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Optimization of Biogas Production from Fresh Cassava Peels and Fresh Cow Dung (Using Pretreatment Chemical): Sodium Hydroxide

Pius Ogbonna[1], Nnabuchi Mishark Nnamdi[2], Nwodo Emeka[3], 1gbo Michael[4], Igbo Nkechinyere Elem[5]
Department of Industrial physics, Enugu State University of Science and Technology (ESUT) Enugu.
Enugu State, Nigeria.

Abstract:- This study was conducted on optimization of biogas from fresh cassava peels and fresh cow dung using sodium hydroxide (NaOH). The possibility of producing biogas from fresh cassava peels and fresh cow dung waste was investigated. Fresh cassava peel and fresh cow dung was used in the study. The feed stocks fresh cassava peels, fresh cow dung and fresh cassava peel mixed with fresh cow dung were charged into the bio-digester and used to investigate the anaerobic digestion in generating biogas for 20days retention period. The digesters were charged separately with these wastes in the ratio of 1:2, 1:3 and 1:3 of waste to water respectively. Pretreatment chemical, (NaOH) solution was used in pre-treating the fresh cassava peel and fresh cow dung slurry. The volume of biogas produced were monitored and recorded daily. The result obtained from the biogas production showed that fresh cow dung produced the highest methane content of 67.9 percent, followed by the mixture of fresh cassava peel and fresh cow dung with 59.7 percent methane content and fresh cassava peels has the least methane content of 51.4 percent. The results also showed that the cow dung also had the highest cumulative biogas yield of 93.3litres, followed by the mixture of cassava peel and cow dung with cumulative volume of 73.8litres and the least was cassava peels with cumulative volume of 61.3litres within the same retention period of 20days. Overall results indicate that these wastes which are always available could be source of renewable natural gas if properly treated.

***Keywords**:- Biogas, Fresh Cassava Peels, Fresh Cow Dung, Sodium Hydroxide.*

I. INTRODUCTION

A huge amount of wastes are being generated daily from the various processing industries in Nigeria. These wastes are usually disposed off, either in the sea, river or on the land surface as a solid waste material, and can cause odour problems, support fly breeding, create toxic contaminants in soil and ground water, thus constitute health hazards to people living around the area. Biogas production is also a waste management technique because the anaerobic treatment process eliminates the harmful micro-organisms in the waste. These wastes may be converted into biogas by anaerobic digestion [2]. What was considered as waste many years ago have in recent time become useful, implying that in life there is nothing that is a waste. There could only be waste when we lack useful technology for their transformation and application. Sustainable resources management of waste and the development of alternative source of energy are the present challenges of the industrial age due to economic growth. Anaerobic biodegradation of cellulosic materials is a biological process, the end products of which are methane-rich gas called biogas and a spent slurry of fertilizer value. It is a process by which organic materials such as weeds, straw, and garbage, domestic sewage, animal and human excrete, sludge, and organic liquid waste from factories, etc. are degraded by huge number of various microbes of different functions under anaerobic conditions to yield methane in the end. Biogas is a composition of colorless, odorless and flammable gasses derived from organic waste materials such as cassava peels during anaerobic digestion. The overall composition of biogas is typically 60-70% methane (CH_4), 28–30% carbon (IV) oxide (CO_2) as well as 2% of Nitrogen (N), Hydrogen (H) and hydrogen sulphide (H_2S).[4] maintained that biogas 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. Our result shows that the biogas generated in this work contains significant amount of methane.

Biogas is majorly known as sewage gas or marsh gas because they are mostly produced from agricultural waste like cassava peels when subjected to anaerobic process involving micro-organisms. The basic micro-organisms that are involved in the process of biogas production are categorized into four groups (Bacteria hydrolysis, Acidogenic bacteria, acetogenes and methanogenes). The decomposition of waste involves three anaerobic stages (hydrolysis, acidification, fermentation and methanogenesis) of biochemical processes with release of biogas. The organic substances are biodegraded externally by specific cellular enzymes in the initial phase. The next phase (intermediate) is converted to low molecular weight compound by acid producing bacteria (Acidogene) in an anaerobic condition which facilitate methane (CH_4) production by specific micro-organisms. Hydrolytic bacteria produce enzymes that decompose substrate to some molecules of water, soluble molecules as well as polymers to be converted into monomers. During hydrolytic reaction, partial anaerobiosis occurs due to oxygen consumption and thereby enhancing a

