AN INVESTIGATION INTO THE ENERGY POTENTIAL OF ABATTOIR WASTE AND PALM OIL MILL EFFLUENT

C. O. Sam-Anyaoma & S. A. Anjorin
Department of Mechanical Engineering, Federal University of Technology, Akure
PMB 704, Akure, **NIGERIA**

ABSTRACT

This research work investigated the energy potential from the co-digestion of abattoir waste (AW) and palm oil mill effluent (POME). Three anaerobic digesters were employed for this research work. Substrates were collected from various abattoir (Slaughterhouses) around Akure metropolis and a palm oil mill at Ibule near Akure. The substrates were mixed together and characterized before being fed into the digesters in the following proportion; digester A (67% AW + 33% POME), digester B (33% AW + 67% POME) and digester C (50% AW + 50% POME). The digester was equipped with a thermometer for daily temperature monitoring while the pH of the substrates was monitored weekly. The average minimum and maximum temperature for the digesters were recorded to be 26.3^{o}C and 31.5^{o}C which indicates that the biogas were produced in the mesophilic range. The pH values were also recorded to be between 6.8 - 7.4, 6.4 - 7.6, and 6.6 – 7.3 for digesters A, B and C respectively. The volume of biogas produced by 1 kg of each substrate were calculated to be 0.0325 m^3/kg, 0.0311m^3/kg and 0.022m^3/kg for digesters A, B and C respectively. Hence, co-digestion of abattoir effluent and palm oil mill effluent has a high potential to be used as a renewable source of energy.

Keywords: Abattoir effluent, palm oil mill effluent, bio-gas, bio-reactor, characterization.

INTRODUCTION

Biomass is defined as an organic material, available on renewable basis, which are produced directly or indirectly from living organisms without contamination from other substances or effluents (Diji, 2013). Biomass encompasses materials derived from plants, animals, humans as well as their wastes. Depending on the characteristics of wastes, they can be converted into energy and/or fuel by combustion, gasification, co-firing with other fuels and ultimately by anaerobic digestion (Federal Energy Management Program, 2004).

According to International Energy Agency (IEA 2010), the total primary energy demand (TPED) for Africa is predominantly determined by biomass demand with almost half of the energy demand (47.9%) being covered by biomass and waste. IEA projects a decline in the total energy share of biomass and wastes by 2035, but biomass will still continue to remain an important energy resource for Africa in the future (IEA, 2010).

As the world's population continues to increase with its associated rapid development, especially in areas where the demand on fossil resources had been very low per capita, it is expected that the energy and material needs of human society will become unprecedented in the near future. This will lead to more demands and increasing cost of fossil resources for energy, fuels, chemicals and materials. It has also become apparent that fossil fuels emit greenhouse gases and the continued emissions of these gases are influencing the world climate. The reduction of global demand for fossil fuel resources has been proposed as a major strategy to better the effects of climate change (Okorie, 2010).

Bio-energy has been recognised as one of the solutions to energy future. It is a renewable source of energy that can provide heat, electrical energy, and transportation fuels which can reduce CO_2 emissions, Sulphur and Heavy Metals in the atmosphere (Okorie 2010). Biomass also has the potential of improving rural income and energy security.

A lot of researchers have worked on biogas technology in Africa and the world at large. Budiyono *et al* (2011) studied the potential and characteristics of slaughter-house waste for biogas production. Rabah *et al* (2010) investigated the biogas production potential of abattoir waste at different retention time using the fresh content from cattle rumen. Ohimain and Izah, (2014), evaluated the biogas potential of palm oil mill effluent (POME) that is being discharged to the environment without treatment from 2004 to 2013. Linne *et al.*, (2008) studied the biogas potential of cattle and pig manure in Sweden and resolved that cattle and pig manure is capable of producing 2.7 TWh/year and 0.5 TWh/year respectively.

Nigeria is a developing country and her technological endowment has not reached a very high level of development. To a large extent, the use of traditional biomass is still predominant, although appreciable progress is being made towards making the economy more market oriented. Biomass resources available in the country include: Agricultural crops, agricultural crop residues, fuel wood and forestry residues, waste paper, sawdust and wood shavings, industrial wastewater, palm oil mill effluent, residues from food industries, energy crops, animal dung/poultry droppings, industrial effluent/municipal solid waste etc. (Sambo, 2009; Edirin and Nosa, 2012).

