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Preparation of Biogas from Plants and Animal Waste

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ABSTRACT

The study investigated biogas potentials of six different plants, Cow rumen liquor, Cowpea, and poultry waste. The Slurry used was prepared by mixing 60 g of plants sample with 20 g of chicken dropping in the ratio of 3:1 W/W (weight for weight). These were moistened with varying volumes of pre – warmed water at 37 ºC. The results show nonlinear production of gas during the retention period of 16 days, with corresponding increase in cumulative volume of biogas. Digesters containing *Steculia Setigera* and *Grewia mollis* produced cumulative volumes of 267 cm^3 and 245 cm^3 respectively; while *Lannea sp, Ficus Capensis, Ficus Trichopoda* and *Piliostigma Thonnigii* produced cumulative volumes of 241, 185, 181 and 95cm^3 respectively. The entire samples produced biogas at early retention time not later than 10 days. The results are such that the higher the lignin contents in the plants, the lower its biogas yield. Low moisture contents (9.1 – 4.6 %) of was observed for all the samples. The pH range of 7.53 – 6.80 was found for the samples' slurry. The pH of 7.53 was associated with the sample with highest cumulative volume of biogas. The range 49.02 – 41.18 % was observed as the ash contents for the materials used. These plants have good potentials as biogas producers. Therefore details studies of biogas production should be done on them and subsequent commercialization.

Keywords: *Biogas, Steculia Setigera, Grewia mollis, Lannea sp, Ficus Capensis, Ficus Trichopoda and Piliostigma Thonnigii*

