yield was obtained throughout the retention time of 45 days. Besides, it was observed that a good mesophilic temperature and a neutral pH reading favor optimum biogas yield.

CONFLICT OF INTEREST

There is conflict of interest associated with this research work.

REFERENCES

Adegbayi, O.A. (2016). Investigation of the purification of biogas from domestic wastes using local materials. Unpublished thesis submitted to the Postgraduate School, University of Benin in partial fulfilment for the award of master degree of Engineering (M.ENG) in Design and Manufacture, Department of Mechanical Engineering, Faculty of Engineering

Adekunle, I.M., A.A. Adebola, K.A. Aderonke, O.A. Pius and A.A. Toyin, (2011). Recycling of organic wastes through composting for land applications. A Nigerian experience Waste Manag. Res., 29(6): 582-93

Adeoti, O. (1998). Engineering economy studies of biogas as a renewable energy source at household level in Nigeria. Unpublished MSc thesis in Technology Management, Technology Planning and Development Unit, Faculty of Technology, Obafemi Awolowo University, Ile-Ife, Nigeria

Bhattacharya, S.C., Abdulsalam, P., Runqing, H., Somashekar, H.I, Racelis, D.A, Rathnasiri, P.G., Yingyuad, R. (2005). An assessment of the potential for non –plantation biomass resources in selected Asian countries. Biomass Bioenergy. 29:153-166.

Chima C.N., Jude N.O., Justina C.O. and Ekpewerechi S.A. (2013). Biogas potential of organic waste in Nigeria. Journal of Urban and Environmental Engineering, 7(1): 110-116

Ebunilo, P.O., Aliu, S.A. and Orhorhoro, E.K. (2015a). Performance Study of a Biogas Pilot Plant using Domestic Wastes from Benin Metropolis. *International Journal of Thermal & Environmental Engineering volume,* 10(2): 135-141.

Ebunilo P., Aliu S., Orhorhoro K. (2015b). Comparative Analysis of Biogas Yield from Different Composition of Domestic Wastes from Benin City, Nigeria. *Journal of Advanced & Applied Science (JAAS),* 04(05): 169-177, 2015

Ebunilo, P.O., Orhorhoro, E. K., Oboh, V., Onochie, P. U (2016a). Effect of Temperature on Biogas Yields Using South-South Nigeria as a Case Study. *International Journal of Technology Enhancements and Emerging Engineering Research*, 4(3): 50-54

Ebunilo, P.O., Orhorhoro, E.K., Adegbayi, O.A. (2016b). Investigation of the purification of biogas from domestic wastes using local materials in Nigeria. International Journal of Scientific & Engineering Research, 7(2): 505-515

Elijah T. Iyagba, Ibifuro A. Mangibo and Yahaya Sayyadi Mohammad (2009). The study of cow dung as co-substrate with rice husk in biogas production, Scientific Res. & Essay., 4 (9): 861-866

Eurostat (2013). Energy statistics: Supply, transformation, consumption - all products - annual data. Energy statistics: Supply, transformation, consumption - renewables and wastes (total, solar heat, biomass, geothermal, wastes) - Annual data. Energy statistics: Supply, transformation, consumption - renewables (hydro, wind, photovoltaic)-annual data Available from: http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database

Ge, X., Matsumoto, T., Keith, L., and Li, Y. (2014). Biogas energy production from tropical biomass wastes by anaerobic digestion. Bioresource Technology, 169: 38–44.

Igbinomwanhia D.I., Ohwovoriole E.N., Ejovo N. (2012). A study of the constraints to Residential Solid Waste Management in Benin Metropolis, Nigeria. Journal of Emerging Trendsin Engineering and Applied Science (JETEAS) 3(1): 103-107

Igbinomwanhia, D.I., Obanor, A.I., Olisa, Y.P. (2017). Characterisation of Domestic Solid Waste for the Determination of Waste Management Option in Amassoma, Bayelsa State, Nigeria. J. Appl. Sci. Environ. Manage, 18(2): 211-215

Itodo, I. N. and Kucha, K. I. (1997). The prospect of biogas technology in the agricultural development in Nigeria. Nigerian Journal of Renewable Energy 5 (1), 21-24.

Hamawand, I., Yusaf, T., Hamawand, S (2014). Growing algae using water from coal seam gas industry and harvesting using an innovative technique: A review and a potential. Fuel, 117: 422–430

Mavropoulos. A (2010). Waste Management 2030 the future of waste management on an overcrowded plane. Waste Management World. March –April 2010

Mihelcic, J. R., Fry, L. M., Myre, E. A., Phillips, L. D., & Barkdoll, B. D. (2009). Field guide to environmental engineering for development workers: Water, sanitation, and indoor air. Reston, VA: American Society of Civil Engineers

Ofuefule A.U., Uzodinma E.O., and Onukwuli O.D. (2009). Comparative study of the effect of different pretreatment methods on biogas yield from water Hyacinth (Eichhornia crassipes). *International Journal of Physical Sciences,* 4(8): 535-539

Orhorhoro, E.K., Ebunilo, P.O., and Ikpe, A.E., (2016). Effect of pH on Anaerobic Digestion (AD) of Organic Municipal Solid Waste in Benin City, Nigeria. *Journal of the Nigerian Association of Mathematical Physics,* 36(1): 369-374

Orhorhoro, E. K., Ebunilo, P. O., and Sadjere, E. G., (2017a). Development of a Predictive Model for Biogas Yield Using Artificial Neural Networks (ANNs) Approach. American Journal of Energy and Power Engineering, 4(6): 71-77

