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Production of Biogas from Chicken and Goat Wastes

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ABSTRACT

One of the problems facing the world today is waste management, particularly those generated from animals. Examples of such wastes include goat waste and chicken droppings. This paper presents the performance evaluation of five 32 litre capacity biogas digesters that were used to investigate the anaerobic digestion of chicken and goat wastes. Biogas was produced from chicken and goat wastes with different mixing ratios: 100:0 (Sample I), 30:70 (Sample II), 70:30 (Sample III), 50:50 (Sample IV) and 0:100 (Sample V) from digesters 1, 2, 3, 4 and 5 respectively. The digesters were charged differently with these wastes and the mesophilic ambient temperature range attained during the experiment were 26-38 ^{o}C and a slurry temperature of 25-32 ^{o}C. The result showed that the samples were capable of producing a total of 17.3, 44.3, 74.3, 86.2 and 113.2 litres of biogas respectively, using the 32 litre capacity digesters for 30 days. The result obtained from the gas production showed that sample IV produced the highest methane content of 63.3% followed by sample III with 59.4% and sample II with 59.2%. Sample I produced a methane content of 59.1% while sample V had the least methane content of 57.3%.

1. INTRODUCTION

Due to the process of diversification of the Nigerian economy towards agriculture, studies have been carried out on the use of agro waste especially, animal wastes to produce biofuel (Ojolo *et al.*, 2012; Owama *et al.*, 2014). This is also a strategic approach towards supplementing the persistent intermittent power supply and driving small and medium scale business in grid depleted communities. Anaerobic digestion technology is gaining prominence as a means of waste management as it generates energy from industrial and municipal wastes. As a result of global rise in population, the livestock industry which contributes to major food supply is growing significantly. The daily production of animal wastes in Nigeria was estimated to be 227, 500 tons (Adelere and Uduoghene, 2017). Waste products from this sector are mainly composed of nitrates, ammonia and carbon (IV) oxide gasses that pollute the environment and constitute to global warming. Bio-digesters can be used to convert animal wastes using anaerobic digestion for the production of biogas.

Biogas technology provides a very attractive route to utilize certain categories of biomass for meeting partial energy needs. The anaerobic fermentation of animal waste for biogas production does not reduce its value as a fertilizer supplement, as available nitrogen and other substances remain in the treated sludge (Alnaney and Liden, 2008). During anaerobic digestion, microorganisms are employed to decompose the proteinaceous and carbonaceous materials producing biogas and sludge (Krishan*et al.*, 2014). Depending on the type of raw material, biogas contains an average of 50 -70% methane, 30-40% carbon dioxide, 1-2% nitrogen, 5-10% hydrogen, and trace amounts of hydrogen sulfide and water vapour (Nitin *et al.,* 2012). Four major groups of bacteria which are hydrolytic, acidogenic, acetogeneic and methanogenic, are responsible for breaking down the complex polymers in biomass waste to form biogas at anaerobic conditions (Krishan *et al.*, 2014). Biogas production rate in batch condition is directly proportional to specific growth rate of methanogenic bacteria in the bio digester (Nordberg and Edstrom 2005).

Several studies have been carried out regarding biofuel production technology using agro-based wastes in a digester machine. Peter *et al.* (2017) explored the design, exploration and performance evaluation of a cost-effective anaerobic plant using local materials. In the study, cow dung mixed with measured quantity of water was used as a specimen in the digester. The quantitative analysis of the produced biogas showed that the biogas contained 85.331% methane, 0.014% air, 0.013% carbon monoxide, 1.596% nitrogen and 13.011% carbon dioxide which indicates that the waste contains reasonable quantity of methane for power generation. Eze *et al.* (2011), carried out a performance evaluation and characterization of 11 m^3 dome biogas plant. Anaerobic digestion of cow dung was initially performed using a semi-continuous batch process and the volume of gas production at full capacity was found to be 1.13 L/kg. In another phase of the procedure, the cooking capacity of the produced biogas was tested using hard-beans, rice, soup flavoring agent and yam amongst others. Overall result showed that at full capacity, the biogas can suffice for 5-hour period and can serve a family of eight on daily bases. Other studies worthy of mention includes but not limited to the following: Ofoefule *et al.* (2010) who studied the effect of anaerobic digestion on the microbial flora of animal waste. Uzodinma *et al.* (2006) carried out a performance evaluation of cylindrical clay wood-stove. Owama *et al.* (2014), carried out an optimization of a biogas from chicken droppings with *Cymbopogon citratus*. Alfa *et al.* (2014), carried out a comparative evaluation of biogas production from poultry droppings, cow dung and Lemon Grass. A review was also presented in Ojolo *et. al.* (2012) considering the technical potential of biomass technology in Nigeria.

