African Journal of Environment and Natural Science Research

Vol.1, No.1, pp.24-32, 2018

www.abjournals.org

ESTIMATION OF BIOGAS PRODUCTION FROM ANAEROBIC DIGESTION OF PALM OIL MILL EFFLUENT (POME) IN REAL OIL MILLS PALM PLANTATION, ODUKPANI L.G.A., NIGERIA

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ABSTRACT: *This study evaluated extractable biogas from anaerobic digestion of palm oil mill effluent (POME). This study made use of a laboratory experiment involving a simple batch experimental setup employing the volumetric displacement principle for quantifying the amount of biogas produced from organic waste using a bio-digester and a gasometric chamber. Biogas was extracted anaerobically using locally manufactured bio-digesters and a comparison in production rates was made between the control and catalysed experimental setups. The catalysed substrate produced more biogas (19,402.5ml, equivalent to 0.0194025m^3) than the controlled (27.00ml, equivalent to 0.000027m^3). Biogas production was highest on the 70th day of the experiment (5,000ml, equivalent to 0.005m^3). The result revealed that it is possible for biogas to be generated without methane or with just very low methane content. Burning of biogas tells whether or not it contains methane whereas the intensity and colour of the flame could serve as good indicator of the methane concentration in biogas. The result of this study also led to the conclusion that biogas production during anaerobic digestion gradually builds up with time and then starts dropping with depleting nutrient content of the feedstock. From the findings of this study, it is recommended that; more research on other microbial manipulations of the substrate should be done with the aim of improving on the amount of biogas that can be obtained from POME; also, other catalysts should be used to increase the volume of biogas generated within a shorter period of time*

KEYWORDS: Palm Oil Mill Effluent (POME), Anaerobic Digestion, Biogas, Methane, Bio-Digester, Gasometric Chamber.

INTRODUCTION

Fossil fuel no doubt has been proven to impact negatively on the environment. Its depleting supply today has increased the world's interest in exploring an alternate source of energy which is renewable, affordable, cleaner and eco-friendly. Some renewable energy resources include biomass, solar, hydropower, wind, tidal waves, geothermal and nuclear. Comparatively speaking, biomass has a substantial advantage over other renewable resources due to their ability to mitigate carbon dioxide emissions through the mechanism of photosynthesis and providing energy without any interruption. In both developed and developing countries like Nigeria, several feedstocks have emerged as having potential for energy production, some of which include oil palm, sugar cane, cassava, rice, and sweet sorghum. However, factors such as initial investment and operating cost, safety and sustainability are some of the sociological and economical considerations that are very paramount to the implementation of any renewable energy scheme.

Oil palm is one of the most productive oil-bearing crops in the world and it thrives in both the tropical and subtropical regions (Izah & Ohimain, 2013). It is a perennial crop which is traditionally grown for its oils (that is, palm oil and palm kernel oil) and palm kernel cake. Palm oil and palm kernel oil are extracted from the mesocarp and kernels of the fruits respectively.

The production of palm oil also leads to the production of large volumes of waste of which palm oil mill effluent is the largest and is substantially acidic in nature. Due to the harmful nature of POME with respect to its very high biochemical oxygen demand and acidic nature, palm oil mills are required to treat their liquid waste before its discharge on land and in water bodies (Ma & Basiron, 2006). Moreover, modern large-scale agricultural activities such as oil palm plantations which generate large volumes of liquid waste must be managed properly; else it may contaminate surface or ground water (NI, 2016; Oko *et al.*, 2014). Anaerobic digesters are commonly used by mills to treat their effluent. The anaerobic treatment of POME gives rise to biogas. Biogas is a renewable source of energy produced from the biological breakdown of organic matter such as manure, plant biomass, crops, sewage and municipal waste in the absence of oxygen.

