Production of Biogas from the blend of Poultry Wastes and Pig Slurry

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Abstract: A small biogas digester was constructed to provide an anaerobic condition for a sample of feedstock prepared from the mixture of poultry waste and pig slurry added with water in a ratio 1:2 to facilitate quick breakdown and digestion of the feedstock for biogas production. The whole biogas set-up was left for a period of 7 weeks, and the gas produced during this period was collected into a rubber tube for further analysis of the gas in order to determine the constituents of the biogas. The result shows that of the main constituent in the biogas is methane (CH_4) with the percentage of 67.29% and this was followed by carbon dioxide (CO_2) with a composition of 20.74%. Other constituents of the gas are not prominent but exist in traces, which include hydrogen sulphide (H_2S) and water vapour with a percentage composition of 9.89% and 2.88% respectively. Traces of nitrogen (N) and carbon monoxide (CO) were found to be 0.18 and 0.02% respectively. The study concluded that biogas production took place at mesophillic temperature range of 28-34^oC after a minimum retention time of 49 days from microbial digestion of poultry wastes and pig slurry in an anaerobic condition.

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1. Introduction

The importance of energy to a nation's development cannot be over emphasized; this is because energy is the cornerstone for the economic and social development of a nation (El-Saeidy, 2004). In fact, the amount of energy a country has, can contribute significantly to the prosperity and well being of her citizenry (Oladeji and Lucas, 2011).

The demand for energy being an important factor to global prosperity has increased over the years because of the increasing world population and expansion of global industries, especially food and agricultural industries (Oladeji, 2012 Pacific). As a result of scarcity of wood fuel in many parts of the developing world, an increasing number of people have been forced to turn to straw, crop stalk, animal dung and other agricultural residues as an alternative source of cooking and heating (Aremu and Agarry, 2013;John Taiwo Oladeji, 2011). These residues often discarded or burnt as wastes occur in large amounts and they have the potential to be an important source of fuel for many people in rural areas (Jekayinfa and Scholz, 2009; Oladeji, 2011). Agricultural biomass waste, if converted to energy can substantially displace fossil fuel, reduce emission of greenhouse gasses and provide energy to some 1.6 billion people in the developing countries which lack access to electricity (El-Saeidy, 2004).

Poultry refers to all birds of economic value to man. Examples include chicken, pigeon, duck, goose, turkey, pheasant, quail, guinea fowl and recently ostrich, all of which belong to the zoological class "*Aves*" (Atteh, 2004). Poultry waste originates from three main sources on the farm namely; dead birds, hatchery waste and manure from the live birds. On a large farm, tonnes of poultry droppings can be accumulated within a short time. Pigs are omnivores (consume both plant and animal) and are highly social and intelligent animals. The domesticated pig is one of the most numerous mammals on the planet and it is commonly raised as livestock (Omer, 2011). Some of the services of pigs to men include the following among others:

They serve as a source of meat (generally called pork, hams, gammon or bacon).Their bristly hairs are used for brushes. They can also serve as source of leather. Their manure is an economical fertilizer.

One of the feasible methods of converting these animal residues into energy is production of biogas through the process of anaerobic digestion. Biogas is produced when bacteria convert organic matter to methane gas, carbon dioxide (CO_2) and traces of hydrogen sulphide (H_2S). In addition to the gases produced, the fermentation of these materials reduces them to slurry containing high concentrations of nutrients making them especially effective and valuable fertilizers.

Biogas as a source of renewable energy is a type of fuel that can be obtained from a variety of residues and wastes, but majorly the organic ones (from process of photosynthesis). Some of these organic matters may include dead plant and animal materials, animal wastes, kitchen wastes etc (Itodo, et al., 2007).

According to Itodo and Kucha (1997), biogas is a methane-rich gas that is produced from the anaerobic digestion of organic materials. Furthermore, they described it as a colourless, blue burning gas that can be used for cooking, heating and lighting. It has a heating value of between 22 and 27 MJ/m^3. Biogas can be produced by the microbial digestion of organic matter in the absence of air. Various wastes, such as municipal wastes, kitchen waste, and animal waste such as cattle, poultry and piggery wastes as well as crop residues can also be used in the production of biogas. Thus, biogas is a renewable, high quality fuel, which can be utilized for various energy services such as heat, combined heat and power or a vehicle fuel (Mshandete and Parawira 2009).

Biogas production technology has established itself as a technology with great potential, which could exercise major influence in the energy scene especially in the rural areas. Therefore, the aim of this work was to quantify and characterise products of anaerobic digestion of the blend of poultry litter and piggery slurry.

