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Comparative Biogas Production from Cow Dung Obtained from Cattle fed on Guinea and Gamba Grass Based Diet

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Abstract *— The production of biogas from agricultural waste is seen as one of the alternative source of energy that is being used in most developed and developing countries. In addition, it is a way of solving the environmental pollution and health hazards caused by the emission of dangerous gases from the cow dung when littered. This paper looks at the effect of changing temperature on the rate of production of biogases from cow dung (methane, carbon dioxide, nitrogen), using cow dung of initial moisture content of 77% obtained from a Fulani cow that is feed on 60 % guinea/gamba grass mixed feed and guinea and gamba feed separately. A 2 litre Erlenmeyer flask was used as the batch digester with water as reacting medium. The cow dung was finally diluted to a moisture content of 85%. The result shows that running the experiment at 30℃, 32 ℃, 35 ℃, 37 ℃ and 38 ℃, with 1.4 kg feed weight, the rate of gas production was faster and higher methane composition of 59.02% was obtained at 37^oC for the mixed feed thus, faster degradation of waste taking place at this temperature. The average gas production rate at 30 minutes interval was 5.8 millilitres (0.0058 litres) and per minute approximately 0.2 millilitres (0.0002 litres) at 37℃. The result recorded inconsistencies in the rate of gas production at 30 ℃, 32 ℃ and 38 ℃. For the separate feed intake, cow dung from the guinea grass feed had higher methane composition (50.63%) compared to the gamba grass (48.21%) when ran at 37^oC. This indicates that the guinea grass produced more methane gas in the mixed feed than the gamba grass.*

Keywords—Biogas; Cow dung; temperature; rate of gas production; Gamba and Guinea grass feed

1. INTRODUCTION

The diversification on the use of energy has become an important issue in the world because of the over dependence on crude oil and its effect to the environment. Alternative energy sources such as the use of agricultural wastes as energy source have become inevitable. Biogas from agricultural waste is one of the ways to reduce this over dependence on crude oil and its depleting sources. Biogas can also reduce the high consumption of fire wood in the rural areas in third world countries such as Nigeria, which has led to the destruction of forest and the environment. The use of biogas not only conserves our fossil fuels, it also recycles our waste material thus, controlling odours, ground water contamination, less greenhouse emission and nutrient recovery.

Biogas is a mixture of methane (also known as Marsh gas or natural gas) and carbon dioxide generated when bacterial degrade biological material in the absence of oxygen, a process known as anaerobic digestion. Biogas produced in an anaerobic digestion consist of methane (50%-70%), carbon dioxide (30%-40%) and trace level of other gases such as hydrogen, carbon monoxide, oxygen and hydrogen sulphide [1]. But the relative percentage of these gases depends on the feed material and management of the process.

Anaerobic digestion can be described as a two-stage process accomplished by several types of bacteria, which flourish in the absence of oxygen. The first stage is the Acidification process in which acid forming bacteria breakdown complex organic wastes into volatile fatty acids. In this process, protein is broken down into amino acids and further into volatile fatty acids, carbohydrate is broken down into simple sugars and further into volatile fatty acids while fat and oil are broken down into long chair fatty acids and further into volatile fatty acids. Acetogenic bacteria makes use of the volatile fatty acids formed and converts them into acetic, propionic and lactic acids, carbon dioxide and hydrogen gases are released in this process [2]. The second stage is the methane production stage where methane-forming bacteria (methanogens) uses the acid formed in the first stage to produce methane while other bacteria's uses the carbon dioxide and hydrogen formed to produce methane [2-4].

Anaerobic digestion is carried out in an anaerobic digester made of concrete, steel, brick or plastic, and shaped like silos, troughs, basin or ponds placed underground or on the surface. There are two basic types of digester, Batch and continuous. In Batch-type digester a full charge of raw materials is placed into it, sealed off and left to ferment as long as gas is being produced. When the gas production ceases, the digester is emptied and refill with a new batch of raw materials. In continuous digesters organic material are constantly or regularly fed. This is done by adding small quantity of raw material every day or so. The material moves through the digester either mechanically or by the force of the new feed pushing out the digester materials. These enable the rate of production of both gas and sludge to be more or less continuous and reliable. This digester are especially efficient when raw material consist of a regular supply of easily digestible wastes from nearby sources such as livestock manure, seawood, river or algae from production sludge ponds.

