African Research Review

An International Multi-Disciplinary Journal

***ISSN** 1994-9057 (**Print**)* ***ISSN** 2070-0083 (**Online**)*

Volume 2 (4) September, 2008 **Special Edition: *Engineering***

Comparative Study of Biogas Yield Pattern in Some Animal and Household Wastes (pp.54-68)

J. O. Babatola - Department of Civil Engineering, Federal University of Technology, Akure, Nigeria delebabatola@yahoo.com

Abstract

This research was a laboratory based work which compared Biogas yield patterns in some animal and household wastes. The parameters studied included dilution and concentration of substrates, the effect of available space in the digester, and the comparative biogas yield from different wastes. The method of research involved keeping all parameter constant and varying just one, to enhance accurate experimental results. Hence, parameters such as ambient temperature, volume of pyrex, weight of substrate, was kept constant while the water dilution ratio was being varied to achieve the optimum dilution ratio. In the same vein, all other parameters were constant while the volume of pyrex was varied to achieve the optimum digester space. The results showed that the optimum dilution and concentration were 2ml/g and 500mg/l respectively and the tighter the digester, the more the volume of biogas produced. It was also discovered that rabbit waste produced the highest volume of biogas, followed by pig waste.

Introduction

The recent rapid increase in human population has strained the earth's ability to provide food, shelter, clothing and most especially energy. As the standard of living increases in the developing countries, the average consumption and need for energy has increased drastically too and thus, when viewed on a long-run period, it can be concluded that eventually there will not be sufficient resource and energy to meet the ever increasing demands by the populace, hence there is urgent need to seek for alternative sources of sustainable energy (Bhatia, 1990). However, man has depended to a large extent on sun, wood, and animal dung for their sources of fuel until the discovery and use of fossil fuel in the early 19th century, which has proved a better alternative and substituted the latter source most especially in the urban sector of the nation. So with the rapid growth of scientific knowledge and the resultant introduction of new technologies, many wood burning applications and the old sources of energy were gradually wiped out by the huge use of fossil fuels.

According to the BIO-METHAINE (2006), it was established that the hydrogen gas in the long run is the alternative energy carrier, providing an environmentally friendly and sustainable production. However, when considering the short run term, Biogas and Bio-methane gas through gasification and methanation of wastes, energy crops and forest residues are on the agenda. Hence, the gaseous fuels (energy fuel) will no doubt constitute a significant part of the future energy supply and plays important roles in the transfer towards the long awaited source of sustainable energy system (Lawbruary, 2006).
This work looked into the gas yield patterns of different kinds of wastes that can be fed into a prototype household digester unit for optimum production of biogas.

Justification

In a developing country such as Nigeria, though there is a huge reserve of crude oil, it is discovered that year in and year out there is an ever increasing cost of petroleum based fuels that serves as a major

Indexed African Journals Online: www.ajol.info

source of energy in the country hence, it is imperative that the search for alternative source of energy resources has become a major serious issue to be considered not only by the government but also by individual. While we could have adopted and copied the various designs of biogas digesters in the advanced countries, the high cost and low energy output of these digesters has necessitated the search for modification. Hence, this research work undertakes some parameters that aid the optimum gas production and provide information for further work.

Production of Biogas

We have had it good for many years, using and misusing fuel supplies at will for many decades. In the United States, according to GATE (1999), this practice will necessarily have to come to a halt at some point in the nearest future, since the present rate of consumption should exhaust the known reserves of refineable crude oil in about 30 years. The constant efforts of our oil companies to sell more and more of this 'black gold' makes it likely that today's consumption will definitely increase in the future.

Hence, it is imperative to find an alternative and ecologically sound source of power for the future unless we want to face the consequence, i.e., rocketing of power prices and possible rationing in our life times as we are experiencing in Nigeria already. Fortunately enough, we have a major alternative, i.e., methane, which is barely exploited up till now. Millions of cubic metres of methane in the form of swamps gases are produced every year by decomposition of organic matter, both animal and vegetable (Bhatia, 1990).