2. Materials and Methods

The raw materials used for this research work were the poultry wastes and pig slurry. The poultry waste was obtained from the university poultry farm, while the pig slurry was obtained from a local government piggery farm in Ogbomoso. They were actually manure from the live birds and pigs. The poultry litter was sundried to retain very little water content in it and mixed with the same equal quantity of pig slurry. Water was added to the mixture in the ratio 2:1. A biogas digester, which was airtight, was fabricated for the purpose of anaerobic digestion. The digester consists of bio-reactor, which is the main component of the biogas plant. The bioreactor on its own is made up of three main parts, which are the inlet pipe, which was used for feeding the substrate and was made airtight to avoid leakage, the digester chamber, which is the reservoir, where the mixture of the substrates and water are being fermented and the man hole, where the organic fertilizer and mineralized water are collected. The outlet pipe is another important part. It is where the gas passes through to the storage vessel that was prepared. The substrates were fed into the digester via the inlet pipe for seven weeks and then made to undergo digestion/fermentation inside the digestion chamber. The temperature range of 28-34^{0}C was used. The pH level of the substrate and water was maintained at 6.24. This is because a too acidic or base level will kill the bacteria that cause the production of biogas and hence a relatively neutral level of pH was maintained throughout the digestion process period. The micro-organisms (bacteria) acted on the substrates to yield biogas (methane) and other gases that were produced in the chamber. A rod was made to pass into the chamber from the outside with two blades attached to it for the continuous mixing of the substrate and water in the chamber. Provision was also made for the reading of the temperature of the digester in the course of the digestion of the biomass feedstock in the chamber. The temperature reading of the chamber is taking daily (morning, afternoon and evening) so as to know the temperature at which the process is been carried out, since temperature plays an important role in the gas to be generated. The biogas generated was collected with a strip of rubber hose and polyvinylchloride (PVC) tube and was taken to laboratory for further chemical analysis.

3. Results and Discussion

Table 1 showed chemical properties of the substrates before digestion, while Table 2 depicts the composition of produced biogas. Table 3 gave the average daily and weekly temperature readings of digester. The same information was illustrated in Fig. 1.

Table 1. Chemical Properties of the substrates before digestion

Parameters Determined	**Replicates**		
	I	**II**	**Average**
% D.M at 105^{o}C	26.78	26.76	**26.77**
% O.D.M at 550^{o}C	67.28	67.29	**67.285**
NH_4-N (g/kg)	16.12	16.14	**16.13**
Nitrogen (g/kg)	38.46	38.41	**38.435**
% K on DM	1.44	1.49	**1.465**
Phosphorus (g/kg)	3618.00	3619.00	**3618.50**
% C.F	13.67	13.63	**13.65**
% Lignin	7.80	7.90	**7.85**
% O.C	33.21	33.24	**33.225**
pH	6.24	6.23	**6.235**

Legend :-(i) D.M: Dry Matter (ii) O.D.M: Organic Dry Matter (iii) NH_4-N: Ammonium – Nitrogen
(iv) K: Potassium (v) C.F: Crude fibre (vi) O.C:-Organic Content

Table 2. Biogas Composition based on chemical analysis

Substance	**Formula**	**Percentage (%)**
Methane	CH_4	**67.29**
Carbon dioxide	CO_2	**20.74**
Nitrogen	N	**0.18**
Carbon monoxide	CO	**0.02**
Hydrogen sulphide	H_2S	**9.89**
Water vapour	H_2O	**2.88**

Table 3. Average Daily and Weekly Temperature Readings of Digester

Time (in weeks)	**Average Daily Temperatures (°C)**	**Average weekly Temp (°C)**
1	27, 28, 27.5, 28.5, 27.5, 28.5, 30	**28.14**
2	30, 30.5, 29, 30, 33, 32, 31.5	**30.86**
3	31, 32, 32, 32.5,34, 33, 31	**32.21**
4	34, 33, 32, 33, 35, 33.5, 33	**33.36**
5	29, 31, 29.5, 32, 30.5, 30, 32	**30.57**
6	28, 28, 29, 28.5, 32, 30.5 , 33	**29.86**
7	30, 33, 30.5, 29, 29, 28.5, 32	**30.29**

