Nigerian Journal of Engineering Science Research (NIJESR).
Department of Mechanical Engineering, Gen. Abdusalami Abubakar College of Engineering, Igbinedion University, Okada, Edo State, Nigeria.
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ISSN: 2636-7114
Journal Homepage: https://nijesr.iuokada.edu.ng/

Performance Evaluation of Biogas Yields from Co-Digestion of Kitchen Waste and Pig Dung

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Manuscript History
Received: 25/11/2023
Revised: 10/12/2023
Accepted: 20/12/2023
Published: 30/12/2023
https://doi.org/10.5281/zenodo.13901070

Abstract: *Because guidelines are not being followed, kitchen trash is produced and disposed of carelessly in Nigeria, endangering the environment and public health. Only 20–30% of the more than 32 million tons of solid garbage produced in Nigeria each year are collected and dumped in open sites. The performance evaluation of the biogas potential yields from co-digestion of kitchen wastes and pig manure is the main topic of this research project. Pig manure and kitchen garbage were co-digested using a 0.040 m^3 anaerobic digester. The pH range for the experiment was 5.8–7.4 m, and the temperature range was mesophilic. The findings demonstrate that a cumulative biogas production of 51.5 cm^3 was produced from 20 kg of substrates made up of pig manure and kitchen garbage. Furthermore, the optimal mesophilic temperature was reached to give the highest biogas outputs.*

Keywords: *Biogas Yield, kitchen Waste, Pig Dung, Mesophilic Temperature, pH Range*

INTRODUCTION

The availability of energy for home, industrial, and agricultural uses is the most exciting aspect of any civilized culture (Orhorhoro *et al.*, 2017a; Erameh, & Orhorhoro, 2018; Olusey, 2010). Nigeria's energy crisis impacts the entire nation; therefore, all governmental levels must collaborate on numerous energy-related choices (NESP, 2015). A more pressing issue is the growing population, which has led to high energy demand and a finite, quickly running out energy supply, creating a serious energy crisis (Aliyu *et al.*, 2013). Nigeria's energy sector has a negative impact on the environment, primarily through pollution and deforestation (Adelekan, & Adelekan, 2010; Oyedepo *et al.*, 2012; Orhorhoro *et al.*, 2018a; Oghoghorie *et al.*, 2020; Erhinyodavwe *et al.*, 2024). Nigeria has access to wood, fossil fuels, sun, wind, tidal, and terra-thermal energy sources (Ebunilo *et al.*, 2015a; Ebunilo *et al.*, 2016a; Igbagbon *et al.*, 2024). Since the oil business and the energy sector as a whole were liberalized and reformed a few years ago, the cost of energy in Nigeria for residential, commercial, and industrial applications has skyrocketed (Orhorhoro, & Oghoghorie, 2024).

This necessitates taking significant action and enacting suitable legislation to optimize the use, discovery, and exploitation of present energy sources as well as the search for new, alternative energy sources and their preservation. One such method is the biogas technology, which has been shown to be both economical and environmentally friendly (AA Global Energy Network Institute, 2016; Franqueto *et al.*, 2020; Hoang *et al.*, 2020; Ma *et al.*, 2020; Meng *et al.*, 2020; Cudjoe *et al.*, 2022; Orhorhoro *et al.*, 2022). Biogas is a combustible mixture of methane gas produced by the breakdown of organic materials at a sufficient and stable temperature, leaving behind a slurry known as biofertilizer (Orhorhoro, & Oyejide, 2018b). It is defined as an ecology-oriented type of appropriate technology (Ebunilo *et al.*, 2015b; Orhorhoro *et al.*, 2017b; Chow *et al.*, 2020). Reducing the usage of fossil fuels, greenhouse gas emissions, pollution, and waste management issues can all be achieved by using waste biomass to generate electricity (Ionescu et al., 2013; Anwar *et al.*, 2014; Paramagurua *et al.*, 2015; Orhorhoro *et al.*, 2019). According to IEA (2019), by 2020, biomass will provide 19 million metric tons of oil, of which 46% will come from waste streams that decompose naturally, such as farm waste, agricultural residues, municipal solid wastes, and other biodegradable waste streams. As a potentially endless supply of methane, biomass provides a portion of the answer to the ultimate problem of fossil fuel depletion. Furthermore, biomass may be profitably converted to biogas on a range of scales, making it possible to customize its supply to meet local, regional, and national biogas requirements.

