Nig J. Biotech. Vol. 22 (2011) 53-59
ISSN: 0189 17131
Available online at www.biotechsocietynigeria.org.

NIGERIAN JOURNAL OF BIOTECHNOLOGY

Effect of Retention Time on Biogas Production from Poultry Droppings and Cassava Peels.

Ezekoye, V.A[1]., Ezekoye, B.A[2]. and Offor P.O[3].
[1]School of General Studies, Natural Science Unit University of Nigeria, Nsukka, [2]Department of Physics and Astronomy, University of Nigeria Nsukka, [3]Department of Metallurgical and Materials Engineering, University of Nigeria, Nsukka.

(Received 10.7.10, Accepted 12.7.11)

Abstract
A study was carried out on different retention times in the anaerobic fermentation of slurry from poultry droppings and cassava peels. The system adopted in this work was batch-type. Daily gas production fell slightly from 130 to 32 litres as retention time was increased from 10 to 40 days for poultry droppings. For cassava peels the daily gas production fell slightly from 30 to 15 litres as retention time was increased from 5 to 75 days. The amount of gas produced per unit of volatile substrate charged into a polyethylene digester showed a linear increase with retention time. The total biogas produced from poultry and cassava wastes was 1.508m^3 and 1.179m^3 for 42 days and 79 days respectively. The ambient and slurry temperature for poultry and cassava were (33.6^{o}C, 33.0^{o}C) and (29.4^{o}C, 35.6^{o}C) which are under mesophilic temperature.

Key word: Batch-type, Anaerobic, Substrate, Volatile, Polyethylene.

Correspondence: vaezekoye@yahoo.com

Introduction

The continuing energy crisis has reawakened interest in the anaerobic fermentation of animal and plant waste to produce methane. The utilization of these organic wastes for biogas production has been known for over 100 years by the Indians. (Boodoo, 1979, and Dioha, et al, 2006).

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) condition. Biogas is a mixture of gases that is composed chiefly of methane (CH_4): 40 – 70 vol. %. Carbon dioxide (CO_2): 30 – 60 vol. %, hydrogen (H_2): 0 – I vol. %– and hydrogen sulfide (H_2S^2): 0.3 vol.%. The characteristic properties of biogas are pressure, retention time and temperature-dependent. They are also affected by the moisture content. The factors of main interest are: change in volume as a function of temperature and pressure, change in water-vapour content as a function of temperature, pressure and retention time. (Biogas Digest, 1980)

Biodigesters play an important role in the recycling of organic wastes, producing methane-rich gas for cooking, with positive impacts on the environment and on human and animal health. The effluent is good source of fertilizer nutrient for crops growing on land and water (Buntha, et al, 2009). The retention time can only be accurately defined in batch-type facilities. The length of time that volatile solids remain in an anaerobic digesters is an important factor in the digestion process. The solids retention time (SRT) represents the average time microorganisms spend in the system. Minimum solids retention times for anaerobic digestion system are in the range of 2-6 days depending on the temperature. In completely mixed anaerobic digester where no recycling occurs, the SRT is equal to hydraulic retention time (HRT). Hydraulic retention time usually varies from 10 to 30 days depending on the temperature. (Jenargi, 2002).

The longer a substrate is kept under proper reactor conditions the more complete its degradation will become. But the reactor rate will decrease with increasing residence time. The disadvantage of a longer retention time is the increasing reactor size needed for a given amount of substrate to be treated. A shorter retention time will lead to a higher production rate per reactor volume unit, but a lower overall degradation. These two effects have to be balanced in the design of the full scale reactor (BTG, 2003). If the retention time is too short, the bacteria in the digester are "washed out" faster than they can reproduce, so that the fermentation practically comes to a stand still, while a long retention time requires a large digester. (Biogas Basic, 2009).

Many factors influence gas production and the fertilizer value of the effluent in polyethylene bodigesters. In principle, all organic materials can ferment or be digested. However, only homogenous and liquid substrate can be considered for simple biogas plants. The maximum of gas production from a given amount of raw material depends on the type of substrate. (Ezeonu, et al, 2005)

Volatile solids are the portion of the solid that are organic in composition. The biological organism utilise a portion of this material as a substrate and make volatile solids an important parameter in estimating potential gas production. (Eboatu, et al, 2006). This work was therefore undertaken to identify the effect of retention time on biogas production from plant and bird waste.

