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Investigating the Production of Biogas from Pig Waste and Cattle Dung

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Abstract
A study on the production of biogas from pig waste and cattle dung was carried out. The pig waste and cattle dung were obtained from pig farm and abattoir respectively, and analysed for carbon to nitrogen (C/N) ratio. A biogas digester of 225 L was designed, fabricated and used with a substrate ratio of 1:1 (pig waste or cattle dung to water). The substrate was mixed properly to allow for easy decomposition. The retention time for the experiment was 30 days during which gas samples were collected and analysed using Gas Chromatography Mass Spectrometer. Results obtained showed biogas production of 62.01% methane, 28.52% carbon dioxide, 1.15% oxygen, 1.04% hydrogen sulphide, 0.02% water vapour and 7.26% other impurities from pig waste, while it was 76.22% methane, 20.09% carbon dioxide, 0.08% oxygen, 0.81% hydrogen sulphide, 0.00% water vapour and 2.3% other impurities from cattle dung. The statistical analysis carried out indicated that the collective biogas production pattern is statistically similar for both substrates. Therefore, it is concluded that biogas could be produced from pig waste and cattle dung but that the production of methane, the main gas of interest, would be more with cattle dung than with pig waste.

Keywords: *Biogas, Pig waste, Cattle dung, Digester, Anaerobic, Reactor*

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1. Introduction

There is an increasing worldwide interest in renewable energy sources. Biogas technology, the generation of combustible gas from anaerobic biomass digestion, is a well-known technology which has captured the interest of many due to environmental pollution caused by the use of conventional energy sources (Luostarinen et al., 2011). As the world globalizes, demands for energy sources will increase. Fossil sources meet a large part of this demand but emit greenhouse gases like carbon dioxide, methane, and nitrous oxide, and increase in these gases has been linked to irreversible problem known as global warming. On the other hand, the renewable energy sources have many advantages such as being harmless, cheaper than fossil sources, and inexhaustible. Given the increasing prices of fossil fuels, the need to include renewable energy sources into the current energy system is becoming imperative. There are various types of renewable energy sources, namely solar energy, geothermal energy, wind energy, and biofuel energy. The animal manure is one of the renewable energy sources, which has huge biogas energy potential and readily available.

Direct conversion of biogas to electricity can be achieved with fuel cells, a technology that is still a matter of research. Fuel cells are power-generating systems that convert the hydrogen formed from biogas and oxygen directly into energy. They have extremely low emissions and high electric efficiencies of more than 50%. However, widespread commercial use of fuel cells is yet to be achieved (IEA, 2015). The current practical option is the conversion of biogas to electricity with a generator. Biogas can be used as fuel in a combustion engine, which converts the biogas energy to mechanical power to generate electricity. Biogas can be used as fuel in spark-ignition (gasoline) engines, compression-ignition (diesel) engines, gas turbines, and external combustion (Stirling) engines. An advantage of using biogas in engines is that it has high knock resistance and can be used in engines with high compression ratios. However, biogas has smaller volumetric efficiency in spark-ignition engines and therefore lower power output (Rakoupolos and Michos, 2014). Biogas can be used for small generators (0.5 to 10 kW) and large power plants. The flameless combustion of biogas in combustion engines also has the advantage of combustion stability and low pollutant formation (Hosseini et al., 2014).

The presence of pig waste and cattle dung in the environment can be very problematic, and requires to be managed in a sustainable way to minimize risk to human health, reduce environmental burdens and maintain an overall balance in the ecosystem (Khalid et al., 2011). The ecological consequences are typically drastic, with high level of nutrients such as phosphorous and nitrates leading to spread of waterborne pathogens and growth of harmful algal blooms in surface water. Thus, the anaerobic digestion of organic waste materials, such as farm manure, accompanied by the recovery of methane for fuel, will make an important development in rural sanitation, and could very well substitute (especially in the rural sector) for conventional sources of energy (fossil fuels) which are causing ecological and environmental problems and at the same time depleting at a faster rate (Yadvika et al., 2004). Therefore, the aim of this study was to investigate the production of biogas from pig waste and cattle dung. The objectives were to collect and prepare pig waste and cattle dung, and set up an experimental system to monitor the production of biogas from the substrates.

2. Materials and methods

2.1 Pig waste and cattle dung

The substrates used in this study were pig waste and cow dung. The pig waste was obtained from a pig farm located in Rukpokwu, Obio-Akpor, Rivers State, Nigeria. The cattle dung was obtained from an Abattoir in Rukpokwu, Obio-Akpor, Rivers State, Nigeria. Both samples were scraped from the floor with a spade and bagged and then transported to the laboratory for characterisation.

