

Comparative Biogas Ignition Time from Cattle Dung Mixtures with Cassava and Plantain Peels

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Abstract

This paper compares the biogas ignition time from 8 kg cattle dung, 4 kg each of cattle dung and cassava peels, and 4 kg cattle dung with 4 kg plantain peels. Digesters with 1 m diameter, 0.75 m height and 2 mm thickness made of mild steel were used for the anaerobic digestion of the three substrates in a mesophilic environment. The substrate was charged to the digester after thorough mixing with water at 1:2 by mass. The biogases were daily tested for combustion. Temperatures and pressures of the digesters were monitored at 10 am and 4 pm daily with mercury thermometers and pressure gauges installed on them. The biogas from every digester was measured by water displacement approach. The cattle dung biogas ignited on the 14th day, cattle dung with cassava peels mixture on the 55th and cattle dung with plantain peels mixture, 146th day of digestion. Their biogas volumes were 6450, 7000 and 6500 ml. Bacteria identified on the three digestates were *Clostridium spp.* and *Bacillus licheniformies* with a population of 2.5×10^4 , *Pseudomonas spp.* and *Bacillus licheniformies* 3.8×10^4 , and *Bacillus licheniformies* with 2.3×10^4 cfu/ml. Cattle dung biogas recorded the least ignition time.

Keywords: Biogas; ignition time; cattle dung; cassava peels; plantain peels.

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INTRODUCTION

Deriving thermal energy from fossil sources emits large amount of carbon dioxide (CO₂), a greenhouse gas (GHG), to the atmosphere [1]. This forms a shield which traps and prevents the infrared rays escaping from the earth surface to higher levels of troposphere after the earth had been warmed from the solar rays. This brings about a general and unusual rise in the earth's average surface temperature known as global warming [2].

To mitigate global warming and climate change, renewable energy with negligible carbon emission is explored. Biomass is a potential renewable energy source due to the adverse environmental effects caused by the combustion of fossil fuels and their expected exhaustion in with time [3]. One such energy is biogas and it is obtained through the anaerobic digestion of plant and animal wastes. This anaerobic digestion is the most suitable approach for biomass waste disposal/management and sustainable development [4]. It comprises multifarious self-regulating, sequential and parallel biological reactions in oxygen deficient environment. The products from

one set of microbes serve as substrates for the subsequent one, resulting in conversion of organic matter mainly into a mixture of methane (CH₄) and carbon dioxide (CO₂), the biogas [5]. However the substrates do not have the same incubation period to achieve a combustible biogas mixture. Also the amount of biogas generated from these substrates varies from each other. There is the need to investigate this for different biodegradable materials used for biogas generation.

Many research works have been done on the production of biogas from biomass. For instance, biogas produced from cow dung, goat dung and a poultry dropping was found to be more quantitative and qualitative than that from goat dung and poultry droppings [6]. It was also reported that cow dung yielded the highest biogas when cow dung, swine dung, poultry droppings and plantain peels were seeded with cowpea coat [7]. The mixing together of biodegradable substrates in some cases increase their biogas yield potential. Therefore biogas was produced by combining cattle dung and poultry droppings in different percentages. The mixture of 80% cattle dung with 20% poultry droppings recorded the highest biogas yield

among different ratios [8]. Gedefaw [9] produced biogas from the co-digestion of cow dung and food wastes at a thermophilic temperature of 58.5 °C. He reported that cumulative biogas of 0.035 m³/kg was recorded at a pH range of 6.6 to 7.6. Adebayo, et al. [10] produced and evaluated the biogas from cow slurry, pig slurry and chicken waste at a mesophilic temperature of 37 °C in fed-batch reactors. They reported that the chicken waste yielded biogas with more methane and hence higher energy content compared to the biogases from the cow and pig slurries. Asikong et al. [11] generated biogas from the mixtures of poultry droppings and cow dung to form 1kg, 2 kg and 3 kg respectively for three digesters. Another set of these combinations were mixed with starter culture. The culture was formed from the cow dung digestate and activated carbon obtained from the treatment of charcoal with acetate. They reported that the starter culture increased the bacterial load and also the biogas yield. Chomini, et al. [12] also generated biogas from the co-digestion of cow dung and poultry manure and they reported that the mixture with 1:1 cow dung to poultry manure recorded the highest biogas production.