Materials and Methods

Design of Digester: The digester system consists of a tank measuring 1.00m high and 3.20m wide. Its capacity is approximately $0.971m^3$, and made of a density polyethylene material that can withstand high temperatures and pressures. The major unit of the polyethylene digester is the stirring unit. It comprises a shaft of 5.5cm diameter and 100 cm long.

Treatment and Designs: The treatments were different retention times of 42 days and 79 days and there were two type of wastes.

Procedure: A total of 9 bags of dry poultry waste was collected, weighed and crushed to aid its dissolution in water in batches. A total of 229 kg of waste was used, in the ratio of 1:1.5 (waste: water). The slurry of 585 kg was used. After one day from charging, biogas generation commenced. The biogas becomes combustible from the 14^{th} day to the end of the digestion. The temperature range was within the mesophilic range (29.4 -33.6^{o}C).

Cassava peels were collected from Nsukka Market Garri Mill and pre-decayed for 13 days in a polyethylene sack before charging, the slurry of the pre-decayed cassava was obtained by diluting the solid cassava peels with water in the ratio of 1 waste to 6 water that is, 1:6 (waste and water). This implies that 74 kg of waste was mixed with 46 kg of water. A total mass of 538 kg slurry was introduced into the digester and all openings were closed. After one day of charging gas generation commenced. The biogas became combustible from the 63^{th} day to the end of the digestion. The temperature range was within the mesophilic range (26.29^{o}C).

Measurement: Each experiment lasted for 1 complete cycle i.e. 42 days and 79 days according to the treatment. Gas production was measured at interval of about 24 hours by volume displacement; the temperature of the gas was measured with a digital thermocouple thermometer. The range of the instrument was -80^{o}C – 199.9^{o}C.

The pressure gauge measurements were taken using One Pressure Gauge. It was made by VDO pressure gauge. It ranges from 0 to 6 bars at 0.02 bar interval. For cassava peels, the highest pressure was 0.02 bars. On the day the gas became combustible, the pressure built was 0.016. For poultry droppings the maximum pressure was built on the 3^{rd} day and it was 0.140 bars. The volume of biogas produced on that day was 125 litres.

pH meter was used to measure the pH value every week. The pH values were recorded .The weighing balance used was "five goats" brand model 2051599 and were graduated in imperial system and metric scales of 0-50.0 kg

Table 1: Maximum Values of the Parameters

Waste	Max slurry Temp (^oC)	Max. Ambient Temp.(^oC)	pH	Pressure (bar)	Water (kg)	Waste (kg)
Poultry droppings	29.4	33.6	8.60	0.14	356	229
Cassava peels	35.6	33.0	6.57	0.02	464	74

Table 2: Biogas Production from Waste at Different Retention Time

Waste	retention time (days)	Charging ratio	Charging percent (%)	Total Vol. of gas	Flammability	Day of max. production
Poultry droppings	42	1:1.5	100	1.508	14	3rd
Cassava peels	79	1:6	100	1.179	63	2nd

Proximate analysis of the wastes: Proximate analysis of waste was carried out on the major components of waste which include moisture content, ash content, crude fibre, total solid, volatile solid, carbon content, nitrogen content potassium and phosphorus. About 0.05 kg weight of each waste was collected and analyzed in the laboratory for determination of concentration of different component of the slurry before and after digestion using Association of Official Analytical Chemists (AOAC) method. (AOAC, 1980).

The percentage total solid of the substrate was determined using the method of Meynel. (Meynel, 1982). The pH of the sample was determined by using digital pH meter. Total alkalinity, ammonia nitrogen and volatile acids were measured by Pearson method (Perason, 1976).

Gas production in different retention time: Gas production was measured daily using the system of water displacement. A gas compressor is a mechanical device that increases the pressure of gas by reducing its volume, which obeys Boyle's law. Biogas produced was compressed by two pistons into the reconstructed storage cylinder. It is powered by electricity. Biogas was stored to be used at home. The stored biogas was passed to the gas burner and it burnt with blue flame. Daily gas production fell slightly from 28 litres to 12 litres as retention time was increased from 5 days to 79 days using cassava peels. For poultry droppings the daily production fell from 125 litres to 21 litres as the retention time increases from 10 to 42 days.

Results and Discussions

The results of some of the biogas digester performance indices monitored during the period are presented in Table 3. From Table 3, it is being observed that both the total solids and volatile solids decreased steadily as the fermentation period progressed. However, toward the end of the experiment the total solids remained static. This result falls within the range, which Meynell (1982) reported to favour biogas production.

