Research Article

EFFECT OF INNOCULUM ON BIOGAS PRODUCTION FROM CASSAVA PEELS.

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Abstract:

This paper investigated the innoculum effect on cassava peels for biogas production. Cassava peels was mixed with cattle dung and poultry droppings as innoculum by mass into six different combinations. Each mixture was mixed with 12 litres of water before charging to different digesters made of plastics and equipped with mercury-in-glass thermometers and pressure gauges on their top surfaces. The mixtures include 6 kg of cassava peels; 3 kg each cassava peels and cattle dung; 3 kg cassava peels with 3 kg poultry droppings; 2 kg each of cassava peels, cattle dung and poultry droppings; 2 kg cassava peels with 3 kg cattle dung and a kilogram of poultry droppings; and 2 kg cassava peels with a kilogram of cattle dung and 2 kg poultry droppings. The pH of the contents of the digesters was also monitored. The digesters were monitored for 100 days for biogas production in a laboratory at the Federal Polytechnic, Ado-Ekiti, Nigeria. Biogas from each digester was daily tested for combustion as their temperatures and pressures were monitored at 10 am and 4 pm. The results indicated that pH 6.2 for the cassava peels digester. This increased to 7.0 as the quantity of cassava peels reduced in other digesters. The lowest morning ambient and digesters temperatures were respectively 22 oC and 21 oC while the maximum temperatures were 39 oC and 40 oC for the evenings. There were earlier and higher biogas productions with the addition of the innoculum in the digesters. The combustion time of the biogas reduced with increase in the masses of the innoculum.

Keywords:

Effect, inoculum, biogas, cassava peels, digester, cattle dung.

Introduction

Biogas is produced when organic matter of animal or plant origin ferments in an oxygen-free environment; Its production can be induced artificially in digestion tanks to treat sludge, industrial organic waste, and farm wastes (Igoni, et al., 2008). Biogas primarily consists of methane (CH_4)and Carbon dioxide (CO_2), with varying amounts of water vapour, hydrogen sulphide (H_2S) And gases like oxygen and hydrogen, (Madu and Sodeinde, 2001).

Biogas, the cheapest form of renewable source of energy, according to Mshandete and Parawira (2009), can be used to replace fossil fuels in the generation of heat and power and by implication reduce greenhouse gases (GHGs) emission, slows down global warming and climate change. The gas has a lot of applications which includes its use for lighting, driving automobiles, and cooking (Eze, 2011).The sources of biogas are common biological wastes from humans, animals and plants. These wastes increase with increasing population and if they are not well managed they would pose serious health hazards as they become breading places for diseases and their vectors (Adelegan, 2002).

Cassava peels is an example of plant waste which can be used to produce biogas. Cassava is one of the major root crops produced in Sub-Saharan Africa. World cassava production in 2002 was estimated at 184 million tons (Odomenem and Otanwa, 2011). Africa exported only one million ton of cassava annually (FAO, 2001) but by 2007, out of more than 228million tons of cassava produced worldwide, Africa accounted for 52% and Nigeria produced 46 million tons making it the world's largest producer of cassava (IITA-1).

