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Comparative study of biogas production from cow dung, cow pea and cassava peeling using 45 litres biogas digester

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ABSTRACT

A 45 Litres capacity metallic prototype biogas plant constructed at the National centre for Energy Research and Development, University of Nigeria, Nsukka was used to investigate the anaerobic digestion in generating biogas from three types of wastes: Cow dung, Cowpea and Cassava peeling. The experiment was batch operated and daily gas yield from the plant was monitored for 30 days. The ambient and slurry temperature, pH, and Pressure were also monitored and presented. The digester was charged differently with these wastes in the ratio of 1:2, 1:5 and 1:5 of waste to water respectively. The mesophilic ambient temperatures range attained within the testing period were 20 - 32^o C and a slurry temperature range of 22 – 36^0 C. The result obtained from the gas production showed that cowpea produced the highest methane content of 76.2%, followed by cow dung with 67.9% content and cassava peeling has the least methane content of 51.4%. The cow dung had the highest cumulative biogas yield of 124.3 L/total mass of slurry (TMS) while cow pea had 87.5 L/TMS and cassava peeling with lowest cumulative biogas yield of 87.1 L/TMS within this retention period. During the digestion period, the volume of biogas production and the changes in pH indicate that at neutral pH, the highest peak of gas production was attained and that at slightly acidic pH range, there was no gas production. In terms of flammability, they became flammable at different period during the digestion. Cow pea was favoured in terms of volume of flammable gas production of biogas and flamed on the 7th day. These results showed that these wastes could be a source of renewable gas if managed properly since each of the waste sluggishly continued gas production after the 30 days retention time.

Keywords: Cow dung, Cowpea, Cassava peeling, Biogas production, Renewable natural Gas.

INTRODUCTION

In evaluating national development and the standard of living of any nation, the supply and consumption of energy are very important. Human energy consumption has been moderate before the industrial revolution in the 1890s. Man has mostly relied on the energy from brute animal's strength to do work. Recently, man acquired control over coal, electricity, crude oil, natural gas, etc. Sustainable resource management of waste and the development of alternative energy source are the present challenges due to economic growth. The history of waste utilization shows independent developments in various developing and industrialized countries. Anaerobic digestion can convert energy stored in organic matter present in manure into biogas. Energy supplied from fossil fuels is not easily recycled and takes a long time to form, hence is exhaustible and not renewable. Renewable energy has remained one of the best alternatives for sustainable energy development since the grid electricity has become too expensive. Sources of renewable energy are wind, hydro, ocean waves, geothermal energy resources and solar energy, which can be applied as solar thermal and solar electricity (photovoltaic). Heat-based technologies developed for the utilization of heat energy from the sun (solar thermals).They are applied in water heaters, drying, chick-brooding, cooking, manure dryers, biogas and thermal refrigerators. With the advent of industrialization and energy based intensive agriculture, chemical pathways for raw materials conversion became predominant with extensive use of petrochemical based feedstock. The damaging long term environmental impacts and resource depletion indicate un-sustainability of the current methods.[12].

Biogas is another source of renewable energy, it is produced when biomass is subjected to biological gasification and a methane-rich gas is produced from the anaerobic digestion of organic materials. Achieving solutions to possible shortage in fossil fuels and environmental problems that the world is facing today requires long-term potential actions for sustainable development. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions [10]. Biomass is the biological organic materials that are renewable and can be recycled to produce biogas. A huge amount of wastes is generated daily from the various processing industries in Nigeria. The wastes that are usually disposed off either into the sea, river, or on the land as a solid amendment materials, which causes support for breeding of flies, and constitute health hazards to people living around the area are converted into biogas by anaerobic fermentation [5]. What is considered as waste many years ago have in recent time become useful that it can be inferred that in life, nothing is a 'waste'. They are only waste when they lack the useful technology for their transformation and application. The biomass wastes are held in a digester or reactor. The gas is produced from a three-phase process namely, hydrolysis, acid-forming and methane-forming phases. It is a biological engineering process in which a complex set of environmentally sensitive micro-organisms are involved. The gas is typically composed of 50-70% Methane, 30-40% Carbon dioxide, 1-10% Hydrogen, 1-3% Nitrogen, 0.1% Oxygen and Carbon monoxide and trace of Hydrogen sulphide [6], [1].Biogas is also a waste management technique because the anaerobic treatment process eliminates the harmful micro-organisms. It is a heap source of energy due to the feed stock is usually waste materials. The technology ensures energy independence as a unit can meet the need of a family or community. The digester slurry is a good fertilizer. It is claimed that its value as fertilizer could double crop yield. Biogas when further refined burns as well as liquefied gas, but does not add to global warming like liquefied natural gas [1].Cow dung has high nitrogen content and due to pre-fermentation in the stomach of ruminant, and has been observed to be most suitable material for high yield of biogas through the study made over the years [4]. Thermal decomposition of the ligand and synthesized complexes were studied by thermogravimetric analyses (TG) in order to evaluate their thermal stability and thermal decomposition pathway [2]. Plant materials such as crop residues are more difficult to digest than animal wastes (manures) because of the difficulty in achieving hydrolysis of cellulosic and lignin constituents with attendant acidity in the biogas systems leading to reduction and sometimes cessation of gas flammability / gas production [11], etc. Flammable gas which helps in reducing forestation and desert encroachment is produced through the conversion of this organic matter such as animal and plant wastes into biogas [8]. The objective of this study was to investigate the biogas production potentials of Cow dung, Cowpea, Cassava Peeling and to compare them.

