academicJournals

Vol. 8(23), pp. 1291-1297, 23 June, 2013
DOI: 10.5897/IJPS2013.3909
ISSN 1992 - 1950 © 2013 Academic Journals
http://www.academicjournals.org/IJPS

International Journal of Physical Sciences

Full Length Research Paper

A comparative study of biogas production using plantain/almond leaves and pig dung, and its applications

EZEKOYE, V. A.

Department of Physics and Astronomy, University of Nigeria, Nsukka, Nigeria.

Accepted 10 June, 2013

Plantain/almond leaves and pig dung were used as substrates in anaerobic biodigester for producing biogas by batch operation method within the mesophilic temperature range of 20.0 to 31.0°C. The study was carried out to compare biogas production potential from plantain/almond leaves and pig dung wastes. The cumulative biogas produced from the plantain/almond leaves was 220.5 L while the cumulative biogas from the pig dung was 882.5 L. Orsat apparatus was used to analysize the gas produced. The methane component of gas from pig dung was 70.2% while that for plantain/almond leaves with algae was 72.7%. The biogas from the almond/plantain leaves became combustible on sixteenth day while the biogas from the pig dung was combustible on fourteenth day. Results showed that pig dung produced more biogas than the almond/plantain leaves within the same period.

Key words: Mesophilic, anaerobically, almond/plantain, combustible, algae.

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 (Boyd, 2000). In 2008, about 19% of global final energy consumption came from traditional biomass, which is mainly used for heating and 3.2% from hydroelectricity (Ross, 1996). In other words, animal and agricultural wastes constitute a high proportion of biomass and their utilization is important for economical and environmental aspects possessing suitable climatic and ecological conditions (Oktay, 2006).

Biogas as a renewable energy source could be a relative means of solving the problems of rising energy prices, waste treatment/management and creating sustainable development. Anaerobic digestion has been recognized as an effective way to partially solve the growing concern of solid waste management by reducing the weight of organic waste, as well as controlling the soil pathogens (Ieshita and Sen, 2013). The production of biogas involves a complex biochemical reaction that takes place under anaerobic conditions in the presence of highly sensitive microbiological catalyst that are mainly bacteria. Biogas technology has in the recent times also been viewed as a very good source of sustainable waste treatment/management, as disposal of wastes has

E-mail: vaezekoye@yahoo.com.

become a major problem especially to the third world countries. The effluent of this process is a residue rich in essential inorganic elements needed for healthy plant growth known as bio-fertilizer which when applied to the soil enriches it with no detrimental effects on the environment (Energy Commission of Nigeria, 1998). The raw materials used in many places for the gas production include agricultural wastes and animal manures which are called Biomass. The greatest potential to increase the use of biomass in energy production seems to lie in forest residues and other biomass resources e.g. agro biomass and fruit biomass (Kramer, 2002; Eija et al., 2007). The plantain/almond leaves, algae from sewage and pig dung used in this research work are readily available in our environment. These biomasses are highly degradable in nature. However the rate of efficiency of digestion of feedstock depends on its physical and chemical form.

Plant materials especially crop residues are more difficult to digest than animal manures. This is because hydrolysis of cellulose materials of crop residues is a slow process and can be a major determining step in anaerobic digestion process. Raw plant materials are bound up in plant cells usually strengthened with cellulose and lignin, which are difficult to digest. In order to let the bacteria reach the more digestible foods, the plant material must be broken down (Kozo et al., 1996; Fulford,1998). Addition of bacterial seed or inoculum accelerates biogas generation and also reduced the lag time (number of days required for biogas production to start). The inoculum is known to enrich the bacterial of the digester which will enhance their action on the substrate and hence on the quantity as well as quality of the biogas generated. Biogas microbes play different roles in the conversion of the organic substances, according to their nutrient requirements (Maishanu and Maishanu, 1998). Maximum methane yield requires adequate and efficient nutrient supply for micro-organisms in the digester (Thomas et al., 2006).