The aim of this paper is to study the production of biogas from cow dung from White Fulani (Bunaji) cattle fed with supplemented 60% guinea/gamba grass mixed feed and 60% guinea (Panicum maximum) and 60 % gamba (Andropogon gayanus) grass

separately all with initial moisture content of 77% using a batch digester at varying temperatures. This study gives insight on the percent composition of gas (methane) that can be obtained if the cattle feed is supplemented with these grasses and the type of gases emitted to the environment using this mixed feed and separate feeds and the optimum temperature for the gas production.
Several research work on biogas has been studied, in 1776 Count Alessandro Volta concluded that the amount of gas that evolves is a function of the amount of decaying vegetables and the sediments from which the gas emerges and that in certain proportion, the gas obtained forms an explosive mixture with air [2-4]. In 1808, Sir Humphrey Davy showed that methane was present in decomposition cattle manure [5]. In similar studies, Bechamp named the "organism" responsible for methane production and he was able to show that, depending on the substrate, different fermentation products were formed and that the organisms were apparently a mixed population [5]. While Herter in his investigation reported that acetate in sewage sludge was converted stoichiometrically to equal amounts of methane and carbon dioxide [5]. Other research work has shown that biogas can be produced from animal and agricultural waste and co-digestion of organic waste with sludge or cow dung [6-12].
Cow dung composition depends on the feed intake by the cattle's reared. The white Fulani cattle's reared by the nomadic Fulani people of Nigeria and in the Sahel zone of Africa, feeds on grass, hay, roughages, silage, grains, oilseeds, leftover food products such as sweet corn, bakery wastes etc., depending on the grazing area and the product expected from the cattle such as beef or milk. Generally, grasses cattle eats are Gamba grass, Guinea grass, Elephant grass, bluegrass, ryegrass, bermuda grass, fescue, Timothy grass, foxtail, sorghum, brome grass, orchard grass, quack grass, and canary grass [13].

Research on guinea and gamba grasses, their nutritive values and chemical compositions have been well documented [14-17] in relation to their growth environment and other external factors.

2. MATERIALS AND METHOD

An airtight 2-litre Pyrex Erlenmeyer vessel, model BS1739 was used as a batch digester for loading and digesting the waste (cow dung mixed with water). Grant water bath, model SS-30, frequency 50-60 hertz, voltage range of 220-240V and power supply of 900watts was used as a medium for maintaining even temperature around the digester placed in it. Temperature controller with temperature range of 0^oC-400^oC and tolerance of $\pm 5^oC$ with thermocouple was used to regulate the temperature of the water in the water bath. Griffin thermometer with range 10-100℃ and tolerance of $\pm$ 10^oC was used to monitor the temperature inside the water bath. A 2070/E5 magnetic stirrer with adjustable power supply of 110-220V and frequency of 50-60 hertz was used to stir the waste periodically in the digester. Hanna instrument microcomputer pH meter, model HI8424 was used to determine the initial and final pH of the waste in the reaction vessel. An airtight 30 ml glass gas collection vessel was fabricated at the engineering workshop at University of Port Harcourt with tolerance ± 0.25ml to enable the amount of gas produced in the digester to be determined and its rate of production. The vessel was filled to the 30ml mark with acidified water ($pH \leq 3.5$). 10 ml Pyrex measuring cylinder was used for collecting the displaced acidified water from the gas collection vessel via a rubber hose and through a funnel placed on top of the cylindrical vessel. The funnel prevents vaporization of the water. Baking soda was used to adjust the cow dung mix pH to range 6.7-8.0. Finally a 500 millilitre low density polythene (LDPE) bag was bought and used for collecting the gas sample for analysis in a gas chromatograph.