MATERIALS AND METHODS

The biodigester used for this research is a 45L capacity metallic prototype digester (Fig 1) and the study was carried out between August and September 2011 at Ebonyi state University Abakaliki. Cow dung, Cowpea and Cassava peeling were the three wastes used for this study. Fresh cow dung was collected from the slaughter house, in Abakaliki, Ebonyi state whereas cowpea waste were procured from local akara processor in Abakaliki town and the cassava peelings where collected from one of the local garri processors at Abakaliki Ebonyi state. Other materials such as Top loading balance (50kg "Five goat" model Z051599), 13L calibrated plastic transparent bucket, and Digital pH meter and thermometer were used. A minimum and maximum ambient temperature of 20^0C and 32^0C respectively and a minimum and maximum slurry temperature of 22^0C and 36^0C respectively were recorded at the pH range of 5.57 - 8.07.

Table 1: Mix Masses of Charge Stock and Water

WASTES	MASS OF WASTE (kg)	MASS OF WATER (kg)	Mix Ratio
Cow dung	17	34	1:2
Cow Pea	6	30	1:5
Cassava Peeling	6	30	1:5

Experimental Procedure

17kg of cow dung was charged into the digester with 34kg of water in the ratio of 1:2 of waste to water and the slurry was properly stirred. Also 6kg of cowpea waste and 30kg of water was mixed into the digester in the ratio of 1:5 of waste and water. For the cassava peeling, a 6kg of waste was charged into the digester with 30kg of water in the ratio of 1:5, of waste to water respectively. The mixing ratio was determined by the moisture content of the different wastes. The daily ambient and slurry temperatures were measured using thermometer (-10 to 110^0C), The pH Values were monitored on 3 days interval to determine the action of methanogens, which utilize the acids, carbon dioxide and hydrogen produced by non-methane producing bacterial using a digital pH meter (PHS-3c pH meter). The volume biogas produced was measured by a downward displacement method using a transparent 13L calibrated plastic bucket as used by [7]. The composition of the flammable biogas produced from each of the waste was determined through the use of Orsat apparatus. In checking the flammability of the gas, a locally fabricated biogas burner was used. A top loading balance (50kg capacity, "five goat models no Z051599) was used in the measurement of the water and waste volumes.

The plant consists of the fermentation chamber, the inlet and outlet pipe, the gas pipe and the stirrer. The digester was charged and its performance monitored for 30 days. The organic wastes were allowed to stabilise, anaerobic fermentation involving the degrading of the wastes by the action of various microbes of different sizes and functions, leading to the production of biogas in the absence of oxygen was achieved [9]. The main functions of this plant are:

i To collect the gas for processing and storage
ii To regularly stir and mix the charge.
Iii To accept new quantities of charge
iv To keep the charge at operating temperature
v To provide a means to discharge the spent contents
vi To allow access for repairs and maintenance

Figure 1: Experimental biogas plant set up

RESULTS AND DISCUSSION

Table 1 shows the mixed mass of charge stock and water ratio for the different wastes. A close examination of table 2, (Biogas composition by % volume) shows that cowpea has the highest carbon dioxide content of 33.2%, followed by cassava peelings with 32.2% of carbon dioxide and lastly cow dung has 27.2% content of carbon dioxide. Cow dung yield the highest biogas with methane content of 67.9%. Cow pea yielded 56.2% methane content. The lowest methane content was produced by cassava peelings with 51.4%.

Table 3 shows the summary of the result for the three wastes for the 30 days retention period. From the table, cow dung generated the highest total gas volume of 124.3 litres, followed by Cow pea with 97.5 litres of gas and lastly cassava peelings produced 87.1 litres of gas.