Anaerobic digestion (AD) is a well-established method for treating wastewater and biodegradable organic wastes (BOWs) (Marshall, 2000; Akintokun *et al.*, 2011; Orhorhoro *et al.*, 2017c). From the AD of biodegradable kitchen waste, nutrients and renewable energy may be recovered (Orhorhoro *et al.*, 2016a). When substrates are digested alone in ADs, instability may result from the generation of volatile fatty acids (VFAs) and ammonia, which have repressive effects on methanogenic-producing bacteria and, consequently, biogas yield (Makaruk *et al.*, 2010: Orhorhoro, & Oghoghorie, 2024). By co-digestion of multiple BOW substrates, some of the limitations associated with solely digesting BOWs can be mitigated. Anaerobic co-digestion increases methane generation because of the advantageous interactions in the acclimation media (Niesner *et al.*, 2013; Orhorhoro, & Oghoghorie, 2024). It is generally acknowledged that animal dung does not produce enough methane to support digestion economically. When fermentable organic materials, such kitchen trash, are subjected to anaerobic digestion in the presence of methanogenic bacteria, biogas is the resultant of the bio-methanation process (Makaruk *et al.*, 2010). Methane and carbon dioxide make up the majority of biogas, with trace amounts of other gases and vapors like hydrogen, nitrogen, and hydrogen sulfide (H_2S) (Osunde *et al.*, 2017). Biogas is a desirable fuel due to its high methane concentration, and since methane is a greenhouse gas that is several times more destructive than CO_2, using it to tackle emission problems is a solution (Ebunilo *et al.*, 2016b; Orhorhoro *et al.*, 2016b). Biogas is an odorless and colorless gas that burns with a clear blue flame at a temperature of 870^0C. It is about 20% lighter than air and has an ignition temperature in the range of 650^0C to 750^0C compared to diesel oil at 350^0C, petrol and propane at roughly 500^0C. Numerous terms are used to refer to biogas, including marsh gas, swamp gas, and "will o' the wisp" gober gas (Orhorhoro *et al.*, 2016b).

Many Nigerian urban and rural regions lack proper and efficient waste management. Nigeria's inadequate handling of organic waste is a cause for concern for the community. This garbage is hazardous to citizens' health because it clogs drainage systems, causing erosion and flooding, and it threatens urban management by destroying the beauty of the nation's cities through the accumulation of solid waste.

Because they serve as a mosquito breeding ground, the people of Nigeria are seriously at danger for health problems (Igbinomwanhia *et al.*, 2012; Orhorhoro, & Oghoghorie, 2019; Orhorhoro, & Oghoghorie, 2023). Only 20–30% of the more than 32 million tons of solid garbage produced in Nigeria each year are collected and dumped in open sites (Titus, & Anim, 2014; Owamah *et al.*, 2015; Orhorhoro *et al.*, 2017d). According to several studies, Nigeria produces the largest amount of solid waste—more than fifty percent—of which is organic garbage (Orhorhoro, & Oghoghorie, 2019). Regretfully, the production of biogas from this fraction of generated solid waste has not been adequately boosted (Orhorhoro *et al.*, 2017d). If appropriately utilized, a significant portion of the solid waste produced and carelessly disposed of in open landfills can be beneficial to humans. Using biogas technology is one of the greatest ways to do this.

MATERIALS AND METHODS

The biogas reactor was constructed using a plastic container and has a 30-liter capacity. The setup of the experiment was done as (Orhorhoro, & Oghoghorie, 2024) advised. The reactor was connected to the inlet valve for slurry charging, the thermometer for slurry temperature, the pressure gauge for gas pressure, the outlet valve for slurry discharge, the stirrer for slurry continuous stirring, and the gas discharging valve for biogas evacuation (Fig. 1).