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suitable anaerobic environment for production of methane by methane-producing bacteria. The next phase involves fermentation stage where the products of hydrolysis (soluble organic monomers of sugar and amino acids) are degraded by acidogenic bacteria to produce alcohol, aldehydes and volatile fatty acids (VFA) and acetate together with hydrogen (H_2) and carbon (IV) oxide(CO_2) [7]. Evaluation of effect of sodium hydroxide solution on biogas yield of anaerobic digestion of poultry waste and the digestate reported by [1] that the effect of adding an alkaline solution, sodium hydroxide (NaOH) in optimizing biogas and methane yield from poultry waste anaerobically was very effective. The co-digestion of animal and plant waste helps in optimizing biogas production [6].

II. MATERIALS AND METHOD

A. Waste and Materials collection

The following materials were collected and used for the experiment, locally fabricated bio digester from Ebonyi state University, fresh cassava peel (ground), fresh cow dung, hose pipe (three yards of length), big funnel (for easy feeding of the slurry), calibrated bucket for measuring daily gas collection, digital pH meter, gallons of clean water, rubber bowl, thermometer (for measuring temperature), weighing balance, Sodium hydroxide (NaOH),MATLAB (Matrix Laboratory).

B. Method of Experiment

20kg of fresh cassava peel was washed with clean tap water to remove sand and the water was allowed to drain for about 30 minutes. The washed fresh cassava peel was ground into smaller particles. Then **10kg** of the ground cassava peels was mixed with **30k**g of water in the ratio of 1:3 to form slurry. The slurry (ground fresh cassava peels and water) was treated with 5% of Sodium Hydroxide (NaOH) and fed into the digester **A**. The quantity of the slurry was pre-determined by measuring it to make sure it occupied about 65%-75% volume of the digester **A**. During the charging of the digester **A**, the main solvent used for dilution of organic waste is water. The purpose was to determine the volume of biogas produce daily by cassava peels only.

Then **15kg** of fresh cow dung was mixed with **30kg** of water in the ratio of 1:2 of waste to water, which was measured using a weighing balance. The waste and water mixture (fresh cow dung slurry) was also treated with Sodium Hydroxide (NaOH) then fed into the digester **B**. with the purpose of determining the volume of biogas produced by fresh cow dung slurry.

For digester **C**, **5kg** each of ground fresh cassava peel and fresh cow dung was mixed with 30kg of water in the ratio of 1:3. The two wastes were first poured into a plastic bowl and with stirrer were thoroughly mixed. The mixture of cassava peels and cow dung was then pretreated with Sodium Hydroxide (NaOH) and transferred into the digester **C.**

The set up connected to digester **A** was to measure the volume of biogas produced daily by fresh cassava peel slurry only. The set up connected to digester **B** was to measure the daily volume of biogas produced by cow dung slurry only. The set up connected to digester **C** was also to measure daily volume of gas produced by the mixture of fresh cassava peel and fresh cow dung only.

C. Determination of the slurry concentration

Concentration of slurry has to be in such a way that correct percentage was obtained during charging of the bio-digester. This can be done thus;

$$\%\text{Concentration of slurry} = \frac{M_0 - W_r}{W_r + M_w} \times \frac{100}{1} \quad (1)$$

Where
w_r= weight of the raw material (waste)
M_o= weight of total solution of raw waste (waste + water)
M_w= weight of water for dilution.