Bio-energy holds great potential for better energy future in Nigeria due to the continual bombing of pipelines. This is one of the major reasons this research work is embarked on. Other reasons include, the susceptibility to depletion of fossil fuels as well as their negative environmental impact. This however can be doused, since bio-energy portends better prospects for future energy sustainability and a cleaner environment.

MATERIALS AND METHODS.

Materials

Materials used in this research were palm oil mill effluents (POME) which was collected from a palm oil mill in Ibule, Akure south local government area and waste from abattoir including by-products such as; blood, sludge, water, stomach content as well as paunch. Abattoir waste was collected from different abattoir (slaughter house) in and around Akure metropolis. A clean container with cover was used for the collection of the samples. The samples were transported immediately to the Department of Chemistry at The Federal University of Technology, Akure for characterization before it was fed into the digester.

Apparatus and Equipment

The apparatus and equipment used for this research are as follows;

Bio-Reactor

In this study, the three digesters employed were of laboratory scale and constructed from plastic with a volume of 4 litres each. Each digester was equipped with thermometer for daily temperature check and pH check point to allow for pH check. A gas outlet was connected to the top of the digester fitted with a control valve. The other end of the gas outlet was connected to a gas holder for storage of the biogas produced.

Bio-Gas Cylinder

This was used to collect the non-condensable gas (bio-gas) digester. It is a locally sourced refrigerant cylinder. It has a resistance to heat and equipped with a pressure valve to avoid leakages. It is connected to the gas pipe with aid of manifold hose.

Weighing balance

Digital top weighing balance with weighing scale accuracy of 0.001g was used to measure the mass of the samples before and after digestion.

Design and Construction of Bio-Reactor

The design consideration of the bio-reactor was based on the diameter of the bio-reactor and calculated as follows.

Design of the Digester

(a) Volume of the Digester

The volume of the digester was obtained using equation (1).

$$V_T = \frac{\pi d^2}{4} \quad (1)$$

where d is the diameter of the digester (m), h is the height of the digester (m) and V_T is the total volume of the digester in (m^3)

(b) Maximum Pressure in the Digester

The pressure expected in the digester was calculated based on the following assumptions;

1. The biogas to be produced would comprise mainly of methane (CH_4) 60% and carbon dioxide (CO_2) 40% by volume.
2. The substrate (feedstock) would occupy 3/4 the total volume of the digester
3. One kg of cow dung can produce 0.037m^3 of biogas (Rouf and Haque, 2008).

Thus, the maximum pressure expected in the digester is given by equation (2) (Dalton's law of partial pressure).

$$P_T = P_{CH_4} + P_{CO_2} \quad (2)$$

where P_T is maximum expected pressure, P_{CH4} is partial pressure of methane, P_{CO2} is partial pressure of carbon dioxide. The schematic diagram of the bio-reactor is shown in Figure 1 and experimental setup of the process in plate 1