Table 4 shows the 30 days daily and volume of biogas production for the three wastes. A close observation shows that cow dung started daily production on the second day, reaching peak on the 10th day and yielding 8.2 litres of biogas. A cumulative of 124.3 litres of biogas was produced at the end of the 30 days retention period from the cow dung waste. Cow pea gas production started at the 6th day after the charging of the digester, the gas production ranges from 4.8-7.3 litres and a cumulative of 97.5 litres was produced. Also from table 4, cassava peelings were the lowest in terms of gas production, started daily gas production on the 5th day. The maximum volume of biogas generated from cassava peelings was 6.3 litres and a total volume of 87.1 litres of biogas was produced at the end of the 30 days. From this table, it shows that the biogas production varied from the three wastes and also in the days. Cowpea yielded higher methane gas than cow dung and cassava peeling waste. The digester containing cow dung was favoured in terms of volume of flammable gas production.

Table 2: Biogas Composition by % Volume

WASTE STOCK	CARBONDIOXIDE	HYDROGEN SULPHIDE	CARBON MONOXIDE	METHANE
Cow dung	27.2	0.1	4.7	67.9
Cowpea	33.2	0.5	10.1	56.2
Cassava peeling	32.2	3.1	13.3	51.4

Table 3: Summary of Results for the three wastes

Items	**Cow Dung**	**Cowpea**	**Cassava Peeling**
Mass of Waste Used(kg)	17	6	6
Mass of Water Used (kg)	34	30	30
Total Mass of slurry(kg)	51	36	36
No of Days of Digestion	30	30	30
Total Volume of Gas Generated (L)	124.3	97.5	87.1
Maximum Ambient Temp. (^oC)	32	32	32
Maximum Slurry Temp. (^oC)	36	38	35
Peak volume of Gas (L)	8.2	7.3	6.3

Table 4: 30 days of Daily / Volume of Biogas products (Litres) for the three Wastes

Waste	Cow Dung		Cowpea		Cassava Peeling	
No of Days	Daily Volume of gas (L)	Cumulative Volume of gas (L)	Daily Volume of gas (L)	Cumulative Volume of gas (L)	Daily Volume of gas (L)	Cumulative Volume of gas (L)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	4.9	4.9	0.0	0.0	0.0	0.0
3	6.2	11.1	0.0	0.0	0.0	0.0
4	7.7	18.8	0.0	0.0	0.0	0.0
5	3.2	22.0	0.0	0.0	1.5	1.5
6	3.9	25.9	4.0	4.0	2.6	4.1
7	4.5	30.4	3.4	7.4	2.8	6.9
8	2.9	33.3	1.3	8.7	1.1	8.0
9	2.9	36.2	3.3	12.0	2.6	10.6
10	8.2	44.4	6.6	18.6	5.5	16.1
11	7.9	52.3	5.8	24.4	6.4	22.5
12	7.2	59.5	6.2	30.6	6.3	30.8
13	5.4	64.9	4.3	34.9	5.8	36.6
14	4.5	69.4	6.8	41.7	3.1	39.7
15	2.5	71.9	4.3	46.0	3.5	43.2
16	2.8	74.7	3.5	49.5	1.9	45.1
17	5.2	79.9	7.3	56.8	5.0	50.1
18	5.6	85.5	6.9	63.7	5.3	55.4
19	4.2	89.7	5.2	68.9	5.7	61.1
20	3.9	93.6	2.4	71.3	2.2	63.3
21	3.0	96.6	1.3	72.6	2.4	65.7
22	3.2	99.8	2.3	74.9	3.0	68.7
23	3.0	102.8	1.6	76.5	1.5	70.2
24	2.0	104.8	1.4	77.9	1.1	71.3
25	3.3	108.1	2.7	80.6	1.8	73.1
26	2.7	110.8	3.5	84.1	2.1	75.2
27	3.2	114.0	2.1	86.2	2.3	77.5
28	3.0	117.0	3.3	89.5	2.7	80.2
29	3.0	120.0	3.2	92.7	3.0	83.2
30	4.3	124.3	4.8	97.5	3.9	87.1