Currently, there is increase in campaign for expanding the cassava production scale in Nigeria. The implication of this is that there will be increased waste production from cassava processing. According to FAO (2001), about 250 to 300 kg of cassava peels is produced per ton of fresh cassava root processed, this suggests huge sum of waste production in form of peels from cassava production and processing. Hence, there is need to design and adopt a system capable of handling huge waste accruing from this development and anticipated problems such as unpleasant odour. One of the ways by which cassava peels can be managed in addition to using it as animal diet (Okeudo and Adegbola, 1993) is by anaerobic digestion for methane and bio-fertilizer production. However, cassava peels is a material with high carbon to nitrogen ratio (Adelekan and Bamgboye, 2009).The Carbon-to-Nitrogen (C/N) ratio expresses the relationship between the quantity of carbon and nitrogen present in organic materials. Materials with different C/N ratios differ widely in their yield of biogas. The ideal C/N ratio for anaerobic bio digestion is between 20:1 and 30:1 (Marchaim, 1992). If C/N ratio is higher than this range, biogas production will be low. This is because the nitrogen will be consumed rapidly by methanogenic bacteria for meeting their protein requirements and will no longer react on the left over carbon remaining in the material. In such a case of high C/N ratio, the gas production can be improved by adding nitrogen in cattle urine or by fitting latrine to the plant (Fulford, 1988). Materials with high C/N ratio typically are residues of agricultural plants. Conversely, if C/N ratio is very low, that is, outside the ideal range, nitrogen will be liberated and it will accumulate in the form of ammonia. Ammonia will raise the pH value of the slurry in the digester. A pH value higher than 8.5, will be toxic to the methanogenic bacteria in the slurry. The cumulative effect of this is also reduced biogas production. Materials having low C/N ratio could be mixed with those having high C/N ratio so as to bring the average C/N ratio of the mixture to a desirable level. Human excreta, duck dung, chicken dung cattle dung are some of materials which typically have low C/N ratios (Karki and Dixit 1984).Since cassava peels is a material with high C/N ratio, it will not yield much biogas and to enhance biogas production there from it, it could be mixed with other readily degradable materials with low C/N ratio such as cattle dung and poultry droppings (Adelekan and Bamgboye, 2009).

Several researchers have reported biogas production from various materials including pigeon droppings (Aliyu *et al*., 1995); water hyacinth, *Eichhornia species* (Bamgboye and Abayomi, 2000); manure from the major farm animals (Adelekan, 2002); and camel and donkey dung, (Dangoggo, *et al*., 2004). Yaru, *et al*., (2013) compared biogas production of cattle dung and a mixture of cattle dung with plantain peels and they reported that the mixture produced more biogas than cattle dung alone. Ojike (2012) also studied biogas production from maize cobs, stalks and chaffs. They reported that maize chaffs produced the biogas followed by the stalks and then the cobs. Adelekan (2012) produced ethanol only from the fermentation of cassava peels alone. Gopinatthan, *et al*., (2015) revealed that cassava peels as such is not a good substrate for biogas production without appropriate pretreatments .Adegun and Yaru (2008) produced biogas from cassava and found out that animal dung is a better substrate than plant wastes in biogas production. Yaru, *et al*., (2015) carried out comparative study on ignition time of biogas from cattle dung and mixtures of cattle dung with cassava peels; the result showed that cattle dung produced biogas earlier than the mixture of the two wastes and the combustion time increased with increase in the mass of cassava peels in the mixture. The pH for cattle dung slurry and those of the mixtures in order of increasing mass of cassava peels were respectively 6.9, 6.6, 6.4 and 6.3 while the pH values of the effluents were 7.12, 7.16, 7.14 and 7.21. Adebayo, *et al*., (2013) studied the effect of co-digestion on anaerobic digestion of cattle slurry with maize cob at mesophilic temperature and they showed that co-digesting cattle slurry with maize cob at different ratios resulted into an increase in biogas and methane yields. The study also revealed that co-digesting cattle slurry with maize cob at 3:1 was optimum for biogas production. Oparaku, *et al*., (2013) investigated the biodigestion of cassava peels blended with pig dung for methane generation and they discovered that the blending improved the methane production of cassava peels alone and reduced the retention time from about 59 days to five days when cassava peels was mixed with piggery dung. Ezekoye and Ezekoye (2009) combined cassava peels with rice husk in the ratio of 1:5 for biodegradation of the waste. It was also gathered that this set up was inoculated with cow dung mixed with water. From the result, flammable biogas was produced after 30 days with a total volume of 3.45 m^3. It was observed that combination of two plant biomass was not a favourable combination in anaerobic digestion since animal protein is important for microbial activity of the methanogens. Ilaboya, *et al*., (2010) blended cassava peels with pineapple and plantain peels in a laboratory set up. Their work was intended to monitor the effect of alkaline addition to the substrate in biogas generation potential of the mixture. It was observed that addition of sodium hydroxide, NaOH (alkaline) solution resulted in an increase in biogas production over the set up without the alkaline. Also, there was a positive effect in increase of biogas generation by different ratios of alkaline mixture. However, the work did not address the effect of mixing the cassava peels in different ratios of other wastes. Adeyanju (2008) demonstrated the effect of adding wood ash to the biodigestion of mixture of piggery wastes and cassava peels in a laboratory scale. It was found that the wood ash addition increased the biogas production of either the biodigestion of piggery wastes and cassava peels only or in combination of both wastes in different proportions.