Plantain leaves (*Musa paradisiaca*) are readily available in the tropics, while the almond tree (*Terminalia catappa*) popularly known as fruit or umbrella tree are found around the school premises (University of Nigeria, Nsukka), their wastes constitutes a nuisance in the school environment. However, these wastes can be converted to a renewable energy source. This experiment was carried out to find out the effect of parameters such as pH level, temperature, retention time and the biodegradability of these biomass. When the temperature is high, the activity of bacteria is simply more vigorous, so that the fermentation period becomes shorter. When the temperature is low digestion is slow, and the fermentation period is longer (Goodger, 1980).

The anaerobic digestion processes is carried out by a delicately balanced population of various bacteria. These bacteria can be very sensitive to change in their environment. Temperature is a prime example. It has been determined that 35°C is an ideal temperature for anaerobic digestion (Kucha and Itodo, 1998).

AIMS AND OBJECTIVES

This paper determined the effect of environmental and operational parameters on the fermentation/production rate of biogas from organic waste. It also studied the extent to which plantain leaves/almond leaves; algae from sewage pond and pig dung generate gas, and transformed the organic wastes into high quality fertilizer.

The chemistry of biogas production

Generally, the production of this biogas involves a complex biochemical reaction that takes place under anaerobic conditions in the presence of highly sensitive microbiological catalysts that are mainly bacteria. The major products of this reaction are methane (CH_4) and carbon-dioxide (CO_2) (Hashimoto et al., 1980). The anaerobic biological conversion of organic matter occurs in 3 stages Figure 1).

Factors affecting biogas production

Many factors that are affecting the fermentation process of organic substances under anaerobic condition include:

i. Temperature
ii. Nature of raw material
iii. pH of slurry and alkalinity
iv. Stirring
v. Carbon/nitrogen ratio (C/N)
vi. Nutrients addition
vii. Retention time
viii. Total solid
ix. Volatile solid x. Mixing
xi. Inhibition.

The length of fermentation period is dependent on temperature. Keeping the digestion chamber at nearly constant temperature is important.

Smaller particles would provide large surface area for adsorbing the substrate that would result in increased microbial activity and hence increased gas production. pH is an important parameter affecting the growth of microbes during anaerobic fermentation. Stirring of digester content needs to be done to ensure intimate contact between microorganisms and substrate which ultimately improves digestion process. It is generally found that during anaerobic digestion microorganisms utilize carbon 25 to 30 times faster than nitrogen. Thus to meet this requirement, microbes need a 20 – 30: 1 ratio of C to N with the largest percentage of the carbon being readily degradable (Bardiya, and Gaur, 1997; Malik and Tauro, 1995). Addition of inoculum tends to improve both