III. RESULT AND DISCUSSION

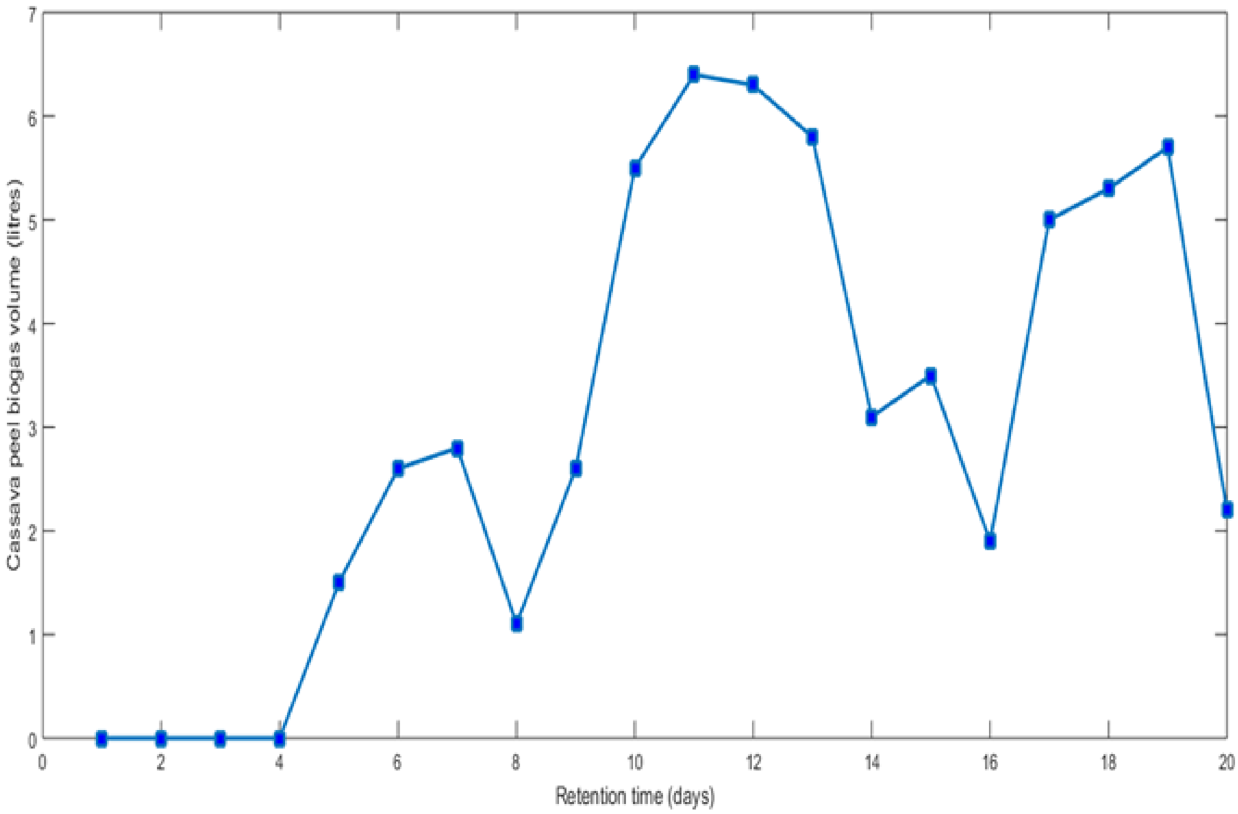
Table 1: Mass of the wastes and water (mix ratio) in different digesters

Wastes	Mass of Waste (Kg)	Mass of Water (Kg)	Mix Ratio
Fresh Cow dung	15	30	1:2
Fresh Cassava peels	10	30	1:3
Fresh Cassava peels + Fresh cow dung	10	30	1:3

Table 1 contains calculated values for the mixed ratio masses of the wastes and water in kilogram. It shows the mixed masses of charge stock and water ratio for the different wastes. Water was the main solvent used for dilution of the organic wastes during charging. The mixing ratio were determined by the moisture content of the different wastes, the ratio of waste to water were 1:2 (for fresh cow dung), 1:3 (for fresh cassava peels) and 1:2 (for fresh cassava peels + fresh cow dung) respectively. However, the cassava peels wastes contain less amount of water, the volume of water used in the dilution of these wastes was increased to arrive at the desired slurry ratio. This value is within what is expected in the charging of the digester [3].

Table 2: The daily and Cumulative Volume of Biogas Produced from fresh Cassava Peels
Date: November 12th –December 1st, 2022.

S/NO	**Number of Days**	**Daily Volume of gas(dl)**	**Daily Volume of gas (L)**	**Cumulative volume of gas (L)**	**Ambient temperature (^0C)**
1	1	0.000	0.000	0.000	33.00
2	2	0.000	0.000	0.000	32.50
3	3	0.000	0.000	0.000	35.00
4	4	0.000	0.000	0.000	34.00
5	5	15.00	1.500	0.150	36.00
6	6	26.00	2.600	0.410	35.50
7	7	28.00	2.800	0.690	30.50
8	8	11.00	1.100	0.800	33.00
9	9	26.00	2.600	1.060	34.50
10	10	55.00	5.500	1.610	38.50
11	11	64.00	6.400	2.250	35.00
12	12	63.00	6.300	2.880	34.80
13	13	58.00	5.800	3.460	33.50
14	14	31.00	3.100	3.770	34.00
15	15	35.00	3.500	4.120	32.80
16	16	19.00	1.900	4.310	33.50
17	17	50.00	5.000	4.810	35.00
18	18	53.00	5.300	5.340	35.00
19	19	57.00	5.700	5.910	33.60
20	20	22.00	2.200	6.130	34.50



