The Effect of Temperature on the Rate of Digestion and Biogas Production using Cow Dung, Cow Pea, Cassava Peeling.

Ukpai, P. A., Agbo, P. E and Nnabuchi, M. N.
Department of Industrial Physics, Ebonyi State University Abakaliki.
E-mail: ukpaipatricia@gmail.com

ABSTRACT: Biogas production from 3-batch biogas plant containing different ratio of mixture of Cow dung, Cassava and cowpea peeling was studied for a period of one month. The ambient and slurry temperature were taken into consideration. Different regression models were used to describe the biogas cumulative production from the plants and the effect of temperature on the volume of gas produced. The study showed that for increase in gas production, a temperature of between 32-40OC is favourable and optimum. Our result revealed that gas production is dependent on temperature of operation of the digester and the nature of waste used.

Keywords: Temperature, Slurry, Cassava peeling, Cow dung,Cowpea peeling, Biogas Plant

INTRODUCTION

The current energy demand and consumer's buying capacity calls for alternative energy sources. Biogas technology is one of the reliable alternative energy source. The development of biogas has helped in reducing the rate of deforestation; improve health and sanitation in rural areas, while the residue which is used as fertilizer has increase agricultural production [1]. Gas produced by the digester in an anaerobic decomposition is called biogas; Biogas is methane–rich gas that is produced from the anaerobic digestion of cellulosic matter. It is denser than air and has a density of 1.2kg/L at atmospheric pressure. This gas is produced from a three-phase process namely; hydrolysis, acid forming and methane forming phase. This gas is composed of methane(50-70)%, carbon dioxide(30-40)% and traces of other gases such as carbon (11) oxide(Co), Nitrogen gas(N_2), Water vapour($H_2O_{(g)}$), Ammonia(NH_3) and hydrogen sulphide(H_2S), [8]. Temperature is one of the most factors that affect the production of gas, it has been observed that the ideal temperature for anaerobic digestion is 35^oC. As the temperature increases, some bacteria begin to die and biogas production decreases. It is also a waste management technique because the anaerobic treatment process eliminates the harmful micro – organisms [15]. It is a cheap source of energy because the feedstock is usually waste materials and ensures energy independence; as a unit can meet the needs of a family or community. Gas yield from the digester may not be steady which therefore makes it unreliable thereby necessitating storage. Another advantage of methane is that unlike other fuels, it does not give off poisonous carbon monoxide when burnt, so it is safer to use in the home than other gases for cooking and heating [7]. Due to the changes in temperature there is low pressure gas production system and as such cannot be bottled for use outside the site of production thereby restricting the technology only to the site of production [4]. Temperature is an important parameter in biogas production, due to its effect on the enzymatic activities of the micro–organism responsible for the bioconversion of substrates into gas. The operating temperature ranges of particular bacterial types are at the psychophilic (below 20^{0}C), mesophilic (20^{0}C – 40^{0}C) and thermophilic (40^{0}C - 65^{0}C) temperature. At a physchophilic temperature range, the Bioconversion is slow and incomplete, and requires longer retention time. For the case of mesophilic, the temperature corresponds to the ambient temperature of the tropics and as such no heating is required thus reducing cost of production and requires longer retention time to complete the conversion of the available carbon, while in the thermophilic, digestion is easily upset at this temperature, there is high rate of gas production [12]. Also in this temperature range, it allows heavier organic loading, lower retention time, this temperature range also enables the use of comparatively smaller size digester. When the temperature is high, the mechanical transport and handling of the digester is easier because the slurry is less viscous and the digestion is much more sanitary than digestion at the other temperature because of the few pathogens that can survive at this temperature.

The quantity of waste that is fed into a digester depends on the capacity of the digester, the temperature at which digestion is taking place and the retention time. The efficiency of bioconversion of the waste into biogas, lower digester temperature and causes high fluctuation in gas pressure. Thirty days is chosen as a minimum time frame for optimum bacterial decomposition to take place to produce biogas and destroy many of the toxic pathogens found in wastes. A site that is open and exposed to the sun is necessary in selecting the location for biogas plant [3]. The active or main flammable component of biogas is methane, when used as fuel; it burns to minimal carbon dioxide and water. The digester varied in form of “batch” or “continuous”; the batch digester operates on a single charge until it is exhausted at the end of the digestion cycle, it is emptied, cleaned, recharged and restarted for a new cycle then left until done while in continuous feed digesters have increments of charge added and so subtracted on a daily basis to provide an ongoing replenishment of charge materials and waste and the quantity withdrawn should be equal to the quantity added to the digester to avoid the slurry from being under charge or over charge. At a low temperature, excessive feed rates at start–up can cause an inhibiting scum to form on the surface of the digester contents, stifling gas production [2].