Co-digestion of substrates increases biogas production than single substrates alone. It improves methane production and at the same time minimizes the hydraulic retention time [1]. Stanley, et al. [13] investigated the biogas production from cow dung, mixtures of one kilogram each of cow dung with equal masses of poultry droppings, pig wastes, palm fruit wastes, plantain peels and orange waste, and the mixture of all these substrates for eighty one days. They reported that the mixture of the cow dung with palm fruit waste had the highest yield of biogas and the cow dung the lowest. Olawale, et al. [14] also compared the biogas generation from mixtures of cow dung with cassava peels, cow dung with sawdust and cow dung alone. They reported that the mixture of cow dung with sawdust recorded highest biogas yield and this was due to the high energy content of the saw dust that sustained the microbial action and their multiplication. Biogas production from the mixtures of banana/plantain peels, plantain/rice husk and banana/rice husk was equally carried out by Sambo, et al. [15]. They reported that plantain/rice husk mixture gave the highest biogas yield. Laskari and Nedjah [16] compared biogas generation from waste water and landfill organic matter, and they reported that the biogas yield from waste water sludge was ten times higher than that from that from the landfill organic matter. Uzodinma, et al. [17] produced biogas from pumpkin pod, maize extract, cow dung and swine dung. They reported that mixture of the maize extract, pumpkin pod and cow dung recorded the highest biogas yield.

In plant wastes, the presence of cellulose, hemicelluloses and lignin make it difficult for the microbes to easily break them down to produce biogas [4]. El Bashiti [18] investigated the biogas yield from

the mixtures of pigeon wastes and rabbit wastes each separately with olive cake in different ratios. He reported that the biogas production decreased with increase in the percentage of olive cake as the cake was lignocellulose material with low nitrogen content and the presence of phenylpropionic compounds which are not easily degraded by microorganisms. However, plants with high fibrous and soft tissues but low lignin content have potential for high biogas yield [19]. These microorganisms are the fermentative, syntrophic, acetogenic and methanogenic bacteria [20]. In addition, a stable by-product for land application without adverse effects to the environment is formed [21]. The microbial population and structure can be identified by the combined use of culture-based, microscopic and molecular techniques [22].

According to Asgari, et al. [23] the microbes involved in fermentation need a neutral, mildly or slightly alkaline environment for best performance. A neutral pH of 7 is most suitable for biogas production in the digester [24] in the optimum mesophilic temperature range of 20-40 °C [25].

Tchobanoglous, et al. [26] identified four microbial sequential growth rates during anaerobic digestion as the lag phase; the exponential growth rate; the stationary phase; and the death phase with declining bacteria population. The lag phase is due to formation of organic acid at the initial stage as the microbes at this phase of fermentation are inactive [27]. The *Bacillus* spp. gram-positive bacteria hydrolyse the substrate while the *Clostridium* spp. gram-negative ones take part in the methanogenesis stage of fermentation [28, 29] and they are the archae bacteria [30, 31].

This paper therefore compares the combustion time and volume of biogases from the cattle dung and equal mixtures of 4 kg each of cattle dung with cassava and plantain peels.

Theory of biogas production

There are four interdependent stages in the anaerobic digestion that eventually result in the biogas generation. These stages are hydrolysis, fermentation (acidogenesis), anaerobic digestion (acetogenesis) and methane formation (methanogenesis) [32].

Hydrolysis is the initial phase of the anaerobic decomposition process in which complex carbohydrates, proteins and fats are broken down into simpler organic compounds in the form of simple sugars, amino acids, fatty acids and some alcohols. This is achieved through the action of extracellular enzymes like the saccharolytic and proteolytic enzymes for the decomposition of sugar and protein respectively.

The fermentation period utilizes the products of hydrolysis in the substrates for the microbes to produce a variety of acids such as the acetic,

propionic, butyric, succinic and lactic acids. Alcohols, ammonia, carbon dioxide and hydrogen are as well formed. The active bacteria involved here are the Bacteriodes, Acetobacterium, and Eubacterium. The fatty acids from the hydrolysis of fats, oils and polycyclic aromatic hydrocarbons (PAH) are spared until at the anaerobic stage. The acids are the charged devoid of protons as shown in equation (1) for ethanoic acid.



The anaerobic oxidation is the point where products of fermentation are broken down further by a mixture of anaerobic reactions in addition to the oxidation of the fatty acids formed during hydrolysis. The substrates involved in this oxidation include alcohols, some amino acids and aromatics such as phenols and benzoic acid. Acetate and carbon dioxide are equally produced. This needs limited hydrogen gas concentration because the protons are used to keep this stage alive. The hydrogen gas is thus removed through consumption by the bacteria as it is produced as methane formation starts.

The last stage in the biogas production is the methanogenesis stage where methane and carbon dioxide are principally the final products. The important substrates here are the acetate, hydrogen and carbon dioxide. The acetate is split into two; one part forming methane and the other part carbon dioxide.

MATERIALS AND METHODS

Materials

The materials used for anaerobic biogas production were the cattle dung and plantain peels which were used as substrates, digesters made of mild steel, pressure gauges and mercury-in-glass thermometers. The pressure gauge was used to measure the pressure in the digester while the thermometers were used for measurement of digester and ambient temperatures. The valve and the hose were for the discharge of the biogas while the burner was for the ignition test of the biogas.