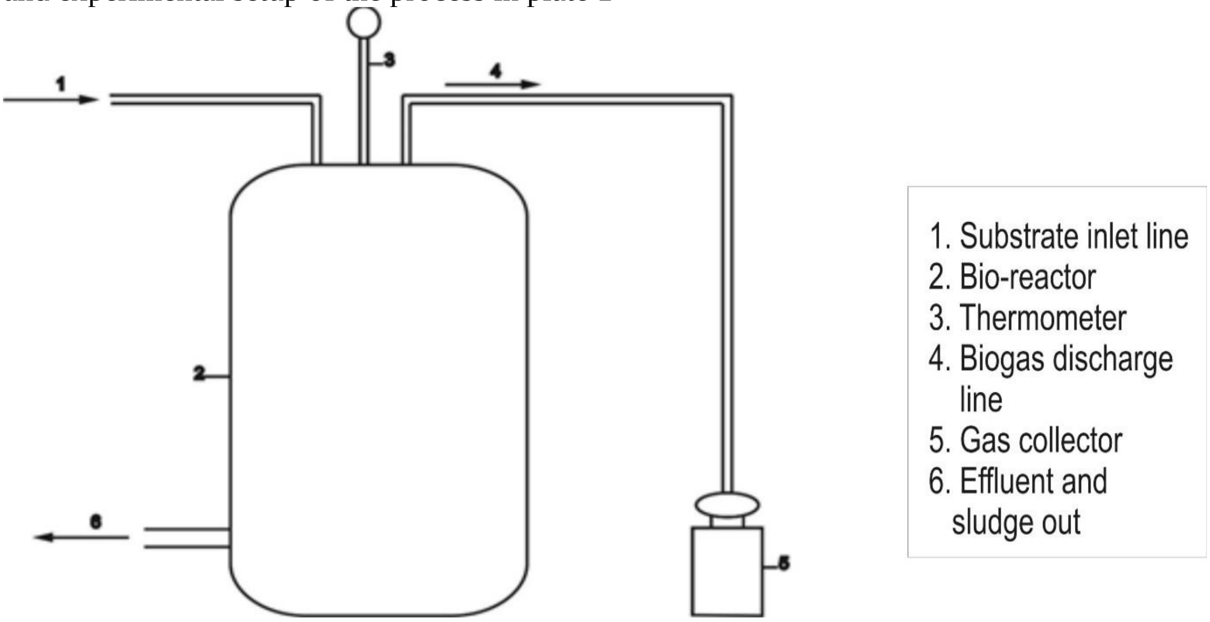

Fig. 1: Schematic diagram of the bio-reactor, measuring unit and gas collector

Plate 1: Experimental setup of the process.

Characterization of Substrates

The main source of abattoir waste (AW or slaughterhouse waste water) is the faeces, urine, blood, hair, fat, carcasses, non-digested food in the intestines of the slaughtered animals, production leftovers and the cleaning of the facilities (Bustillo-Lecompte *et al.* 2016). The AW composition varies according to the industrial process and water demand. However, they usually contain high levels of organics and nutrients, and these organics and nutrients was characterized as biological oxygen demand (BOD), chemical oxygen demand (COD), total solids (TS), volatile solids (VS), and total suspended solids (TSS).

Substrate mix ratio

A total of three (3) ratios of abattoir waste and palm oil mill effluents were evaluated. Table 1 shows the different mix ratios. Each experimental run was evaluated over a given period of 30 days.

Table 1: Mix ratio of abattoir waste to palm oil mill effluent

	Mix Ratios	
S/N	**Abattoir Waste (%)**	**POME (%)**
1	67	33
2	33	67
3	50	50

Monitoring of process parameters

The process parameters monitored were Temperature and pH. The temperature was monitored on a daily basis, while the pH was monitored on a seven days interval basis. The temperature of the substrate was measured using a mercury-in-glass laboratory thermometer calibrated in degree Celsius, while the pH value was determined using a hand held digital pH meter. The pH meter was calibrated weekly using buffer 4 and buffer 7 solutions.

Volume of Biogas produced

The volume of biogas produced during the period of the experiment (30 days) was determined using equation (3)

$$V_g = \frac{M_b + M_a}{\rho} \quad (3)$$

Where V_g is the volume of biogas produced (m^3), M_b is the mass substrate at day 1 (kg), M_a is the mass of substrate after 30 days retention time (kg), ρ is the density of biogas (kg/m^3)
The volume of gas produced by 1kg of each substrate was calculated using equation (4)

$$V_u = \frac{V_g}{M_b} \quad (4)$$

Where; V_u is the volume of biogas produced per kg of substrate (m^3/kg), V_g is the volume of biogas produced (m^3) and M_b is the mass substrate at day 1 (kg).

RESULTS AND DISCUSSION

Characterization of Substrate

The characterization of substrates A (67% AW + 33% POME), B (33% AW + 67% POME) and C (50% AW + 50% POME) are given in Table 2.

Table 2: Characterization of Substrates

Parameters (mg/L)	A	B	C
BOD	19,450	22,230	20,840
COD	35520	43270	39400
TS	16,945	32,315	24,630
	6420	19,905	10,281
TSS	6.8	6.4	6.6
pH			

Note: All values are in mg/L except for pH.

pH concentration

The pH value is regarded as a key indicator of operational stability in anaerobic digestion. It gives an approximate indication on the fermentation process. Optimum pH value for anaerobic digestion process is between the range of 6.5 to 7.5 (Lazor *et al* 2010). During the period of the experiment, the pH value for digester A (67%AW + 33%POME) varies between 6.8 and 7.5, while for digester B (33%AW + 67%POME), the pH value varied from 6.4 to 7.6, and the pH value for digester C (50%AW + 50%POME) varied from 6.6 to 7.3 as shown in figure 2. The initial pH decrease in digester A shows an increase in volatile fatty acids (VFAs) production by acidogenic bacterial as well as carbonic acid to high concentration of carbon dioxide gas. The easily digestible fraction of organic matter was hydrolysed and converted to fatty acids rapidly. The pH began to rise gradually as the Volatile Fatty Acids (VFA) was consumed by the methanogens to produce methane. The substrate was able to buffer itself and prevented the acidification occurrence during digestion which was also reported by Pritima and Bhakta (2015).