In Nigeria especially and other developing countries, the common practice is the disposal of POME on land. This is a harmful practice to humans; surface and subsurface water bodies, plants, animals and the environment as a whole. This is because the methane gas produced during POME decomposition has the potential of trapping even more heat (up to about twenty-one times more) than carbon dioxide, thus contributing to global warming. Its disposal on land can lead to contamination of ground water through seepage and surface water bodies through runoffs during heavy rains due to is high biochemical oxygen demand and acidity. Even the gases released are harmful to human health. Arguably, generation of POME will continue to rise in tonnes as production and processing of palm oil continue to rise to meet both domestic and global demand. This research is aimed at quantifying the amount of biogas generated by the control and experimental setups

Study Area

Real Oil Mills Palm Plantation limited is located in Odukpani Local Government Area of Cross River State. Real Oil is located about 22 km from the Calabar city centre along the Calabar-Ikom highway receding about 5 km off the junction opposite the Federal Housing Estate in Odukpani. The oil mill itself is located precisely at 5^{o}8’16’495”N and 8^{o}21’54.499”E with an altitude of 43m above sea level. On the other hand, Odukpani lies between latitude 4^{o}00N and 5^{o}00N, and longitude 8^{o}00E and 8^{o}30’ Odukpani is mainly populated by the Efik people.

MATERIALS AND METHOD

Waste Material/Substrate

Palm oil mill effluent (POME) was used as the substrate in this study. POME is the largest by-product from the palm oil industry and is made up of the following: water, solids, oil and grease (Otti, Ifeanyichukwu, Nwaorum & Ogbuagu, 2014). Palm oil mill effluent in its fresh state is defined by Ismail (2012) as “a thick brownish in colour colloidal slurry made up of water, oil and fine cellulosic fruit residues”.

The POME used in this study was gotten from Real Oil Mills Palm Plantation, Odukpani, Cross River State of Nigeria. The sample was collected aseptically in its fresh state. This was gotten at the first point of waste discharge from the mill.

Experimental Setup

This was a laboratory experiment involving a simple batch experimental setup employing the volumetric displacement principle for quantifying the amount of biogas produced from organic waste using a bio-digester and a gasometric chamber.

The gasomeric chamber used in this study was adapted from Asikong, Epoke, Eja and Antai (2012) who used it in their study on the “Potentials of biogas generation by combination of cassava peels (CP) and poultry droppings (PD) in Cross River State”. The gasometric chamber was made up of a graduated burette containing paraffin oil which was connected to the anaerobic digester through a rubber gas tube. The burette was also connected to a transparent glass funnel through a transparent synthetic rubber tubing. The glass funnel acted as a collector for the displaced liquid from the burette. The burette was linked to the gas pipe from the anaerobic digester by a glass connector with an inlet and outlet tap controlled by a glass stopper. The burette and glass funnel were held in place by a supporting clamp for stability (FIG. 1).

Digester Design

Two locally designed anaerobic digesters were used for this study. One was used for the control setup and the second for the catalysed setup with starter culture. All two digesters were of same capacity (that is, 12 litres by volume). The control digester consisted of an opening which served as substrate inlet with control valves for closing and opening. All the digesters also had taps at the bottom for easy sludge discharge and collection of samples for analysis. Both digesters had controlled openings at their tops for biogas discharge which were each connected to a gasometric chamber for determination of biogas yield. The digesters also had a round base for stabilization and balancing.

The digester with the catalysed substrate however had added modifications mainly for temperature enhancement. These modifications were: a copper pipe with controlled hot water inlet and outlet, and an external insulating box also for temperature control. All the stoppers used in the digester were oil and gas stoppers to make sure that no air enters or leaves the reactors in the course of the experiment.