The choice of the mild steel digester was achieved through proper design as done by [32] with these design assumptions. The assumptions are that: The biogas produced comprised principally methane 60% and carbon dioxide 40% by volume. The slurry would occupy lower half of the total volume of digester with a diameter of one metre and the upper by the biogas. The maximum temperature expected in the digester was 40 °C as Nigeria is in the tropics in the global map. One kilogram of cattle dung anaerobically produces 0.037 m³ biogas of biogas [33]. The quantitative biogas from anaerobic digestion of cattle dung was used as reference point because it is easily

digestible to anaerobic microbes as it is a product of the gut of cattle where microbes had earlier acted on it. Therefore 8 kg of the cattle dung was chosen in order to determine the total volume of the biogas expected. The total volume (V_m) of this biogas was determined using Equation (2).

$$V_m = 0.037 * 8 = 0.296m^3 \quad (2)$$

Therefore the volume (V_T) of the digester was obtained using Equation (3)

$$V_T = 2V_m \quad (3)$$

and height (h) of digester was calculated with Equation (4)

$$h = 4V_T / \pi d^2 \quad (4)$$

The maximum pressure of the digester depended on the volume of the biogas. For biogas which behaves like ideal gas, these properties are related by Equation (5) [34].

$$PV = mRT \quad (5)$$

Since the biogas has majorly methane and carbon dioxide as its constituents, then its total pressure would be the sum of partial pressures of these constituents. The partial pressures of methane and carbon dioxide were determined using Equations (6) and (7) respectively while the total pressure of the biogas was obtained with Equation (8).

$$P_{CH_4} = 2n_{CH_4}RT / M_{CH_4}V_T \quad (6)$$

$$P_{CO_2} = 2n_{CO_2}RT / M_{CO_2}V_T \quad (7)$$

$$P_T = P_{CO_2} + P_{CH_4} \quad (8)$$

The maximum pressure expected in the digester was therefore the total pressure obtained from the sum of the partial pressures of methane and carbon dioxide. This was 409.61 kPa.

Where,

R is the universal gas constant (8.314 kJ/kgK); T is the maximum absolute temperature attainable (313 K); M is the molecular mass of the component gas; and n is the number of moles of the gas.

The number of moles of a gas is the percentage composition of the gas by volume in the biogas mixture in decimal form. For methane, the mole is 0.6 while it is 0.4 for carbon dioxide.

P_T is maximum expected pressure; P_{CH_4} is the partial pressure of methane; and P_{CO_2} is the partial pressure of carbon dioxide; molecular mass of carbon dioxide is 44 kg and molecular mass of methane is 16 kg.

The thickness (t) of the digester wall is usually related with the total pressure and the yield stress of the material. There the thickness was determined using Equation (9) [35, 36].

$$t = P_T n d / 2 \sigma_y = 1.52 \approx 2 \text{ mm}^2 \quad (9)$$

σ_y is yield stress of mild steel (270 MN/m²) [36] and n is factor of safety (2)

A mild steel material of 2 mm thickness was used for the digester. This is commercially available in Nigerian market.

For a thin wall pressure vessel,

$$d/2t > 10 \quad [35] \quad (10)$$

The schematic diagram of the biogas digester is shown in Figure 1

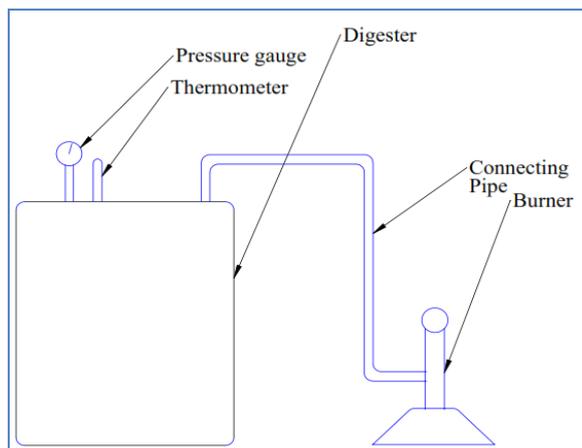


Fig-1: The biogas digester

Figure-1 shows, the biogas digester equipped with pressure gauge, mercury-in-glass thermometer and gas outlet valve. The pressure gauge and the thermometer measure respectively the digester pressure and temperature. The pressure gauge is a Sardonwest sphygmomanometer CE 0219 calibrated in millimeters of mercury from 20 mmHg to 300 mmHg. The thermometer has the range (0 – 360 °C). The hose connects the digester through the valve to the burner. This made the ignition test of the biogas easy.