1. INTRODUCTION

The increase in loading of obnoxious gases; CO_2, N_2O, CH_4, CFCs etc. in the atmosphere as a result of burning of fossil fuels and other anthropogenic factors have led to increase in global warming resulting into climate change with attendant consequences of flooding, desertification, drought etc. The occurrence has necessitated the quest for alternative sources of fuels; 'green fuels' produced from biomass. These fuels are clean burning and result in no net increase in the proportion of greenhouse gases in the atmosphere (Garba *et al.,* 1996, Adeyemo & Adeyanju, 2008). Ukpai & Nnabuchi (2012), reported that in evaluating national development and the standard of living of any nation, the supply and consumption of energy are very important. Human energy consumption has been moderate before the industrial revolution in the 1890s. Man has mostly relied on the energy from brute animal's strength to do work. Recently, man acquired control over coal, electricity, crude oil, natural gas, etc. Sustainable resource management of waste and the development of alternative energy source are the present challenges due to economic growth. The history of waste utilization shows independent developments in various developing and industrialized countries. Society is today confronted with dwindling sources of fossil fuels and chemical feed stock and their proliferation of waste generated by municipalities, agricultural industries. This has brought great interest in the use of agricultural waste as substitute for fossil fuels. But the conversion of renewable sources or waste to chemicals and fuels by microbial fermentation through a biogas reactor represents a challenge in the present day and more so in the nearest future (Garba *et al.,* 1996, Adeyemo & Adeyanju, 2008). Anaerobic digestion can convert energy stored in organic matter present in manure into biogas. Energy supplied from fossil fuels is not easily recycled and takes a long time to form, hence is exhaustible and not renewable. Renewable energy has remained one of the best alternatives for sustainable energy development since the grid electricity has become too expensive. Sources of renewable energy are wind, hydro, ocean waves, geothermal energy resources and solar energy, which can be applied as solar thermal and solar electricity (photovoltaic) (Ukpai *et al*., 2012, Adrian *et al.,* 2012). Biogas is another source of renewable energy, it is produced when biomass is subjected to biological gasification and a methane-rich gas is produced from the anaerobic digestion of organic materials. Achieving solutions to possible shortage in fossil fuels and environmental problems that the world is facing today requires long-term potential actions for sustainable development. In this regard, renewable energy resources appear to be one of the most efficient and effective solutions (Ofoefule *et al.,* 2010). Biomass is the biological organic materials that are renewable and can be recycled to produce biogas (Ilaboya *et al.,* 2010). Liquid fuels from biomass have already entered commercial markets in many countries especially as blends (up to 20 – 25%) with gasoline and diesel (Padma *et al.,* 2005). A huge amount of wastes is generated daily from the various processing industries in Nigeria. The wastes that are usually disposed of either into the sea, river, or on the land as a solid amendment materials, which causes support for breeding of flies, and constitute health hazards to people living around the area are converted into biogas by anaerobic fermentation (Ukpai & Nnabuchi, 2012).What was considered as waste many years ago has in recent time become useful such that it can be inferred in life, nothing is a 'waste'. It can only waste when there is lack of useful technology for its transformation and application. In preparation of biogas, the biomass wastes are held in a digester or reactor. The gas is produced from a three-phase process namely, hydrolysis, acid-forming and methane-forming phases. This can be looked at as a biological engineering process in which a complex set of environmentally sensitive micro-organisms are involved. The gas is typically composed of 50-70% Methane, 30-40% Carbon dioxide, 1-10% Hydrogen, 1-3% Nitrogen, 0.1% Oxygen and Carbon monoxide and trace of Hydrogen sulphide (Nitin *et al.*, 2012, Ilaboya *et al.*, 2010, Ofoefule *et al.*, 2009 & Elijah *et al.*, 2009). Biogas is also a waste management technique because the anaerobic treatment process eliminates the harmful micro-organisms. It is a cheap source of energy because the feed stocks for its production are usually waste materials. The technology ensures energy independence as a unit can meet the need of a family or community. The digester slurry is a good fertilizer. It is claimed that its value as fertilizer could double crop yield. Biogas when further refined burns as well as liquefied gas, but does not add to global warming like liquefied natural gas (Ukpai & Nnabuchi, 2012, Chonkor, 1983). Cow dung has high nitrogen content and due to pre-fermentation in the stomach of ruminant, and has been observed to be most suitable material for high yield of biogas through the study made over the years (Ukpai & Nnabuchi, 2012). Plant materials such as crop residues are more difficult to digest than animal wastes (manures) because of the difficulty in achieving hydrolysis of cellulosic and lignin constituents with attendant acidity in the biogas systems leading to reduction and sometimes cessation of gas flammability / gas production (Ofoefule & Onukwuli, 2010), etc. Flammable gas which helps in reducing forestation and desert encroachment is produced through the conversion of organic matter such as animal and plant wastes into biogas (Jewel, 1976). Ofoefule *et al.*, 2010 reported that, paper waste which abounds everywhere including the immediate environment is a very good feedstock for biogas production. This waste can be utilized for energy generation instead of burning them up or having them littered around and invariably constituting a nuisance to the environment. The study has also shown that blending the paper waste with cow dung or any other animal waste will give sustained gas flammability throughout the digestion period of the waste since animal wastes are good starters for poor producing wastes. The studies on Bambara nut chaff has shown that it has potentials for biogas production though the expected increased biogas yield and extended retention time was not achieved by blending it with both animal and plant wastes. This is an indication that further work needs to be carried out to possibly treat the waste chemically to increase the pH to neutrality. This may give the expected increase in the yield of the biogas with consequent extension of the retention period (Ofoefule *et al.*, 2010). Also, Bhat *et al.*, (2001) and Ofoefule *et al.*, (2010) reported that, Biogas technology among other processes (including thermal, pyrolysis, combustion and gasification) has in recent times also been viewed as a very good source of sustainable waste treatment /management as disposal of wastes has become a major problem especially to the third world countries. The effluent of this process is a residue rich in essential inorganic elements like nitrogen and phosphorus needed for healthy plant growth known as biofertilizer which when applied to the soil enriches it with no detrimental effects to the environment. The objective of this study was to investigate the biogas potentials of six different plants, Cow rumen liquor, Cowpea, and poultry waste.