In the past, biogas has been treated as a dangerous by product that must be removed as quickly as possible instead of being harnessed for major useful purposes. Biogas production by anaerobic digestion is popular for treating biodegradable wastes because valuable fuel can be produced while destroying the disease - causing pathogens and reducing the volume of disposed waste products. It combusts more cleanly than coal and produces more energy with less emission of carbon dioxide. The harvesting of biogas is an important role of waste management because methane is a greenhouse gas with a greater global warming potential than carbon dioxide.

Recently, developed countries have been making increased use of biogas generated from both wastewater and landfill sites or produced by mechanical biological treatment systems of municipal wastes.

Composition of Biogas

The composition of biogas varies depending on the origin of the anaerobic digestion process. The basic constituents of biogas are methane (CH_4) and carbon dioxide (Co_2), found in different proportions depending on input to the system and what the condition during the fermentation process are. Trace of hydrogen, sulphur, ammonia and oxygen can also be found in various degrees relating to feed stock and process. Typical values of biogas composition according to different authors are presented in Table 1.

Table 1: Biogas Composition by Different Authors

Methane Vol. %	Carbon dioxide (Vol %)	Other (Vol %)	S Sources
50%	50%	Traces	(Chawla, 1986)
55-70%	30-45%	1-2%	(Smith, 1993)
65-70%	42%	Traces	(Mathias, 1998)
58%	15-35%	Traces	(Lawbuary, 2006)
65-85%	15-35%	Traces	(Demmis, 2001)

Research Methodology

This research was a laboratory based work; hence, the facilities in the water laboratory of the Federal University of Technology, Akure, Nigeria were utilized.

Procurement of Materials

Four (4) different types of animal manures (Cow dung, Poultry droppings, Pig manure and Rabbit wastes) were used with much more emphasis on poultry droppings, due to its availability in abundance. Also, household wastes (Yam peels, Banana peels,
Vegetable remnants) were considered in the work.
The animal manure was collected from the Research and Teaching Farm of the Federal University of Technology, Akure. The wastes were collected each day in polythene bags to the laboratory where they were measured and fed into 1 litre capacity Pyrex glass. In a similar vein, the household wastes were collected from the senior staff canteen where they were taken directly in a polythene bag to the laboratory. Owing to the possible adverse effect of salts and oils on the mathanogenic bacteria, uncooked household wastes were used.

Experimental Method

The biodegradable samples of wastes were first weighed to a fixed weight (l00g) using a digital electronic weighing balance and fed into the Pyrex conical flask, after which the desired volume of water was measured and added into the flask. Rubber hose or tube was used to connect the outlet of the pyrex to the glass tube. The gas produced was collected by the upward delivery of gas, achieved by filling the measuring cylinder with water and inverted in a bowl while water was poured into the bowl. The cylinder was clamped upside down on a retort stand with some allowance between the cylinder and the base of the bowl containing water to allow for the passage of the glass tube from the pyrex to the cylinder as a link. As a result of equilibrium between the atmospheric pressure and the water in the bowl, the level of water in the cylinder remains unchanged until the cylinder was not raised above the level of water in the bowl.

The joints were thereafter sealed with candle wax to prevent any form of leakage and readings were taken and recorded into a specially ruled sheet. The appendices show a typical record sheet and Plate 1 shows a typical laboratory set up of biogas production. The cumulative change in gas produced was plotted against the cumulative change in time elapsed.

Plate 1 A typical Laboratory Set-up of Biogas Digester

Experimental Set Up

The principle adopted was to keep as much as possible several variables constant and vary just one of the parameters. Typical examples included keeping the weight of the substrate constant and keeping the composition of the waste uniform, one at a time. This was achieved by utilizing the same waste for different setup at every instance. Also, the volume of flask used was constant all through except when investigating the effect of volume space on biogas yield. The temperature, rubber tubing and glass tubing are other elements that were kept constant. The graphs of each setup were carefully examined to know the biogas yield patterns under specific conditions.