Substantial progress has been made in the production of biogas from cassava peels, however cassava peels is a material with high C/N ratio, it has not been yielding much biogas (Ofoefule and Uzodimma, 2009) There is therefore the need to find a productive use of these plant and animal wastes; one area of usage of these wastes is generation of biogas. In this work, animal wastes (cattle dung and poultry dung) were used as catalyst to aid the anaerobic digestion of cassava peels.

Materials and Methods:

Materials- Six (6) pieces of 0.3 m^3 plastic containers with lids were purchased from King's Market in Ado-Ekiti. The substrates for the experiment were collected from Agricultural farm of The Federal Polytechnic, Ado- Ekiti. The cattle dung and poultry droppings were collected fresh from animals and poultry sections of the farm while cassava peels were collected from the Garri processing section of the farm. The cassava peels were sun-dried and grinded at a feed Mill in Ado-Ekiti so as to increase the surface area of the peels during fermentation.

Theory of Biogas Production:-

Biogas production follows three stages in the process of incubation; these are hydrolysis, acetogenesis and methanogenesis; some authors split acetogenesis into acidogenesis and acetogenesis thus bringing the processes to four. In the hydrolysis stage, polysaccharides, proteins, lipids and cellulose are broken down into monosaccharide and amino acids. The bacteria act on carbohydrates to produce hydrogen, fatty acids and carbon dioxide (Appel, *et al*., 2008). Wirth, *et al*., (2012) reported that bacterial such as *Clostridium spp*, *Bacteriodes* and *Clostridium cellolitian*, among others take part in this process. In the acetogenesis, volatile fatty acids, propionate, butyrate, succinate and alcohols produce acetate and carbon dioxide in the presence of carboxydotherms and hydrofomers. The methanogensis of these compounds to produce methane and carbon dioxide takes place in the presence of acetotrophs such as *Methanosacrina bakeri* and hydrogenotrophs. The methane bacteria are most active at neutral pH or slightly alkaline condition at 8.5 for optimum performance. A digester with high volatile acid concentration would require high pH as the pH of 6.2 or below is toxic to methanogenic bacteria (Asgari, *et al*., 2011).

Design Assumptions:-

The following assumptions were used in the design of the digesters:

(i) The biogas composition comprised principally methane (CH_4) and carbon dioxide (CO_2) as other constituents are negligibly small.

(ii) The percentage volume of methane and carbon dioxide were 60% and 40% respectively

(iii) Height (h)and radius (r) of the digester are 0.6 m and 0.125 m respectively

(iv) The maximum temperature (T) of the digester is 40 ^oC (313 K)

(v) The volume of the substrate occupied two third of the total volume of the digester

(vi) 1 kg of cattle dung produces 0.037m^3 of biogas (Rouf and Haque, 2008)

(vii) Mass of the substrate in the digester was 6 kg.

3.1.1 Design Parameters:-

These were the various dimensions of the materials, other variables, constants and the formulae considered during the design of the digester.