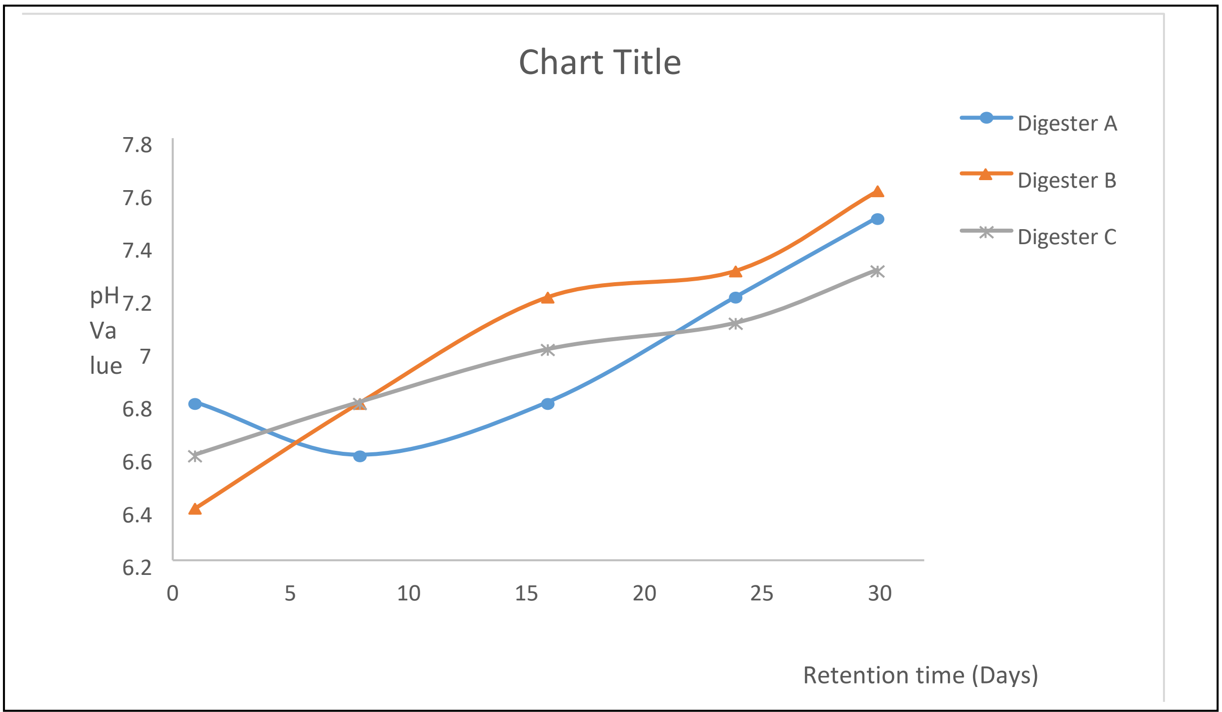

Figure 2: Graph of pH values against time for digesters A, B and C

Temperature

The graph of the ambient and digester temperature temperatures monitored at 9.00 am daily is shown in Figures 3, 4 and 5. There is a difference between the digester temperature and the ambient temperature. The temperature in the digesters was observed to be higher than the ambient temperature due to the fact that environmental temperature become so low especially when it rained the previous night as the anaerobic reaction is exothermic. From Figure 3 the highest temperature in the digester was observed to be 32 ^oC (305 K), while the lowest temperature was observed to be 27 ^oC. Figure 4 shows the plot of temperature for digester B against retention time and from the graph, the highest temperature was observed to be 31.5 ^0C (304.5 K) while the lowest was observed to be 26 ^oC (299 K). Figure 5 illustrate the relationship between ambient and digester temperatures at varying retention time.

The highest temperature was recorded to be 31 ^oC (304 K) while the lowest was recorded to be 26 ^oC (299 K). This indicates that anaerobic digestion took place at the mesophilic temperature range of 26 ^oC – 43 ^oC as stated by Aremu and Agary (2012); Yaru *et al* (2015).