2. MATERIALS AND METHODS

Six different plants, poultry waste and cow rumen liquor were used. The plants materials were collected from the Benue State University's Zoological and amazement park. These plants were: *Grewia Mollis, Lannea sp, Sterculia Setigera, Ficus Capensis, Ficus Trichopofda* and *Piliostigma Thonnigii* which were coded as; S_1, S_2, S_3, S_4, S_5, and S_6 respectively. The materials were sun- dried for nine days and then pounded to a fine powder (Ofoefule *et al.*, 2009). Partially dried chicken droppings were collected from under laying hens in a poultry farm, in Wurukum, Makurdi, Benue State – Nigeria. These were further mixed properly and dried in a drying bed to about 99 % moisture content. The materials were ground to powder and served as digester feed. These also served as nitrogen supplement in digester media (Ofoefule *et al.*, 2009). Rumen content of cow was collected immediately after slaughter in an airtight container (to preserve the anaerobic microbes), achieved with the use of cheese cloth and liquor was used as digester (Ezeonu *et al.*, 2002). This was collected from an abattoir in Wurukum, Makurdi. A set six of improvised I litre cylindrical container were washed and cleansed thoroughly and used as digesters. They were labelled as S_1, S_2, S_3, S_4, S_5, and S_6 according to the plant sample each contained. A hole was made on top of each digester lid, and P.V. C rubber tube of 3 mm in diameter and 20 cm^3 long was inserted into each lid and glued (Ofoefule *et al.*, 2009, Ukpai & Nnabuchi, 2012).

2.1 Experimental Set -Up

The Slurry used was prepared by mixing 60g of plants sample with 20g of chicken dropping in the ratio of 3:1 W/W (weight by weight). These were moistened with varying volumes of pre – warmed water at 37 ºC (Ukpai & Nnabuchi, 2012, Uzodinma *et al.*, 2008). To each digester, appropriate volume was added until the desired slurry mix was obtained. Each digester was thoroughly stirred by mechanical shaking, to ensure the formation of homogenous mixture. A 10 mL of the cow rumen liquor was added to initiate inoculation and each was covered with it lid to ensure airtight. The P.V.C tube from the digester lid was drained into an inverted 100 cm^3 measuring cylinders, filled with brine water in water trough, such that the outlet is directed upward in the cylinder. Fermentation was carried out at room temperature with fluctuation range of 28 and 33 ºC, for fifteen days. Digesters are stirred by shaking and swirling once in a day and medium pH was found to be between 6.6 and 7.8 (Ukpai & Nnabuchi, 2012, Uzodinma *et al.*, 2008).

2.2 Determination of Biogas Yield

The volume of biogas yield was determined as equivalent of the volume of water displaced from the cylinder. The measuring cylinders were refilled as soon as there is complete displacement (Ezeonu *et al.*, 2002). An acidified brine solution was used in order to prevent the dissociation of biogas in the water. This was prepared by adding NaCl (salt) to water until a supersaturated solution was formed. Then 6 - 8 drops of sulphuric acid were added to acidify the brine solution. Since the biogas is not soluble in the brine solution, a pressure build up provides the driving force for displacement of the solution (Itodo *et al.*, 1992, Ukpai & Nnabuchi, 2012, Uzodinma *et al.*, 2008).

2.3 Proximate Analysis of the Waste

Determination of dry matter, moisture content, organic matter/ash content dry matter (total solids) and moisture content of sample was estimated by the method of Uzodinma *et al.*, (2008), Nitin *et al.*, (2012), & Ubua and Idoko, (2008).

3. RESULTS AND DISCUSSION

3.1 Results

The results are presented in Table 1-2 and Figure 1-2.

Table 1: Percentage of pH, moisture content and ash content

Parameter	S1	S2	S3	S4	S5	S6	P
Moisture content (%)	4.8	5.6	4.6	4.9	5.9	9.1	4.9
Ash content (%)	43.14	44.23	41.18	48.08	49.02	47.06	45.10
pH	6.80	7.24	7.53	7.53	6.79	7.32	-

Table 2: Daily yield and cumulative volume (cm^3) of biogas

Day	*Grewia Mollis*		*Lannea sp*		*Steculia Setigera*		*Ficus Capensis*		*Ficus trichopoda*		*Philostigma Thonnigii*	
	DY	CY	DY	CY	DY	CY	DY	CY	DY	CY	DY	CY
1.	-	-	-	-	-	-	-	-	-	-	-	-
2.	56	56	30	30	60	60	20	20	40	40	20	20
3.	24	80	50	80	20	80	21	41	20	60	22	42
4.	14	94	10	90	10	90	49	90	20	80	5	47
5.	10	104	-	90	10	100	20	110	20	100	3	50
6.	5	109	20	110	-	100	5	115	5	105	5	55
7.	11	120	15	125	80	180	5	120	5	110	-	55
8.	10	130	5	130	30	210	5	125	5	115	10	65
9.	7	137	5	135	10	220	-	125	10	125	5	70
10.	20	157	10	145	5	225	5	130	10	135	5	75
11.	15	172	11	156	10	235	10	140	15	150	-	75
12.	15	187	40	196	10	245	20	160	-	150	5	80
13.	-	187	15	211	10	255	5	165	7	157	10	90
14.	4	191	20	231	7	262	-	165	7	164	5	95
15.	25	216	5	236	5	267	10	175	7	171	-	95
16.	30	246	5	241	-	267	10	185	10	181	-	95
Total		246		241		267		185		181		95