Determination of the Total pressure of the Biogas (P_T)

The total pressure comprises the partials pressures of the methane (P_{CH_4}) and carbon IV oxide (P_{CO_2}), mathematically it is expressed with equation (1), using Dalton's law of partial pressure, as:

$$P_T = P_{CH_4} + P_{CO_2} \quad (1)$$

From ideal gas equation, PV = nRT (2)

When equation (2) is substituted in (1) it becomes:

$$P_T = \frac{3RT}{2V_T}\left(M_{CH4} + M_{CO_2}\right) \quad (3)$$

where P_T is the total pressure of the biogas inside the digester (kPa); V_T is volume of the digester (m^3); T the maximum temperature of the digester (K); R the Universal gas constant (8.314 KJ/kgK); n is number of moles, m is mass of substrate (kg); M_{CH4} is molecular mass of methane (16); and M_{CO_2} is molecular mass of Carbon IV oxide (44). When values were substituted, the total pressure of the biogas inside the digester is 1345.78 kPa

Determination of the expected maximum pressure of the Digester (P_{mD})

The expected maximum pressure required in the digester for effective production of the biogas, according to Shingley (2009),is given by equation (4) as:

$$P_{mD} = \frac{2\sigma t}{D} \quad (4)$$

According to Khurmi and Gupta (2009), the working stress (σ) is expressed with equation (5) as:

$$\sigma = \frac{\sigma_y}{F.S} \quad (5)$$

where, F.S is factor of safety (value of 2), t and D are thickness and diameter of digester, σ_y is the yield stress (640 kPa); when values are substituted, the expected maximum pressure is 2,560 kPa. Since the total pressure is less than the expected maximum pressure, the developed digester can withstand the total pressure required without burst or rupture.

3. Description of the Digesters:-

The digester was the incubator in which all constituent wastes were mixed and allowed to ferment in an airtight anaerobic condition. The digester was a plastic drum of capacity $0.03m^3$ with lid (cover). Inserted through the lid were: mercury in glass thermometer to measure the daily temperature of the materials inside the digester; a pressure gauge to measure the daily pressure inside the digester; and a gas valve through which the gas produced can be discharged for testing as shown in Plates 1 . Epoxy steel was applied to all the joints to prevent leakage of the gas.

Plate. 1: Developed Biogas digesters Plate.

2: Loading of Digester with substrates

Methods (Substrate Preparation):-

The following steps were followed in the preparation of the substrate, loading of the digesters and monitoring of the anaerobic digestion of the substrates:

i. The procured pieces of plastics were arranged on the floor and labelled A, B, C, D, E, and F.

ii. 6 kg of cassava peels was mixed with 12 litres of water in the first digester labelled A

iii. 3 kg of cassava peels was added to 3 kg of cattle dung inside the second digester and 0.012 cm^3 of water was added and the mixture thoroughly stirred and the digester was labelled B

iv. 3 kg of cassava peels and 3 kg of poultry dung were mixed with 0.012 cm^3 of water in the third digester labelled C as shown in Plate 2

v. Digester D contained 2 kg of cassava peels, 2 kg of cattle dung, 2 kg of poultry dung and 0.012 cm^3 of water

vi. In the fifth digester labelled E were 2 kg of cassava peels, 3 kg of cattle dung; 1 kg of poultry dung and 0.012 cm^3 of water

vii. The sixth digester labelled F contained 2 kg of cassava peels, 1 kg of cattle dung; 3 kg of poultry dung and 0.012 cm^3 of water as shown in Table 2.

viii. The mixture in each of the digesters was thoroughly stirred for 10 minutes to ensure even mixing.

ix. The pH of the slurry in each of the digesters was taken with a Hanna Instrument pH meter (Model: H196107) as shown in Plate 4.

x. Each of the digesters was properly covered with its lid to ensure a gas tight environment.

xi. The six digesters were placed in an open space where the daily temperature of the digesters and that of the surrounding (ambient temperature) were taken by 10am and 4pm in a laboratory at the Federal Polytechnic Ado-kiti.

xii. The digesters were subjected to periodic shaking to ensure thorough mixing of the digesters' content while maintaining intimate contact between the micro-organism and substrate in order to enhance complete digestion of the substrate.

xiii. The experiment started on 8th August, 2017 and monitored for 100 days.

xiv. During this period the combustion time for each of the digesters was monitored through the gas valve.

xv. At the end of the retention period, the pH of the substrate in each of the digesters was taken.