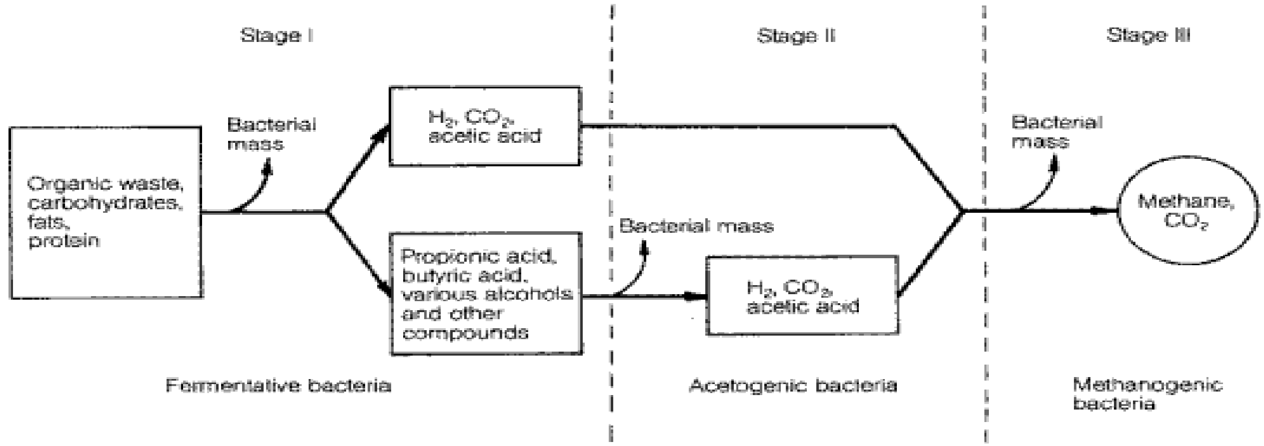

Figure 1. The three-stage anaerobic fermentation of biomass (Hoerz et al., 2008).

Figure 2. Digester used in the experiment.

the gas yield and methane content in biogas. It is possible to increase gas yield and reduce retention period by addition of inoculums (Dangaggo et al., 1996; Kanwar and Guleri, 1995; Kotsyurbenko et al., 1993).Retention time is the average time spent by the input slurry inside the digester before it comes out. Total solid concentration (TS%) is a measure of the dilution ratio of the input material. Some organic materials which contain lignins do not decompose easily. The lignin content even if quite low will decrease the rate of digestion of carbohydrates (cellulose and hemicellulose).

MATERIAL AND METHODS

Apparatus

The biodigester that was used for this study is 0.00147 m^3 in capacity and made of galvanized metal sheet material (Figure 2).

Batch operation method was used. Pre-decayed plantain/almond leaves and pig dung were used for this study. The plantain/almond leaves were obtained from University of Nigeria, Nsukka premises. Pig dung was collected from veterinary farm, University of Nigeria, Nsukka.

Characteristics of the wastes used in this study

The slurry of plantain/almond leaves and algae from sewage pond (P/A and A) was obtained by diluting the solid wastes with water in the mass ratio of 1 : 4 (waste : water). This implies that a total of 23 kg of plantain/almond leaves and algae(P/A and A) from sewage pond was mixed with 92 kg of water giving a total mass of 115 kg of slurry. These were measured using a weighing balance of 0 to 50 kg ranges. Both waste and water were thoroughly mixed in a small drum ensuring that no solid (hard) material, which was not decomposable, was present before introducing the mixture into the digester. Due to the high lignin which is non-degradable material, the waste (leaves) was seeded with algae water from sewage (inoculums) which boosted the rate of gas production. The waste

Table 1. Ratio and the temperature of the samples.

Waste	Mixing ratio	Quantity of waste and water (kg)	Ambient temperature range (°C)	Slurry temp range (°C)	Total volume biogas produced (L)
P/A and A	1 : 4	115	27.0 - 57.0	33.0 - 38.5	220.5
Pig dung	1 : 2	120	26.0 - 31.0	31.5 - 38.0	882.5

occupied about 74% by volume of the digester, this is the loading rate. The remaining part was left for gas collection. After introducing the waste, all openings were closed. After 1 day from charging, biogas generation commenced. The gas became combustible from the sixteenth day to the end of digestion. The total volume of gas produced was 96.0 L. The biogas became combustible as from the fourth day to the end of digestion as show in Table 1.

The initially dry pig dung was pulverized and every hard stones were removed. It was dissolved in water in the ratio of 1 : 2. A total of 40 kg of waste was mixed with 80 kg of water in batches in a small drum after which it was introduced into the digester (Figure 2) while keeping gas outlet open to exhaust trapped air. The fermentation and biogas production started after 1 day. The gas became combustible from the fourteenth day to the end of digestion. Batch operation was adopted.