The anaerobic digestion of the slurry takes place in the digester at airtight conditions. The slurry is first hydrolyzed by breaking the complex polymers of carbohydrates, proteins and lipids to simple monomers of glucose, amino acids and fatty acids by the facultative bacteria [1]. These monomers are transformed during acidogenesis to alcohol, organic acids containing nitrogen and sulphur. The products from here are degraded to acetic, propionic and butyric acid by the fermentative bacteria at the acetogenesis

stage. These products further transform to methane and carbon dioxide by the methanogenic bacteria in methanogenesis.

EXPERIMENTAL PROCEDURE

The cattle dung was collected fresh from a local abattoir around the Federal University of Technology, Akure, Nigeria. Plantain peels were collected from a Food Company behind Chicken Republic in Akure while the cassava peels were collected from a local gari processing point, also in Akure. The plantain peels and cassava peels were sun dried for easy grinding. The peels were grinded at the feed mill of Animal Production and Health (APH) Department of University. The grinding of the substrates was to increase their surface area during fermentation.

Eight kilogram (8 kg) of pure cattle dung was weighed and then mixed thoroughly with 16 kg of water. Four kilograms (4 kg) each of plantain peels and cassava peels were separately mixed with 4 kg cattle dung and then thoroughly with 16 kg of water (i.e. ratio 1:2). Each mixture was then charged to the respective digester to make for half the volume of each digester.

The digesters were made airtight by closing their mouths with lids already using a spanner. The points of attachment of the thermometers and the pressure gauges were sealed with epoxy steel. The digesters were stirred to ensure thorough mixing of the digester content. This was to ensure intimate contact between the microorganism and the substrates so as to enhance their fast and complete digestion. The digesters were placed in the Central Workshop of the School of Engineering and Engineering Technology, The Federal University of Technology, Akure.

The pressures and temperatures of the biogas in the digesters were measured daily using a pressure gauge and mercury -in -glass-thermometer respectively. These readings were taken at 10 am in the morning and 4 pm in the evening. The biogas in each digester was daily tested for combustion. After it ignited, the biogas was collected from each digester over water.

The tests for pH of the slurries and their effluents as well as the microbial constitution of the effluents of the three digesters were also carried out. The pH tests of the cattle dung and mixture of cattle dung with plantain peels were carried out in the Central Workshop. The materials used were the pH meter, distilled water and rubber container. The pH meter is of the make “Combo pH and EC”, “waterproof by Hanna, HI98130 and made in Mauritius.” The pH meter was then inserted into the rubber container with distilled water before it was transferred and dipped into the container with the cattle dung digestate. It was allowed to stabilize in the digestate for the sensor to establish the pH and temperature of the digestate as it became

stable and homogenized. After five minutes, the pH value was read on the display screen of the meter and then recorded. Thereafter, the pH meter was cleaned and rinsed with distilled water and then allowed to dry for ten minutes before dipping it into another digestate.

Determination of Bacteria Viable Count

This was done using the pour plate method with the Nutrient Agar, Egg Yolk Agar, Modified and Plate Count Agar. The Nutrient agar (2.8 g / 100 ml), Egg Yolk Agar, Modified (2.8 g/100 ml) and Plate Count Agar (3.8 g / 100 ml) (oxid) were prepared as culture media in a clean conical flask and were homogenized using a magnetic stirrer on a hot plate. The conical flask was plugged with cotton wool, sealed with aluminum foil and autoclaved at 121 °C for 15 minutes. It was then allowed to cool at 45 °C and poured aseptically into sterile dishes and allowed to solidify.

The slurry was inoculated by introducing the microbes into the cutline to initiate growth in the culture. The inoculum was transferred to the Petri dish and then mixed with the molten agar. Serial dilution was carried out by addition of 1 ml slurry sample into 9 ml cool sterilized clean water in test tubes to a dilution of 10^{-6} . A tenth millilitre (0.1 ml) of 10^{-6} dilutions was pour plated. They were allowed to solidify, inverted and grown at 37 °C anaerobically for 48 hours. The colonies formed were counted and recorded. A representative of

each colony was isolated and purified by streaking repeatedly until pure cultures were obtained. All the pure cultures were kept on agar slant as working and stock cultures with each culture in triplicate [37].

RESULTS AND DISCUSSION

The ambient and digester temperatures for 8 kg cattle dung are plotted in Figure 2. The ambient and digester temperatures in the morning at 10 am were always lower than those in the evening at 4 pm. This is because the temperatures were low in the nights of the previous days which had carryover effects to the early hours of the following day. At the same time the atmosphere had not warmed up enough from the effect of solar energy, hence their low temperatures. In the evening the atmosphere was relatively warmed up and with this interaction, the digester temperature increased as that of the environment.

However the change in the weather conditions due to rainfall or cold breeze resulting from the formation of clouds sometimes brought lower evening ambient and digester temperatures. This was the case for example with days 7, 19 and 31 among others and the temperature difference was between 2 to 3 °C. This temperature difference was small to influence any radical change in the biochemical reaction of the anaerobic digestion. These ambient and digester temperatures fell in the mesophilic temperature range of 26 °C - 43 °C [25, 38].

