Kinetics Of Biogas Potential From Animal And Domestic Waste

[*]L.C. Ngozi-Olehi[2], A.A. Ayuk[1], E.E. Oguzie[1], E.N. Ejike[1], B.C. Ijioma[2]

[1]Department of Chemistry, Federal University of Technology Owerri. Nigeria.
[2] Department of Chemistry, Alvan Ikoku Federal College of Education, Owerri. Nigeria.
bleijioma@yahoo.com; mrs_ngoziolehi@yahoo.ca

Abstract: This paper focuses on the following options from the view point of the Kyoto protocol energy use from cow and poultry droppings as well as domestic waste. Biogas potential was determined using laboratory-scale digesters operated to study the effect of varied conditions of pH, and temperature. Gas volumetric technique was employed for the kinetic study. Significant influence of pH on the amount of biogas generated from each system was observed. Gas yield from all systems was maximal in the pH range 6 – 8 (neutral/near neutral) and minimal at acidic (pH 5) and alkaline (pH 9) environments. Temperature influenced several output parameters in the biogas production process. Anaerobic digestion reaction was observed to have followed a first order kinetics as closely related values were obtained from the rate constant. The trend of activation energy (Ea) (Cow dung > Poultry > Domestic) corroborates the incubation period observed in cow dung and poultry dropping before gas production. The activation enthalpies vary in the same manner as activation energies; the enthalpies of activation were higher in cow dung and poultry droppings than in domestic waste. The results show that maximum gas production was obtained at a temperature of 50^oC. [Report and Opinion 2010;2(9):17-21]. (ISSN: 1553-9873).

Keywords; *Animal and domestic waste, biogas potential, greenhouse gas emission, pH, temperature.*

INTRODUCTION

Every activity about life revolves around energy utilization and production. Global population increase, technological and industrial advancements as well as changes in life styles have led to increased energy demand across the world. Fossil fuel has been a major source of energy supply. Its combustion leads to a lot of environmental problems, one of which is the emission of greenhouse gases that is a major cause of global warming [1]. In addition, these gases generate some soluble gases, carbon dioxide, sulphur dioxide and nitrogen oxide which form acid rain that impact both on natural and man-made structures. Heavy dependence on fossil fuels which is the conventional source of energy is causing this only source to deplete at a faster rate than it is replaced. This has posed a great challenge that has also stirred up a global movement towards the generation of renewable and sustainable energy as alternative to fossil fuel [2]. These renewable sources contribute to sustainable development in diverse ways [3]; which include among others:

(a) providing a secure supply of energy
(b) generating income and employment in the rural areas and use minimal foreign exchange.
(c) having minimal negative environmental impact
(d) being produced close to the site of utilization

The use of both animal and municipal waste has gained considerable recognition as major sources of sustainable alternative energy. These sources are considered renewable since plant and animal life renew rapidly as wastes are generated. This gives the basis for renewable sources being the best solutions to the energy crisis worldwide.

The wastes can be treated in different ways to produce bio-energy that can be in form of liquid or gaseous fuels. One option with distinct advantages in the management of both plant and animal waste is anaerobic digestion of the waste. The anaerobic treatment of organic waste leads to recovery of fuel gas (biogas) which is chiefly composed of methane and carbon dioxide. Combustion of methane in biogas can be used to produce both heat and electricity. Biogas production does not add to global warming potential by increasing carbon dioxide concentrations in the atmosphere, this is because the gas is not directly released into the atmosphere and the carbon dioxide is from an organic source with a short carbon cycle [4].

Suitable substrates for biogas production must be biodegradable. Animal wastes as well as domestic waste serve as good substrates due to their organic composition. The anaerobic process involves the activities of a consortium of microbes that engage in complex interaction that must be in equilibrium to give a significant yield [5]. These microbes are sensitive to environmental conditions and thus are controlled by the environment [6]. Two key parameters that affect the environmental condition of the digester include pH and temperature.

This paper sets out to determine and compare the effect of these controlling parameters on biogas yield as well as rate of gas production from cow dung, poultry droppings and domestic waste.

Methods

Cow dung from the Imo State Veterinary Council and poultry dropping from a small scale individual farm were used for this study. Domestic waste was sourced from the waste bin of a household in Owerri. 0.5kg each of cow and poultry droppings were pretreated by mechanically blending with 150dm^3 of water and then fed into the anaerobic digester. Domestic waste was first sorted to separate biodegradable materials from non-biodegradable materials (like glass, plastics etc). This was then crushed to obtain a uniform homogenous sample. 0.5kg of this processed waste was again stirred with 150dm^3 of water.