RESULTS

Proximate analysis

The sample were analyzed for Ash, PH, total solid, volatile solid, moisture, phosphorus, fiber contents using the method of Association of Official and Analytical Chemistry (Sharma, 2002). Protein, fat contents were determined using Micro-Kjeldahl method. Carbon content was determined by the method of Walkey and Polpraset (Polpraset and Bitton, 1989 ; Aubart and Farinet, 1983).

The growth and catabolism of microbes need various kinds of nutrients especially elements of carbon, nitrogen and phosphorus. For high quality of methane, carbon is required for building of the cell structure of the methanogenic bacteria. Specific group of bacteria always consume carbon and nitrogen elements in a fixed proportion. From Tables 3 and 4, it was discovered that the value of protein/nitrogen, volatile solid, total solid and carbon in both samples decreased in percentage after digestion. Some of them were used up by the bacteria. The percentage of phosphorous was increased at end of digestion. The biofertilizer was rich with phosphorous and nitrogen which produces better yield when apply on farm land.

Storage of biogas

A gas compressor is a mechanical device that increases the pressure of a gas by reducing its volume. The capacity of the compressor used was 1/5 horse-power. Each cylinder was able to compress biogas of 1.2 bars of pressure. The biogas from pig dung and A/P and A became combustible on the fourteenth and sixteenth days respectively and it burned with blue flame Each sample of biogas produced was analyzed using Orsat apparatus. The measuring principle of Orsat apparatus is the measurement of the reduction which occurs when individual constituents of a gas are removed separately by absorption in liquid reagents (Ezekoye and Okeke, 2006).

The daily ambient temperature and slurry temperature for almond/plantain leaves with algae and pig dung were shown in Figures 3 and 4. Almond/plantain leaves with algae recorded the highest temperature range of 27.0 – 37.0°C and the 2 wastes produced biogas within the mesophilic range of temperature (Itodo and Philips, 2002; Goodger, 1980). Orsat apparatus was used to analysis the gas produced. The methane component of gas from pig dung was 70.2% and for almond/plantain leaves with algae was 72.7%.

The daily volumes of biogas yield of the almond/plantain leaves with algae and pig dung were shown in Figure 5. Careful examination of the curves shows that the pig dung generated the highest gas from the first day to the thirty-seventh day. It was followed by almond/plantain leaves with algae which produced the highest between twelfth and thirteenth days.

On the other hand, the pig dung slurry produced combustible gas on the fourteenth day and almond/plantain leaves with algae (A/P and A) the sixteenth day (Table 2). The cumulative biogas yields of the sample are compared in Figure 6. The pig dung gave the highest yield 882.5 L. The almond/plantain leaves with algae produced 220.5 L.

DISCUSSION

For optimum functioning, the anaerobic micro-organisms require a neutral environment. The optimal pH was found to be 6.00 to 7.5 for pig dung, 6.00 to 7.3 for almond/plantain leaves with algae (Tables 3 and 4). Both acid and methane forming bacteria could not survive the pH values of 4 and 10.

Different wastes were used in feeding the digester to find out which one produced more gas. It was found that organic waste which is easily digestible produced more gas. Material with high lignocellulose produces less amount of gas. Carbon, which constitutes the basic frame of all organic substrates, provides microbes with the energy required for their living activities, and is the source

Table 2. Days of flammability and total biogas produced.

Waste	Flammable time (day)	Retention time (days)	Total biogas produced (L)
P/A&A	16	43	220.5
Pig dung	14	43	882.5

Table 3. Proximate analysis for almond/plantain leaves and algae.

Components	Before digestion	After digestion
Protein	1.62%	1.31%
Fats	2.05%	0.86%
pH	6.50	7.30
Moisture	89.32%	65.97%
Ash	0.50%	2.0%
Fiber	5.75%	Trace
Carbohydrate	24.12%	6.50%
Total solid (TS)	14.83%1	13.00%
Volatile solid (VS)	11.50%	6.67%
Carbon	0.29%	0.19%
Phosphorus	1.38ppm	7.71ppm

PPM; Part per million.