Table 2: Compositions of substrate in the Digesters.

Digester	Cassava peels (kg)	cattle dung (kg)	poultry dung (kg)	water (x 10^{-3} cm^3)
A	6	-	-	12
B	3	3	-	12
C	3	-	3	12
D	2	2	2	12
E	2	3	1	12
F	2	1	3	12

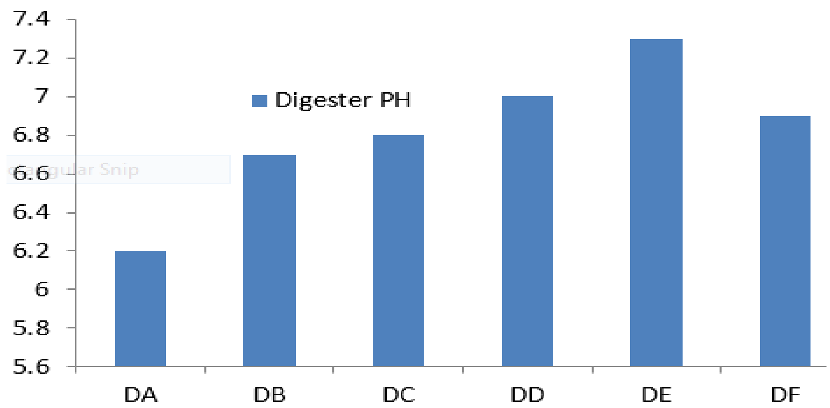

Figure 1: P^H of Substrate in each of the Digesters before digestion.

4: Results and Discussions:-

4.1: Results-

The plots of ambient and digesters temperatures against time (days) for the digesters (A, B, C, D, E and F are as shown in Figures 2 to 7.