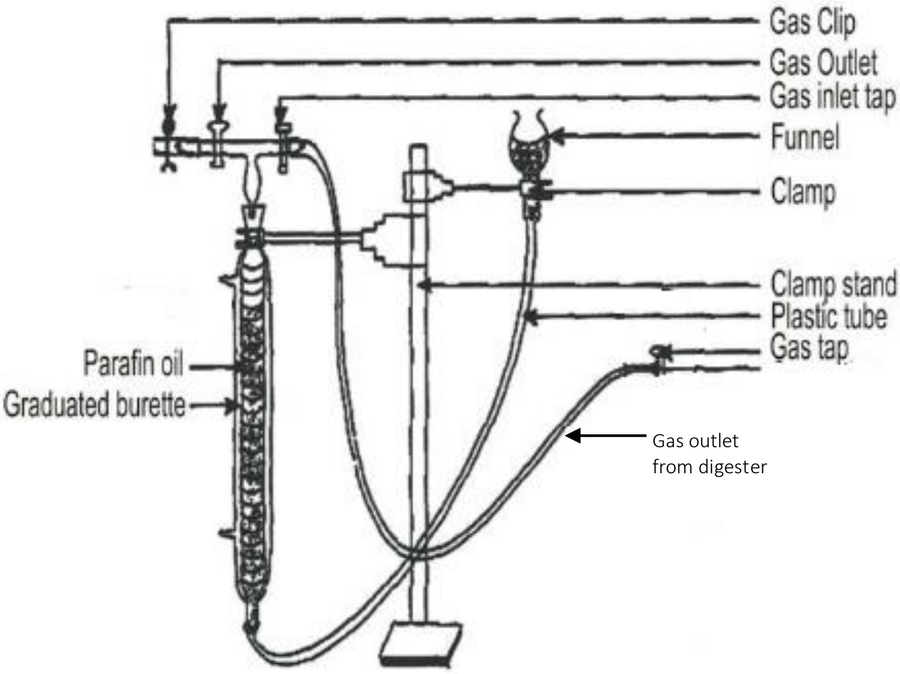

FIG. 1: Gasometric chamber
Source: Asikong et al (2012)

PLATE 3.1c: Digester (control)

PLATE 3.1d: Digester (catalysed)

PLATE 3.1e: Insulating box (catalysed)

PLATE 3.1f: Experimental setup (digester and gasometric chamber)

Experimental Procedure for Biogas Generation

Control

Six kilograms of palm oil mill effluent were diluted with six litres of water to 8.5 litres. That is a POME to water ratio of 1:1 (PLATE 3.2).

Catalysed

This is the experimental batch with seed or bacteria inoculuar. Six kilograms of palm oil mill effluent were mixed with 6litres (i.e. a 1:1 ratio). The catalyst was prepared by mixing 1kg of fresh cow dung with 0.5kg of activated carbon and a litre of water. This mixture was allowed to stand for a while and later poured into the POME mixture followed by proper stirred for uniformity. The advantage of using activated carbon as support is due to its availability, mildness and also because it poses no problem of cell and enzyme inactivation. On the other hand, the choice of fresh cow dung is due to the fact that it is a known methane producing substrate and also has a rich microbial content. Moreover, it has been noted that ruminants have methanogenic bacteria in their intestines. Also, to maintain the temperature of the catalysed digester, hot water was put into the copper pipe every other day.

Procedure for data Collection

The digesters were agitated vigorously as often as possible. This helped in ensuring uniform distribution of microbes within the substrate. In the catalysed experiment, hot water was introduced into the hot water pipe every other day to enhance the digester temperature. Biogas readings were recorded every 10th day for total of 110 days. The biogas generated in the digester was released by opening the outlet stopper of the digester allowing the gas to flow through the gas tube which then displaced the paraffin oil in the graduated burette downward. The volume of biogas generated was gotten from the volume of paraffin oil displaced. That is, the volume of biogas generated was directly proportional to the volume of displaced paraffin oil.