2.1 Procedure

Cow dung was obtained from three white Fulani cattle's weighing approximately 210-250 kg housed in separate pens feed with 60 % unchopped freshly harvested mixed guinea and gamba grass at 50-50 ratio and allowed to go for grazing within confined environment for 7 weeks. This procedure was repeated using 60 % guinea grass and 60 % gamba grass respectively. The cattle's were reared and monitored at the animal science farm yard at the department of Animal and soil science in Niger Delta University. The experimental work was carried out in two phases. Firstly, an Erlenmeyer reaction vessel loaded with 1.4 kg of cow dung (77 %) moisture content was mixed with 0.747kg of water to attain moisture content of 85% was placed inside a water bath equipped with a stirrer and a heater connected to a temperature controller. A digital pH meter was used to measure the initial pH of the mixture inside the reaction vessel before sealing the vessel with rubber cork. The reaction vessel was connected via rubber tubing to a 30 milliliters cylindrical glass airtight gas collection vessel, held in place by retort stand so that the outlet of the reaction vessel was at the same pressure with the inlet and outlet of the gas collection vessel (atmospheric pressure). The gas collection vessel was filled to the 30 milliliters mark with acidified water at $pH \leq 3.5$ using sulphuric acid. The gas collection vessel was then connected via a rubber hose through a funnel to 10 milliliters cylindrical tube used for collecting the displaced water as a result of gas production. A magnetic stirrer was used for periodic stirring of the cow dung mixed with water.

The rate of gas production in the reaction was measured at every 30 minutes interval by monitoring the water displacement in the gas collection vessel. The experiment was carried out for different temperatures (30℃, 32℃, 35℃, 37℃ and 38℃) at different periods during the experimentation runs.

Secondly, the experiment was repeated with the removal of the gas collection vessel which was replaced by a 500 millilitre low density polyethylene bag. The LDPE bag which was connected directly to the outlet of the Erlenmeyer reaction vessel enables the gas produced to be trapped. This second experiment was repeated for the different temperatures, using the same load of waste but at different periods of the experimentation and for cow dung obtained when the cattles where fed guinea and gamba grasses separately. The gas produced was analysed using gas chromatograph (GC) 1-14b Shimadzu. Figure1. shows the schematic experimental set up for the Cow dung research.