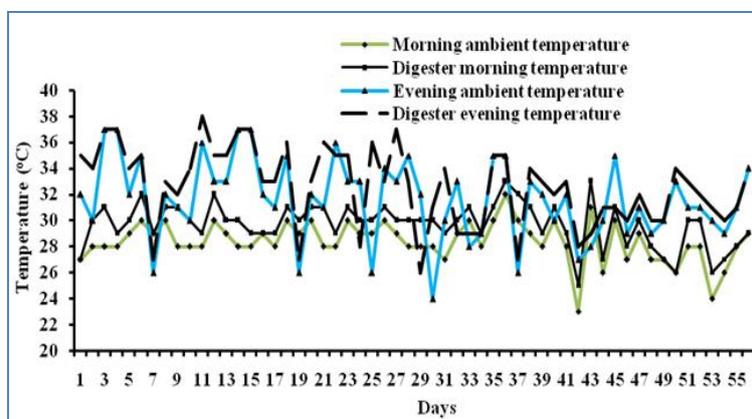


Fig-2: Variation of ambient and digester temperatures with days of incubation for 8 kg cattle dung

The morning and evening digester pressures for 8 kg cattle dung are plotted as shown in Figure 3. It shows the graphs of digester morning measured at 10 am and evening pressures for cattle dung digester taken at 4 pm for the days the incubation lasted.

In the Figure, the first eight days witnessed a lag phase as the bacteria acclimatized to pH and temperature. The implication of this is that there was more substrate; nutrient and low mass concentration of bacteria in the digester [26]. Therefore there was no reasonable biogas production that would create enough pressure to read on the pressure gauge.

However the rise in both morning and evening pressures on the 10th to the 12th day was due to increase in the biogas production. This was as a result of the exponential growth rate of the microbes in the digester [26]. This was made possible because of the availability of the nutrients and other conditions like suitable pH and temperature that supported the growth of the bacteria.

From these points the pressures showed stability up to about day 18 and as a result the plots became relatively horizontal. This was the stationary stage of the biogas production. At this stage the birth

rate of the microorganisms was equal to their death rate and so biogas production stabilized thus forming a plateau. Thereafter the pressure began to record a downward trend. This indicated that the death rate of the bacteria was now more than the rate at which they produced. This was because the nutrients of the substrate had depleted so much that it could no longer support the growth of the bacteria [39]. The pressure

difference between the morning and evening pressures was 1-2 mmHg in the digesters. This insignificant difference could be because the digesters were placed in a mesophilic environment where the temperature range was small and the heat generated as a result was usually evenly distributed, hence no drastic pressure rise from morning to evening.

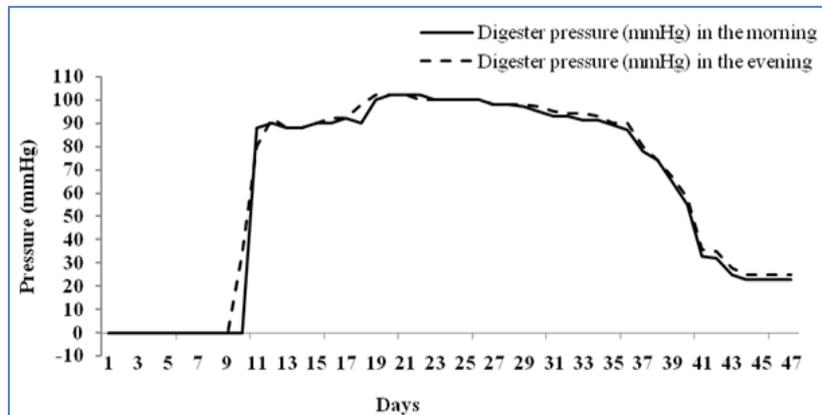


Fig-3: Morning and evening digester pressures of cattle dung biogas against time (days)

Figure 4 presents the plot of the ambient and digester temperatures versus the days of incubation for 4 kg cassava peels and 4 kg cattle dung. In the figure, the ambient temperatures were lower than the temperatures of the digester for both morning at 10 am and evening at 4 pm. The digester temperatures were

higher than those of the ambient because the anaerobic reaction in the digester evolved thermal energy due to the collision of the biogas molecules in a fixed volume. Similar phenomenon as that of the Figure 2 was the case in Figure 3.

