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Original Research Article

Investigation of Biogas Yield from Blend of Cassava Peel and Water Hyacinth

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Abstract: In this research work, a blend of cassava peel and water hyacinth were co-digested to generate energy through biogas production. A 0.030 m^3 anaerobic digester was used to digest 55 kg of the blend of cassava peel and water hyacinth. The ratio of mixture of cassava peel to water hyacinth was 3:1. The mixture was properly ground, mixed and charged into the mild steel digester under mesophilic slurry temperature range of 32 ^oC to 37 ^oC. The results obtained showed that a minimum pressure reading of 148.438 kPa and a maximum pressure reading of 170.659 kPa were obtained. This suggests sufficient microbial activities in the digester, thus, good biogas production. The analysis of biogas yields showed that an average of 0.005148 m^3 of biogas was generated and this gives an average of 0.0121 kWh of electricity.

Keywords: Biogas, Energy generation, Water Hyacinth, Cassava peel, Co-digestion.

INTRODUCTION

The generation of a combustible gas from anaerobic digestion process, is a well-known technology. There are already millions of biogas plants in operation throughout the world. Whereas using the gas for direct combustion in household stoves or gas lamps is common, producing electricity from biogas is still relatively rare in most developing countries (Appels *et al.,* 2008). In industrialized countries, power generation is the main purpose of biogas plants; conversion of biogas to electricity has become a standard technology. The energy content of the gas depends mainly on its methane content. High methane content is therefore desirable. A certain carbon dioxide and water vapour content is unavoidable as earlier discussed, but sulphur content must be minimized - particularly for use in engines. The average calorific value of biogas is about 21-23.5 MJ/m³, so that 1 m³ of biogas corresponds to 0.5-0.6 l diesel fuel or about 6 kWh (FNR, 2009). Theoretically, biogas can be converted directly into electricity by using a fuel cell. However, this process requires very clean gas and expensive fuel cells. Therefore, this option is still a matter for research and is not currently a practical option. The conversion of biogas to electric power by a generator set is much more practical. In contrast to natural gas, biogas is characterized by a high knock resistance and hence can be used in combustion motors with high compression rates. In most cases, biogas is used as fuel for combustion engines, which convert it to mechanical energy, powering an electric generator to produce electricity. In theory, biogas can be used as fuel in nearly all types of combustion engines, such as gas engines, diesel engines, gas turbines and Stirling motors etc.

Furthermore, Nigeria's increasing population has contributed greatly to sustained demands for energy source that is renewable and readily available. At presence, the major means of energy generation in Nigeria is from fossil and wood fuels which have huge negative effect on our environment especially the ozone layer depletion. Also, there is possibility of scarcity of fossil and wood fuels in the future. However, large percentage of solid waste generated and dump indiscriminately in an open dump site can be useful to us if properly harnessed. Waste management situation in Nigeria currently requires concerted effort to sensitize the general public on the need for proper disposal of solid waste (Igbinomwanhia *et al.,* 2012; Titus and Anim, 2014). The problems of inadequate generation of energy and poor solid waste management are enormous and require urgent attention (Orhorhoro *et al.,* 2017a). Therefore, there is need to exploit all available options that will ameliorate the situation. Production of biogas from organic fraction of generated solid waste will contribute to the country's energy mix and reduce the effect of increased waste generation in Nigeria. In Nigeria today, there is epileptic power supply which has crippled the economy of the country. This is so because Nigeria depends mainly on fossil fuel and wood fuel as means of energy generation (Ebunilo, *et al.*, 2016). This continuous dependency on fossil fuel as the major sources of energy generation in Nigeria has slowed down the development of alternative forms of energy source (Agbo and Eze, 2011). The use of fossil fuel and wood fuel for energy production in Nigeria are linked with increasing greenhouse gas emissions (Sambo *et al.,* 2005). There are human factors which limits the supply of fossil for power stations leading to this epileptic power supply in Nigeria.

MATERIALS AND METHOD

2.1 Collection of Feedstock

In this present research work, cassava peel and water hyacinth were used as the feedstock. The cassava peel was collected in large quantity from farm within Warri metropolis while the water hyacinth used was collected River Ethiope in Eku, Delta State.

