Comparative Analysis of Biogas Yield from Cassava Peel, Yam Peel, *Jatropha* Cake and Cattle Dung

Olawale Olugbenga OLANREWAJU[1, 2]

[1]*Department of Agricultural and Environmental Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Akure, Nigeria.*
ooolanrewaju@futa.edu.ng

[2]*School of Civil and Environmental Engineering, University of the Witwatersrand, Johannesburg, South Africa.*
olawale.olanrewaju@wits.ac.za

Corresponding Author: *ooolanrewaju@futa.edu.ng*

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Abstract: *A comparative analysis of biogas yield from a Cassava peel, Yam peel, Jatropha cake and Cattle dung was investigated at the mesophilic temperature. The mesophilic ambient temperatures range attained within the testing period were 24°C to 37°C. The objectives of this work were to compare biogas yield in animal dung and agricultural wastes and to monitor the production rate of the biogas from co-digestion of cassava peel, yam peel, cattle dung and Jatropha cake. In determining some of the parameters controlling anaerobic digestion, four small-sized laboratory digesters (conical flasks) were setup in the Soil and Water Laboratory, Department of Agricultural and Environmental Engineering, Federal University of Technology Akure, Nigeria. These digesters were employed in order to examine the biogas production potential from cassava peel, yam peel, Jatropha cake and cattle dung. Water displacement method was used in this experiment. Each of the waste types was anaerobically digested for a 35-day detention period. The result shows that the volume of biogas yield from cassava peel was the highest at the end of the experiment compared to yam peel, Jatropha cake and cattle dung. The total biogas yield observed for cassava peel was 449.00ml, yam peel was 327.50ml, Jatropha cake was 219.00ml and cattle dung was 206.00ml. Findings from this research revealed that out of the substrates tested for methane production, the peel of cassava anaerobically yielded the highest volume of biogas. It is evidenced that with respect to methane generation in commercial quantity, production of biogas from cassava peels, amongst all other substrates, remains the lasting resource.*

Keywords*: Mesophilic temperature, Animal dung, agricultural waste, biogas yield, detention period.*

1. INTRODUCTION

Biogas originates from the process of bio-degradation of organic material under anaerobic (without air) conditions. In the absence of oxygen, anaerobic bacteria decompose organic matter and produce a gas mainly composed of methane (60%) and carbon dioxide called biogas. This gas can be compared to natural gas, which is 99% methane. Biogas is a 'sour gas' in that it contains impurities which form acidic combustion products [1]. In India, about 19% of global final energy consumption came from traditional biomass, which is mainly used for heating and 3.2% for hydroelectricity [2]. In other words, animal and agricultural wastes constitute a high proportion of biogas and their utilization is important for economic and environmental aspects possessing suitable climatic and ecological conditions [3].

The urgent need for alternate source of renewable energy apart from crude oil cannot be over emphasized especially due to issues bothering on climate change, the price of petroleum products and over-dependence on oil. One of the major reasons for the spread of renewable energy sources is to increase the security of the supply or, in optimal case, to realize total energy independence.

Biogas is the gas generated as a result of fermentation of biodegradable waste like animal waste, kitchen waste, human waste and other organic waste like agricultural waste, garden waste etc. It is a very clean gas and completely environmentally friendly. It is not only an eco-friendly alternative source of energy but also a means of producing organic manure for soil fertilization [4, 5].

In recent years, the need for alternate energy sources has been so glaring especially for a country like Nigeria who solely depends on crude oil. Biogas systems have attracted considerable attention as a promising approach to decentralized rural development. Biogas is one of the sources of renewable energy.

2. MATERIALS AND METHODS

The conical flask was used as a digester and tightened with cork made from Dunlop slippers to prevent air from entering the conical flask. Cassava and yam were thoroughly washed with water before peeling to remove stones, sand and foreign material, each of the crop was peeled with knife and their peels were blended with blender for the size reduction of the peels. *Jatropha* cake was extracted from *Jatropha* seed while cattle dung was collected from cattle rearing section of Animal Production and Health department in Federal University of Technology Akure (FUTA), Nigeria.