RESULTS AND DISCUSSIONS OF THE FINDINGS

The biogas production result from TABLES 1a, 1b and FIG. 2 show that the catalysed substrate produced more gas than the controlled. While the catalysed generated up to 19,402.5 ml (equivalent to 0.0194025m^3) of biogas, the controlled only produced 27.00ml (equivalent to 0.000027m^3). Also, biogas production in the catalysed setup was evident on the 10th day of the experiment while in the control, biogas production was only evident on the 20th day of the experiment. Methane production in this study was determined by burning (PLATES 1a – 1d). This was supported by the statement that the main combustible component of biogas is methane (Abbas, 2013). There was no evidence of methane production in the control because the gas did not burn. This means other gases were produced but methane was absent, or the methane concentration was extremely low for ignition.

On the other hand, there was evidence of methane production in the catalysed setup on the 30th day but the gas did not burn with a blue flame, it burned with a yellowish flame. However, on the 40th and 50thdays of the experiment with a production of 161ml (equivalent to 0.000161m^3) and 170ml (equivalent to 0.00017m^3) respectively, the biogas from the catalysed setup burned with a mixed yellow and blue flame. However, from the 60th day, the gas burned with a clear blue flame indicating a high concentration of methane build up in the digester. The highest quantity of biogas (5,000ml, equivalent to 0.005m^3) was gotten on the 70th day of the experiment. Biogas production in the catalysed setup increased steadily from the 10th day to the 70th day and dropped steadily from the 80th day to the end of the experiment. This is in line with the conclusion by Tan *et al.*, 2015, which states that methane production increases steadily in the course of biogas production when the quantity of carbondioxide drops.

Table 1a: Biogas production in the control and catalysed experimental setups in millilitres (ml)

	Duration (Days)	10	20	30	40	50	60	70	80	90	100	110	Total
Biogas production (ml)	Control	00	25	00	2	00	00	00	00	00	00	00	27.00
	Catalysed	7.5	22	96	161	170	3,140	5,000	4,650	3,658	1,502	996	19,402.5

TABLE 1b: Biogas production by control and catalysed experimental setups in cubic metres (m^3)

	Duration (Days)	10	20	30	40	50	60	70	80	90	100	110	Total
Biogas production (m^3)	Control	00	0.000 025	00	0.000 002	00	00	00	00	00	00	00	0.000 027
	Catalysed	0.000 0075	0.000 022	0.000 096	0.000 161	0.00 017	0.00 314	0.005	0.00465	0.00 3658	0.001 502	0.000 996	0.019 4025