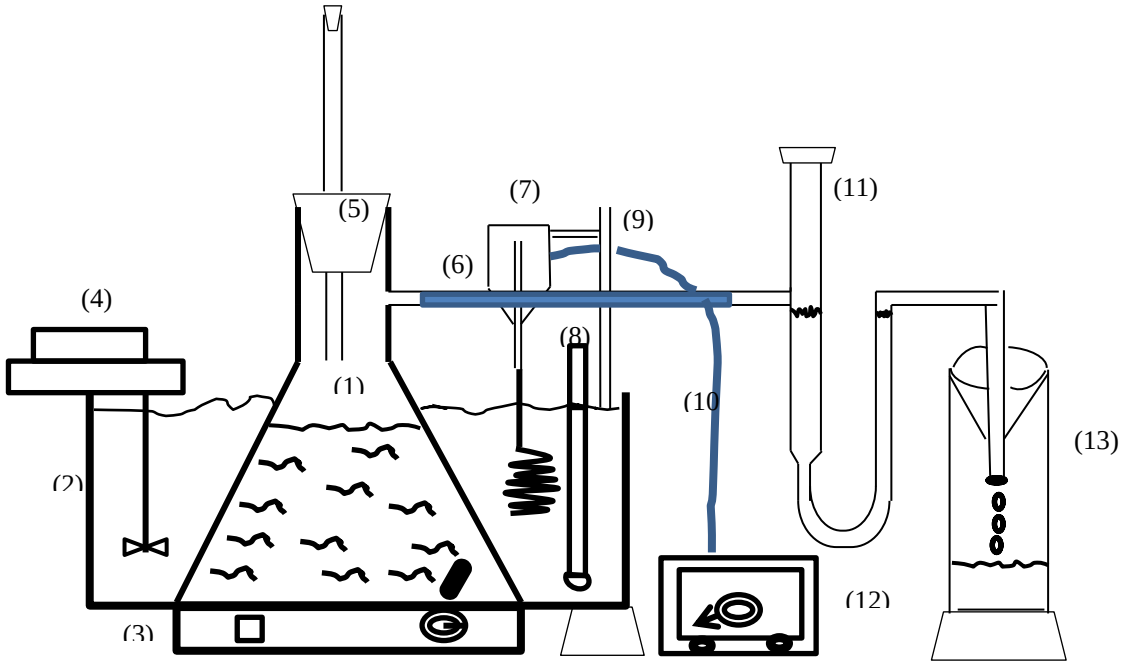

Figure1. Experimental set-up : (1) Reaction vessel, (2) Water bath, (3) Magnetic stirrer, (4) Mechanical collection stirrer, (5) Stopper, (6) Rubber hose, (7) Water heater, (8) Thermometer, (9) Retard stand, (10) Cable, (11) Gas vessel, (12) Temperature controller, (13) Measuring cylinder

3. RESULT AND DISCUSSION

The results on table1, 2, 3, 4 and 5 shows the rate of gas production with respect to displacement of 29 milliliters of acidified water in a gas collection vessel using a 1.4kg (1400 grams) of cow dung at temperature 30 ^{o}C, 32^{o} C, 35^{o}C, 37^{o}C and 38^{o}C respectively. The experiment at 37^{o}C with a load of 1.4kg of cow dung mixed with a 0.747kg of water as reacting medium, took 150 minutes (2-hours, 30 minutes) to produce 29 milliliter (0.029 liters) of gas by the displacement of 30milliliter acidified water in the gas collection vessel to its 1 milliliter mark. The total volume of gas produced at the end of the experiment was 940 milliliters (0.94 litres) at the time of 3-days and 8 hours (4800 minutes). The average gas production rate at 30 minutes interval was 5.8 milliliters (0.0058 litres) and per minute approximately 0.2 milliliters (0.0002 liters). Reducing the quantity of cow dung to 1.2kg, 1.0kg and 0.8kg mixed with 0.640kg, 0.533kg and 0.427kg of water respectively as reacting medium to attain 85% moisture content, the result showed that the rate of gas production was faster with smaller quantity of cow dung but with smaller volume of gas produced as shown in table 6. For 1.2kg it took 145 minutes to produce 29 milliliters (0.029 liters) of gas and approximately 3-days to produce a total gas volume of 840 milliliters (0.84 liters) with average gas production rate at 30 minutes interval of 6.31 milliliters (0.00631 liters) and approximately 0.21 milliliters (0.00021 liters) per minute. For 1.0kg and 0.8kg it took 130 minutes and 110 minutes respectively to produce 29 milliliters of gas and approximately 2 days and 11 hours (3540 minutes) to produce a total gas volume of 765 milliliters (0.765 liters) for 1.0kg while it took approximately 2 days (2880 minutes) to produce 700 milliliters (0.7 liters) of gas for 0.8kg cow dung.

At 35^{o}C, with a feed weight of 1.4kg, it took 180 minutes (3hours) to produce a 29 milliliters of gas and approximately 4-days to produce a total gas volume of 910 milliliters (0.91 liters).The rate of gas production at 30 minutes interval was 4.79 milliliters (0.00479 liters) and approximately 0.16 milliliters (0.00016 liters) per minute. The gas composition at this temperature is 53.55 % methane, 30.78% carbon dioxide and 15.67% nitrogen. At 32^{o}C, with a load of 1.4 kg it took 480 minutes (8 hours) to produce a 29

ml of gas and approximately 5-days 7 hours to produce a total gas volume of 735 milliliters (0.735 liters). The rate of gas production could not be determined because of inconsistency in the rate of gas produced. The percentage composition of gases produced at this temperature is shown in table 6. At 30^{o}C, with a load of 1.4 kg, gas production started after 3- hours and 30 minutes has elapsed and it took 600 minutes (10-hours) to produce 29 milliliters (0.029 litres) of gas, and approximately 6 days to produce a total gas volume of 650 milliliters (0.65 litres). The rate of gas production could not be determined because of inconsistency in the rate of gas produced. The composition of gases at this temperature is shown in table 6.