Table 3: Composition of Input Slurry and of Digested Effluent

Parameters	Poultry dropping		Cassava peels	
	Before digestion %	After digestion %	Before digestion %	After digestion%
Nitrogen	1.99%	2.25%	0.49%	0.80%
Carbon	14.12%	8.27%	4.74%	8.49%
Ph	8.10	8.60	4.00	6.57
Ash	4.90%	1.90%	0.50%	5.02%
Moisture	69.80%	87.4%	92.00%	84.30%
Phosphorus	0.31%	0.90%	3.01%	5.67%
Potassium	14.40%	52.7mg/100g	28.85mg/100g	48.90mg/100g
Volatile solid	81.38%	81.11%	86.55%	49.78%
Total solid	87.40%	70.79%	96.32%	76.30%

Retention time has a significant effect on the digester's performance. Figure 1 shows an initial increase in biogas production during the first 5 days to 15 days, then a somewhat constant rate for the next 20 days to 30 days and a final (almost exponential) decline. Figure 6 shows the effect of retention time on cumulative biogas production for poultry droppings and cassava peels. From the graph, it was deduced that as retention time increased, the cumulative biogas equally increased. Retention time increase is expected because of the conversion of the volatile solid to monosaccharides, polysaccharides, amino acids etc. This conversion of volatile solids to metabolic products is responsible for the low initial pH values obtained in this study in figure 7. The compounds were converted to methane and ammonium compound that turned the pH to higher values of 8.60 and 6.57 which favoured methanogenesis. The quantity and rate of biogas yield depend on the amount of volatile solids present in the wastes and their digestibility. (Ezeonu, 2005).

Table 4: Effect of Retention Time on Gas Production

Retention time (Days)	Biogas production from poultry droppings (litre/day)	Slurry temperature (^oC)	Ambient Temp.(^oC)
3	125	29.4	29.2
6	36	25.5	32.2
12	51	24.1	27.0
24	31	26.1	28.6
41	21	25.4	22.7
Retention time (days)	Biogas production from cassava peels (litre/day)	Slurry temperature (^oC)	Ambient Temp.(^oC)
13	27	31.2	25.6
39	18	28.2	26.9
52	21	24.5	28.9
65	13	27.3	27.8
78	0	28.6	27.3

R. time=Retention time A. Temp=Ambient temperature

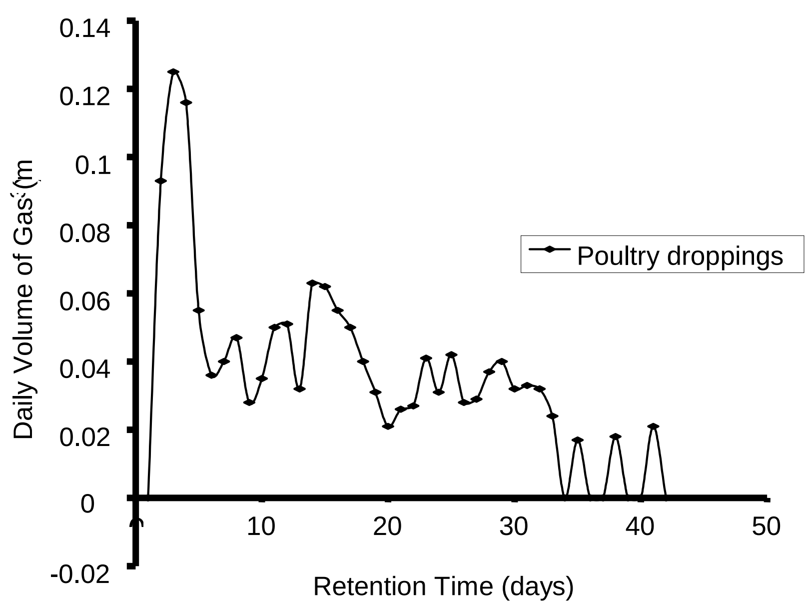

Figure 1: Effect of Retention Time on Biogas production

The ambient and slurry temperature in figures 3 and 4 were within the mesophilic range that had earlier been reported to favour methane generation from organic wastes. Figure 2 shows an increase in pressure at retention time of 7, 20 and 32 days initially but this trend was changed later. As the pressure in the digester increased, the volume of biogas generated also increased and vice versa. All substrates contain nitrogen. For higher pH values, even a relatively low nitrogen concentration may inhibit the process of fermentation.