Fig, 1: Graph of fresh cassava Peel biogas production volume (litres) against retention time (days)

Fig.1 shows that in the first four days, there was no biogas production from the digester containing fresh cassava peel slurry. The digester started production of gas on the fifth day and produced 1.5litres (15decilitre) of gas. The highest volume of gas was produced on the eleventh day, when it produced 6.4litres (64dl) of gas. The delay in the production of biogas for about 96hours by fresh cassava peel was as a result of high concentration of hydro cyanide (HCN) on fresh cassava peel which affected the process of digestion that delayed fermentation. Though, fresh cassava peel has high carbon-nitrogen ratio, activities of microbes and the slurry temperature also played role in the volume of biogas produced on 11^{th} day of the experiment.

Table 2: The daily and cumulative volume of biogas produced from fresh cow dung
Date: December 16th – January 4th, 2023.

S/NO Days (L)	**Number of gas(dl) (^{0}C)**	**Daily Volume of of gas (L)**	**Daily Volume volume of gas**	**Cumulative temperature**	**Ambient**
1	1	0.000	0.000	0.000	33.00
2	2	49.00	4.900	0.490	38.00
3	3	62.00	6.200	1.110	37.60
4	4	74.00	7.400	1.880	39.50
5	5	32.00	3.200	2.200	37.50
6	6	39.00	3.900	2.590	36.00
7	7	45.00	4.500	3.040	38.50
8	8	29.00	2.900	3.330	34.60
9	9	29.00	2.900	3.620	35.00
10	10	82.00	8.200	4.440	40.30
11	11	54.00	5.400	5.230	40.00
12	12	72.00	7.200	5.950	39.30
13	13	54.00	5.400	6.490	33.50
14	14	45.00	4.500	6.940	34.00
15	15	25.00	2.500	7.190	36.60
16	16	28.00	2.800	7.470	33.00
17	17	52.00	5.200	7.990	35.30
18	18	56.00	5.600	8.550	36.00
19	19	42.00	4.200	8.970	33.00
20	20	39.00	3.900	9.360	34.80