DY = daily yield; CY = cumulative yield, *Grewia Mollis* (SI), *Lannea Sp* (S2), *Sterulia Setigera* (S3), *Ficus Capensis* (S4), *Ficus Trichopoda* (S5), *Piliostigma Thonnigii* (S6) and Poultry Waste (P)

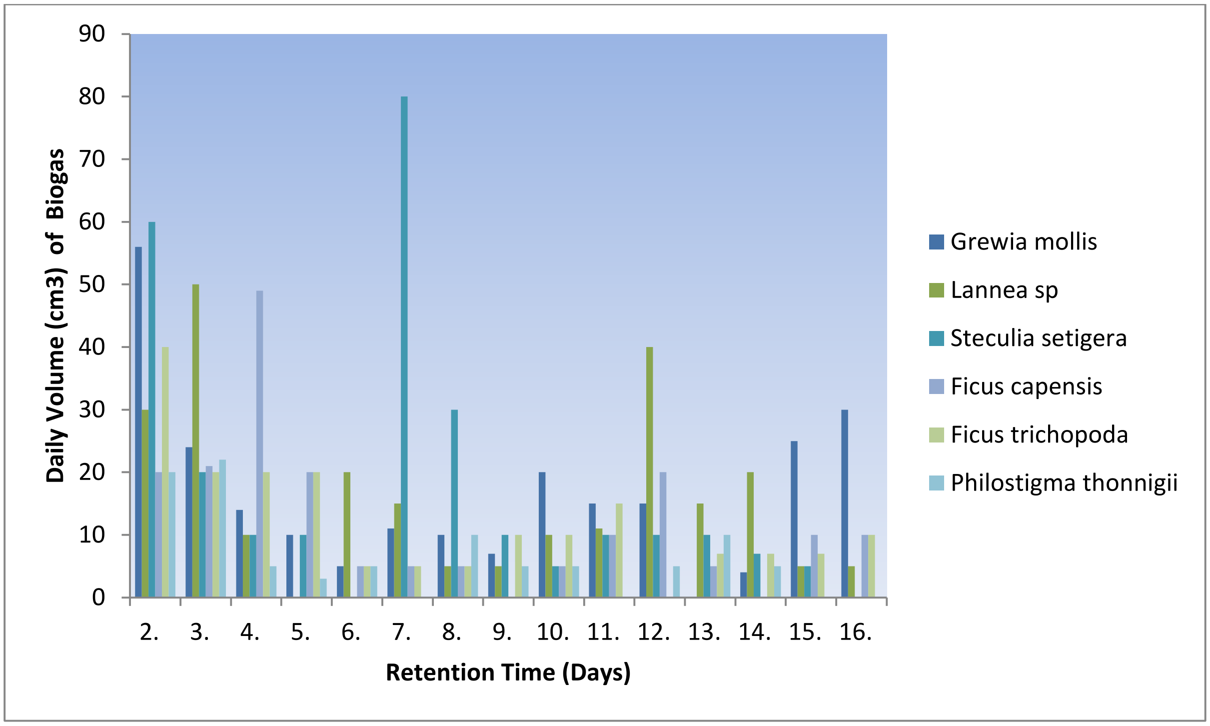

Figure 1: Daily Biogas Volume (cm^3) Vs Time

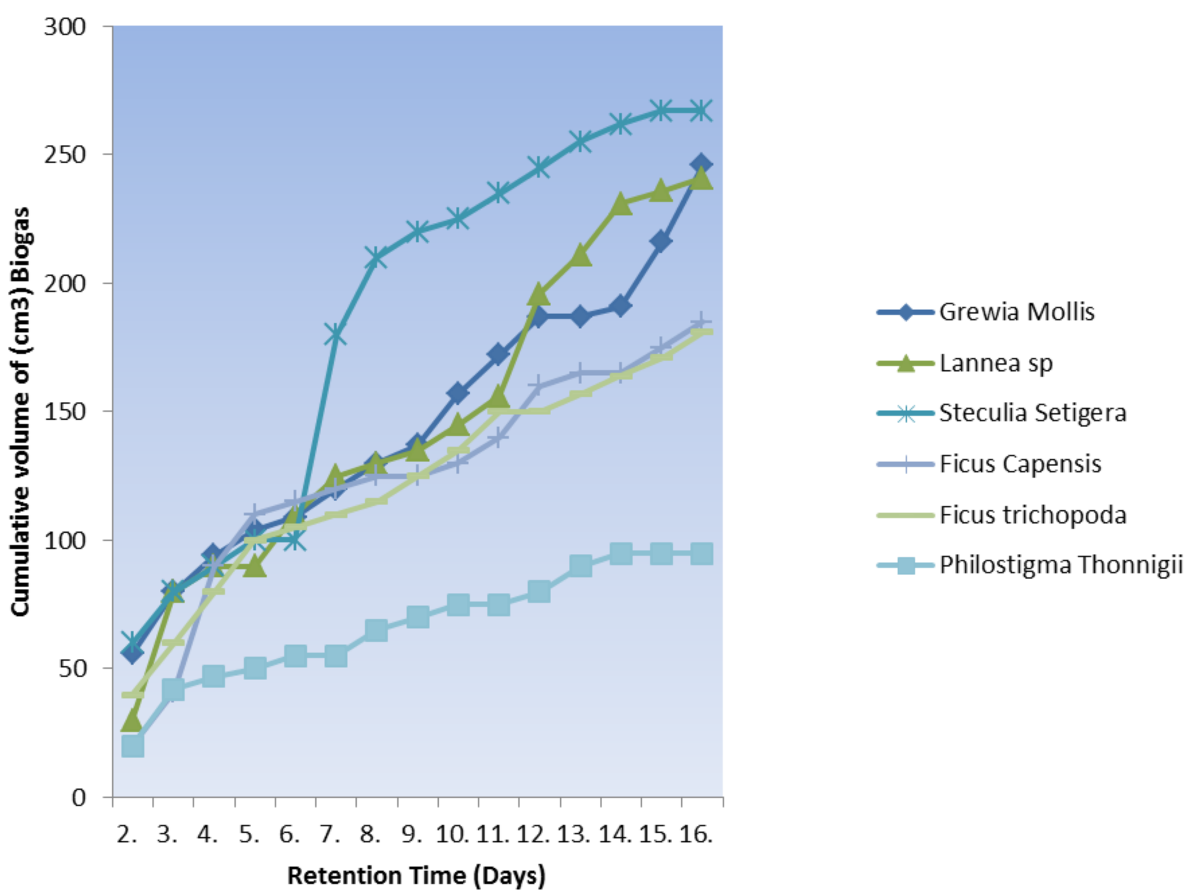

Figure 2: Cumulative Biogas Volume (cm^3) Vs Time

3.2 Discussion

The results in Tables 1-2 and Figures 1-2 above, show nonlinear production of gas during the retention period of 16days. On the first day, there was no production of biogas (Adeyemo, *et al.,* 2008; Itodo, *et al.,* 1992), thus suggesting that fermentation has not started. The samples were found to have low moisture contents (9.1 - 4.6%) and this appeared to increase the cumulative volume of gas produced (Maishanu and Sambo, 1991). The generation of biogas depends on several factors such as, pH, temperature, total solid of the slurry, and microbial activities (Elijah *et al.,* 2009). These samples have ash contents as S_1(43.14), S_2(44.23), S_3(41.18), S_4(48.08), S_5(49.02), S_6(47.06) and P(45.10). The ash content of an organic matter is an excellent index for measuring its mineral contents and its nutritional values to both man and animals (Dangogo and Fernando, 1086). High ash content of these samples suggests they are valuable substrate for biodertilizer (Ezeonu *et al*., 2002). The pH range of 7.53 – 6.80 was found for the samples slurry. The pH of 7.53 was associated with the sample with highest cumulative volume of biogas. It was reported that at an appropriate pH of 7, there is balance in the population of the acidogens and methanogens, such that an equal amount of the acid intermediates produced during the digestion process is converted to biogas (Garba *et al*., 1996; P. A. & Nnabuchi, M. N., 2012). If the methanogens are not present in suitable number or are inhibited by unfavourable conditions (At low pH), they will not use the acids as rapidly as they are produced (Nnabuchi, M. N., 