The biogas generated was measured by displacement method using water as a displacement liquid. The water was displaced upward in the measuring cylinder because air is denser than the gas produced (biogas). The volume of the biogas was measured by the water rise in the calibrated measuring cylinder.

Table 1: Mix masses of the substrates and water

Waste	Mass of waste(g)	Mass of water (g)	Mix ratio
Cassava peel	100	50	2:1
Yam peel	100	50	2:1
Jatropha cake	100	50	2:1
Cattle dung	200	50	4:1

2.1 Experimental procedure

The viability and feasibility of four materials (without treatment) to produce biogas was investigated in this project. The amount of mixture of the substrates was calculated to adjust the carbon/nitrogen ratio of the digested content because the greatest volume of methane production can be observed in digesters operating on a substrate of low carbon/nitrogen (C/N) ratio while lowest volume of methane production can be investigated in digestion operating on a substrate of high carbon/nitrogen (C/N) ratio. The blended cassava peel and the cattle dung was weighed by using digital weighing balance, the same procedure was repeated for other substrates. The four slurries were poured into four different conical flasks (500ml calibrated), labelled first batch, second batch, third batch and fourth batch while the conical flasks were corked with Dunlop slippers and 7mm glass tubing was inserted in the cork and the other end of the glass tubing was inserted in a water trough otherwise called beaker and inverted measuring cylinder was placed on it.

Figure 1 shows the experimental rig of the apparatus used in the laboratory for the production of biogas. The experimental set up was carried out at Soil and Water Laboratory of Agricultural and Environmental Engineering department located at School of Engineering and Engineering Technology central workshop, FUTA. Wooden stand was used as a retort stand while metal sheet was used as a clip to hold measuring cylinder. Four conical flasks were used as digesters and corked with Dunlop slippers to prevent air from entering the 500ml calibrated conical flasks.

Beakers were used as water trough; 7mm glass tubing was connected to the cork placed on conical flask and the other end of the glass tubing was placed in the beakers while inverted measuring cylinder was placed on it. The function of inverted measuring cylinder is to measure the volume of gas that will be generated when there is rise in the volume of water placed in the beaker. Biogas produced from cattle dung, *Jatropha* cake, yam peel and cassava peel were examined in batch mode using conical flask as digester. First batch 100g of blended cassava peel, 200g of cattle dung with 50ml of distilled water were mixed together thoroughly. Second batch 100g of blended yam peel, 200g of cattle dung with 50ml of distilled water were mixed together. Third batch 100g of *Jatropha* cake, 200g of cattle dung with 50ml of distilled water were mixed together. Four batch 200g of cattle dung with 50ml of distilled water were mixed together. The mixing ratio was in accordance with experiment conducted by Adelekan and Bamgboye [6]. It was noticed that irrespective of livestock waste type, biogas production decreased with increasing mixing ratio used. Therefore, the reason for a lower peel ratio to animal dung of 1 to 2.

Figure 1: Experimental set up of anaerobic digester with substrates

Experimental data was collected 5pm daily every 24 h. The room temperature was monitored every day because mesophilic bacteria required mesophilic temperature which ranges between 30°C – 45°C for growth and respiration. This was achieved by lagging the temperature-controlled environment where the research was conducted. There was a change in the colour of water to light green after a week, this is as a result of chemical reaction that has been taken place and also the impurities present in the gas, also there was a change in the colour of 7mm glass tubing from transparent to brown colour, fluctuation in the volume of gas produced was as a result of frequent rainfall and low temperature.

The pH of cassava peel, yam peel, cattle dung and *Jatropha* cake were monitored on daily and weekly basis (Table 2) using Jenway 3510, digital pH meter. Total viable counts (TVC) for cassava peel, yam peel, *Jatropha* cake and cattle dung slurries were carried out to determine the microbial load of the samples using the modified Miles and Mirsa [7] method as described in Okore [8].