However, what has not been adequately reported is the volume of biogas produced with chicken and goat wastes individually as well as combined blends of chicken and goat wastes. In this paper, biogas produced from chicken and goat droppings by adopting different mixing ratios of the wastes in a 32 litres bio-digester is presented.

2. MATERIALS AND METHODS

2.1. Materials

The chicken waste that was used for investigation was collected from an artisan market in Enugu State, Nigeria while the goat waste was collected from a local farm in Nsukka, Nigeria. The anaerobic digestion experiment was carried out using the digesters located at the National Center for Energy Research and Development (NCERD), University of Nigeria, Nsukka. The materials that were used for investigation are listed in the following section. The other materials used for the investigation are as follows:

1. Thermocouple: was used to obtain daily temperature in the digester throughout the retention period

2. Weighing balance: was used to measure the weight of the waste
3. 10-litre plastic bucket: was used to measure equal volume of waste to water
4. Digester stirrer: was used for mixing the waste
5. Water proof sacks: was used to convey the waste to site
6. Funnel: was used to feed the slurry into the digester
7. Jenway pH meter model 3510: was used to measure the pH of the slurry during the retention period
8. Nose masks: was used to prevent inhalation of unwanted odour emanating from the waste
9. Protective gloves: was worn to avoid contaminations
10. Burner: To test the flammability of the gas produced

2.2. Methods

The experiment was carried out using five fixed dome anaerobic digesters with 32 litres capacity each. Different quantities of goat and chicken wastes were mixed in three of the digesters while the other two contained the control samples of goat and chicken wastes. The mixing ratios in the three digesters were set as follows. Digester II (chicken and goat: 30/70), digester III (chicken and goat: 30/70) and digester IV (chicken and goat: 50/50). In digester I, 6 kg each of chicken and goat wastes and 18 kg of water were mixed. Digester II contained 1.8 kg of chicken waste, 4.2 kg of goat waste and 18 kg of water. In digester III, 4.2 kg of chicken waste, 1.8 kg of goat waste and 18 kg of water were mixed. Digester IV contained 3 kg of chicken each of chicken and goat wastes and 18 kg of water. In digester V, 6 kg each of chicken and goat wastes and 18 kg of water was mixed. The samples in digesters I and V were set as control samples. The wastes were properly mixed with water in order to achieve a suitable slurry mix and as such creating a favourable environment for microorganisms to feed on the nutrients. The digesters were properly covered and were operated under mesophilic conditions for 30 days. The pH, ambient temperature and slurry temperature were measured daily while the total solid, volatile solid and moisture content were measured weekly. The flammability of the daily gas production was monitored using a burner. The daily produced biogas was analysed using gas analyzer using a Eurotron based unigas 3000 + BTU. The gas analyzer is equipped with sensors capable of determining the concentrations of CO_2, NO, NO_2, CO and O_2. The H_2S was measured using Crowcon Gasman monitor (model 19576H). Since biogas is a mixture of mainly 50 to 70% methane, 30 to 40% and traces of other gases such as CO, NO and H_2S, the percentage concentration methane in the biogas was estimated by subtracting the percentages of the other gases from 100%.