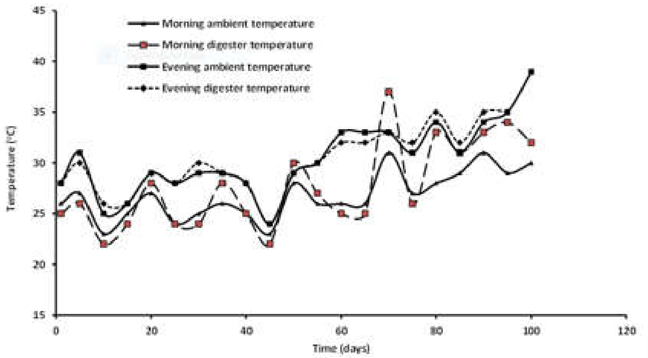

Figure 2: Plot of ambient with temperatures against Time (min) for Digester A

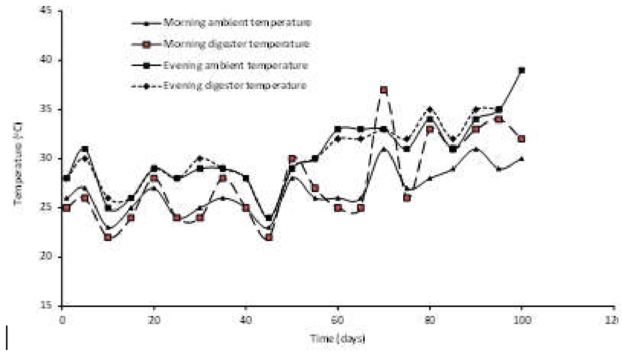

Figure 3: Plot of ambient temperatures against Time (min) for Digester B

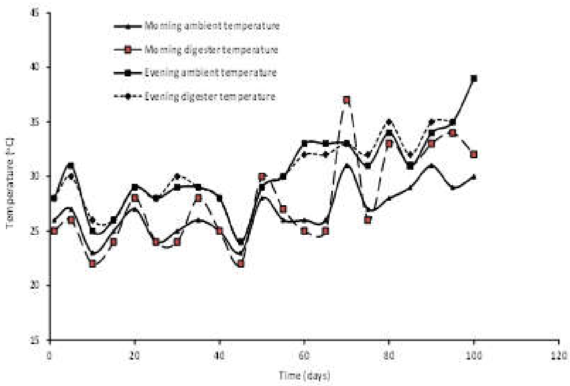

Figure 4: Plot of ambient with temperatures against Time (min) for Digester C

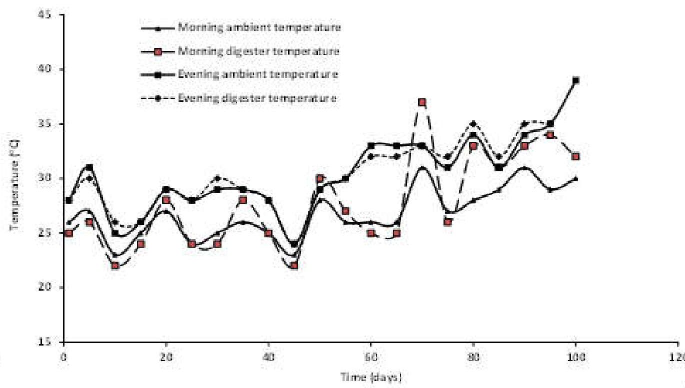

Figure 5: Plot of ambient with temperatures against Time (min) for Digester D

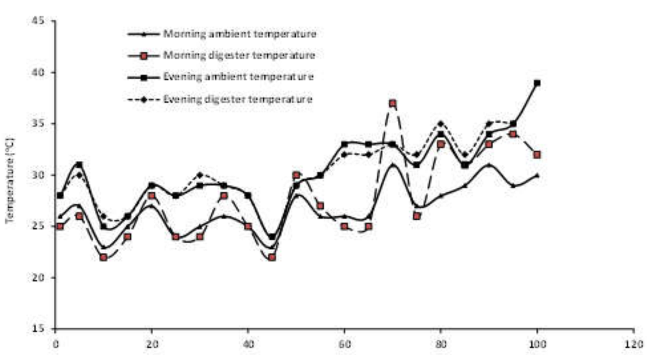

Figure 6: Plot of ambient with temperatures against Time (min) for Digester E

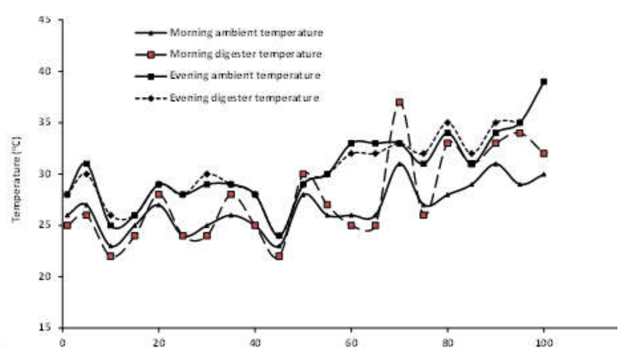

Figure 7: Plot of ambient with temperatures against Time (min) for Digester F

Figure 8 shows the onset of biogas production and Figure 9 the column chart of the ignition time of biogas from for each of the digesters.