Orhorhoro, E.K., Ebunilo, P.O.B., and Sadjere, E.G. (2017b). Determination and Quantification of Household Solid Waste Generation for Planning Suitable Sustainable Waste Management in Nigeria. *International Journal of Emerging Engineering Research and Technology,* 5(8): 1-9

Orhorhoro, E.K., Ebunilo, P.O.B., and Sadjere, E.G. (2017d). Experimental Determination of Effect of Total Solid (TS) and Volatile Solid (VS) on Biogas Yield. American Journal of Modern Energy; 3(6): 131-135

Orhorhoro, E.K., Oghoghorie, O. (2019). Review on Solid Waste Generation and Management in Sub-Saharan Africa: A Case Study of Nigeria. J. Appl. Sci. Environ. Manage., 23 (9): 1729-1737

Ejiroghene Kelly, Orhorhoro, Andrew Amagbor, Erameh (2019). Performance evaluation of the effect of temperature and pH on biogas yield from anaerobic co-digestion of food waste and pig dung. Proceedings of Igbinedion University First Annual Research Day and Conference (5th August, 2019). Theme: Greening Academia/Industry Research Synergy: To Promote Sustainable Development Goals in Nigeria. Nigerian Journal of Engineering Science Research (NIJESR): 50-59, 2021

Odeyemi, O. (1981). Biogas from *Eupatorium odorantum*, an alternative cheap energy source for Nigeria. In Global impacts of Applied Microbiology, 6th International Conference, 246-252

Ojolo, S.J., Oke, S.A., Animasahun, O.K., and Adesuyi, B.K. (2007). Utilization of poultry, cow and kitchen wastes for biogas production: A comparative analysis. Iranian J. Environ. Health Sci. Eng. 4, 223-228.

Omer, A.M., and Fadalla, Y. (2003). Biogas energy technology in Sudan. Renew. Energ. 28, 499-507

Orhorhoro, E.K., Lindsay, E.E., Oyejide, J.O. (2022). Analysis and Evaluation of a Three-Stage Anaerobic Digestion Plant for Management of Biodegradable Municipal Solid Waste. *International Journal of Engineering Research in Africa,* 60: 75-87. doi:10.4028/p-a24obb

Owamah, I.H., Izinyon, O.C., Igbinewekan, P. (2015). Characteristics and quantification of solid waste generation in the Niger Delta Region of Nigeria: a case study of Ogbe-Ijoih community in Delta State. *Journal of Material Cycles and Waste Management,* 19(1): 366-373

Paramagurua, G., Kannanb, M., Lawrencec, P., Thamilselvand, P. (2017a). Effect of total solids on biogas production through anaerobic digestion of food waste. Desalination and Water Treatment, 63: 63–68

Paramagurua, G., Kannanb, M., Lawrencec, P. (2017b). Effect of pH on Biogas Production through Anaerobic Digestion of Food Waste. Journal of Advanced Engineering Research, ISSN: 2393-8447, 4(1): 59-62

Park, W.J. and Ahn, J.H. (2011). Optimization of microwave pretreatment conditions to maximize methane production and methane yield in mesophilic anaerobic sludge digestion. Environ Technol. 32: 1533–1540

United Nations Environment Programme (2009). Converting Waste Plastic into a resource. United Nations Environmental Programme Division of Technology, Industry and Economics International Environmental Technology Centre, Osaka/Shika. .10, pp.12-73. [Online] Available from:http://www.unep.or.jp/Ietc/Publications/spc/WastePlasticsEST_Compendium.pdf.

World Bioenergy Association. Biogas - an important renewable energy source. Stockholm: WBA, 2013.

Worldometer (2016). United Nation World Population Estimation (UNWPE). http://www.worldometers.info/world-population/nigeria-population/

World Health Organization. (2011). Health statistics and health information systems: Global burden of disease. Retrieved August 29, 2016, from http://www.who .int/healthinfo/global_burden_disease/en/

Reza, A., Ali, S., Alibakhsh, K., Hossein, H., and Majid, A.T. (2016). The role of biogas to sustainable development (aspects environmental, security and economic). Journal of Chemical and Pharmaceutical Research, 8(4): 112-118

Sajeena, B.B., Jose, P.P. and Madhu, G. (2013). Effect of Total Solid Concentration on Anaerobic Digestion of the Organic Fraction of Municipal Solid Waste". International Journal of Scientific and Research Publications, 3(8): 1–5

Zhang, C., Su, H., Baeyens, J., and Tan, T. (2014). Reviewing the anaerobic digestion of food waste for biogas production. Renewable and Sustainable Energy Reviews, 38: 383–392

Zhang, T., Mao, C., Zhai, N., Wang, X., and Yang, G. (2015). Influence of initial pH on thermophilic anaerobic co-digestion of swine manure and maize stalk. Waste Management, 35: 119–126

Zhou, Q., Shen, F., Yuan, H., Zou, D., Liu, Y., Zhu, B., and Li,X. (2014). Minimizing asynchronism to improve the performances of anaerobic co-digestion of food waste and corn stover". Bioresource Technology, 166: 31–36. http://dx.doi.org/10.1016/j.biortech.2014.04.074

Uzodinma E.O., Ofoefule, A.U., and Enwere, N.J. (2011). Optimization of biogas fuel production from maize (zea mays) bract waste: comparative study of study of biogas production from blending maize bract with biogenic wastes. *American Journal of Food and Nutrition*, 4(2): 091- 095