2.2.1. Determination of moisture content, total solids and volatile solids

In order to determine the moisture content of the raw wastes, the recommendation according to the Association of Official Analytical Chemists (AOAC, 1990) was used. Prior to the determination of the moisture content, 1 g of each of the raw wastes was placed in washed and dried porcelain crucibles, and was heated in the oven at a temperature of 105 °C for 4 hours. The samples were then removed from the oven, cooled and weighed. The moisture content was determined using Equation 1.

$$\% \, moisture = \frac{A-B}{A} X \frac{100}{1} \tag{1}$$

Where A is the original weight of the sample and B is the weight of the dried sample.

To determine the total solid (TS), Meynell (1982) method was used. A mass of 3 g was measured from the raw waste and was dried in an oven at 105 ^{o}C for 5 hours. It was then cooled in the desiccator and weighed. The total solid was then determined using Equation 2.

$$\% \, TS = \frac{D-C}{g} X \frac{100}{1} \tag{2}$$

Where *TS* is the total solid, *D* is weight of crucible +dry residue, *C* is weight of crucible and *g* is the original weight of the sample.

Meynell (1982) method was also used to determine the volatile solid. The solid residue obtained from the total solid was heated in a muffle furnace at 600 ^{o}C for 2 hours. The heated residue was then cooled in a desiccator and weighed. The volatile solid was then determined as:

$$VS = \frac{R-R_h}{g} X \frac{100}{1} \tag{3}$$

Where *VS* is total solid, *R* is weight of dried residue for total solid determination, R_h is weight of residue after heating.

3. RESULTS AND DISCUSSION

3.1. Total Solids and Volatile Solids

The experimental results obtained during the monitoring period of the study were recorded and analyzed. Table 1 shows the physical properties of the waste (chicken droppings (CD) and goat dung (GD)). Sample II gave the highest value of total solid which is the amount of nutrient capable of sustaining the micro-organisms in the waste and highest volatile solid which represents the percentage of the waste convertible to gas. The least value of total solid was sample IV. The amount of total solid and volatile solid shows the viability of the waste to produce gas. The results of sample II and sample IV show a decrease in the percentage total solids and volatile solids from 3.43 to 2.15 and 2.66 to 1.45 respectively. This may be due to the utilization of the wastes by micro-organisms.

Table 1: Physical properties of the waste

Samples	Total solid (%)	Volatile solid (%)	Moisture content (%)
I	2.22	1.52	97.80
II	3.43	2.66	96.60
III	2.23	1.53	97.80
IV	2.15	1.45	97.90
V	2.63	1.75	97.40

3.2. Biogas Production from the Waste

Table 2 shows the daily pH and volume of gas produced. The daily biogas productions by co-digestion of chicken droppings and goat dung during the 30 days of digestion were calculated under different mixing ratio. Samples from the mixing ratio of samples I, II, III, IV and V were measured. The results of the experiments indicate that there was no good start-up of biogas yield at the beginning. Production of biogas for goat waste (sample I) started on the 5th day with a value of 0.3 litres. The maximum yield of biogas was attained on the 20th day with a value of 1.6 litres, while the lowest value of biogas for goat waste was on the 28th day with a value of 0.1 litres. Also, for the chicken waste and goat waste (sample II), there was no biogas production for day 1, day 2 and day 3, while production of biogas started on the 4th day with a value of 0.3 litres. The maximum yield of biogas was attained on the 18th day with a peak value of 4.8 litres. Chicken and Goat waste (Sample III) gas production started at the 4th day after charging the digester with a value of 0.7 litres. The maximum yield of biogas was attained on the 11th day with a peak value of 7.1 litres. Chicken and goat waste (Sample IV), biogas production started on the 4th day after charging the digester with a value of 2.8 litres. The maximum value of biogas obtained was on the 11th day with a peak value of 5.2 litres. For chicken waste (sample V), biogas production started on the first day with a value of 0.5 litres. There was a decrease in biogas production from the 14th day to 17th day. The maximum yield of biogas was attained on the 24th day with a peak value of 7.8 litres. The poor start-up of anaerobic digestion may be due to the activity of bacteria in facilitating the digestion, which can also be considered as a time dependent process. Ukwuani and Ugwuoke (2016), observed that as the anaerobic digestion progresses to a certain stage, the biogas yield decreased due to decrease in the activity of anaerobic bacteria. A similar phenomenon relating to the influence of anaerobic bacteria on biogas yield was also reported by Ugwuoke *et al.* (2015).