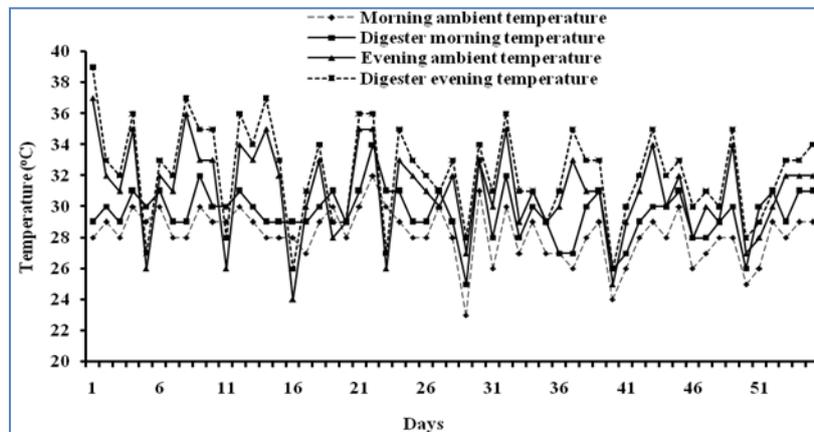


Fig-4: Ambient and digester temperatures versus days of fermentation for 4 kg cassava peels and 4 kg cattle dung digester

The relationship between pressure of the digester with the days of incubation for the morning at 10 am and evening at 4 pm for 4 kg each of cattle dung and cassava peels is presented in Figure 5.

The pressures of the digester at 10 am were lower than those at 4pm because of the temperature effect at these periods. Since the temperatures in the evening at 4 pm were always higher than those at 10

am, so also were the digester pressures as these were directly proportional to the digestion temperatures.

The slow rate of biogas production could be due to presence of complex starch like cellulose and hemicelluloses in the cassava peels [4].

The momentary drop in the digester pressures at about the 38th day of incubation could be due to some resistance against the action of the microbes in the breakdown of lignin part of the cassava peels.

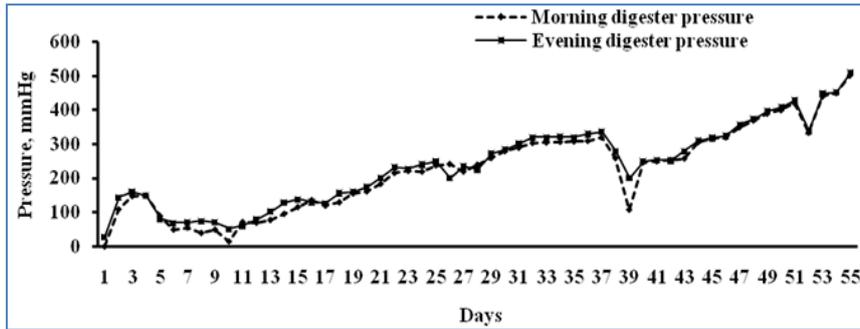


Fig-5: Morning and evening digester pressures versus days for 4 kg cassava peels with 4 kg cattle dung

The ambient and digester temperatures for 4 kg each of cattle dung and plantain peels mixture are presented in Figure 6. The morning ambient and digester temperatures were always lower than those in the evening except for cold days resulting from cold

weather or rain during the day. In the same vein, digester temperatures were always higher than those of the ambient and the general behaviour of the plots were sinusoidal in nature [32, 40-42].

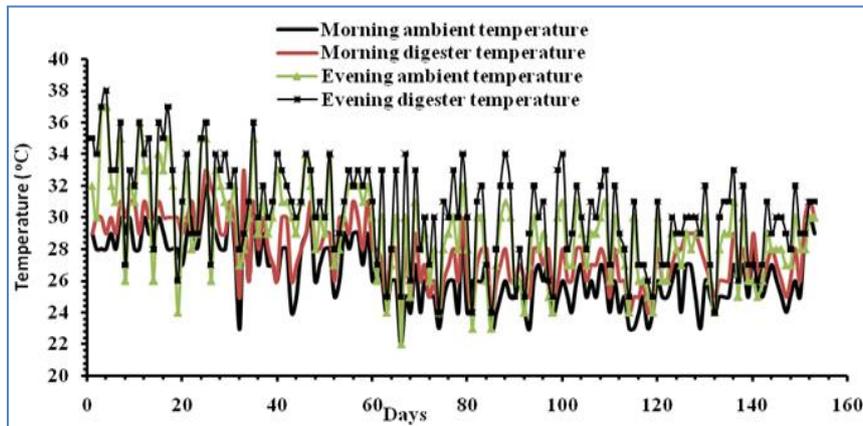


Fig-6: Ambient and digester temperatures versus days of incubation for 4 kg cattle dung and 4 kg plantain peels

The digester pressures at 10 am and at 4 pm for 4 kg cattle dung and 4 kg plantain peels are plotted in Figure 7. There was a lag phase from day 1 to day 7 which was characterized by low biogas production. The

momentary stability from time to time was the stationary stage where the death rate of the bacteria was equal to the birth rate as there was resistance in the digestion of the substrate.