Temperature is a very important physical condition in biogas production; two kinds of bacteria that will bring about this production operate at two different temperature; mesophilic and thermophilic ranges [17]. Any chosen environment for the digestion must maintain one of these temperature ranges. The optimum temperature is usually about 40^oC, for the mesophilic range, and when the temperature of the ambient goes down to 10^oC, gas production virtually stops. Useful gas production takes place at the mesophilic range between 25^0C and 40^oC [9] and [16] and 45^oC to 55^oC for thermophilic range. The optimum temperature for the thermophilic fermentation is 55^oC. Higher temperature shortens the retention time but can lead to increase rate of biogas production.

Several report have shown that some factors such as environmental and slurry temperature of the fermenting medium, pH, nature of waste, have been identified to affect the rate of waste digestion and biogas production [5], [6], [8] and [15].

EXPERIMENTAL

The studies of anaerobic digestion of cow dung, cow pea, cassava peeling lasted for 30 days. A model type biogas plant was used for the studies. The study was carried out between August and September 2013 at Ebonyi state University Abakaliki. Cow dung, Cowpea and Cassava peeling were the three wastes used for this study. Fresh cow dung was collected from Abakaliki Abatour, cowpea waste were procured from local akara processor in Abakaliki town and the cassava peeling was collected from one of the local garri processors at Abakaliki Ebonyi state South East Nigeria. Other materials such as Top loading balance (50kg “Five goat” model Z051599), 13 Litres calibrated plastic transparent bucket, Digital PH meter, thermometer and burner to assist in checking gas flammability were used. 35kg of cow dung waste was charged into the digester with 70kg of water in the ratio of 1:2 of waste to water and the slurry was properly stirred. Also 15kg of cowpea waste and 30kg of water was mixed into the digester for cowpea in the ratio of 1:2 of waste and water. For cassava peeling waste, a 15kg of waste was charged into the digester with 30kg of water in the ratio of 1:5, of waste to water respectively. The mixing ratio was determined by the moisture content of the different wastes. The daily ambient and slurry temperatures were measured using thermometer (-10 to 110^{0}C), The PH Values were monitored on 3 days interval to determine the action of methanogens, which utilize the acids, carbon dioxide and hydrogen produced by non-methane producing bacterial using a digital PH meter (PHS-3c PH meter). The biogas production was measured by a downward displacement method using a transparent 20 Litres calibrated plastic bucket [10]. The composition of the flammable biogas produced from each of the waste was determined through the use of Orsat apparatus. In checking the flammability of the gas, a locally fabricated biogas burner was used. "Five goat models Z051599 of Top loading balance was used in the measurement of the water and waste volumes. The plant consists of the fermentation chamber, the inlet and outlet pipe, the gas pipe and the stirrer.

The digester was charged and its performance monitored for 30 days. The organic wastes were allowed to stabilise and anaerobic fermentation involving the degrading of the wastes by the action of various microbes of different size and functions leading to the production of biogas in the absence of oxygen [14]. The volume of biogas was measured on daily basis and the result in tables.

RESULTS AND DISCUSSION

Figures 1-3 shows the plot of Ambient Temperature ^{o}C Vs time of the Digester, Daily Slurry Temperature (^{o}C) of Cow Dung, Cow pea, And Cassava Peeling Vs Time (Days) and Biogas Volume Vs Time (Days) respectively. In fig.1, the ambient temperature varies from 20^{0}C to 32^{0}C. From Fig.2, cow dung had a slurry temperature range of 21^{0}C to 38^{0}C. Cow pea had minimum and maximum slurry temperature of 21^{o}C and 38^{o}C respectively while cassava peelings had a minimum slurry temperature of 21^{0}C and a maximum slurry temperature of 35^{0}C. Ambient and slurry temperature fluctuated due to weather conditions. There is a correlation between temperature and volume of gas produced due to rainfall on each part of the day. The mesophilic (21^{0}C-38^{o}C) is the temperature range that was identified from the slurry temperature (Ts). In the mesophilic temperature, the reaction of the slurry is slower with longer retention time as displayed in fig.2. From the result obtained, anaerobic bacteria thrive best at a mesophilic temperature of about 37^{0}C .