Table 2: Daily pH and volume of gas

Days	pH					Volume of gas (L)				
	1	II	III	IV	V	I	II	III	IV	V
1	8.9	8.6	7.7	8.4	7.6	0	0	0	0	0.5
2	8.4	8.2	7.6	8.4	7.5	0	0	0	0	1.0
3	8.3	8.3	8.0	8.3	8.2	0	0	0	0	1.5
4	8.0	7.7	7.4	7.1	7.5	0	0.3	0.7	2.8	1.8
5	8.2	8.3	8.0	7.7	8.0	0.3	0.4	1.0	3.3	2.6
6	8.3	7.9	7.5	7.3	7.7	0.1	0.3	1.1	2.8	3.2
7	7.6	7.2	6.8	6.8	6.8	0.3	0.3	4.7	3.5	5.6
8	7.9	7.2	7.0	7.4	7.2	0.4	0.4	4.8	3.2	6.0
9	8.2	7.3	6.8	6.8	6.6	0.4	1.1	1.9	3.3	3.8
10	7.8	6.8	7.0	6.8	6.6	0.6	1.2	5.2	5.0	4.8
11	7.6	7.2	7.0	6.9	6.6	0.6	1.6	7.1	5.2	4.8
12	7.6	7.2	7.2	7.0	6.6	1.1	1.4	3.1	3.4	1.9
13	8.2	7.5	7.4	7.5	7.4	1.0	1.4	3.4	3.6	4.0
14	7.9	7.3	7.6	7.5	6.8	1.4	1.7	2.4	3.0	3.2
15	7.6	7.2	7.6	7.6	6.9	0.5	1.4	1.6	2.0	2.4
16	8.3	7.5	7.6	7.6	6.8	0.6	1.9	1.9	3.2	2.7
17	8.0	7.4	7.3	7.7	6.9	1.0	4.4	4.4	3.2	3.2
18	7.9	7.7	7.7	7.7	6.8	1.2	4.8	5.4	4.1	3.8
19	8.0	7.6	7.6	7.7	7.0	1.6	2.4	1.6	4.2	4.2
20	7.5	7.9	7.8	7.7	6.8	1.6	3.2	4.1	4.1	4.1
21	7.6	7.5	7.4	7.4	6.6	0.8	2.2	3.2	3.8	7.6
22	7.9	8.1	7.7	7.9	7.2	0.3	1.1	0.5	2.4	7.6
23	7.6	8.0	7.6	7.7	7.0	0.1	1.1	0.8	2.2	7.4
24	7.1	7.4	7.6	7.3	7.6	0.4	1.6	1.0	2.9	7.8
25	8.5	7.8	7.7	8.0	7.6	0.5	2.3	3.2	3.3	3.2
26	7.5	7.4	7.4	7.3	7.3	0.8	2.1	3.2	2.4	3.2
27	7.7	7.4	7.3	7.3	7.3	0.2	1.1	2.4	1.6	2.8
28	7.7	7.9	7.7	7.6	7.5	0.1	0.9	0.3	1.6	3.2
29	7.9	8.0	7.7	7.8	7.6	0.8	2.1	3.7	4.3	3.9
30	7.9	8.1	8.3	7.9	8.1	0.5	1.6	1.6	2.1	1.4
Total						17.2	44.3	74.3	86.5	113.2

In this study, it was observed that biogas production was less and gradual in the first week of the investigation. This suggests that the biogas producing micro-organisms are in the lag phase of growth where acclimatization or adaptations of the cells take place (Abubakar and Ismail 2012). This explanation is in agreement with that of Abubakar and Ismail (2012). From the second week of the study, results indicated a progressive increase in biogas production, while in the third week there was a decline in biogas production.