3. RESULTS AND DISCUSSION

Table 1 shows the mix masses of the substrates and water. Table 2 shows that all the substrates used have similar pH value. The pH value of cassava peel was 6.80 on the first day and it decreases gradually to 5.96 on the last day of the experiment, the pH value of the yam peel was 6.92 on the first day and it was 5.70 on the last day of the experiment. While, cattle dung has 6.78 pH value on day one and gradually decreased to 5.55 on the last day. Also, *Jatropha* cake have 6.75 as the pH value on the first day of the experiment and reduced to 5.63 on the last day of the experiment. The reason for the decrease in the pH value of the substrate is as a result of rapid reduction in gas production during the digestion period. The volume of biogas production and the changes in pH indicates that at higher pH, the highest peak of gas production was attained and that at slightly acidic pH range, there was little or no gas production.

Table 3 shows the summary of the result for the four organic wastes for the 35 days retention period. From the table, cassava peel generated the highest total biogas volume of 449ml, followed by yam peel with 327.50ml, *Jatropha* cake with 219ml and lastly cattle dung with 206ml of biogas. Highest volume of biogas was generated from cassava peel because it has high biodegradable solid. Table 4 shows the 35 days daily volume of biogas production for the four wastes. A close observation shows that cassava peel started daily production on the tenth day, reaching 35ml of biogas. A cumulative of 449ml was produced at the end of the 35 days retention period from the cassava peel. Yam peel biogas production started at the seventh day and cumulative of 327.50ml was produced at the end of the retention period. Also from table 4, *Jatropha* cake started daily production on the twelfth day, reaching peak on the twenty second (22^{nd}) day and have cumulative of 219mlat the end of 35 days retention period.

Lastly, cattle dung was the lowest in terms of biogas production, which started daily biogas production on the eleventh day. The maximum volume of biogas generated from cattle dung was 22ml and a total volume of 206ml of biogas was produced at the end of 35 days. From this table, it shows that the biogas production varied from the four substrates (wastes). Cassava peel yielded higher methane gas than yam peel, *Jatropha* cake and cattle dung, while cattle dung has least volume of biogas because it has high carbon/nitrogen ratio and low biodegradable solid.

Table 2: Daily pH values of the substrates for 35 days

Days	Cassava Peel	Yam Peel	Cattle Dung	*Jatropha* Cake
1.00	6.80	6.92	6.78	6.75
2.00	6.80	6.92	6.78	6.75
3.00	6.80	6.92	6.77	6.73
4.00	6.75	6.88	6.75	6.70
5.00	6.75	6.88	6.75	6.65
6.00	6.75	6.87	6.75	6.65
7.00	6.70	6.82	6.70	6.65
8.00	6.70	6.82	6.69	6.65
9.00	6.70	6.81	6.68	6.48
10.00	6.68	6.76	6.66	6.47
11.00	6.67	6.76	6.65	6.46
12.00	6.67	6.75	6.65	6.39
13.00	6.64	6.73	6.64	6.38
14.00	6.64	6.72	6.65	6.35
15.00	6.62	6.71	6.50	6.30
16.00	6.60	6.70	6.49	6.28

17.00	6.60	6.69	6.40	6.25
18.00	6.59	6.69	6.40	6.23
19.00	6.58	6.67	6.38	6.23
20.00	6.57	6.66	6.36	6.20
21.00	6.57	6.64	6.36	6.14
22.00	6.57	6.62	6.00	6.00
23.00	6.56	6.62	5.97	5.97
24.00	6.56	6.60	5.86	5.97
25.00	6.54	6.50	5.75	5.86
26.00	6.54	6.50	5.70	5.86
27.00	6.53	6.49	5.70	5.80
28.00	6.52	6.00	5.65	5.80
29.00	6.51	5.97	5.64	5.76
30.00	6.51	5.97	5.64	5.73
31.00	6.00	5.96	5.62	5.72
32.00	5.99	5.94	5.61	5.72
33.00	5.98	5.93	5.59	5.64
34.00	5.97	5.74	5.57	5.64
35.00	5.96	5.70	5.55	5.63