Optimum Dilution Ratio

From literature, it was discovered that the amount of water present in the biodegradable waste has a major influence on biogas yield. Hence,

much time was dedicated to this part of the work to investigate the actual optimum water needed for different wastes.
However, the major problem encountered at the initial stage of the work was the inconsistencies of data gotten, there were so many research noise which was thereafter discovered to be associated with malfunctioning laboratory apparatus, (3 sets of digester) and as such made subsequent experiment set up differ in constituent. Another problem at the initial stage was the use of very dry poultry droppings which produced no gas at all and it was later discovered that the methanogenic bacteria in the dry poultry dropping were inactive.

However, these two major challenges were tackled by replacing the faulty apparatus and the use of fresh animal manure, though the desired dilution ratio of 100ml - 900ml with an interval of 100 could not be undertaken at a stretch, hence, it was done in two sets, (1) 100 ml- 500ml (ii) 500ml - 900ml and wherein the 500ml was the control to ensure appropriate conformance with the two sets (i) and (ii). Adequate care was taken to ensure that the prevailing conditions were not altered during the setups of the two experiments. The reading recorded on the graduated inverted cylinder was taken at regular interval and the flask shaken.

Determination of the Appropriate Volume of Digestion
It is essential to determine the volume - slurry ratio of the digester. Hence, this was achieved in the laboratory by feeding a known and constant weight of manure (25kg) into varying volumes of the glass flasks of 250ml, 500ml and 1000ml capacity with a constant water volume of 144ml, as shown in Plate 2.

250ml Pyrex

500ml Pyrex

1 Liter Pyrex

Plate 2 Biogas digester in different volumes of flasks

Comparison of Cow Dung, Rabbit and Piggery Waster Biogas Yields

In a bid to investigate into the yield patterns of different types of animal wastes, the Cow dung, Rabbit and Piggery manure, 100g of each waste was fed into separate 1 litre conical Pyrex flask simultaneously to keep to a minimum variation and experimental errors. Equal volume of water (500ml) was added to each of them, and the readings were recorded and relevant curves plotted.

Results and Discussion

Determination of Optimum Water Dilution

One of the factors that enhance digestion is the presence of water. Too little and too much of water will affect adversely the rate of digestion of the substrate. Hence, the first experimental set up was to determine the optimum water dilution which will produce the maximum biogas yield. Poultry droppings of constant weight (100g) were loaded into several conical flask with varying amount of stream water being added; 100ml, 200ml, 300ml, 400ml, 500ml, 600ml, 700ml, 800ml, and 900ml, and the rate and the pattern of gas produced was closely monitored over a period of days to ascertain the highest yield of the gas.

The data of this was presented in terms of type of waste, volume of water added, type of water added, date of set up, date of readings, time of reading, volume produced and temperature. It was however discovered from the readings that 200ml of water to 100g of waste produced the highest, as shown in Figs 1 and 2

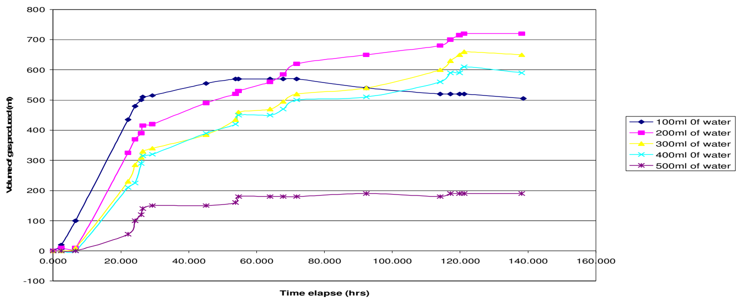

Fig.1 Plot of Biogas Production Using 100g of Poultry Waste for 100ml – 500ml of Stream Water

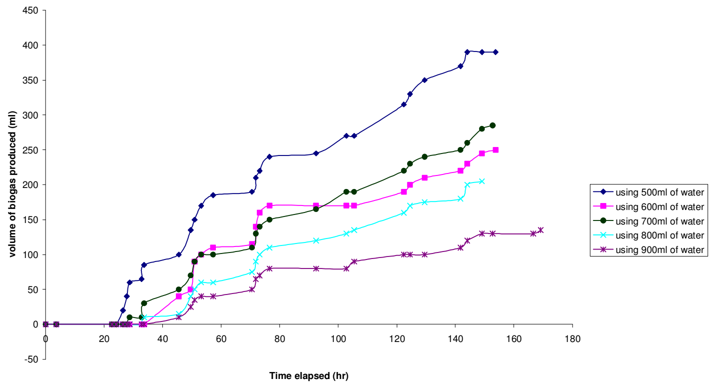

Fig.2 Plot of Biogas Production Using 100g of Poultry Waste for 500ml- 900ml of Stream Water