This indicates that the methanogenes are in their exponential stage of growth. However, this agrees with the findings from the work of Rabah *et al.* (2010) where biogas production experienced a decline in the third week. Another possible explanation may be due to the different breeds of chicken and goat found in the different locations. However, tests on the influence of animal breed on biogas yield from wastes may be needed in future studies in order to confirm this claim. Also, climatic factors, the nature or quality of feed or pasture that the goat were exposed to, may be considered as other possible factors that could contribute to the differences in the rate of biogas production. Rainfall affected production of biogas especially on days 15 -16 and days 21-30. Increase in temperature increased the rate of biogas production.

The digestion of single substrate chicken waste produced biogas earlier than others starting from the 1st day with relatively highest peak value of 7.8 litres on the 24th day. It was observed that goat waste alone produced the smallest peak value of 1.6 litres on the 19th day. These results indicate that the single digestion of Chicken droppings and Goat dung could significantly delay the attainment of the highest gas production. It was also observed that biogas production was slow at the beginning and slightly slow at the end period. This agrees with what was stated by Rabah *et al.* (2010) that biogas production rate in batch production is directly proportional to specific growth rate of methanogenic bacteria in the bio-digester.

3.3. pH of Digester Contents

The pH of Sample I was within 7.1 to 8.9 all through the digestion period as shown in Table 2. The pH values were unfavorable for microbial growth and affected the volume of gas produced. For samples II, III, IV and V with pH ranges of 6.8 to 8.3, 6.8 to 8.3, 6.8 to 8.4 and 6.8 to 8.2 respectively, the volume of gas produced improved. Speece and Mccarthy (1964) reported that biogas production would always continue as the digester slurry, pH is maintained between 6.6 to 7.6 and with optimum range between 7.0 and 7.2. Below the pH of 6.2, the bacteria become inactive since the methanogens are very sensitive to pH changes and which implies that they may not survive at low or high pH (Speece and Mccarthy 1964). This suggests that the high pH of sample I of goat waste may be controlled by blending with an additive. The pH ranges obtained for chicken and goat waste of various samples II, III, IV and V were favourable for microbial growth. This is evident from the volume of gas produced as shown in Table 2. In the work of Okoroigwe *et al.* (2010) the pH was in range of 6.6 to 7.8, the difference could be attributed to normal biological reaction of the microorganisms.

3.4. Temperature of Digester Contents

Figure 1 shows the digester temperature for the five substrates. The temperatures were recorded daily using a thermocouple. The figure shows that the temperature within the digesters fluctuated optimally between 25 ^oC and 38 ^oC which conforms to the mesophilic range. This agrees with the findings of previous work carried out by Ugwuoke *et al.* (2015) and Verma, (2002) whose temperatures were within the same range. Since all the digesters were operated simultaneously, the temperature across them was the same. Gas production was observed with increase in temperature. This agrees with the work of Lawal *et al.* (2001) which explained that biogas production was favoured with an increased temperature and as temperature drops, the rate of biogas production declined.

The ambient temperature affects the rate of digestion due to the direct contact of outside walls of the digester with the environment. This implies that seasons affect the rate of heat loss or gain from the digester which in turn affects the microbial activities in the slurry at each stage. Ambient temperature fluctuated due to climatic conditions. The highest ambient temperature was 32 ^oC while the lowest was 25 ^oC. This condition is favourable for anaerobic digestion. The mesophilic temperature (25 ^oC – 45 ^oC) is the temperature range that was identified for the slurry temperature. The cumulative volume of biogas produced increased progressively from sample I to V.