Table 3: Summary of result for the four wastes

Items	Cassava Peel	Yam Peel	*Jatropha* Cake	Cattle Dung
Mass of waste used (g)	100	100	100	200
Mass of water used (g)	50	50	50	50
Mass of additive (g)	200	200	200	-
Total mass of slurry (g)	350	350	350	250
No of days of digestion	35	35	35	35
Total volume of gas generated (ml)	449	327.50	219	206
Peak volume of gas (ml)	35	21	20	22

Table 4: Volume of biogas produced from co-digestion of cassava peel with cattle dung, yam peel with cattle dung, jatropha cake with cattle dung and cattle dung only on daily basis

Days	volume of cassava peel with cattle dung	volume of yam peel with cattle dung	volume of *Jatropha* cake with cattle dung	volume of cattle dung
1.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00
3.00	0.00	0.00	0.00	0.00
4.00	0.00	0.00	0.00	0.00
5.00	0.00	0.00	0.00	0.00
6.00	0.00	0.00	0.00	0.00
7.00	0.00	6.50	0.00	0.00
8.00	0.00	8.00	0.00	0.00
9.00	0.00	10.50	0.00	0.00
10.00	10.00	13.00	0.00	0.00
11.00	17.00	16.00	0.00	3.00
12.00	20.00	19.00	5.00	5.00
13.00	24.00	21.00	5.50	6.50

14.00	25.00	24.00	6.50	8.00
15.00	28.00	27.00	9.00	10.00
16.00	30.00	29.00	11.00	13.00
17.00	33.00	25.00	11.50	14.50
18.00	35.00	21.00	14.00	17.00
19.00	31.00	18.00	15.00	18.00
20.00	28.00	15.00	14.00	22.00
21.00	27.00	12.00	17.00	20.00
22.00	23.00	9.00	20.00	18.00
23.00	22.00	8.00	18.00	16.50
24.00	20.50	7.00	17.00	13.50
25.00	18.50	7.50	15.00	11.00
26.00	16.00	5.00	13.00	9.00
27.00	14.00	4.00	9.00	8.50
28.00	11.00	4.00	7.50	4.00
29.00	9.50	4.00	6.00	3.00
30.00	4.00	4.00	3.50	3.00
31.00	2.50	3.50	1.00	0.50
32.00	0.00	3.50	0.00	0.00
33.00	0.00	2.00	0.00	0.00
34.00	0.00	0.00	0.00	0.00
35.00	0.00	0.00	0.00	0.00