From these figures, it can be seen that the 100ml yield a very fast initial gas production and the 500ml dilution has the lowest yield from the set, and it can be observed that it attained its optimum gas production in a shorter duration. However, for a digestion period of about 3 days the optimum dilution rate was 2ml/g, for the poultry droppings. So, to calculate the concentration of such waste,

200ml of stream water ⟶ 100g of Poultry droppings
Therefore, 0.001L ⟶ 500g/L

Hence, at a standard volume of 1litre, 500g of waste can be added to yield the optimum dilution.

Appropriate Volume of Digester

A typical set of results shows the readings and results of the varied volumes of digester- 250rnl, 500ml and 1000ml used. The cumulative change in gas produced against cumulative change in time elapsed was shown in Figure 3.

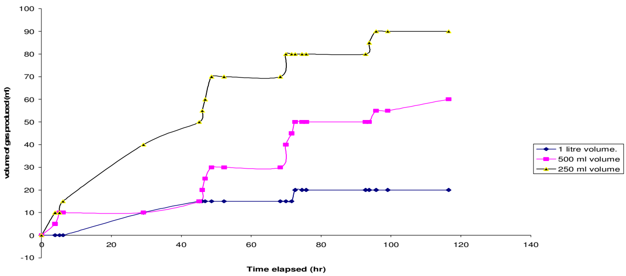

Fig. 3 Plot of Biogas Production Using 100g of Poultry Waste for Varying Volumes of Digesters.

Varying Volumes of Digesters

It can be seen that the highest gas produced was the 250ml volume flask and the lowest was the 1 litre pyrex. Hence, it can be concluded that the smaller the space the more gas produced because anaerobic digestion is favored.

Indexed African Journals Online: www.ajol.info

Cow Dung, Rabbit and Pig Manure
As is the usual practice, the cumulative change in gas produced was plotted against the cumulative change in time elapsed and Figure 4 shows the trend of biogas yields.

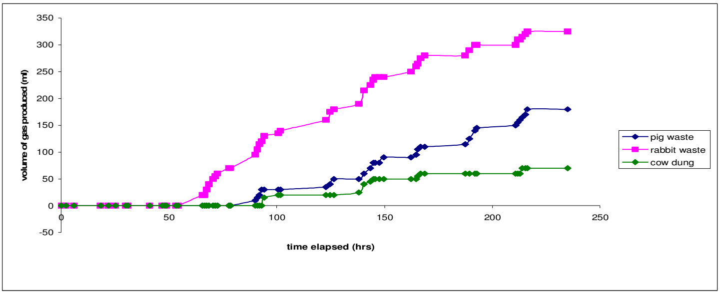

Fig. 4 Plot of Biogas Production from Pig, Rabbit and Cow dung

From the graph, it can be seen that the rate of production of biogas varied amongst the different types of wastes, the rabbit being the earliest of about 55 hours (a little more than 2 days), the pig manure was about 80 hours (a little more than 3 days) and the cow dung was the slowest amongst the 3 wastes with an initial production of 95 hours (about 4 days). This definitely can be attributed to the composition of their feeds. It was discovered that cows feed mainly on fibrous material and the decomposition of the fibrous matter takes longer time by the micro-organisms.

However, it can be seen that after about 240 hours (10 days) the rabbit manure yielded the most biogas, followed by the piggery and lastly, by cow dung. This result will help a further work/research on composite wastes (i.e. the mixing of waste together in the biogas plant).