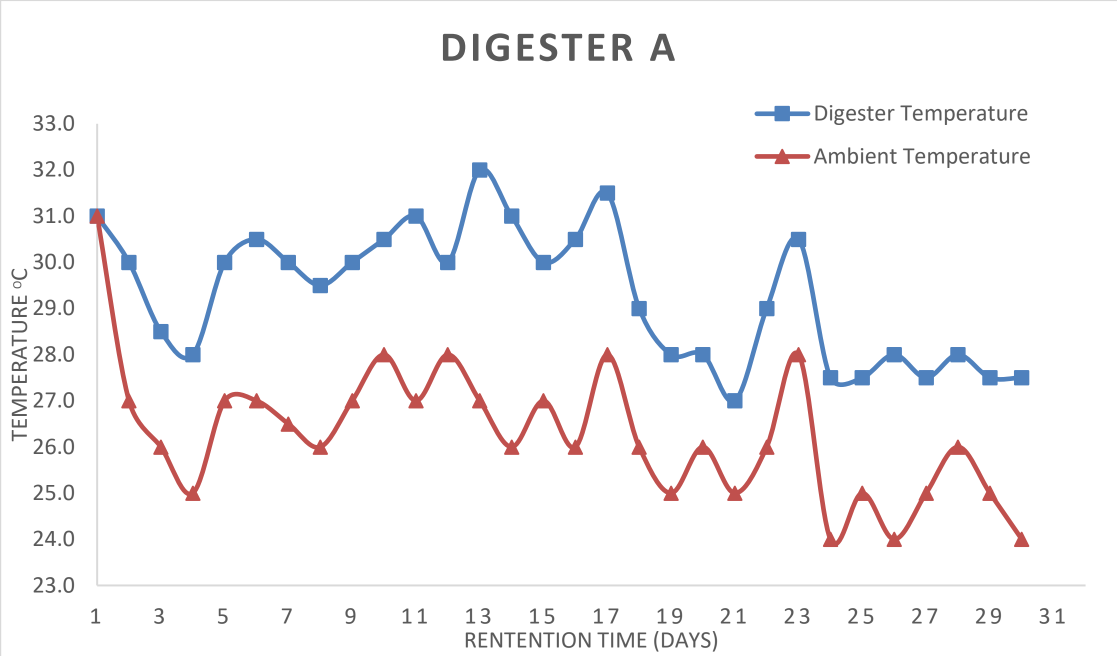

Figure 3: Temperature and Retention time (Days) relationship for digester A

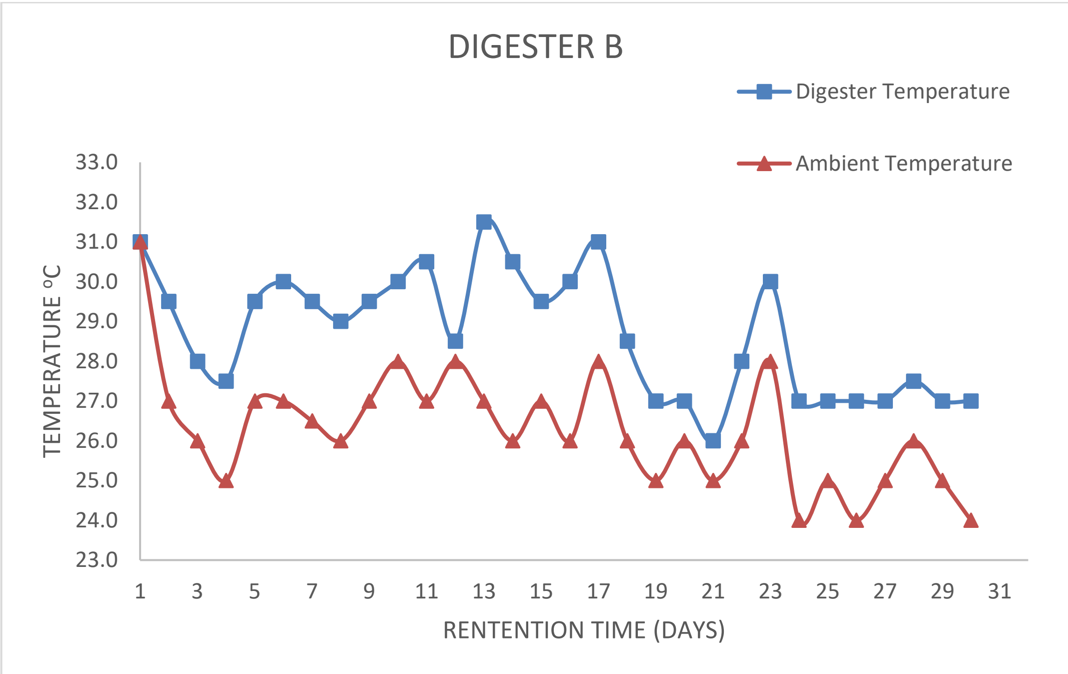

Figure 4: Temperature and Retention time (Days) relationship for digester B

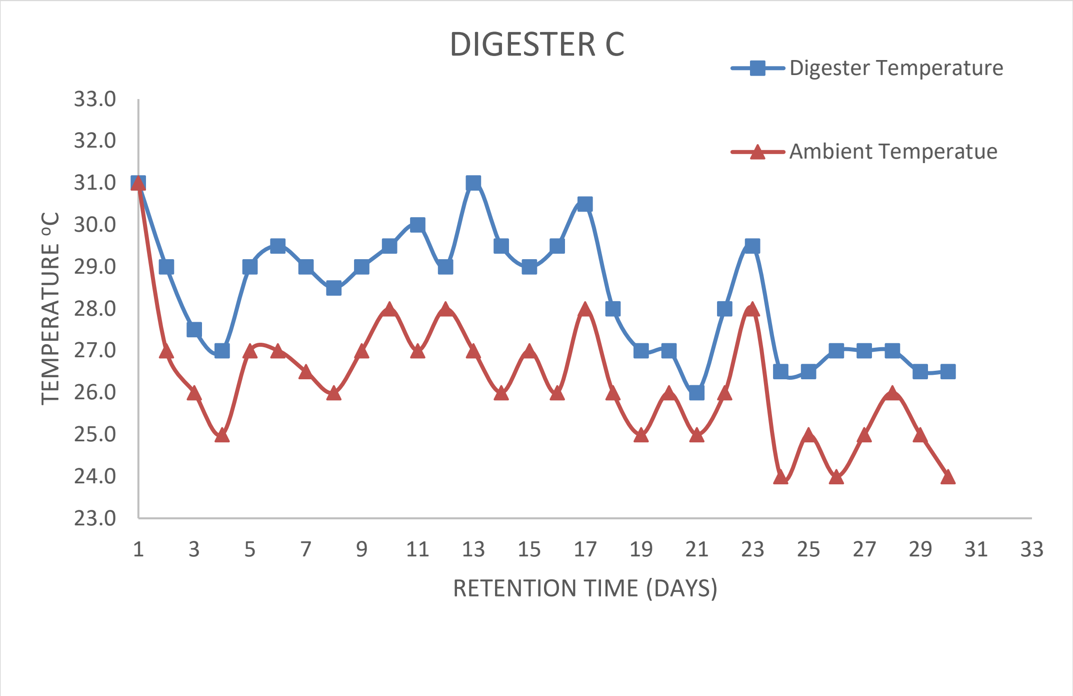

Figure 5: Temperature and Retention time (Days) relationship for digester C

Volume of gas produced

Table 3 shows the weight of the digesters measured at the beginning of the experiment and the end of the experiment.

Table 3: Weights of digesters day 1 and day 30

Digesters	Initial Weight (kg)	Weight at day 30 (kg)
A	1.508	1.452
B	1.522	1.460
C	1.6055	1.564

From Table 3, it can be seen that there was a reduction in the weight of the digesters at the end of the experiment, which points to the fact that biogas was produced. When the values of reduction in weight were substituted into equation (3), the results shows that; digester A produced a total 0.0487 m^3 volume of biogas, digester B produced a total 0.047391 m^3 of biogas, while digester C produced a total volume of 0.036 m^3 of biogas. These volumes of biogas were produced with the weight of substrate as 1.508 kg, 1.522 kg and 1.6055 kg for digester A, B and C respectively. Thus, the specific volume of biogas produced per kg of substrate is 0.0323 m^3/kg, 0.0311 m^3/kg and 0.0224 m^3/kg for substrate A, B and C respectively.

CONCLUSION

This research work shows that the co-digestion of Abattoir Waste and POME shows a promising result in biogas production by anaerobic digestion under mesophilic temperature (25 ^oC to 35 ^oC) conditions. The characterization of the substrates shows an average ratio of BOD to COD of about 0.53, indication the presence of high biodegradable organisms. From the results, substrate A (67% AW + 33% POME) produced the highest volume of biogas per kilogram (0.0325 m^3/kg) while substrate B (33% AW + 67% POME) and C (50% AW + 50% POME) produced a volume of 0.0311 m^3/kg and 0.022 m^3/kg of biogas respectively.

These results show that the co-digestion of slaughterhouse effluent with palm oil mill effluent can be a good feedstock for the production of biogas.

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