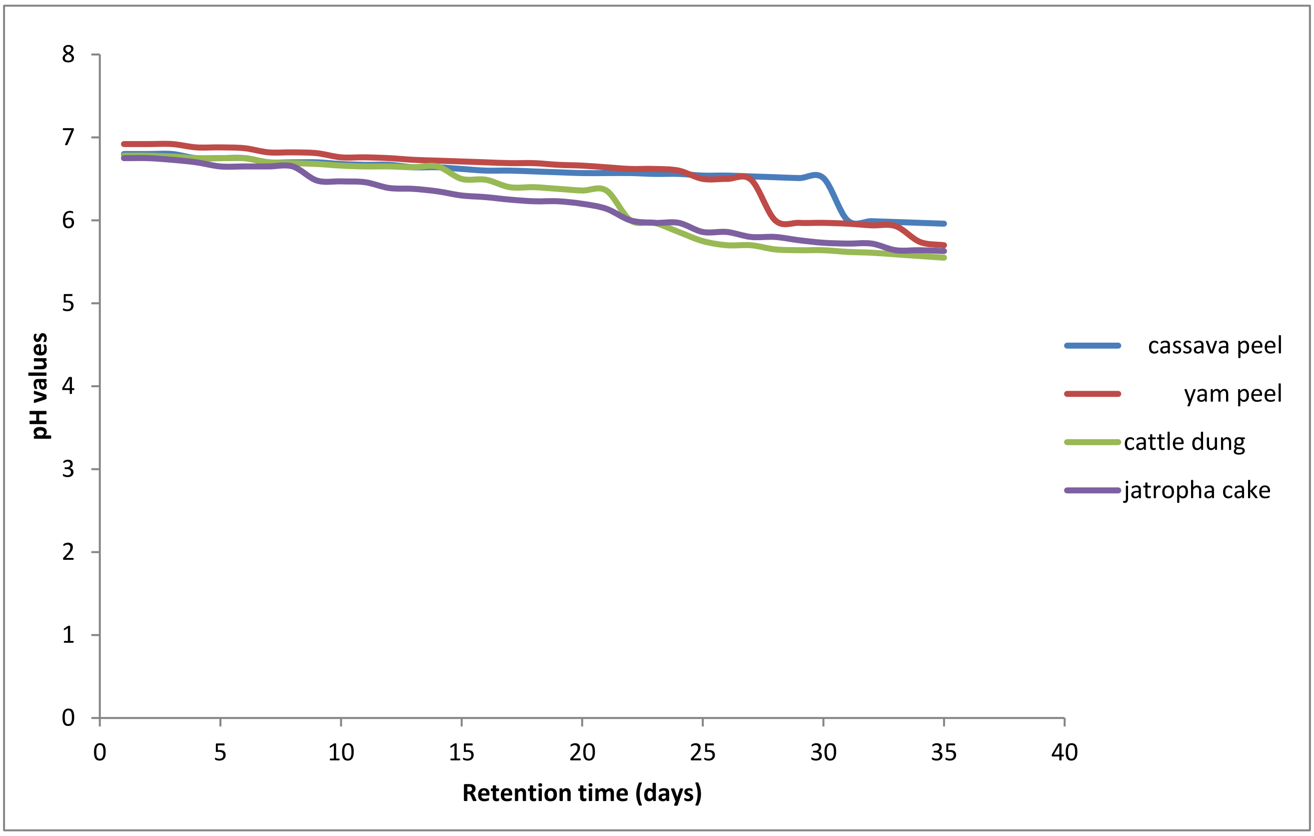

Figure 2: pH values versus Retention Time

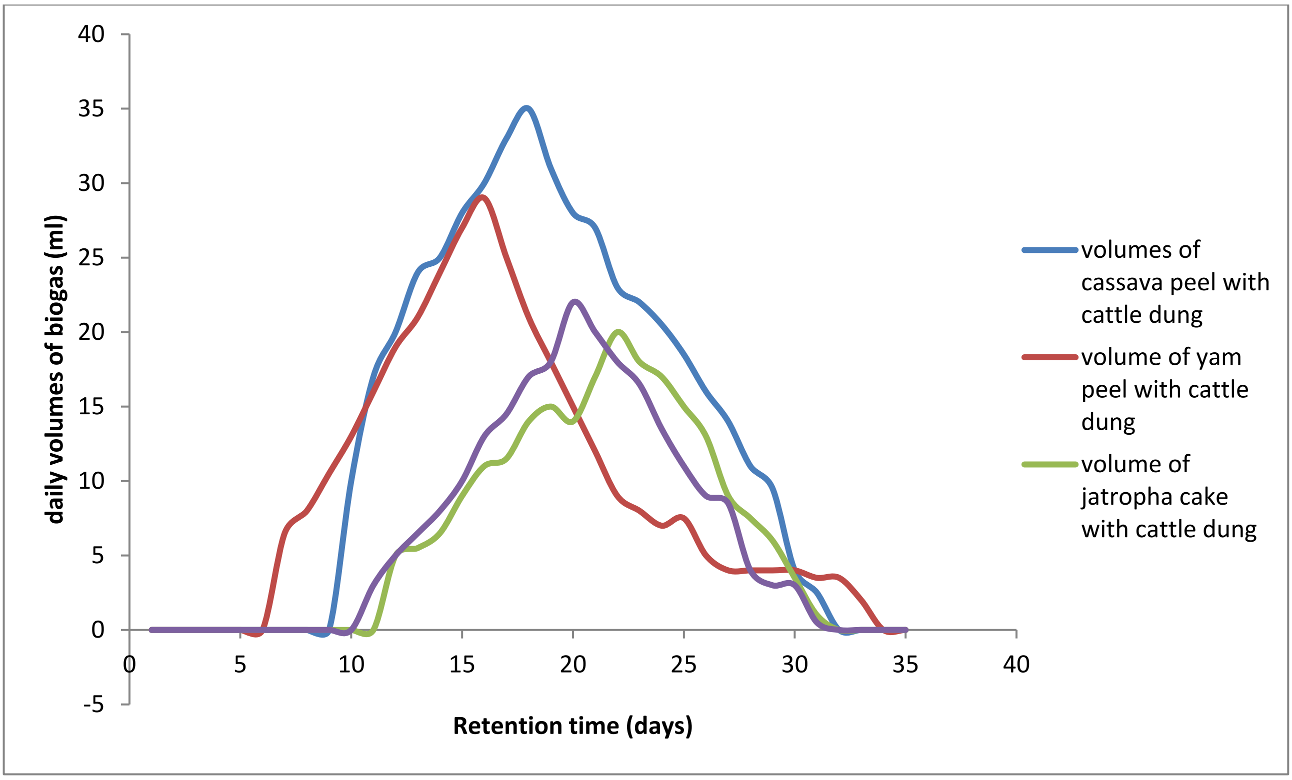

Figure 3: Daily volume of biogas versus Retention Time

The results show that the methane gas (biogas) produced from cassava peels are higher than other materials because the carbon –nitrogen ratio (C-N ratio) in cassava is less than other material (yam peel, *Jatropha* cake and cattle dung). According to Adelekan [9], cassava has a very high C-N ratio in tropical countries and has a high potential for the production of ethanol and methane in tropical countries, most notably, Nigeria. The biogas production was low in the first week, increased in the second week and third week when anaerobic bacteria must have used-up all the oxygen in the digester (conical flask) to release carbon dioxide (CO_2).

From the peaks of biogas production recorded in table 4, it was observed that in the third week (pronounced on day 17 and 18) when all the oxygen in the digester has been used up and also the reaction was very fast compared to the rest of the other weeks of the experiment. The bacterial growth was initially observed to be at lag phase (little or no growth) from day 1 – 9. The growth became exponential (log phase) and was later observed to be at peak levels at day 18th(stationary phase) after which there were gradual decline in bacterial growth from the 19th day until their life terminates at day 32 – 35 (death phase).This was further supported by the fact that the bacteria acted first on the dung which were possibly contained in similar substances which were already being digested (Oluka and Nnamani, 2004) [10]. The amount of biogas produced from cassava peel was higher than that of yam peel, cattle dung and *Jatropha* cake. The reason for the cassava peel higher than that of the yam peel was because yam peels contains less biodegradable solid than cassava peels and C-N ratio in yam peel is higher than that of cassava peel.

From the result above it shows that biogas produced from cattle dung and *Jatropha* cake were very close, this is because cattle dung and *Jatropha* cake have a very close carbon-nitrogen ratio and biodegradable solid. Also, from the result above, it shows that biogas produced from cassava peel and yam peel were higher compared to that of cattle dung. This is because cattle dung has higher Carbon-Nitrogen ratio and less biodegradable solid compared to cassava peel and yam peel.

The temperature of the reaction varied from 24 to 37 °C and 28 to 42°C respectively. The result shows that methane gas production fluctuates, increasing and decreasing with time without any definite pattern. One of the reasons for the fluctuation was increase and decrease in temperature. For instance, in table 4 (yam peel with cattle dung), in the second week and third week, the biogas production was very high, due to cooled weather experienced in the fourth week which reduces the temperature and volume of biogas produced. Another reason is that the bacteria that are involved in anaerobic digestion must have died. From the result, it was deduced that the bacterial growth was initially observed to be at lag phase (little or no growth). The growth became exponential (log phase) and was later observed to be at peak levels (stationary phase) after which there were gradual decline in bacterial growth until their life terminates (death phase). The temperature of the experimental environment was boosted above ambient through lagging.