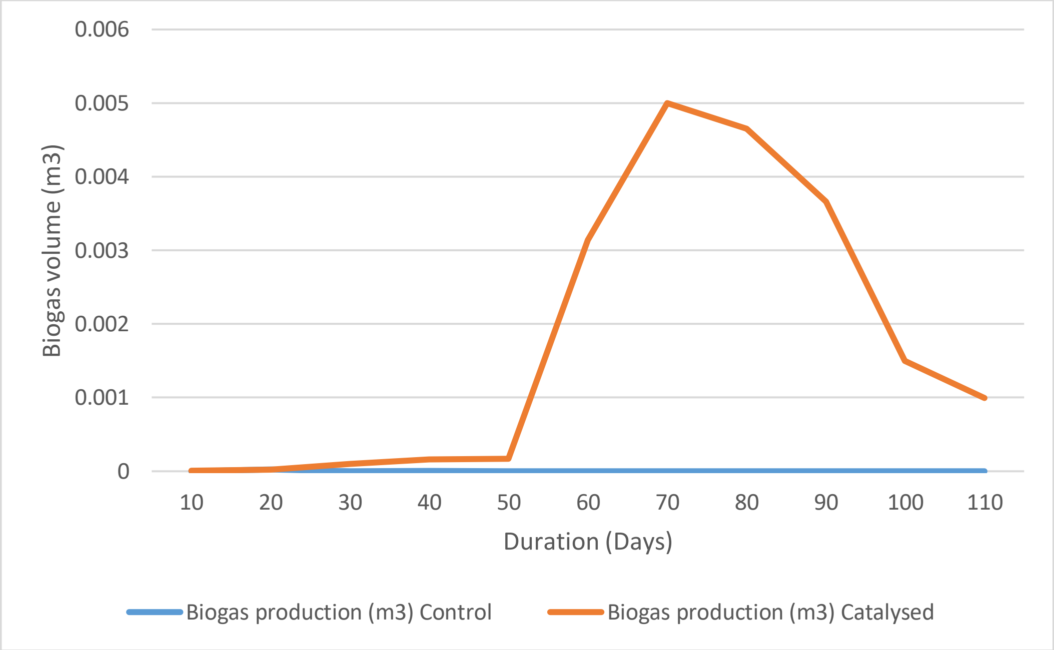

FIG. 2: Biogas production by control and catalysed experimental setups

PLATE 1a

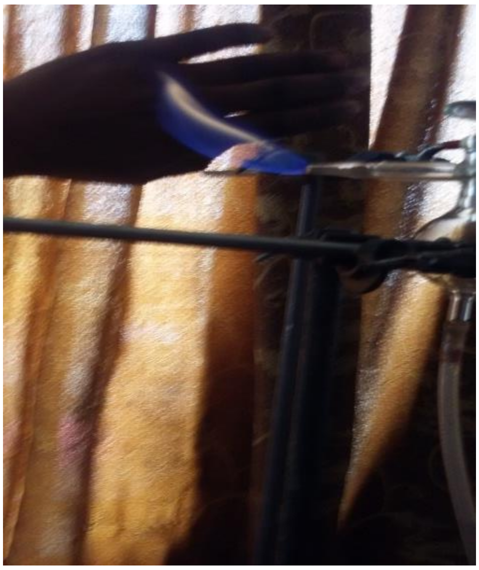

PLATE 1b

PLATES 4.1a and 4.1b: burning of gas (gas burns with a mixture of blue and yellow flame indicating high methane content. Yellow flame indicates the presence of other gases)

PLATE 1c

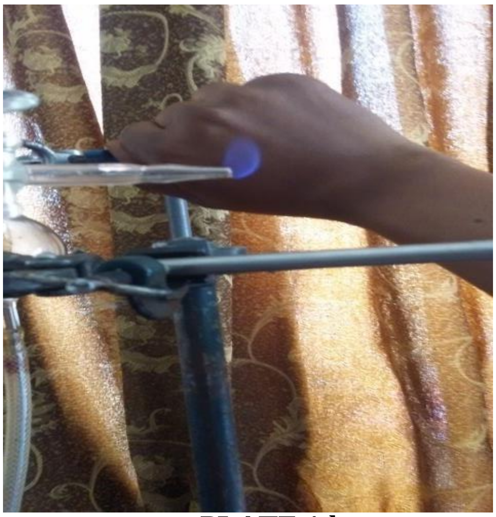

PLATE 1d

PLATES 4.1c and 4.1d: burning of gas (gas burns with visible pure blue flame indicating very high methane content)

CONCLUSION

It is possible for biogas to be generated without methane or with just with a very low methane content. Burning of biogas tells whether or not it contains methane whereas the intensity and colour of the flame could serve as a good indicator of the methane concentration in biogas. Visible clean blue flame indicates very high methane concentrations. The result of this study also leads to the conclusion that biogas production during anaerobic digestion gradually builds up with time and then starts dropping with depleting nutrient content of the feedstock.

From the findings of this study, it is recommended that: a similar study should be carried out with the aim of investigating what affects biogas generation most, whether it is temperature, pH, pressure or catalyst. This is because this study has revealed that biogas can still be generated at pH values of less than 5, which is contrary to the 'no biogas production' at pH values of less than 5 stipulated by other researchers; more research on other microbial manipulations of the substrate should be done with the aim of improving on the amount of biogas that can be obtained from POME; other catalysts can be used to increase the volume of biogas generated within a shorter period of time.

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