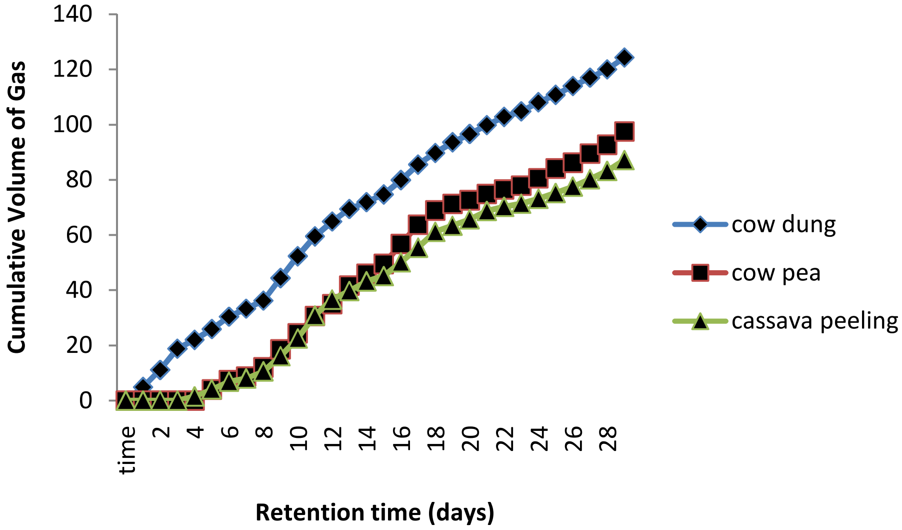

Figure 2: Cumulative Biogas Volume Vs Time

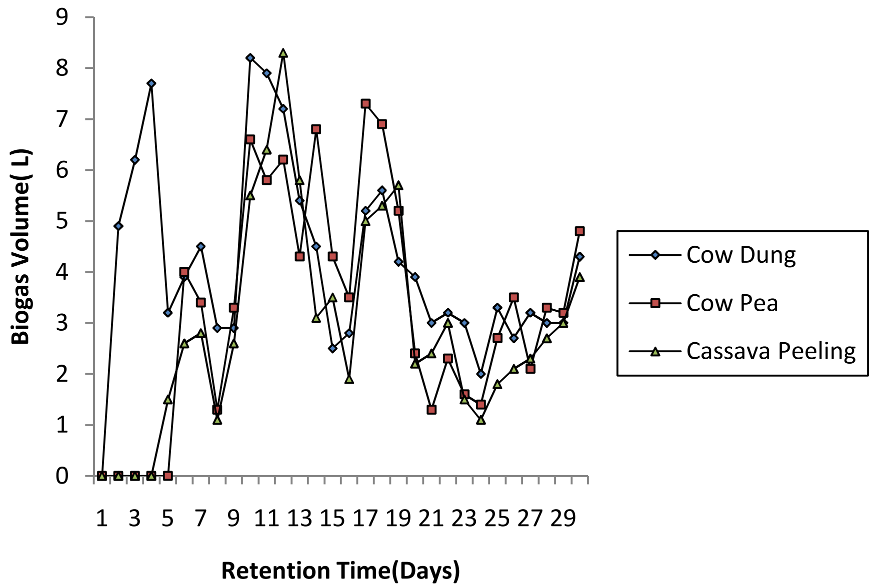

Figure 3: Biogas Volume Vs Time (Days)

The results show that factors like temperature, pH, concentration of total solids, etc affect the production of the biogas. The ambient and slurry temperature values were monitored in determining the rate of digestion and retention of the process, since temperature is very important. The ambient temperature affects the rate of digestion due to the outside walls of the digester surface make direct contact with the atmosphere, hence the digester walls absorb or loose heat depending on the temperature gradient between the digester and its immediate 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. The bacterial involved may not play its role completely. Ambient temperature fluctuated due to climatic conditions. The mesophilic (20^0C - 45^0C) is the temperature range that was identified for the slurry temperature (Ts). In the mesophilic temperature, the reaction of the slurry is slower, long retention time and moderate gas production. With experiment carried out during the season showed that slurry temperature up to 32^0C can at times be recorded whereas ambient temperature varied between 20^0C and 32^0C. A pH of 7 was found to be the most favourable at the mesophilic temperature range, as the organic acids were always formed during the anaerobic decomposition process**.**

In general, as gas produced by the microbial is evacuated from the top of slurry, it is automatically replaced by new gas molecules formed in the slurry. It was observed in the three test carried out with cow dung, cowpea and the cassava peelings, that the more the gas was removed from the system the more it is replaced.

An Orsat apparatus was used for volume analysis of the biogas yields. The experiment was carried out during rainy season which affected greatly the production of biogas, increase in temperature increases the rate of biogas production. The results of the evaluation of the production of biogas from the organic waste are presented in the tables and figures.

CONCLUSION

The result of this research on the production of biogas from cow dung, cowpea and cassava peeling has shown that flammable biogas can be produced from these wastes through anaerobic digestion for biogas generation. These wastes are always available in our environment and can be used as a source of fuel if managed properly. The study revealed further that cow dung as animal waste has great potentials for generation of biogas and its use should be encourage due to its early retention time and high volume of biogas yields. Also in this study, it has been found that temperature variation, PH and Concentration of Total solid etc, are some of the factors that affected the volume yield of biogas production.

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