Our observation as shown in fig.3 shows that cow dung started daily production on the second day, reaching peak on the 12th day and yielding 13.2 litres of biogas. A cumulative of 167.7 litres of biogas was produced at the end of the 30 days retention period from the cow dung waste. Cow pea gas production started at the 9th day after the charging of the digester, the gas production ranges from 8.8 - 9.3 litres and a cumulative of 108.5 litres was produced. Cassava peelings were the lowest in terms of gas production, started daily gas production on the 7th day. The maximum volume of biogas generated from cassava peelings was 6.8 litres and a total volume of 95.7 litres of biogas was produced at the end of the 30 days. The foregoing shows that the biogas production varied from the three wastes and also in the days. The digester containing cow dung was favoured in terms of volume of flammable gas production. The summary of the result for the three wastes for the 30 days retention period shows that, cow dung generated the highest total gas volume of 167.7 litres, followed by Cow pea with 108.5 litres of gas and lastly cassava peelings produced 95.7 litres of gas.

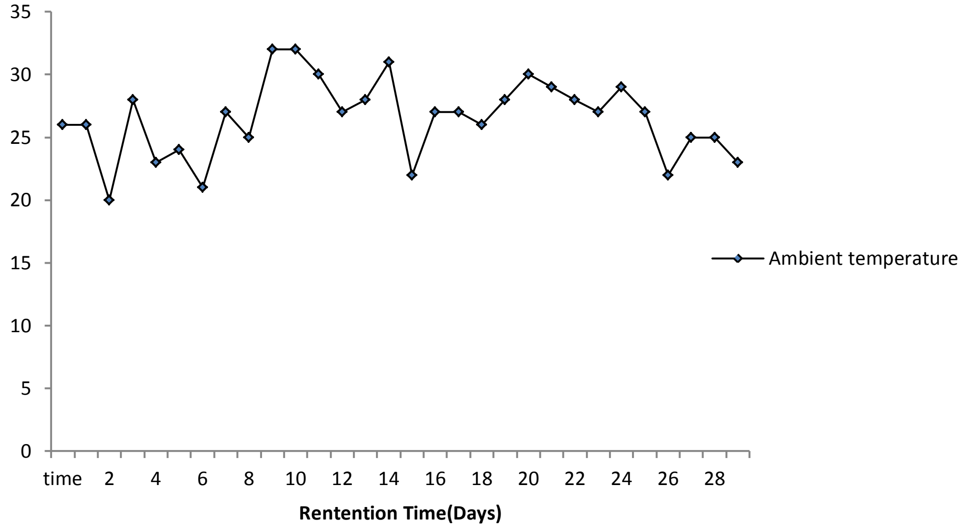

Fig. 1: Ambient Temperature °C Vs time of the Digester

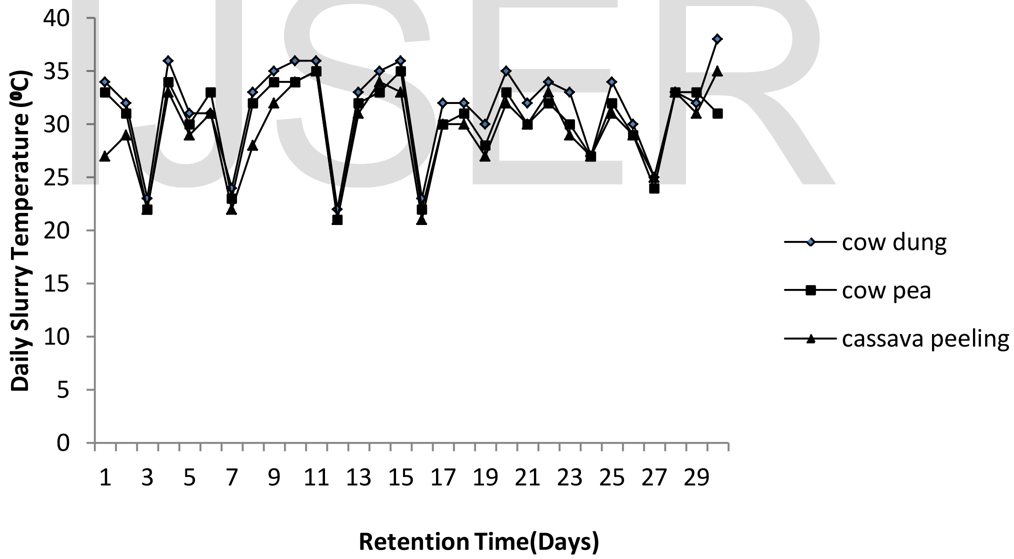

Fig.2: Daily Slurry Temperature (°C) of Cow Dung, Cow pea, And Cassava Peeling Vs Time (Days).