2.2 Preparation and Charging of Feedstock

The roots of the water hyacinth were removed and a grinding machine was used to grind 55 kg of water hyacinth and cassava peel for the formation of slurry. The reason for grinding is to increase the surface area of contact for the microbial activity, so that biogas production would begin within the shortest possible time (Orhorhoro *et al.,* 2017b). The preparation of fermentation of slurry was by addition and vigorous mixing of total feedstock with an equivalent amount of water needed for maximum yield. The ratio of total feedstock to water was 1:2 as recommended by Ebunilo *et al.,* (2015). The mixture was introduced into the batch AD digester (Figure 1 and Figure 2) and observed for 21days. The temperature and pH of the digester was monitored using mercury in glass thermometer and analogy pH meter respectively. The experiment was conducted within a pH range of 6.89 to 7.01 (Table 4) and mesophilic temperature range of 32 ^{0}C to 37 ^{0}C (Table 2). The digester has a capacity of 0.030 m^3 and was fabricated using a mild steel material. The inlet valve for charging of slurry, thermometer for taking the temperature of the slurry, pressure gauge for taking the gas pressure, outlet valve for discharge of slurry, stirrer for continuous stirring of slurry, and gas discharging valve for evacuation of biogas were all connected to the digester.

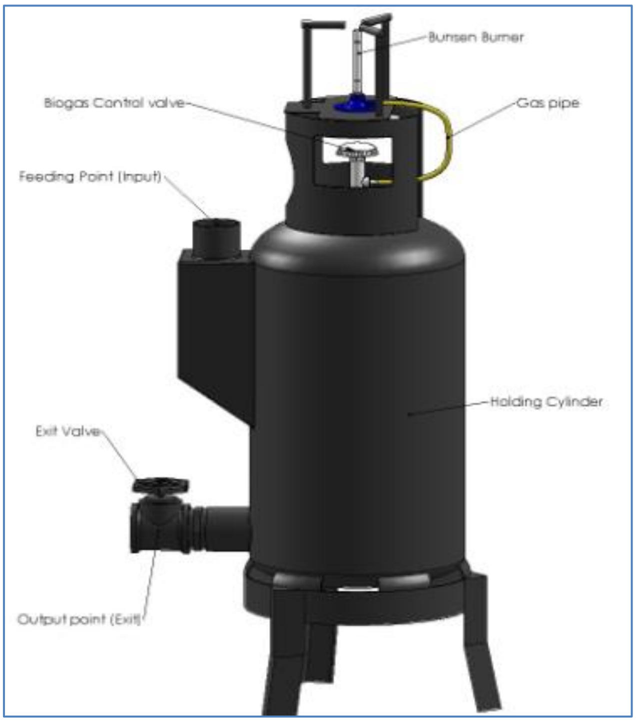

Fig-1: Isometric View of AD Batch Digester

Fig-1: Fabricated Batch AD Digester

2.3 Charging of Feedstock into the Batch AD Digester

This stage involves pressure testing of the batch AD digester and charging of the blend of cassava peel and water hyacinth into the digester. The collected feedstock was thoroughly grinded to increase its surface area, and then mixed with water in ratio of one to two. The mixture is finally charged into the digester and made air tight. The digester content was stirred several times per day with the aim of mixing the substrates inside the digester for efficient biogas generation. 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. The pressure and temperature readings are taken daily and this. The gas generated was determined using displacement method.

RESULTS AND DISCUSSION

The amount of gas produced was measured at 48 hours (2 days) interval after the first ten (10) days using the displacement method. In other words, gas was released from the digester through the valve control into a 1000 cm^3 water level of the measuring cylinder. The measuring cylinder was then inverted with the gas pressure displacing equal amount of water and the readings were recorded. This procedure was repeated ten (10) times to ascertain the total volume of biogas produced. The results obtained are tabulated as shown in Table 1.

Table-1: Volume of Biogas Produced

No	Days	Volume (m^3)
1	10	0.00506
2	12	0.00520
3	14	0.00508
4	16	0.00515
5	18	0.00502
6	20	0.00501
7	22	0.00510
8	24	0.00510
9	26	0.00576
10	28	0.00500
Total		0.0 5148
Average		0.005148

Figure 1 shows the plot of volume of biogas yields against days of production. The results showed that the hydraulic retention time was 28 days. That is, 18 days of continuous biogas yields in interval of two days and the first 10 days of anaerobic digestion without biogas yields. Minimum biogas yields were achieved on the 28th days. However, maximum biogas yield was obtained on the 26st day. The drop in production of biogas on 28th day was as result of completion of digestion. Also, the production rate was not uniform and this was as a result of differences in mesophilic temperature as shown in Table 2.