Conclusion

Considering the results obtained from this study, the following conclusions are made:

1. In the use of poultry droppings for biogas production, a concentration of 500g/1 is needed to yield optimum gas.
2. Due to the anaerobic process undertaken in the digester, the lesser the volume of flask or digester, the more the biogas produced.
3. Rabbit waste has the smallest detention period followed by pig manure and lastly by poultry droppings.
4. Rabbit manure also produces much more biogas as compared to the cow and pig manure.

Recommendations

Considering the scope and limitation of this study and the need to embrace the integration of biogas technology in Nigeria, research should be extended into the investigation of parameter guiding the composite substrates, that is, mixing of different wastes to achieve an optimum biogas yield. Also, detailed study should be carried out into the identification of local organic materials that could aid biogas production such as organic catalysts. A further investigation should be pursued on household waste since this aspect could not be covered adequately in this research. In addition, a study into the effect of the composition of feeding stock to the yields of biogas production should also be carried out.

References

Akilapa O.O. (1991). A Preliminary Investigation of Some Parameters Affecting Digester Design. Unpublished B Sc. Thesis, Civil Engineering Department, Obafemi Awolowo University, Ile-Ife, Nigeria.

Barnett O.T., Mathur A.N. and Chbabra K.T. (1978). Adoption of Biogas Plants in Rural and Tribal Villages, *Journal of Rural Development Vol. 5.*

Bhatia R. (1990). Diffusion of Renewable Energy Technologies in Developing Countries: A Case Study of Biogas Engines. *India World Development. Vol. 18*, No 4, pp 575 - 590.

Biometha Inc. (2006). www.info.@biometha.com Accessed February, 2007

Chawla P. (1986*).* Socio-Economic Problems of Community Biogas Plant in Punjah. *Journal of Rural Development, Vol. 17*(5) pp. 591 - 599

Demmis T. (2001). Management Information System for Biogas Development. *Economics and Political Weekly. Vol. 22,* No 48

Feacheam R., McGarry M. and Mara O. (1978). *Water Wastes and Health in Hot Climates.* John Wiley, Chistester.

GATE (Deutshes Zentrum Fur Entewick lungs technologies) (1999). *Biogas Technology in Orissa*, *India*. Eschbom Germany.

Hagerty D. J., Pavoni J.L and Heer J.E. (1973). *Solid Waste Management.* Van Nostrand Reinhold Co., New York.

Lawbuary J. (2006). *Biogas Technology in India: More than Ghandhi's Dream. HE20: Energy in Its Natural Environment Dissertatio,* New Delhi..

Mathias G. (1998). *Biogas Technology - A Solution in Search of Its Problem A Case Study of Small Scale Rural Development Technology. Introduction and integration*. Goteborg, Sweden.

McInerney M.J. and Bryant M.P. (1978). Basic Principles of Bioconversions in Anaerobic Digestion and Methanogenesis. In Samir S. S. and Oskar R.Z. (eds) (1978). *Biomass*

Conversion Processes Processed for Energy and Fuels. Plenum Press, New York.

Merkel J. A. (1981). Managing Livestock Wastes. AVI Publishing Co., Connecticut.

Odeyemi O. (1981). Resources Assessment for Biogas Production in Nigeria. Solar World Forum. Proceedings of International Solar Energy Society Conference, Brighton, UK.

Ogendengbe M.O. (1990). Waste Processing and Recycling in the Livestock Feed Industry. Paper Presented at the Symposium on Feed Processing Technology and Equipment Fabrication for Feed Manufacturing and Related Agro-Industries, held at Gateway Hotel, Otta, Ogun State. December 19-21.

Ogedengbe M.O. (2001). Waste Management Systems Potential Impacts. Paper Presented during a Course on Environmental Impact Assessment held at the NAETEM, Obafemi Awolowo University, lle-Ife.

Smith G. (1993). *Bio Energy System and the State of the Art. Biogas Technology.* Bio Energet Publishers, Bangkok, Thailand.

Viyayalekshymy O. (1985). Diffusion and innovation in the Chinese Biogas Programme. *World Development, Vol. 18,* No 4, pp. 555 - 565.

Vogler J. (1981). *Work from Waste- Recycling Wastes to Employment Creation,* Intermediate Technology Publications, Rockville.