At 38^{o}C with a load of 1.4 kg, gas production initially at the first 30 minutes was high before it starts decreasing with time and took 4 hours (240 minutes) to produce a 29 milliliters volume of gas. The rate of gas production could not be determined because of inconsistencies in gas production rate and the gas composition is shown in table 6.

Table 1: Rate of gas production (ml/min) for 1.4 kg at 30^{o}C

Volume displaced (ml)		Average volume Displaced (ml)	Time (min)	Consistency in volume displaced (ml)
First run	Second run			
30.00	30.00	30.00	0.00	0.00
30.00	30.00	30.00	30.00	0.00
30.00	30.00	30.00	60.00	0.00
30.00	30.00	30.00	90.00	0.00
30.00	30.00	30.00	120.00	0.00
30.00	30.00	30.00	150.00	0.00
30.00	30.00	30.00	180.00	0.00
30.00	30.00	30.00	210.00	0.00
28.50	29.00	28.75	240.00	1.25
27.75	26.75	27.25	270.00	1.50
26.00	25.50	25.75	300.00	1.50
20.75	21.75	21.25	330.00	4.50
17.25	16.75	17.00	360.00	4.25
16.50	16.00	16.25	390.00	0.75
12.75	13.75	13.25	420.00	3.00
12.00	12.50	12.25	450.00	1.00
9.75	8.75	9.25	480.00	3.00
6.00	6.50	6.25	510.00	3.00
3.25	3.25	3.25	540.00	3.00
2.75	2.25	2.50	570.00	0.75
1.50	1.00	1.25	600.00	1.25

Table 2: Rate of gas production (ml/min) for 1.4 kg at 32°C

Volume displaced (ml)		Average volume Displaced (ml)	Time (min)	Consistency in volume displaced (ml)
First run	Second run			
30.00	30.00	30.00	0.00	
26.50	26.00	26.25	30.00	3.75
24.75	25.25	25.00	60.00	1.25
24.00	23.50	23.75	90.00	1.25
22.50	22.50	22.50	120.00	1.25
21.25	21.75	21.50	150.00	1.00
17.75	18.25	18.00	180.00	3.50
17.00	17.00	17.00	210.00	1.00
16.00	16.00	16.00	240.00	1.00
14.75	14.25	14.50	270.00	1.50
14.00	13.00	13.50	300.00	1.00
9.50	10.00	9.75	330.00	3.75
7.25	7.75	7.50	360.00	2.25
7.00	6.00	6.50	390.00	1.00
3.75	4.25	4.00	420.00	2.50
3.00	2.50	2.75	450.00	1.25
1.75	0.75	1.25	480.00	1.25

Table 3: Rate of gas production (ml/min) for 1.4 kg at 35°C

Volume displaced (ml)		Average volume Displaced (ml)	Time (min)	Consistency in volume displaced (ml)
First run	Second run			
30.00	30.00	30.00	0.00	
25.25	25.25	25.25	30.00	4.75
21.00	20.50	20.75	60.00	4.50
15.25	15.75	15.50	90.00	5.25
10.75	10.75	10.75	120.00	4.75
7.00	6.00	6.50	150.00	4.25
1.50	1.00	1.25	180.00	5.25

Table 4: Rate of gas production (ml/min) for 1.4 kg at 37°C

Volume displaced (ml)		Average volume Displaced (ml)	Time (min)	Consistency in volume displaced (ml)
First run	Second run			
30.00	30.00	30.00	0.00	
23.50	23.00	23.25	30.00	6.75
17.75	18.25	18.00	60.00	5.25
12.50	12.50	12.50	90.00	5.50
7.50	7.00	7.25	120.00	5.25
1.25	0.75	1.00	150.00	6.25