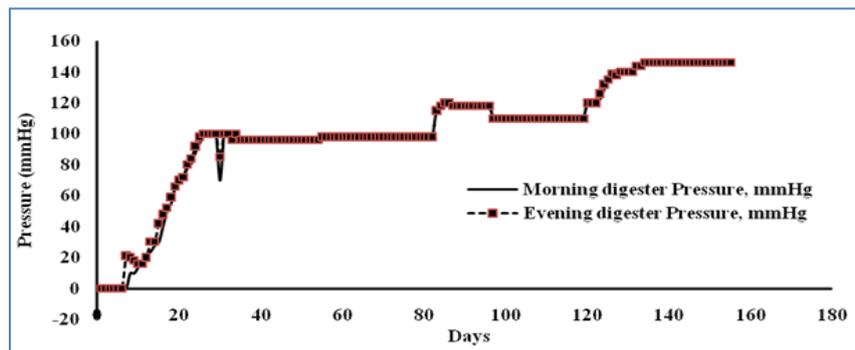


Fig-7: Morning and evening digester pressures versus days of incubation for 4 kg cattle dung with 4 kg plantain peels

Figure 8 shows the column chart of the ignition time of biogas with respect to the substrates used in the digesters for anaerobic digestion. The biogas from the digester containing only 8 kg of cattle dung ignited on the 14th day of incubation. The one from the mixture of 4 kg each of cattle dung and cassava peels burnt on the 55th day while the biogas from the mixture

of 4 kg cattle and 4 kg plantain peels ignited on the 146th day of incubation.

The early combustion of the biogas from the digester containing cattle dung was because the cattle dung was a product of the gut of the cattle. The microbes in the gut of the cattle acted and digested the

complex starches, proteins and lipids into simpler and easily digestible substrates. As a result, the cattle dung digested faster in the digester to produce the combustible biogas, hence the short ignition time of 14 days.

The cassava peels on the other had complex starches like the cellulose, hemicelluloses and possibly traces of lignin which had never been acted upon before by microbes. They therefore posed some resistance to

the microbes and therefore production of combustible biogas was relatively slow and took a retention period of 55 days.

The plantain peels must have contained more of the complex starch than the cassava peels especially lignin. This was very difficult and painfully slow to hydrolyze despite the presence of equal mass of cattle dung in the mixture. Therefore combustible biogas production took a long time to achieve.

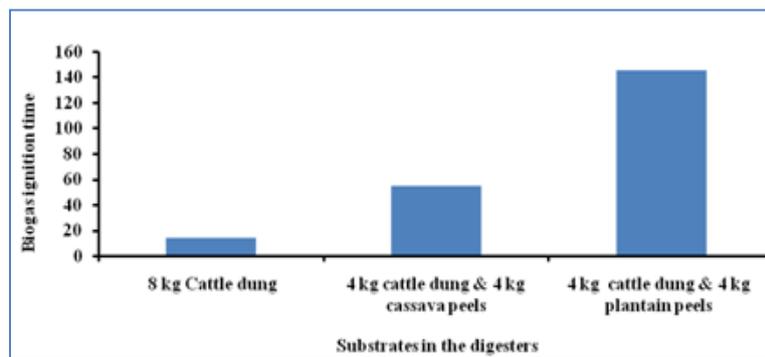


Fig-8: Biogas ignition time versus substrates used in digestion

The quantity of biogas obtained from the anaerobic digestion of cattle and its mixture each with cassava and plantain peels is as presented in Table 1. The cattle dung with cassava peels mixture produced

the highest because of the eventual degradation of the cellulose and hemicellose components. The presence of lignin in the plantain peels could have been responsible for the low production of biogas in this mixture.

Table-1: Substrates and the biogas produced during incubation of the substrates

S/N	Mass of substrate	Volume of biogas (ml)
1	8 kg cattle dung	6400
2	4 kg cattle dung & 4 kg cassava peels	7000
3	4 kg cattle dung & 4 kg plantain peels	6500

The results for the pH of the substrates before digestion and after ignition of their biogases are as presented in Table 2. It also showed that the substrates were relatively more acidic than the digestates. The pH

values for the three substrates were almost at neutral levels of 7.12, 7.21 and 6.90 when their respective biogases ignited. Combustible gas is produced during fermentation at pH 7 [43, 44].

Table-2: The pH of substrate before digestion and after ignition of biogas

S/N	Substrate	pH before digestion	pH after ignition of biogas
1	8 kg cattle dung	6.80	7.12
2	4 kg cattle dung & 4 kg cassava peels	5.90	7.21
3	4 kg cattle dung & 4 kg plantain peels	6.50	6.90

Microbial Analysis

The results of the microbial analysis of digestates are presented in Table 3.