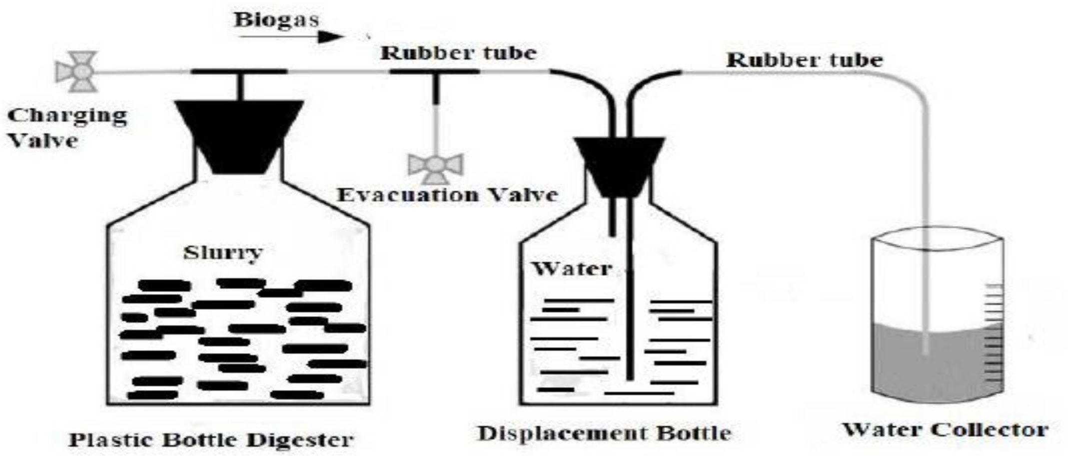

Fig. 1 Experimental setup

While the kitchen garbage was gathered from households, the pig manure was obtained from a farm located in Mosogar. After the kitchen waste was processed, any non-biodegradable foreign elements were taken out. Grinding came next, mostly to lower the particle sizes for simpler breakdown. In order to start producing biogas as soon as feasible, grinding is also done to enhance the surface area of contact for microbial activity (Orhorhoro *et al.*, 2017c). An equal mass of pig dung (10 kg) and kitchen garbage (10 kg) were used in the feedstock preparation process. Ebunilo *et al.* (2015a) recommendations for improved biogas generation were used to calculate the water content of each sample. This served as the foundation for figuring out how much water was added for each mass of total solid. In order to prepare the slurry for fermentation, the entire feedstock was added and well mixed with the same amount of water required for the highest possible production. After the mixture was added to the reactor, the entire hydraulic retention duration was monitored. Mercury was used in a glass thermometer and an analog pH meter, respectively, to measure the temperature and pH. The pH range for the experiment was 6.0–7.4, while the mesophilic temperature range was 21^{0}°C–38^{0}°C.

RESULTS AND DISCUSSION

For this research project, a single batch AD reactor was employed due to maintenance, expense, and technical expertise. Recharging was done only once the hydraulic retention time (HRT) had elapsed, after the initial charging. This design was selected for the study due to its suitability, affordability, and ease of construction. The feedstock is fed into the digester through an intake. The remaining area of the reactor is used to produce gas, and a mark indicates the ideal level of feedstock. Using the displacement method, the amount of biogas produced was monitored every four days following the first forty (40) days. Put another way, the valve control allowed gas to be discharged from the digester into the measurement cylinder's 1000 cm^3 water level. After then, the measurement cylinder was turned upside down such that the gas pressure displaced the same volume of water, and the results were noted. The amount of biogas produced overall was determined by repeating this process. The amount of biogas generated was measured and is displayed in Table-1.

Table-1 Results of performance test evaluation

SN	HRT (Days)	pH (m)	Temp. (^0C)	Pres. (Bar)	Volume (cm^3)
1	13	7.5	35.00	0.75	7.8
2	17	6.8	34.24	0.86	6.0
3	21	6.9	36.24	0.64	6.9
4	25	7.1	37.00	1.00	9.5
5	29	8.0	29.25	0.91	7.6
6	33	7.4	33.00	0.52	6.9
7	37	7.4	21.00	0.50	4.5
8	40	7.4	32.00	0.40	2.3
∑					51.5

The volume of biogas production is plotted versus hydraulic retention time in Fig. 2, while the volume influence of temperature, pressure, and pH on biogas yields is displayed in Fig. 3.