Table 4. Proximate analysis for pig dung.

Components	Before digestion	After digestion
Protein	6.63%	1.06%
Fats	0.78%	1.33%
pH	6.00	7.50
Moisture	85.67%	79.92%
Ash	1.90%	0.44%
Fiber	Trace	Trace
Carbohydrate	10.59%	11.66%
Total solid (TS)	16.00%	12.70%
Volatile solid (VS)	7.70%	5.00%
Carbon	1.09%	0.21%
Phosphorus	3.93ppm	5.76ppm

PPM; Part per million.

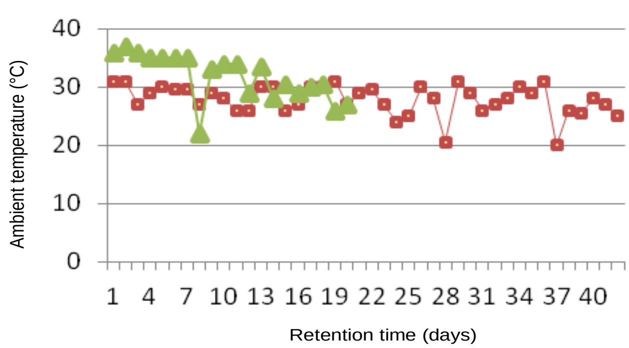

Figure 3. Change in ambient temperature during fermentation.

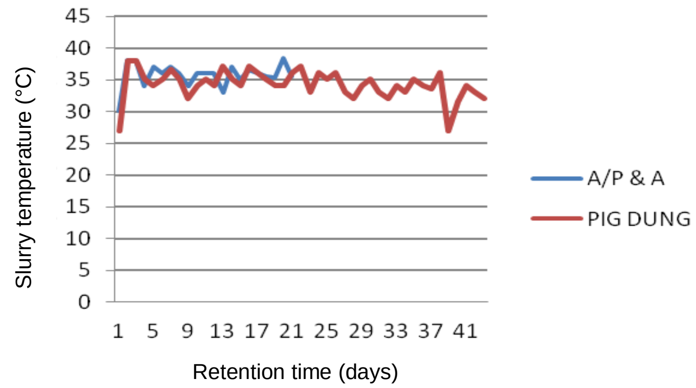

Figure 4. Change in slurry temperature during fermentation.

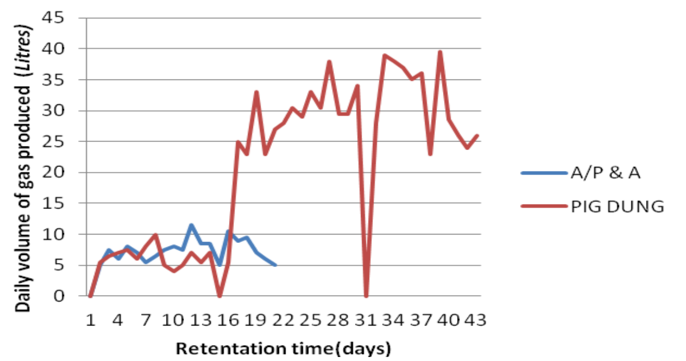

Figure 5. Volume of gas produced by A/P and A and pig dung leaves during fermentation.

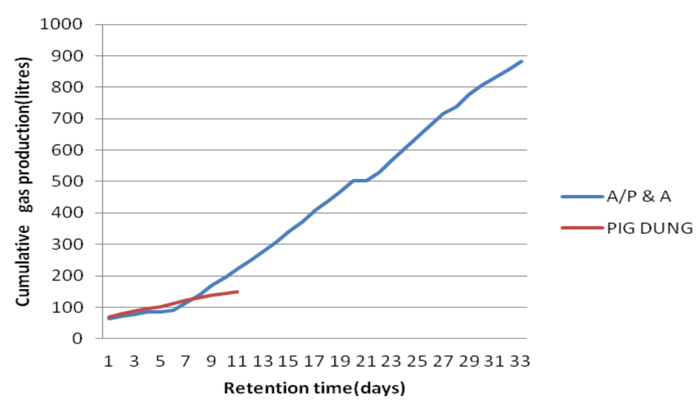

Figure 6. Daily cumulative gas produced by almond/plantain leaves.