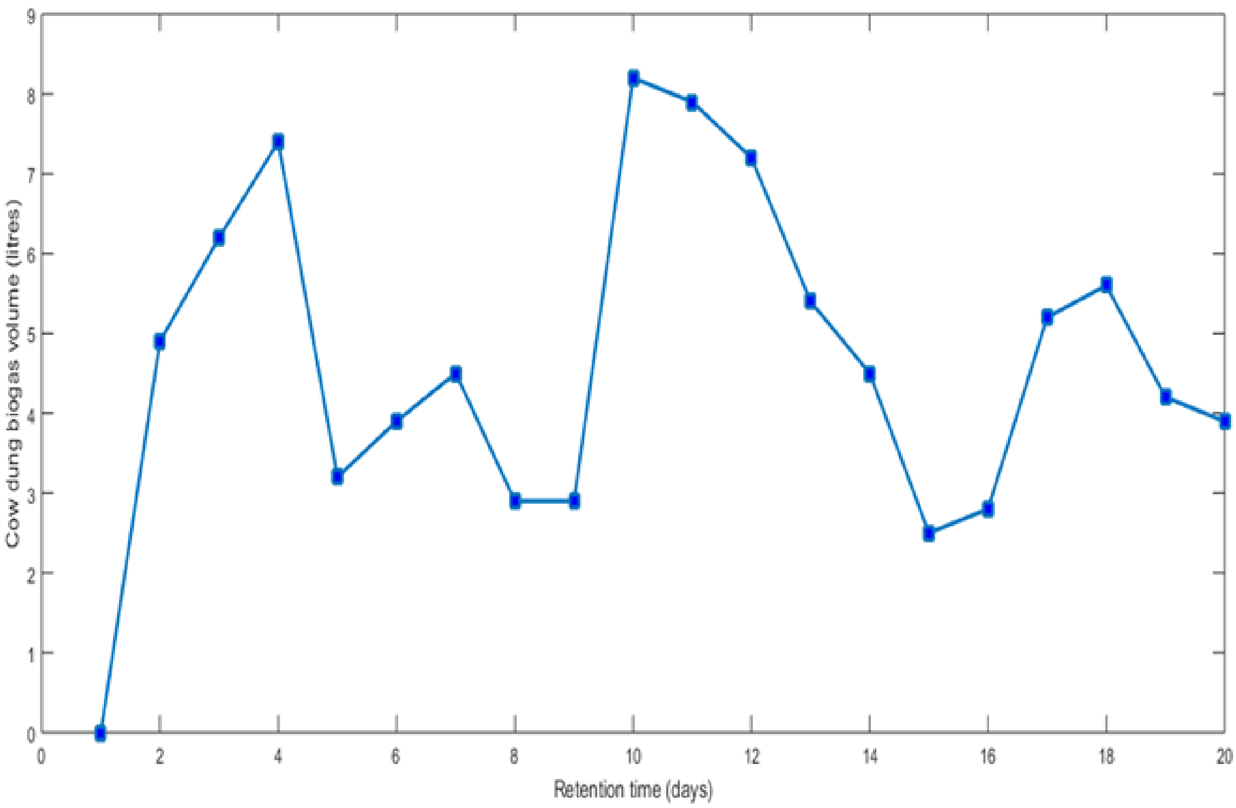


Fig. 2: Graph of fresh cow dung biogas production volume (litres) against retention time (days)

Fig.2 shows the graphical analysis of the biogas production from fresh cow dung. There was no production of biogas on the first day, on the second day 4.9litres (49dl) of biogas was produced. The peak of biogas produced from fresh cow dung happened on the tenth day when 8.2litres (82dl) of biogas was recorded. The fresh cow dung does not contain hydro cyanic acid to have caused delay in the production of biogas. The quantity of biogas produced each day shows how reactive the microorganisms in the fresh cow dung are. The rise and fall in the volume of gas produced each day was as result of the temperature of the reactor which contributes in deciding the level of fermentation leading to higher volume production of biogas in the digester.

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Table 3: The daily and Cumulative Volume of Biogas Produced from mixture of fresh cassava peels and fresh cow dung
Date: January 21st – February 9th, 2023.

S/NO	Number of Days	Daily Volume of gas(dl)	Daily Volume of gas (L)	Cumulative volume of gas (L)	Ambient temperature (^{0}C)
1	1	0.000	0.000	0.000	33.00
2	2	24.50	2.450	0.245	38.00
3	3	31.00	3.100	0.555	37.60
4	4	38.50	3.850	0.940	39.50
5	5	23.50	2.350	1.175	30.50
6	6	32.50	3.250	1.500	31.00
7	7	36.50	3.650	1.865	33.50
8	8	20.00	2.000	2.065	30.60
9	9	27.50	2.750	2.340	32.00
10	10	68.50	6.850	3.025	43.30
11	11	71.50	7.150	3.740	40.00
12	12	67.50	6.750	4.415	39.30
13	13	56.00	5.600	4.975	36.50
14	14	38.00	3.800	5.355	34.00
15	15	30.00	3.000	5.655	32.60
16	16	23.50	2.350	5.890	33.00
17	17	51.00	5.100	6.400	35.30
18	18	54.50	5.450	6.910	35.00
19	19	49.50	4.950	7.405	33.00
20	20	30.50	3.050	7.710	34.80