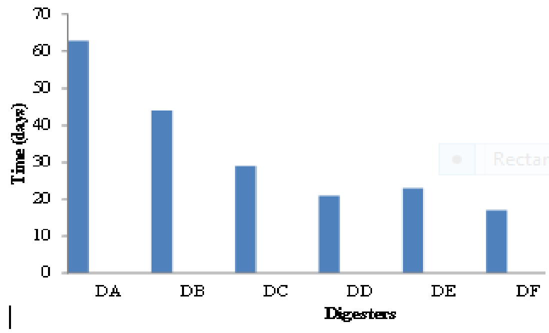

Figure 8: Onset of biogas production of each Digester

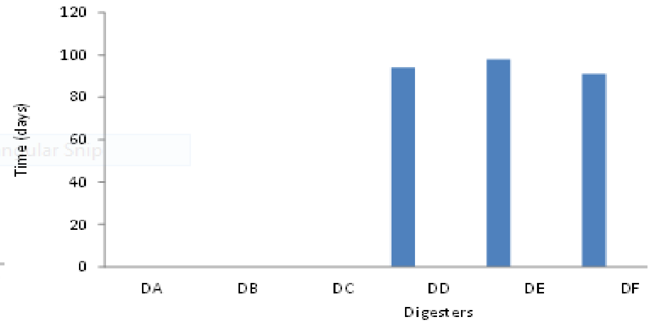

Figure 9: Column chart of ignition time of biogas each Digester

Discussions:-

It was observed from Figure 1 that the digester A with 6 kg of cassava peels has the lowest value of pH (6.2), which implied acidic condition; this is as a result of acidic content in cassava peels due to hydrogen cyanide (Adelekan, 2012). The pH of the substrate rose as the quantity of cassava peels in the substrate reduced. In figures 2 to 7, it was observed that the evening temperatures were higher than the morning temperatures for both the surrounding (ambient) and the digesters. This was because the weather is always cool in the night and therefore the low ambient and digesters temperatures in the morning as the digesters were placed in an open space where the air flow was not controlled. The wavy nature of the graphs was as a of result variation in weather conditions especially when rain fell either in the night or during the day. It was also observed that the temperatures of all the digesters were similar for any given day making the graphs to be identical. It was also observed that the digesters temperatures were proportional to those of the ambient as the temperatures of the digesters were not controlled. The minimum morning ambient and digesters' temperatures were 22 ^{o}C and 21^{o}C respectively while the maximum evening ambient and digesters' temperatures were 39 ^{o}C and 40 ^{o}C respectively. These temperatures are within the mesophilic temperatures.

Figure 8 shows the time (days) for the onset of biogas production for each of the digesters. The onset of biogas production were 63rd, 44th, 29th, 21st, 23rd and 17th days for digesters A, B, C, D, E and F respectively. Digester A containing cassava peels only was the last to produce biogas which means that the addition of animal wastes (cattle dung and poultry dung) as inoculum had catalytic effect that sped up the rate of biogas production from cassava peels in other digesters. It was found that the mixing ratio of the substrate has significant effect on the onset of production of biogas and this could be seen from Figure 8 which is in agreement with findings of Adelekan and Bamgboye (2009). Likewise, it could be seen from same figure that blending the cassava peels with two different animal wastes reduced the time it takes to produce biogas compared to when blended with only one animal waste. This agreed with Oparuku (2013) that said that blending cassava peels with more than one waste improved its biogas productivity.

The ignition time of the biogas from each digester is as shown in Figure 9. In the figure it was revealed that the ignition time for biogas from each of the digesters were 91st, 94th, and 98th days for digesters

F, D and E respectively. The biogas from digesters A, B and C has not shown any sign of combustion after one over hundred days. The implication of this is that mixing ratio of the substrate has effect on the ignition time of biogas from cassava peels. Also blending the cassava peels with two animal wastes reduced the ignition time when compared with blending the cassava peels with one animal waste only.

5. Conclusions:-

In this work, the effect of inoculum (cattle and poultry dung) on biogas from cassava peels was studied. Suitable digesters were successfully constructed for the anaerobic digestion of the plant and animal wastes used. Anaerobic digestion of cassava peels and cassava peels mixed in different ratios with cattle dung and poultry dung was carried out.

The results showed that the addition of these animal wastes hastens the production time and combustion time of the biogas from cassava peels. The study also revealed that mixing ratio of these wastes has significant effect on the production and ignition time of the biogas from cassava peels. Based on this, it is hereby recommended that every household should be encouraged to use biogas as this will serve as alternative source of energy for domestic use; more so, large scale production of biogas should be encouraged in the rural areas where the required wastes are readily available.

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