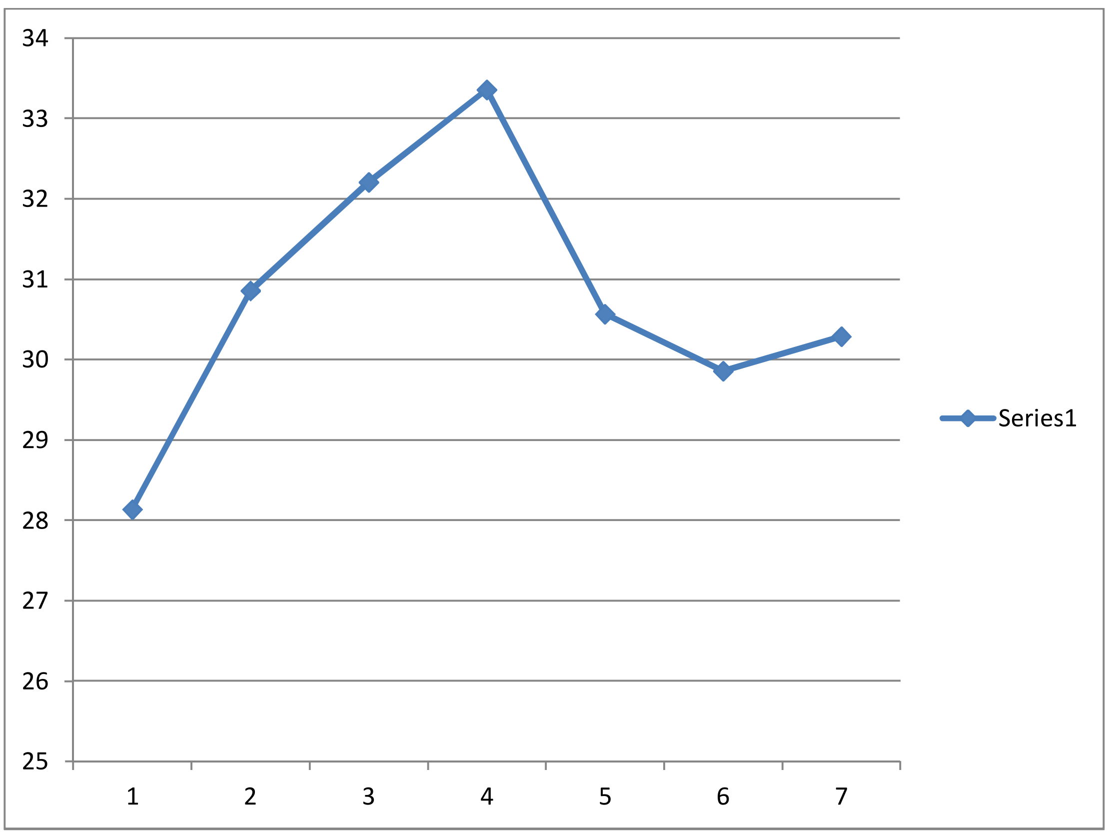

Figure.1. A graph of temperature (°C) against time (week)

Table 1 summarized the properties of the feedstock that was loaded into the digester. The percentage of dry matter of the waste at a temperature of 105°C was 26.77%, while at 550°C it got increased to 67.285%. It can therefore be deduced that the dry matter percentage increases with temperature. Furthermore, the NPK (Nitrogen, Phosphorus and Potassium) values of the substrate are 38.435 g/kg, 3618.5 g/kg and 1.465% respectively, while the percentage of the crude fibre and that of the lignocellulose (lignin) in the feedstock material are 13.65 and 7.85 respectively. Also, the organic content material that makes up the substrate is 33.25%, while the Ammonia-Nitrogen content is 16.13 and importantly, the pH value of the substrate is 6.235 i.e. the substrate is only slightly acidic, which makes it suitable for biogas generation.

Table 2 shows the average weekly temperature readings, beginning from the first week the digester was loaded. It was also observed from Fig. 1 that as the hydraulic retention time (HRT) in weeks increases, the temperature (° C) increases to a maximum point, which shows increase in the rate of biogas production and the temperature later reduces, which shows decrease in the volume of biogas production, that is; decrease in the production rate of the substrate (poultry wastes and pig slurry), because the substrate has reached the maximum biogas yield point. Therefore, it can be deduced that the temperature fluctuates throughout the digestion process of the feedstock. The average temperature readings taken ranges from 28°C to 33°C. Hence, the digestion process can be said to be mesophillic with a retention time of 49 days.

Table 3 gives the detail of the percentage composition of the constituents of biogas that was produced during the experimental work. Since the main constituent that support combustion in the gas is methane CH_4, hence it carries the highest percentage of 67.285% followed by Carbon dioxide (CO_2) with a percentage composition of 20.735%. These are the two major components of biogas. The other constituents of biogas are not prominent, but exist in traces. Hydrogen sulphide (H_2S) occupies a percentage of 8.645%, while water vapour has 1.130% composition. Methane (CH_4) represents the main source of energy In fact, methane (CH_4), which is made up the highest percentage of biogas, forms explosive mixtures in the air.

Biogas mixtures containing more than 50% methane are combustible, while lower percentages may support, or fuel combustion. With this in mind, no naked flames should be used in the vicinity of a digester and electrical equipment must be of suitable quality, normally "explosion proof" (Ubokwe, et al, 2002). However, some of these constituents of biogas are not desirable, because of their adverse effects. For example, the CO_2 and H_2S that were produced alongside the biogas can be very dangerous. The CO_2 can lead to dizziness, restlessness, headache and sweating as Salunkhe et al (2012) noted. While the H_2S also gives undesirable and offensive odour and may also cause irritation and convulsions as a result of its poisonous nature. Therefore the removal of these particular two gases is considered safe before the gas can be put to use.

Conclusion

From the study, the following conclusions were drawn among others:-

The blend of poultry wastes and pig slurry lent itself to process of anaerobic digestion and considerable amount of biogas can be generated. Temperature played an important role in gas generation. Biogas production took place at mesophilic temperature range of 28-34°C. Biogas production took place within a minimum retention period of seven weeks (49 days).

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