2.2 Preparation of pig waste and cattle dung

Both the pig waste and cattle dung were first of all weighed then mixed with water in a bucket to form slurry to facilitate composting for quick production of biogas. The mix ratio adopted was ratio 1:1 for both the pig waste and the cattle dung.

2.3 Experimental system

The biogas reactor comprised a digester tank (plastic drum) of 600mm inner diameter and 900mm depth with influent and effluent pipes and an external gas holder (Fig. 1). The biogas digester tank had a total of 3 holes, 2 on the lid (inlet hole and gas outlet) and 1 on the body of the barrel. The inlet hole was bigger than the gas outlet. The dimensions of the holes were as follows: 2 inches for the inlet, 1.5 inches for the outlet and ½ inches for the gas outlet.

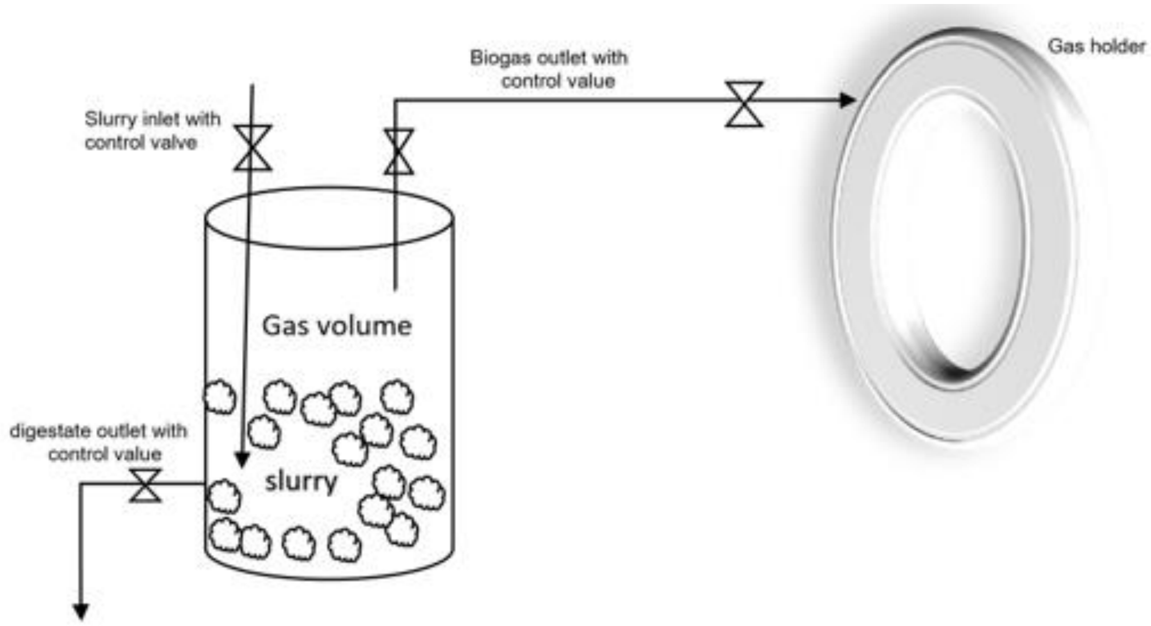

Fig. 1: Biogas digester system

2.4 Experimental system setup

After fabrication, the digester was tested for leakage using water and then emptied afterwards. Before introducing the two samples into the digester, the samples were taken to the laboratory to check for carbon to nitrogen (C/N) ratio. Thereafter the substrates were introduced in turns into the system and mixed with water to a ratio of

1:1. The weight of each substrate was 100 kg while the water was 100 L. Each substrate and water were thoroughly mixed to obtain a homogeneous mixture and then poured into the digester. Each setup was allowed for a period of 30 days. The biogas collected in the gas holder was sent to the laboratory for analysis.