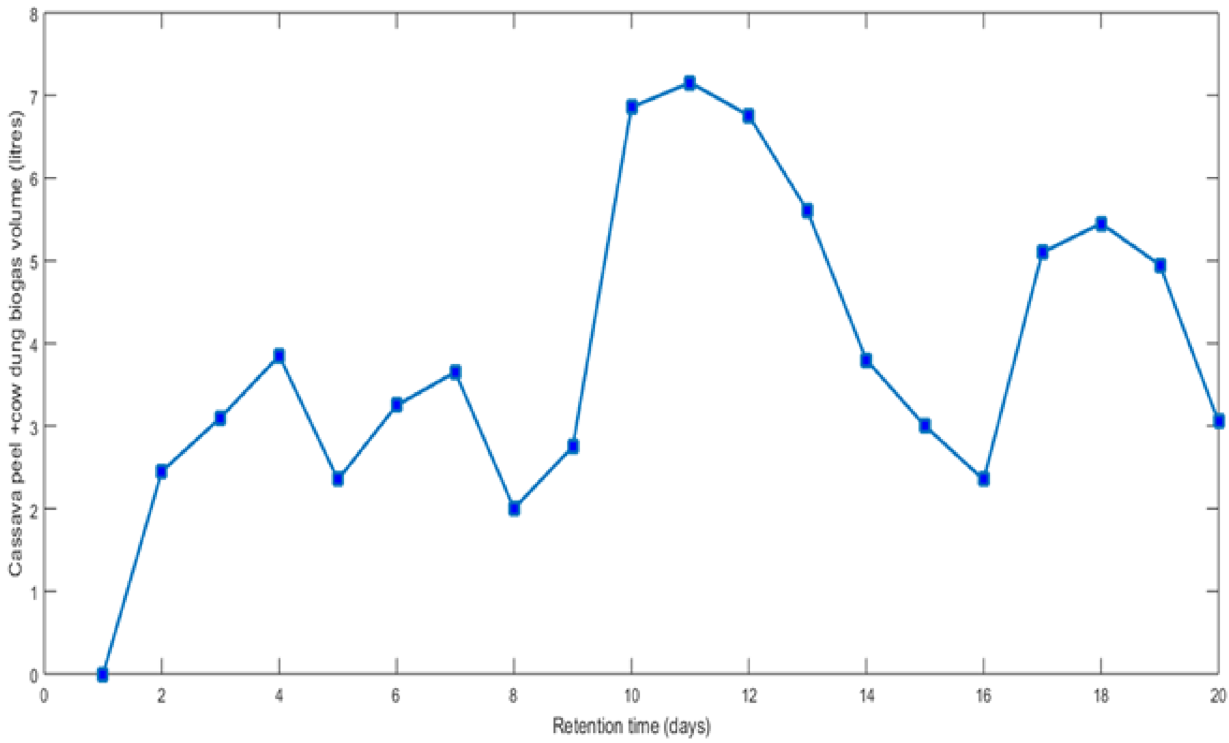

Fig 3: (litres) Graph of mixture of fresh cassava peel and fresh cow dung biogas production volume against retention time (days)

Figure 3 shows the analysis of daily volume of biogas production from the mixture of fresh cassava peels and fresh cow dung. It was observed that no gas was produced on the first day. On the second day 2.5litres (24.5dl) was produced. On the eleventh day, the highest volume of gas was produced, which was 7.2litres (71.5dl). The sinusoidal form shown on the graph depicts the difference in temperature of different days, carbon-nitrogen ratio and irregular activities of the microorganisms in the two wastes mixed together.