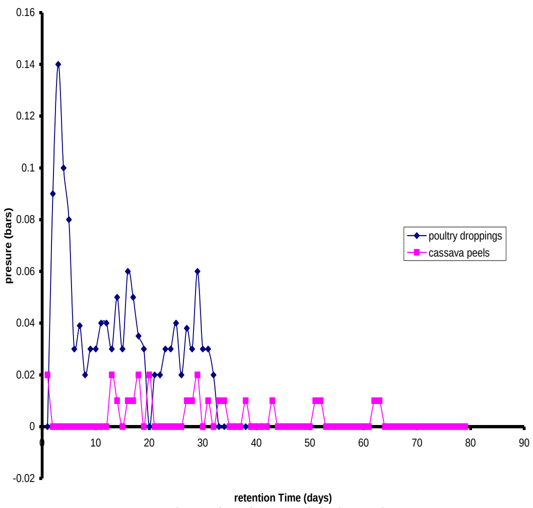

Fig. 2: Change in pressure during fermentation

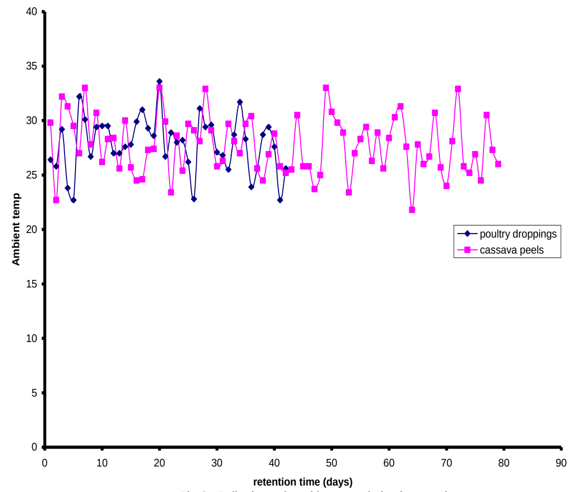

Fig. 3: Daily change in ambient temp during fermentation

The biogas generated from the biogas digester within the hydraulic retention time was shown in figures 5 and 6. Biogas production commenced on the second day of fermentation with accumulation of 125 litres. It however decreased slightly on the 30th, 40th and 70th day, which was occasioned by bad weather which decreases the temperature and pressure in the digester.

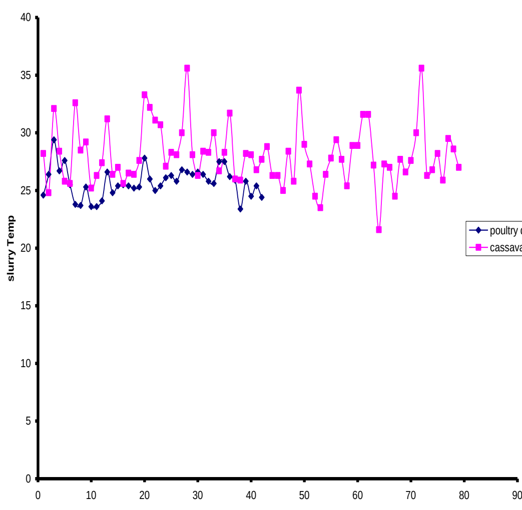

Fig. 4: Change in slurry Temp. during fermentation

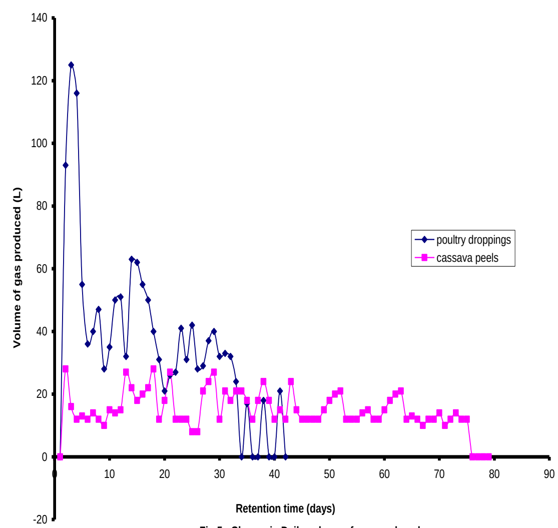

Fig.5: Change in Daily volume of gas produced

Microbial loads expressed as colony-forming units (CFU) of the wastes were done. Cassava peels have 29 X 10^6 cfu/ml and poultry droppings have 1 x 10^7 cfu/ml. The rate of biogas production depends partly on the population of the microorganism. (Garba and Samso, 1992).