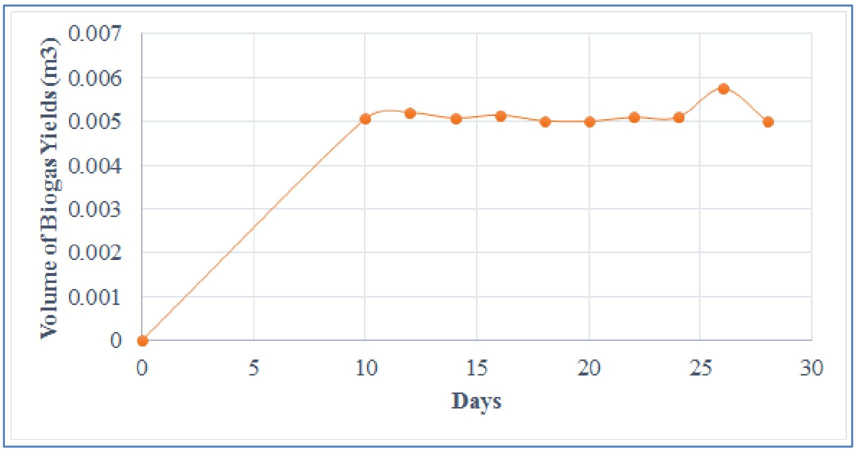

Fig-1: Plot of Volume of Biogas Yields against Days of Production

Table-2: Results of Mesophilic Temperature

No	Days	Volume (m^3)	Ambient Temperature (^0C)
1	10	0.00506	32.00
2	12	0.00520	37.00
3	14	0.00508	35.60
4	16	0.00515	37.00
5	18	0.00502	35.55
6	20	0.00501	34.53
7	22	0.00510	36.00
8	24	0.00510	37.00
9	26	0.00576	36.55
10	28	0.00500	37.00

According to Ebunilo *et al.* (2016), optimum biogas yields are obtained within mesophilic temperature range of 36^0C-37^0C. A good look at Table 2 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.* (2016).

In order to calculate for the pressure of the gas produced, for ideal gas, assuming standard temperature and pressure (STP) before fermentation. From Table 2, the pressure of the biogas at each reading was evaluated using the Boyles law (1).

$$P_1V_1 = P_2V_2 \quad (1)$$

Where,
P_1 = initial pressure of gas = $1\times 10^5 N/m^2$ at standard pressure (SP).
P_2 = final pressure of gas
V_1 = initial volume = 0.00855 m^3 (Measuring cylinder calibration)
V_2 = final volume of gas

Hence, the gas final pressure, P_2, for each volume is given by;
For volume = 0.00506
$P_2 = (P_1V_1) / V_2$
$P_2 = (1 \times 10^5 \times 0.00855) / 0.00506$
P_2 = 168.972 kPa

Similarly, this analysis was used for the calculation of other pressures as obtained in Table 3. The results in Table 3 shows that increase in pressure was as result of improve biogas yields. Therefore, in every pressure build up, there is a biogas yield.

Table-3: Corresponding Pressure of the Volume

No	Days	Volume (m^3)	Final Pressure (kPa)
1	10	0.00506	168.972
2	12	0.00520	164.423
3	14	0.00508	168.307
4	16	0.00515	166.019
5	18	0.00502	170.319
6	20	0.00501	170.659
7	22	0.00510	167.647
8	24	0.00510	167.647
9	26	0.00576	148.438
10	28	0.00500	169.870

The quantity of electricity that can be generated was calculated using Charles (2009) Energy equivalents, the following amount of electricity was determined as depicted in Table 4.

$1m^3$ biogas = 2.14 kWh (electricity) [Charles 2009] (2)

Using energy equivalents as proposed by Charles in 2009, the electricity generation from biogas yields was calculated for a period of 28 days in two days' intervals. The results obtained showed that electricity can be generated on daily basis from mixed substrates of cassava peel and water hyacinth. The results of the pH values at each biogas evacuation as depicted in Table 4 showed that the research work was conducted within recommended neutral pH values for optimum biogas yield.

Table-4: Results of Electricity Generation from Biogas

No	Days	Volume (m^3)	Electricity Generation (kWh)	pH
1	10	0.00506	0.0108	6.98
2	12	0.00520	0.0111	7.00
3	14	0.00508	0.0109	7.00
4	16	0.00515	0.0110	6.99
5	18	0.00502	0.0107	7.02
6	20	0.00501	0.0107	7.00
7	22	0.00510	0.0109	7.01
8	24	0.00510	0.0109	6.99
9	26	0.00576	0.0123	7.01
10	28	0.00500	0.0107	6.89
Total			0.1209	68.89
Average			0.0121	6.99

CONCLUSION

In this research work, biogas was produced from a mixture of cassava peel and water hyacinth. The digester was allowed for ten (10) days to ascertain maximum rate of microbial activities and thereafter, tested for combustion and followed with measurement of the biogas produced. It was observed that optimal biogas production was found to be a function of mesophilic temperature. Significantly, gas production was noted to increase with days. The result of the research work shows that an average of 0.005148 m^3 of biogas was generated.

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