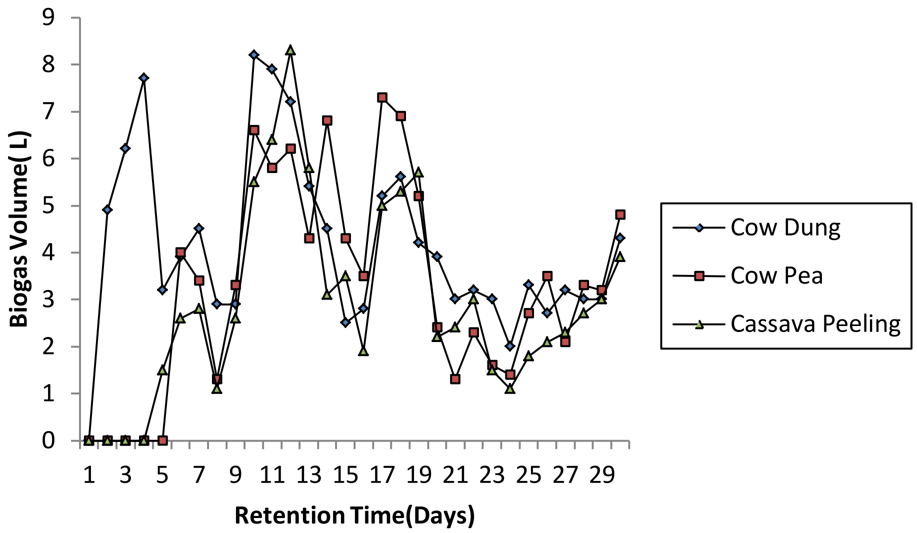

Fig.3: Biogas Volume Vs Time (Days)

CONCLUSION

From the result it has been shown that flammable gas can be produced from Cow dung, Cow pea and Cassava Peeling through anaerobic digestion. The wastes that are always littered in our environment can be used as sources of energy if properly manage. The study revealed that temperature variation affects the volume of gas yield. The digester contents will have to be warmed up to the operating temperature range and preferably maintained near the optimum of 35^0C for mesophilic system. In cold climates this presupposes some form of insulation and in most climates a means of heating the feedstock and digester contents. In hotter temperature area there is need to shade the digester, the mesophilic bacterial will be killed after less than fifteen minutes at a temperature of 50^0C or greater. If the heating fails a digester will typically cool down at about 0.5^0C to 1.0^0C per day depending on the prevailing shade or ambient temperature of the location [11].

ACKNOWLEDGEMENT

We wish to acknowledge the effort of Dr. Eze J. I. of the National centre for Energy Research and Development, University of Nigeria, Nsukka for his effort in sourcing some information used in this work and the workers at Abakaliki Abotour whohelped us in collecting the specimen used in this research.

REFERENCES

[1] Aderson B, Solar Energy: Fundamentals in Building design, Total Environmental Action, INC, Hanisville, New Hampshire, McGrram- Hill Book company, New York.1977
[2] Akpabio O, Sambo S, Effion O, Nigerian Journal of Solar Energy, 1992 28-31.
[3] Akpabio O, Etuk E, Turkish Journal of Physics, 2002 27, 161-167.
[4] Chen RC, Varel VH, Hashimoto AG, The effect of temperature on methane fermentation kinetics of beef manure. Biotech. and Bioeng. 1978 Pp 10, New York.
[5] Eze J, Onwuka D, Okeke E, Journal of Solar Energy 2003 14 115-120
[6] Ezeonu C, Okonkwo J, Nigerian Journal of Renewable Energy, 2005 (1 and 2) 53-57.
[7] Fry, L. John Methane Digesters for fuel Gas and Fertilizer, Privately Published 1973 Pp.28-33.
[8] Garba B, Zuru A, Sambo A, Nigerian journal of Renewable Energy. 1996 38-43.
[9] Hashimoto G, Varried H, Factors affecting methane yield and production rate. American Society of Agriculture Engineers (ASAE). 1979
[10] Itodo O, Onuh E, Ogar B, Nigerian Journal of Energy 1995 36-39.
[11] Marlin, Cynthia *et al Adv. Appl. Sci. Res., 2012, 3(2):1092-1097*
[12] Okogbue E, Adedokun A, The solar radiation climate at a tropical site, Ile-ife, in south western Nigeria conference paper 28th Annual conference of NIP, iie-ife, 2005 Pp. 17-20.
[13] Okogbu E, Ojo B, Nigerian Journal of solar Energy, 2003 121- 125
[14] Richie DJ, (1983).Source book for farm energy alternatives. New York; Mc Graw –Hill Book Company.1983 PP.54.
[15] Sambo A, Journal of solar energy, 1985, 4 59-64.
[16] Smith R, Hein E, and Greiner, Journal of Animal Science 1979 202-212.
[17] Uzodinma E, Ofoefule A, Eze J , Onwuka D, *Adv. Appl. Sci. Res.* (2007) 5-558.