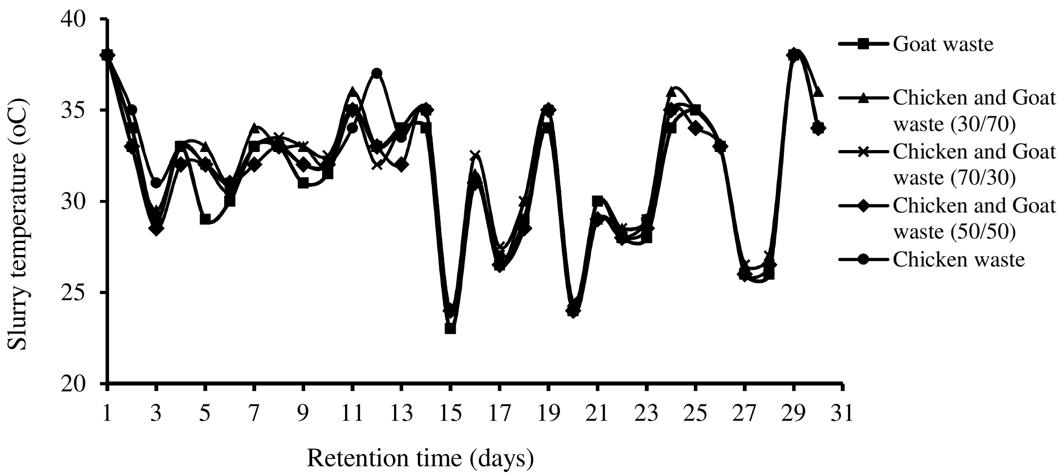

Figure 1: Daily digester temperature of the waste

3.5. Biogas Composition

It has been mentioned that biogas consists of methane (50-70%), CO_2 (30-40%), traces of hydrogen sulphide (H_2S) and water vapor (Nitin *et al.*, 2012). The relative percentages of these gases depend on the type of waste and management of the digestion process. Biogas composition for the waste used in the study is shown in Table 3. The values obtained showed that methane content for goat waste was higher than that of chicken waste. The results fall within the quality range for biogas which agrees with previous works. It can be seen from Table 3 that co-digestion of chicken and goat waste (50/50) had the highest methane content (63.3%). The biogas produced from the co-digestion of chicken and goat waste (30/70 and 70/30) had higher methane contents (59.2% and 59.4%) than when they were digested individually (59.1% and 57.3%). The range of the biogas produced in this work agrees with the explanation given in the work of Oyeleke *et al.* (2003) regarding methane content yield. Results also agree with previous studies by Ukpai and Nnabuchi (2012) for cow dung, cow pea and cassava peeling where the methane contents were 67.9%, 56.2% and 32.2%. The differences could be attributed to type and nature of waste used.

Table 3: Biogas composition for the waste used in the study

Sample	% CO_2	% H_2S	% CO	% CH_4
I	38.2	1.4	1.3	59.1
II	37.6	1.7	1.5	59.2
III	37.4	1.6	1.6	59.4
IV	33.3	1.7	1.7	63.3
V	38.8	2.0	1.9	57.3

4. CONCLUSION

Five 32 litre capacity biogas digesters have been used for the digestion and production of biogas from different mixing ratios of chicken and goat wastes. The experiment was carried out for 30 days. The following conclusions can be drawn:

1. The maximum yield of biogas for sample I was obtained as 1.6 litres on the 20th day, the maximum yield for biogas sample II was obtained as 4.8 litres on the 18th day. The maximum yield of biogas for sample III was obtained as 7.1 litres on the 11th day while the maximum yield of biogas for

sample IV was obtained as 5.2 litres on the 11th day. Sample V produced a maximum yield of 7.8 litres biogas on the 24th day.

2. Chicken droppings produced higher volume of gas than goat waste. In terms of flammability of gas produced, goat waste had higher methane content of 59.1% than chicken waste with 57.3% methane content. A maximum amount of 63.3% methane content was obtained from chicken and goat wastes of mixing ratio 50/50.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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