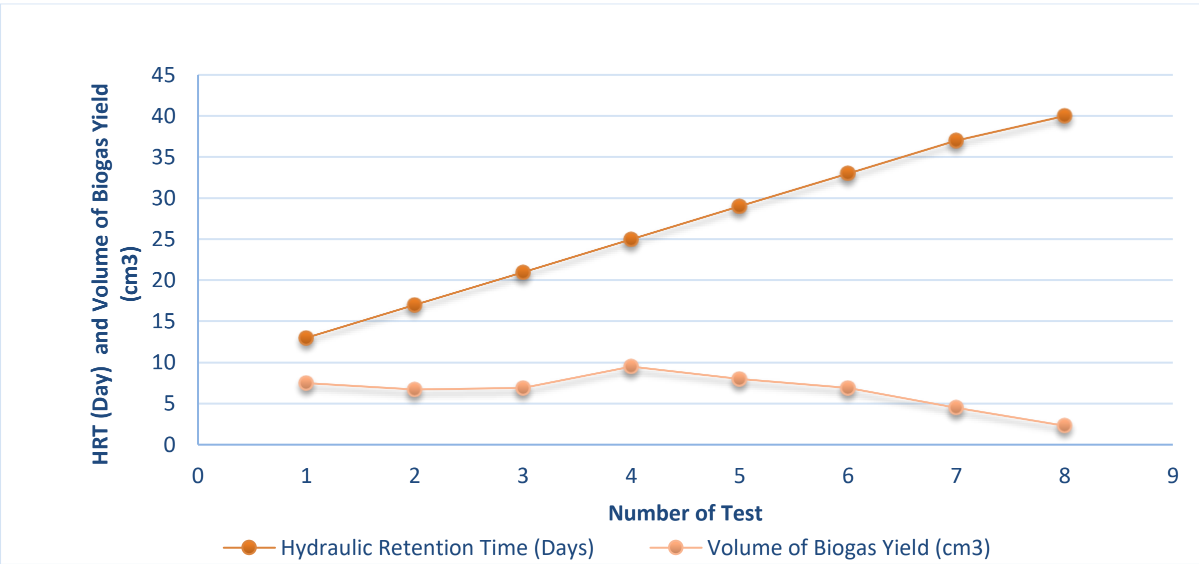

Fig. 2. Volume of biogas yields against hydraulic retention time

The hydraulic retention time was 40 days, according to the results. That is, the first 13 days of anaerobic digestion without any biogas yields, followed by 27 days of continuous biogas yields spaced four days apart. On the 40th day, minimum biogas yields were attained. On the 29th day, however, the maximum biogas yield was achieved. Digestion was complete, which is why there was a decrease in methane generation on day 40. Furthermore, there was change in the mesophilic temperature, which led to an uneven production rate Maximum biogas yields are achieved in the mesophilic temperature range of 36^{0}°C to 37^{0}°C, according to Ebunilo *et al.* (2016c). An examination of Fig. 3 revealed that an ideal mesophilic temperature range of 37^{0}C produced better and increased biogas output. As a result, the research findings are consistent with those of Ebunilo *et al.* (2016c). Additionally, at the ideal mesophilic temperature, superior pressure measurements and a pH value were obtained, which is consistent with the findings of Orhorhoro *et al.* (2016c).

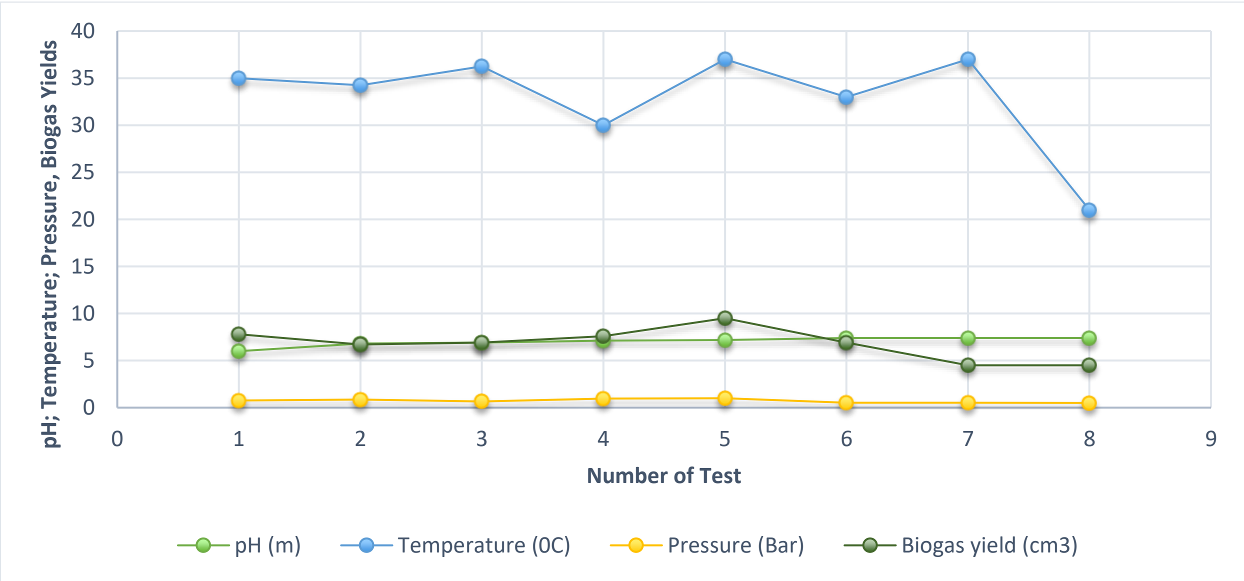

Fig. 3. Volume effect of pH, Pressure, and Temperature on biogas yields

CONCLUSION

Combining the co-digestion of pig dung and kitchen garbage created biogas. It was discovered that ideal biogas generation depended on temperature, as predicted. In essence, thick slurry was used to feed the standard rate digester, which was maintained at standard atmospheric conditions. After 13 days to determine the maximum rate of microbial activity, the digester was tested for combustion and the amount of biogas produced was measured. Notably, it was observed that the generation of biogas rose over time. After 13 days, the biogas's specific pressure was 0.75 bar. It was discovered that the pressure was 1 bar at its maximum point on day 25, and 0.4 bar at its lowest point on day 40. The study's findings indicate that 51.5 cm^3 of biogas were produced in total. Thus, it is possible to co-digest pig dung and kitchen trash to create biogas. With the use of this technology, Nigerian trash production can be controlled, and some of the country's energy crisis may be partially resolved.

CONFLICT OF INTEREST

There is no conflict of interest for this research work.

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