Temperature is a major factor affecting the digestion process. It also influences the length of fermentation period. The higher the temperature, the shorter the fermentation period while the lower the temperature, the longer the fermentation period.

4. CONCLUSION

The results of this study showed that cassava peel, yam peel, *Jatropha* cake and cattle dung which can be regarded as wastes in the environment can be a useful source of energy by subjecting it to anaerobic digestion for biogas production. Also, the concept of laboratory experiment in the production of biogas was embraced in this research work. There are in addition, the abilities of agricultural and animal wastes in the production of biogas undergoing artificial, biological, mechanical and chemical processes. The experiment carried out in the laboratory shows the simplicity of the production of biogas and the potentials of the agricultural and animal wastes of cassava peel, yam peel, *Jatropha* cake and cattle dung.

Biogas technology is an appropriate solution for everyone, if properly managed. It can satisfy the entire requirements of the household by providing energy for various domestic uses. It requires waste as an input to function properly and can easily be found everywhere. One of the potential benefits apart from generation of energy is the ability of the effluent to be used as a fertilizer which means that there is no waste in the production of biogas. The addition of cattle dung to the slurries serves as an additive/catalyst to enhance biogas production. The cassava peel anaerobically digested with highest volume of biogas compared to other substrates showed the highest yield for methane production.

REFERENCES

[1] Boyd, R. (2000). Internalizing Environmental Benefits of Anaerobic Digestion of Pig Slurry in Norfolk. University of East Anglia ENV 4:6- 10.

[2] Ross, C. (1996). Handbook on Biogas Utilization, 2nd Edition Muscle shoals, all Southeastern Regional Biomass Energy Program, Tennessee Valley Authority.

[3] Oktay, Z. (2006). Olive Cake as a Biomass Fuel for Energy Production, Energy Sources, and Part A: Recovery Utilization and Environmental Effects. 28:329-339.

[4] Paustian, K., Conant. R., Ogle. S., Paul, E. (2002) Environmental and management drivers of soil organic C stock changes. Proc. of the OECD Expert Meeting on soil organic C indicators for agricultural land. Ottawa, Canada.

[5] McNeill, A.M., Eriksen, J., Bergstrom, L., Smith K.A., Marstorp, H., Kirchmann, H., Nilsson, I. (2005) Nitrogen and sulphur management: challenges for organic sources in temperate agricultural systems. Soil Use and Man. 21: 82-93.

[6] Adelekan, B.A. and Bamgboye, A.I. (2009). Comparison of biogas productivity of cassava peels mixed in selected ratios with major livestock waste types. *African Journal of Agricultural Research*, 4(7): 571-577.

[7] Miles, A.A. and Misra, S.S. (1938). The Estimation of the Bactericidal Power of the Blood. Journal of Hygiene, 38, 732-749. http://dx.doi.org/10.1017/S002217240001158X.

[8] Okore, V.C. (2004). Surface viable count method: a standard laboratory Technique in pharmaceutics and pharmaceutical microbiology (2nd edition). El Demark publishers' pp 24-26.

[9] Adelekan, B.A. (2011). Cassava as a Potent Energy Crop for the Production of Ethanol and Methane in Tropical Countries. International Journal of Thermal and Environmental Engineering, Volume 4. No. 1 (2012): 25-32. DOI: 10.5383/ijtee.04.01.004

[10] Oluka, S.T. and Nnamani, E.C. (2004). Comparison of Biogas Production from the Wastes of Cassava, Yam and Cocoyam. Proceedings of the 5th International Conference and 26th Annual general Meeting of Nigerian Institution of Agricultural Engineers, Ilorin, Nigeria. 26:459-461.