Table 5: Rate of gas produced (ml/min) for 1.4 kg at 38°C

Volume displaced (ml)		Average volume Displaced (ml)	Time (min)	Consistency in volume displaced (ml)
First run	Second run			
30.00	30.00	30.00	0.00	
22.50	22.00	22.25	30.00	7.75
20.00	20.50	20.25	60.00	2.00
15.50	17.50	16.50	90.00	3.75
13.25	14.25	13.75	120.00	2.75
8.75	8.75	8.75	150.00	5.00
6.00	7.00	6.50	180.00	2.25
2.75	2.75	2.75	210.00	3.75
1.00	1.50	1.25	240.00	1.50

Table 6: Total volume of gas produced at the various temperatures

Temperature (°C)	Mass (kg)	Volume of gas (milliliters)	Volume of gas (liters)	Time (mins.)
30	1.4	650	0.650	8,640 (6 days)
32	1.4	735	0.735	7,620 (5 days 420 min)
35	1.4	910	0.910	5,760 (4 days)
37	1.4	940	0.940	4,800 (3days 480 min)
37	1.2	840	0.840	4320 (3 days)
37	1.0	765	0.765	3,540 (2 days 660 min)
37	0.8	700	0.700	2,880 (2 days)
38	1.4	865	0.865	7,200 (5 days)

Table 7 shows the percentage composition of the gas analysed in a gas chromatograph model (GC) 1-14B Shimadzu for 1.4kg feed weight at temperature 30 °C, 32° C, 35°C, 37°C and 38°C respectively. Feed weight of 1.4kg was chosen because of the quantity of gas produced at this weight and the size of the digester used for the experiment. And table 8 shows the percentage composition of gasses produced from cow dung obtained from the cattle's fed with guinea grass and gamba grass separately ran at 37 °C .

Table 7: Percent composition of gas analysed by GC1-14B for Guinea/gamba mixed feed cow dung

Temperature (°C)	Gases (%)		
	Nitrogen	Methane	Carbon dioxide
30.00	87.99	9.77	2.23
32.00	84.26	15.18	0.56
35.00	15.67	53.55	30.78
37.00	8.48	59.02	32.50
51.10	79.11	30.45	18.45

Table 8: Percent composition of gas analysed by GC1-14B for Guinea and gamba separate dung

Temperature (°C)	Guinea grass cow dung			Gamba grass cow dung		
	Nitrogen	Methane	Carbon dioxide	Nitrogen	Methane	Carbon dioxide

37.00	22.33	50.63	27.04	23.40	48.21	28.39

Table 7 showed that 1.4 kg weight at 37^{o}C had methane, nitrogen and carbon dioxide percentages composition as 59.02, 8.48 and 32.50 respectively. At 35^{o}C the percentage of methane, nitrogen and carbon dioxide are 53.55, 15.67 and 30.78 respectively. It was observed that small quantities of methane gas were produced at temperature 30 ^{o}C and 32^{o} C because of less microbial activities at these temperatures. Also at 38 ^{o}C less methane was produced due to the increased temperature which might have affected the microbial activities responsible for the gas production. The result in table 8 showed that feeding the cattle's with guinea grass, the dung produced higher percentage of methane gas compared to the dung obtained from gamba grass. This indicates that the guinea grass contributed more in the overall methane gas production for the dung obtained from the mixed feed due to its nutritive composition. In general, it was found out that at 37^{o}C, the rate of gas production was faster with the highest methane percentage.

3. CONCLUSION

The experimental result showed that at 37^{o}C the rate of gas production from White Fulani cow feed with mixed guinea/gamba grass based feed was faster and with highest methane composition thus, faster degradation of waste taking place at this temperature. Comparing the methane gas production from dung obtained from the guinea grass and gamba grass respectively, the guinea grass had higher percentage of methane gas compared to the gamba grass dung at 37^{o}C. This indicates that the guinea grass favoured the production of methane gas compared to the gamba grass in the mixed feed. The long time it took to produce gases at temperatures 30^{o}C and 32^{o}C might be due to the low temperature which affects the microbial activities in the Cow dung. Also the decrease in the rate of gas production at 38^{o}C might be due to high temperature affecting the microbial activities in the cow dung. The research work also shows that feed weight affects the quantity and duration of the gas production.

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