Conclusion

Poultry droppings have been found to produce biogas faster than cassava peels within a short period of retention time. Biogas production from cassava peels took longer retention time. Variation in the temperature of the digester affects the rate of biogas production from the two different substrates. The nature of the organic waste and other environmental factors were responsible for biogas production.

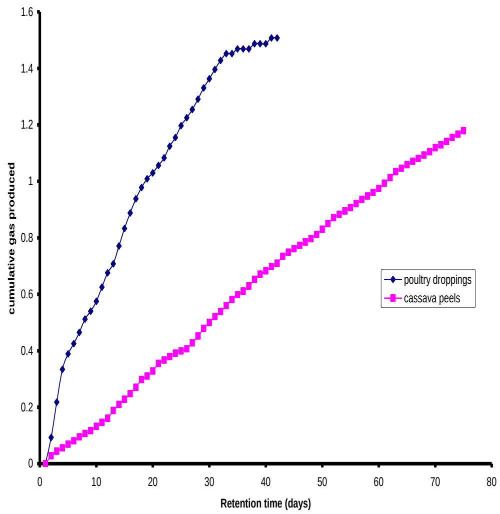

Fig. 6: Cumulative biogas generation during fermentation

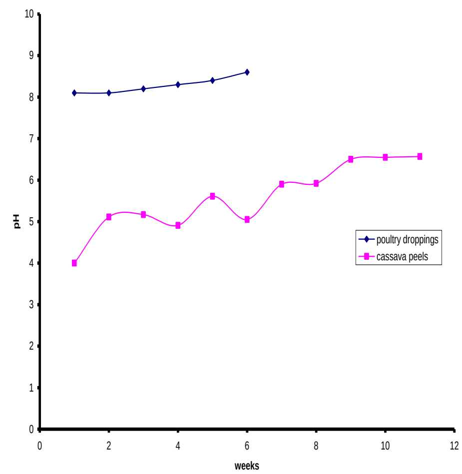

Fig. 7: Change in pH during fermentation

Acknowledgement

The author would like to thank the National Centre for Energy Research and Development (NCERD), University of Nigeria, Nsukka for their co-operation during the period of the experiment.

References

AOAC (1980) Official methods of Analysis. Association office Analytical Chemistry. (14th edition) Arlinton Virginia 22209.

Biogas Digest (1980). Information and Advisory Service on Appropriate Technology (Isat) Biogas Basic (gtz) vol. 1.

Biomass technology Group BTG (2003) BTG Anaerobic Digestion. AD Net Website pp 1 – 4.

Boodoo A., Delaitre C. and Preston T. (1977). The effect of retention time on biogas production from slurry produced by cattle fed sugar cane. Animal production Division, Ministry of Agriculture, Natural Resources and the Environment, Reduit, Mauritius Trop Anim Prod 4(1) 21 – 25.

Buntha .P., Sar T., Vanvuth T., Preston .T.R., Duoug .N.K., Soukanh K., Boualong .P., Choke .M. and Sopharoaek .N. (2009). Effect of length: diameter ratio in polyethylene biodigesters on gas production and effluent composition. University of Tropical Agriculture Foundation Columbia.

Dioha. I. J., Eboatu. A. N., Arinze R. U., Onuegbu. T. U. and Okoy P.A.C (2006). Biogas production from mixture of poultry Droppings and cow dung. Nigerian Journal of Solar Energy 16: 1- 4.

Eboatu .A. N. Dioha .I.J., Akpuaka M.U., Abdullahi .D. Arinze R.U., and Okoye P.A.C. (2006). Comparative studies of the Effects of Brands of cow dung and NPK fertilizers on the growth of okra plants. Nigerian Journal of Solar Energy 16: 15 – 18.

Ezeonu S. O., Dioha I.J., and Eboatu A.N. (2005). Daily Biogas production from different wastes and identification of methanogenic bacteria involved. Nigerian Journal of Solar Energy 15: 80 – 85.

Jenagi .I. (2002). Production methane gas from effluent. Diploma Individual Project. Adelaide University.

Meynell P.J. (1982) Methane: Planning a Digester. Chalmington Dorset: Prism process.

Pearson D. (1979). The Chemical Analysis of Food (7th Edition). Church Livingstone.