2012). The slurry temperature of 28ºC was maintained during the process of fermentation. Ukpai, P. A. and Nnabuchi, M. N. (2012) reported that ambient temperature affects the rate of digestion due to the outside walls of the digester surface make direct contact with the atmosphere, hence the digester walls absorb or loose heat depending on the temperature gradient between the digester and its immediate environment. This implies that seasons affect the rate of heat loss or gain from the digester which in turn affects the microbial activities in the slurry at each stage. The bacterial involved may not play its role completely. Ambient temperature fluctuated due to climatic conditions.

From the results in Table 2 and Figure 1-2 above, biogas was produced within fifteen days retention period. Digesters containing *Steculia Setigera* and *Grewia mollis* produced cumulative total volumes of 267cm^3 and 245cm^3 respectively. While *nannea sp, Ficus Capensis, Ficus Trichopoda* and *Piliostigma Thonnigii* produced cumulative total volumes of 241, 185, 181 and 95cm^3 respectively. Digesters of *Piliostigma Thonnigii*, *Ficus Trichopoda* and *Ficus Capensis* gave low gas yield owing to high lignin content that characterizes their rigidity and its microbiological characteristics which include its resistance to enzymatic degradation (Alexander, 1977). The entire samples produced biogas at early retention time (days) of not later than 10 days (Ukpai & Nnabuchi, 2012; Garba *et al*., 2002). In contrast *Steculia Setigera* and *Grewia Mollis* are fibrous and have soft tissue, hence produce more biogas (Garba *et al*., 2002; Hans, 1977). Generally, from the condition of operation (28ºC), the gas yield is low. The samples could give higher yield at elevated temperature (Dangogo and Fermando, 1986; Garba and Sambo 1995). The breaks or stoppage (nonlinearity with days) of gas production in some days during the 15 days retention period may be due to unfavourable ambient condition and temperature