2.5 Sample analysis

The collected biogas sample was analysed using Agilent 6890N Gas Chromatograph with Agilent 5975 Mass Selective Detector. Gas injections using a gastight syringe and pressure measurements were conducted in an ultrapure He stream. A 200-µl gas sample was injected using a gastight syringe (PS-050033, Valco Instruments Co. Inc.) via the injection port into either a 25- or 50-µl sample loop (AL25CW and SL50CW, respectively, Valco Instruments Co. Inc.) that were fitted to the 8-port valve. Once the sample loop was filled with an injected sample, the valve was switched on manually to supply the gas sample to the GC separation column. By using the 8-port valve fitted with two sample loops, precise injections with two different amounts (25 and 50 µl) could be accomplished. Between sample injections, the injection port and the two sampling loops were flushed with ultrapure He. Sampling needles and syringes were also flushed with a stream of ultrapure He immediately prior to each sampling. A coiled stainless-steel tube (50 cm × 1 mm in diameter) was attached to the split gas vent port and the purging gas vent port for septum injection to prevent the backflow contamination of ambient air. For GC separation, a 200-µl sample was injected via the sample loop into the separation column, which was heated at 50 °C, with a split ratio of 30. Ultrapure He at a flow rate of 2.0 ml min^{-1} was used as a carrier gas. For the MS detection after the electron-impact ionization, the detection voltage was set at 0.8 kV. Mass spectra were obtained in the selected ion monitoring (SIM) mode to ascertain higher sensitivity and selectivity then the percentage composition and gas profile of individual waste substrate was obtained.

3. Results and discussion

3.1 C/N ratio of substrates

Table 1 shows the result for C/N ratio of pig waste and cattle dung. The pig waste has C/N ratio that is almost twice higher than that of the cattle dung. According to Igbum (2019), a higher C/N ratio results in lower biogas production, because the lower nitrogen will be consumed rapidly by the methanogenic bacteria for meeting their protein requirements and will no longer react with the leftover of carbon remaining in the material.

Table 1: C/N ratio of substrates

Sample	C/N
Cattle dung	1.58
Pig waste	3.05

3.2 Biogas composition by substrate

Table 2 presents the concentration in percentage of the various constituents of biogas generated from the studied substrates. As expected of a methanogenic process, the biogas comprised majorly of methane and carbon dioxide. The concentration of methane, the main biogas constituent, was higher for cattle dung than for pig waste, indicating that cattle dung is a better substrate for biogas production than pig waste. This result was expected as the C/N ratio for cattle dung (1.58) is almost twice as low as the C/N ratio for pig waste (3.05), and in agreement with Luostarinen (2011) who reported that a high C/N ratio is an indication of rapid consumption of nitrogen by methanogens and results in lower gas production. Similar percentage of biogas constituent was reported by Anusha (2020) for cattle dung.

Table 2: Composition of biogas from substrates

Compound	**Concentration (%/vol.)**	
	Pig waste	**Cattle dung**
Methane	62.01	76.22
Hydrogen	0.89	0.58
Carbon monoxide	1.18	1.03
Carbon dioxide	28.52	20.09
Hydrogen sulphide	1.04	0.81
Water	0.02	0.00
Nitrogen	5.19	1.19
Oxygen	1.15	0.08

3.3 Statistical analysis

The Analysis of Variance (AONOVA) and t-test outputs of the test for significant difference between pig waste and cattle dung biogas composition percentages are shown in Tables 3 and 4, respectively. For both ANOVA (p-value > 0.05) and t-test (t-statistic < t-critical), the results show that there is no significant difference between the biogas composition percentages from pig waste and cattle dung. The ideal carbon to nitrogen ratio for anaerobic digestion is between 20:1 (20) and 30:1 (30) (Yadvika et al., 2004; Khalid et al., 2011;

Poliafico, 2007). A comparison of these sets of values shows that the C/N ratios obtained from this study are below the optimum values of the C/N ratios and could be the reason both results are statistically similar.

Table 3: ANOVA result of significant difference between percentage composition of biogas from the two substrates

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0	1	0	0	1	4.60011
Within Groups	8406.728	14	600.4806			
Total	8406.728	15				

Table 4: t-test of significant difference between percentage composition of biogas from the two substrates

	Variable 1	*Variable 2*
Mean	12.5	12.5
Variance	491.4508	709.5103429
Observations	8	8
Pearson Correlation	0.981786839	
Hypothesized Mean Difference	0	
df	7	
t Stat	-2.43807E-17	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.894578605	
P(T<=t) two-tail	1	
t Critical two-tail	2.364624252	

4. Conclusion

The production of biogas from cattle dung and pig waste has been investigated. Pig waste with 3.05 C/N ratio produced 62.01% methane while cattle dung having 1.58 C/N ratio produced 76.22% methane. Both substrates have C/N ratio below the ideal C/N ratio for anaerobic digestion hence were seen to be statistically similar. It is therefore concluded that biogas could be produced from pig waste and cattle dung but that the production of methane, the main gas of interest, would be more with cattle dung than with pig waste.

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