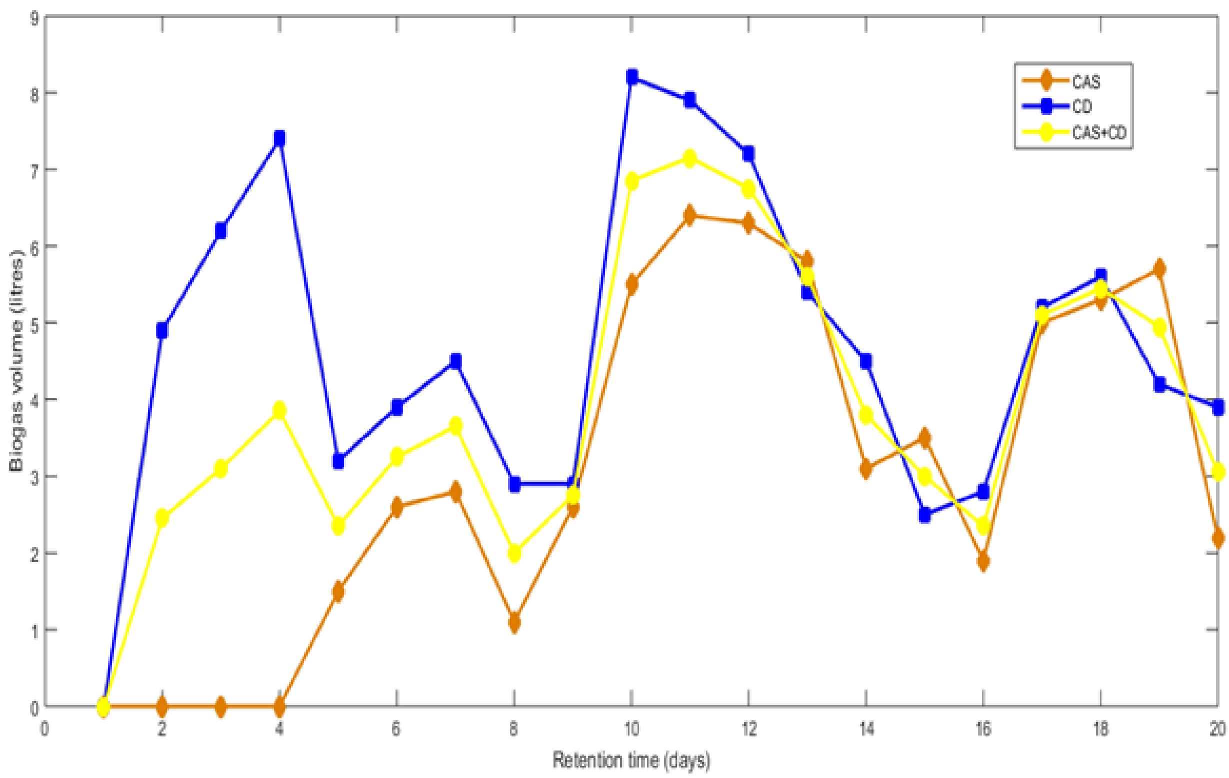

Fig 4: Combine graph of fresh cassava peels, fresh cow dung and the mixture of fresh cassava peels and fresh cow dung biogas production volume (litres) against retention time (days)

Figure 4, shows the comparison of the daily volume of biogas produced from the two wastes (fresh cassava peels and fresh cow dung) separately and when mixed. The blue legend shows the volume of biogas produced from fresh cow dung; the yellow legend shows the volume of biogas produced from the mixture of fresh cassava peel and fresh cow dung while the red legend shows the volume of biogas produced from fresh cassava peel. The results show that for both fresh cow dung and mixture of fresh cassava peel and fresh cow dung, the biogas production started after 24hours. However, it was observed that in the first 5days of the anaerobic digestion, the volume of biogas produced from fresh cow dung was significantly higher than that of the volume of gas produced from mixture of fresh cassava peel and fresh cow dung and that of fresh cassava peel alone. The high rate of production of hydrocyanic acid by fresh cassava peel at early stage of digestion was the possible reason for the reduced volume of biogas production. This is in agreement with what [8] reported that the presence of cyanogenic glucosides in cassava could induce excess acid production and the release of cyanide which reduces biogas production. On the 10^{th} and 11^{th} day of the anaerobic digestion, there was drastic increase in biogas production from the three experiments. The maximum biogas production was recorded on the 10^{th} day for fresh cow dung and 11^{th} day for both fresh cassava peel and mixture of fresh cassava peel and cow dung. This increase in biogas production from cassava peel indicates gradual reduction in the quantity of hydrocyanic acid after 10 days of digestion. Between 18^{th} and 20^{th} day of the experiment, there is an observed decrease in volume of biogas produced for the wastes. This might have been as a result of depletion of nutrient and reduction in the population methanogenic microorganisms in the digesting slurry in both cassava peel and fresh cow dung [5]. It can be concluded that the volume of biogas produced was in a fluctuating manner during 20 days anaerobic digestion.

IV. CONCLUSION

The experiment carried out shows that fresh cassava peel and fresh cow dung can be used to produce biogas. The study shows that fresh cassava peel mixed with fresh cow dung produced more biogas than fresh cassava peel alone because of the carbon nitrogen C/N ratio of the substrates. It was also observed that fresh cow dung digestion yielded 8.2litres, the highest volume of biogas on the 10^{th} day of the experiment. The mixture of fresh cassava peel and fresh cow dung yielded 7.2litres on the 11^{th} day while that of fresh cassava peel yielded 6.4litres on the 11^{th} day of the experiment.

V. RECOMMENDATION

Based on personal experience gained in the course of this study, the following recommendation;

- The waste used should be one that is very close and freely available and requires little or no transportation. Fresh Cow dung is highly recommended, it has the highest rate of biogas yield. It also yields biogas of high methane content and is easily available.
- Compressing the gas into bottle or cylinder is still not economically easy. Research on other means of compressing biogas into cylinder should be intensified.

- Further research should be carried out on biogas purification for good flammability of the gas.

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