Table 5. Percentage of the component of biogas from 2 different wastes using Orsat apparatus.

Waste	Carbon dioxide (CO_2) (%)	Hydrogen sulphide H_2S (%)	Carbon monoxide (CO) (%)	Methane and other components (%)
Pig dung	24.9	1.2	0.5	70.2
A/P&A	17.5	0.8	9.0	72.7

for the formation of biogas. In biogas production, nitrogen provides methanogenic bacteria with ammonia, which is the source of nitrogen for the composition of living matter of new cells. The carbon/nitrogen ratio for pig dung was 8 : 1, for almond/plantain leaves with algae, it was 6 : 1

The slurry should not be too thick nor too dilute. In this experiment the dilution ratios used for pig dung and Almond/Plantain leaves with Algae were 1 : 2 and 1 : 4 respectively. Stirring is necessary for increased gas production. Gas production was found to be low at pH 4 and 9. When the slurry was stirred once in a day, there was an increase in gas production. There was also a drop in gas production, when stirring was completely omitted due to scum formation. The slurry was seeded with bacteria (algae from sewage pond). After the analysis of the slurry, it was discovered that there was an increase in the percentage content of nitrogen, potassium, protein and phosphorus (N P K) after digestion. This shows that the sludge is a better fertilizer to the soil (Tables 3 and 4) (Chemical Land 21, 2006). The importance of inoculum is that it fastened the establishment of anaerobic micro flora and thus eliminates the unnecessary lag phase observed during the start-up.

Table 2 shows that pig dung gives the shortest flammability time of fourteenth (14^{th}) day followed by A/P and A sixteenth (16^{th}) day. This shows that the day the biogas started burning should be in the order: pig dung < A/P and A.

Figure 7 shows the cumulative biogas generation during the fermentation. This connotes that the biogas yield should be in the order: pig dung > A/P and A. This means that pig dung produced the highest biogas. Table 5 shows the composition of biogas produced. Biogas generation has the following applications: production of energy (heat, light, electricity); transformation of organic wastes into high quality fertilizer; reduction of workload, mainly for women, in firewood collection and cooking; and environmental advantages through protection of forests, soil, water and air.

Conclusion

The result of this study showed that almond leaves, plantain leaves, pig dung, and algae from sewage which can cause pollution in the environment can be a useful source of energy by subjecting it to anaerobic digestion for biogas production. The microorganism associated with the fermentation of plantain leaves/almond leaves mainly originated from the inoculum used. The addition of inoculums (algae from sewage pond) to the leaves (almond/plantain) was found to enhance gas production. The pig dung anaerobically digested showed the highest yield for methane production. It is also expected that this will be a source of waste management and pollution control.

ACKNOWLEDGMENT

My sincere appreciation goes to Mr. Emeka of National Center for Energy Research and Development, University of Nigeria, Nsukka who truly helped me during the practical work.

REFERENCES

Aubart C, Farinet JL (1983). Anaerobic digestion of pig and cattle manure in large-scale digesters and power production from biogas. Symp. Pap. Energy Biomass Wastes, pp. 741–766.

Bardiya N, Gaur AC (1997). Effects of carbon and nitrogen ratio on rice straw biomethanation. J. Rural Energy 4:1–16.

Boyd R (2000) .Internallising Environmental Benefits of Anaerobic Digestion of Pig Slurry In Norfolk.University of East Anglia ENV 4:6-10

Chemical Land 21 (2006). NPK, fertilizer E:/NPK (fertilizer) mht.