fluctuation which influenced methane producing bacteria (CSANR, 2012). A. U. Ofoefule & E. O. Uzodinma (2009) posited that the low biogas yield and slow onset of gas production / flammability of digested cassava peels can be enhanced significantly when combined with animal wastes. The blend with cow dung and poultry droppings had the fastest onset of gas flammability while that with swine dung had the highest cumulative volume of gas production.

4. CONCLUSION

Based on the findings made in this work, it is established that plants materials, stems and leaves, especially those rich in fibre content and low in lignin content, with soft tissues, and in combination with poultry waste, are potential sources of biogas and such, could also form enhanced manure for farm application. Therefore, the use of this technology in combining plants and poultry wastes to generate biogas and Biofertilizers should be encouraged in larger scale production in order to reduce the wastage of these biomass materials in our localities. It is imperative to state here that if this technology is enhanced, it will help to harness other benefits such as creating a stabilized resource that retains its fertilizer value of original material and reducing unwanted pathogens, improved public health, monetary returns which come from saving on kerosene gas, cleaner cooking and better hygiene.

5. RECOMMENDATIONS

Biogas producing plants should be cultivated for details studies on them and subsequent commercialization. Also the effluent from biogas digester can be used as biofertilizer.

REFERENCES

[1] Adeyemo, S. B &A.A. Adeyanju (2008). Improving Biogas Yield Using Media Materials. *Journal of Engineering and Applied Sciences* 3 (2): 207-210.

[2] Adrian E Cioabla, Ioana Ionel, Gabriela-Alina Dumitrel and Francisc Popescu. (2012). Comparative study on factors affecting anaerobic digestion of agricultural vegetal residues . Biotechnology for Biofuels, 5:39. Doi:10.1186/1754-6834-5-39.http://dx.doi.org/10.1186/1754-6834-5-39.