Table-3: Digestate microbial type and population for cattle dung and mixtures with cassava an Plantain peels

S/N	Digestate type	Microbial type	Microbial Population (cfu/ml)
1.	Cattle dung	Clostridium spp. and Bacillus licheniformies	2.5×10^{-4}
2.	4 kg cattle and 4 kg cassava peels	Pseudomonas spp. and Bacillus licheniformies	3.8×10^{-4}
3	4 kg cattle dung and 4 kg plantain peels	Bacillus licheniformies	2.3×10^{-4}

Clostridium spp and Bacillus licheniformies with 2.5×10^{-4} cfu/ml were found in the cattle dung slurry while only Bacillus licheniformies with colony population of 2.3×10^{-4} cfu/ml were isolated in the mixture of cattle dung and plantain peels. The Bacillus licheniformies are the lympolytic bacteria in hydrolytic stage while Clostridium spp is one of the bacteria group in the acetogenesis stage of digestion [37]. They are also responsible in degrading volatile fatty acids [45]. This relative higher bacteria colony population in the cattle dung was due to easy digestibility of the substrate as the cattle was had earlier passed through bacteria action the guts of the cattle. This could also be responsible for the cattle dung biogas ignition within two weeks (14 days).

The bacteria type in the digestate of the mixture of cattle dung cassava peels Pseudomonas spp. and Bacillus licheniformies with a population of 3.8×10^{-4} colony forming units per millilitres (cfu/ml). The relative high population of the microbes could have been responsible for the high production of the biogas as the cellulose and hemicellulose digested that ignited with 55 days of incubation.

The biogas from the mixture of cattle dung with plantain peels ignited on the 146th day of digestion. The only microorganism that was detected was Bacillus licheniformies. These Bacillus specie had the highest frequency of occurrence in the digestates of abattoir wastes [29]. This is in line with the report of the work of Victor, et al. [46] that the biogas yields of fruit wastes, vegetable wastes and cow dung when they were treated with Lactobacillus before they were subjected to anaerobic digestion.

Statistical relationship

The statistical relationship using ANOVA among the temperatures and pressures for the digesters with 8 kg cattle dung, 4 kg each of cattle dung and cassava peels, and for 4 kg cattle and 4 kg plantain peels are respectively presented in Tables 4 to 9. The P-values for all the digester showed that the temperatures and pressures were all significant except for those in Tables 7 and 9. The F-values of these tables are also significant as the calculated values are less than the 0.05 confidence recorded.

Table-4: ANOVA relationship among temperatures of 8 kg cattle dung digester

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	610.5491071	3	203.5164	34.08771	3.91613E-18	2.645636537
Within Groups	1313.482143	220	5.970373			
Total	1924.03125	223				

Table-5: ANOVA of pressure for 8 kg cattle dung digester

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	89092.31206	2	44546.15603	39.25959	3.17986E-14	3.0617157
Within Groups	156582.6383	138	1134.656799			
Total	245674.9504	140				

Table-6: ANOVA relationship among temperatures of 4 kg cattle and 4 kg cassava peels digester

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	197.2578125	3	65.7526	23.02127	1.02953E-13	2.628394646
Within Groups	1085.34375	380	2.856168			
Total	1282.601563	383				

Table-7: ANOVA relationship among the pressures of 4 kg cattle and 4 kg cassava peels digester

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	41.19032258	1	41.19032	0.031666	0.858880039	3.871827567
Within Groups	400640.6452	308	1300.781			
Total	400681.8355	309				

Table-8: ANOVA relationship among temperatures of 4 kg cattle and 4 kg plantain peels digester

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	41.19032258	1	41.19032258	0.031665832	0.85888	3.871828
Within Groups	400640.6452	308	1300.781315			
Total	400681.8355	309				

Table-9: ANOVA relationship among pressures for 4 kg cattle dung and 4 kg plantain peels digester

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	289709.315	4	72427.32876	181.955	2.5799E-109	2.383648844
Within Groups	302518.6013	760	398.0507912			
Total	592227.9163	764				

CONCLUSIONS

Biogas was generated from the anaerobic digestion of 8 kg of cattle dung and the separate mixtures of 4 kg each of plantain peels and cassava peels with cattle dung as sources of renewable energy. The cattle dung exhibited the least ignition time to generate combustible biogas. This was followed by the mixture of cattle dung and cassava peels and then the plantain with cattle dung mixture. The pH for the optimum biogas production from the substrates was at neutral range of 7.12, 7.21 and 6.90 respectively for the cattle dung, its mixture with cassava peels and that with plantain peels. The mixture of cattle dung with cassava peels recorded the highest biogas 7000 ml production compared with 6400 ml for cattle dung and 650 ml for mixture of cattle dung with plantain peels. The mixture containing cassava peels also had the highest bacteria population of 3.8×10^4 cfu/ml compared with that of cattle dung with 2.5×10^4 cfu/ml and the mixture with plantain peels 2.3×10^4 cfu/ml. Therefore cattle dung mixture with cassava peels with ignition time of 55 days and highest bacteria population was the best among three substrates in the biogas production.

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