Dangaggo SM, Aliya M, Atiku AT (1996).The effect of seeding with Bacteria on biogas production rate. Renewable Energy— An Int. J. 9:1045–1048.

Eija A, Antti H, Terhi L , Pirkko V (2007). Biomass Fuel Trade in Europe. Summary report V T T-R-03508-07.

Energy Commission of Nigeria (1998). Rural renewable energy needs and five Supply technologies, pp. 40–42.

Ezekoye VA, Okeke CE (2006). Design, Construction, and Performance Evaluation of Plastic Biodigester and the Storage of Biogas.The Pacific J. Sci.Tech. 7:176-184.

Fulford D (1998). Running Biogas Programing. A handbook. 'How Biogas Works'. Intermediate Technology Publication. 103-05. Southampton Row, London. WCB, UK, pp. 30-34.

Goodger EM (1980). Agricultural Biogas Casebook. Great lakes Regional Biomass Energy Programme Council of Great Lakes Governors.

Hashimoto AG, Chen YR, Vare VI (1980). Theoretical aspects of biogas production.state of art. In proceedings livestock waste: A Renewable Resource 4th International Symposium on livestock wastes. ASAE,pp. 86-91.

Hoerz T,Kramer P, Klingler B, Kellner C, Thomas W, Klopotek FV,Krieg A, Euler H (2008) Biogas Digest Volume i, ii ,iii Biogas Basics. Isat Information and Advisory Service on Appropriate Technology gtz

Itodo IN, Philips TK (2002). Covering Materials for Anaerobic Digesters Producing Biogas.Nig. J. Rene Ene. 10:48-52.

Kanwar SS, Guleri RL (1995). Biogas production from mixture of poultry litter and cattle dung with an acclimatized inoculum. Biogas Forum I. 60:21–23.

Kotsyurbenko OR, Nozhevnikova AN, Kalyuzhnyy S, Zavarzin G (1993). Methanogenic digestion of cattle manure at low temperature.Mikrobiologiya. 62:761–771.

Kozo I ,Hisajima S, Darryl RJ (1996). Utilization of agricultural wastes for biogas Production in Indonesia,: In traditional technology for environmental conservation and sustainable development in Asia Pacific Region. 9th Ed, pp. 137-138.

Kramer JM (2002). Agricultural Diogas Casebook, Resource Strategies,INC,Great Lakes Regional Biomass Energy Program Council Of Great Lakes Governors. pp. 41-42.

Kucha EI , Itodo IN (1998). An empirical relationship for predicting biogas yield from Poultry waste slurry. Niger. J. Rene. Ene. 2:31–37.

Ieshita P, Sen SK (2013). Microbial and physico-chemical analysis of composting process of wheat straw. Indian J. Biotech. 12:120-128.

Maishanu SM , Maishanu HM (1998). Influence of inoculum age on Biogas generation from cowdung. Niger. J. Rene. Energy 6:21-26.

Malik RK, Tauro P (1995). Effect of predigestion and effluent slurry recycling On biogas production. Indian J. Microbiol. 35:205–209.

Oktay Z (2006). Olive Cake As A Biomass Fuel For Energy Production,Energy Sources, Part A: Recovery Utilization And Environmental Effects. 28:329-339.

Polpraset C, Bitton G (1989). Organic Waste Recycling In Waste Water Microbiology ,John Wiley and Sons, New York; U.S.A.

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

Sharma DK (2002). Studies on availability and utilization of onion storage waste in a rural habitat. PhD dissertation, Centre for Rural Development and Technology, Indian Institute of Technology, Delhi, India.

Thomas A, Barbara A, Vitaliy K, Werner .Z, Karl M, Leon hard G (2007). Biogas Production from maize and dairy cattle manure- Influence Of Biomass Composition On The Methane Yield. Science Direct. Agriculture Ecosystem And Environment 118:173-182.