[3] Bhat P.R., Chanakya H.N. and Ravindranath N.H. (2001). J. Energy Sust. Dev. 1:39 – 41. http://dx.doi.org/10.1016/S0973-0826(09)60019-3.

[4] Chonkor P.K. (1983). Microbial Ecology during Anarodic Fermentation of cellulose waste Materials in S.K.Vyas, Grewal, N.S (Ed), *Biogas Technology USG Publisher*, Luthiana, India.**:** 21-26.

[5] Elijah T. Iyagba, Ibifuro A. Mangibo & Yahaya Sayyadi Mohammad. (2009). Journals The study of cow dung as co-substrate with rice husk in biogas production, *Scientific Research and Essays*, 4 (9): 861–866. ISSN 1992- 2248.

[6] Ilaboya, I. R; F.F. Asekhame, M.O. Ezugwu, A.A. Erameh and F.E. Omofuma. (2010). Studies on Biogas Generation from Agricultural Waste; Analysis of the Effects of Alkaline on Gas Generation. *World Applied Sciences Journal* 9 (5): 537-545. ISSN 1818-4952

[7] Itodo, I.N., E.B. Lucas and E.I.Kucha (1992). The effects of Media materials and its quantity on biogas yield. *Nig. J Renewable Energy*, 3 (1 and 2): 45- 49.

[8] Jewel W.J, Bioconversion of agricultural Waste for pollution control and energy conservation in Livestock waste: A Renewable Resource; Proceedings of the 4th International Symposium on Livestock wastes, Michigan, USA. 1976:76.

[9] Nitin A.Wankhade, S.B.Thakre A.V.Dhote, P.S.Wankhade. (2012). Enhancement of Biogas From Abattoir Cow Liquor Waste With Some Agro-Industrial Wastes. *International Journal of Engineering Research and Applications* (IJERA) 2 (5): 1383-1388 1383. ISSN: 2248-9622.

[10] Ofoefule, A. U. & E. O. Uzodinma (2009). Biogas production from blends of cassava (*Manihotutilissima*) peels with some animal wastes. *International Journal of Physical Sciences* ; 4 (7):398-402. http://www.academicjournals.org/IJPS. ISSN 1992 - 1950.

[11] Ofoefule A. U., Uzodinma E. O. & Onukwuli O. D. (2009). Comparative Study of the Efect of different Pretreatment methods on Biogas yield from water Hyacinth (*Eichhornia crassipes*). *International Journal of Physical Sciences* 4(8): 535 – 539. http://www.academicjournals.org/ijps. ISSN1992 - 1950.

[12] Ofoefule, Akuzuo U and Onukwuli, Okechukwu D. (2010). Biogas production from blends of bambara nut (*Vigna subterranea*) chaff with some animal and plant wastes. Advances in Applied Science Research, 1 (3): 98-105. ISSN: 0976-8610

[13] Ofoefule, Akuzuo U, & Onukwuli, Okechukwu D. (2010). Biogas production from blends of bambara nut (*Vigna subterranea*) chaff with some animal and plant wastes. *Advances in Applied Science Research*, 1 (3): 98-105.

[14] Ofoefule, Akuzuo U., Nwankwo, Joseph I., Ibeto, Cynthia N. (2010). Biogas Production from Paper Waste and its blend with Cow dung. *Advances in Applied Science Research*, 2010, 1 (2): 1-8. ISSN: 0976-8610

[15] Padma Vasude Van, Satyawati Sharma and Ashwani Kumar (2005). Liquid fuel from Biomass: An overview .*Journal of Scientific & Industrial Research*. Vol. 65: 822 – 831

[16] Ukpai, P. A. and Nnabuchi, M. N. (2012). Comparative study of biogas production from cow dung, cow pea and cassava peeling using 45 litres biogas digester. *Advances in Applied Science Research*, 3 (3):1864-1869. ISSN: 0976-8610. www.pelagiaresearchlibrary.com.

[17] Uzodinma, E. O ; A. U. Ofoefule, J. I. Eze, I. Mbaeyi and N. D. Onwuka (2008). Effect of some organic wastes on the biogas yield from carbonated soft drink sludge. *Scientific Research and Essays*, Vol. 3 (9): 401–405. ISSN 1992- 2248.