These prepared study samples were fed into different laboratory-scale batch fed digesters. Anaerobic digestion experiments were carried out for 21days for each digestion system to study the effect of varied experimental conditions of pH and temperature. The pH was varied between the ranges of 5.0-7.0 while the temperature range was varied within the range of 293K-333K, using an air thermostat. Gas-volumetric measurements were taken daily to determine gas produced as well as carry out kinetic study of the reactions.

Results and Discussion

Effect of pH on gas yield and rate of gas production

Table 1 and Fig.1 give the maximum biogas yield at five different pH values for the anaerobic digestion maintained at the mesophilic range. The results show a significant influence of pH on the amount of biogas generated from each system. The highest gas yield was around pH 7.0 (neutral range), minimal gas yield at acidic and alkaline environments. The mechanism corresponds to [7]

$$nC_6H_{12}O_6 \leftrightarrow 3nCH_3CO_2^- + H^+ \quad (1)$$

An increase in H^+ ion concentration will favour the backward reaction thus reducing the amount of $CH_3CO_2^-$ available for methanogenesis. Fig 2 compares the gas production rate of the three substrates at the varied pH ranges. The highest production rate was observed around the neutral pH range (6.0-8.0), with the maximum in all systems at pH 7 suggesting that neutral pH is more conducive for the anaerobic microbes.

Table 1: Maximum biogas yield at the varied pH ranges for the substrates

pH	5.0	6.0	7.0	8.0	9.0
Cow dung gas production (dm^3)	9.2	27.4	32.2	28.2	13.3
Poultry droppings gas production (dm^3)	7.3	25.8	30.0	27.0	11.1
Domestic waste gas production (dm^3)	3.0	28.8	34.1	30.0	4.3

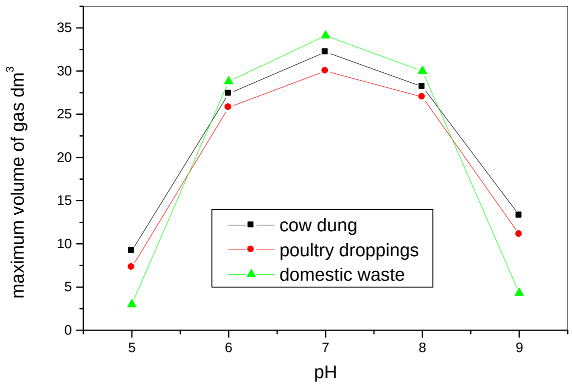


Fig.1: Effect of varied pH on gas yield of the different substrates.

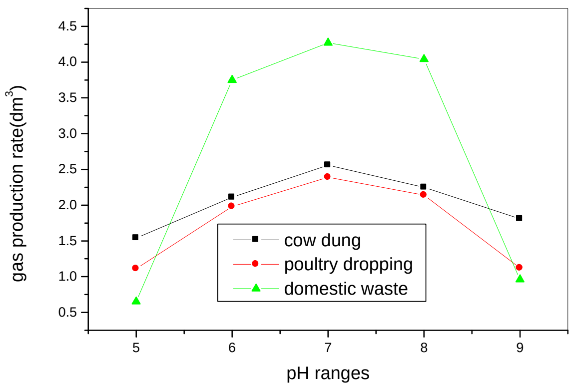


Fig.2: Effect of pH on gas production rates (dm^3/day) for the different substrates.

Effect of temperature

Temperature influences several output parameters in the biogas production process. These include the gas yield, gas production kinetics, attainment of peak production and the optimum gas yield. The effect of temperature on the daily gas yield follows the trend (Poultry < Cow < Domestic). Domestic waste still exhibited the highest yield at short exposure times, which was not diminished at any of the studied temperature. Table 2 shows the gas yield from the various waste materials at varying temperatures of 293K, 303K, 313K, 323K and 333K. At 293K, the gas yield as well as its rate of production was low but as the temperature was increased, a sharp increase was observed. (Figs. 3 & 4). At 323K, the volume of gas produced was highest. Such observation could be the well known increase in reaction rates with temperature increase. It is also possible that the increased temperature (up to 323K) makes the anaerobes to be more active at the different stages of anaerobic digestion thereby increasing the volume of gas produced. At 333K a sharp drop in biogas yield was noticed (Fig.4). This temperature is considered high for the microbial activities, thus biogas production was affected. The quantity of gas produced is therefore affected by the temperature of the digesting slurry. Figure 5 shows that commencement of gas production became more rapid with rise in temperature whereas Figure 6 reveals that peak production was more rapidly attained as temperature increased. Due to the strong dependence of the anaerobic digestion process rate on temperature, it is therefore considered as one of the most critical parameters that need to be maintained in the desired range so that drastic thermal changes should be avoided.

Table 2: Volume of gas yield at the varied temperature for different substrate

substrate	293K	303K	313K	323K	333K
Cow dung (dm^3)	23.2	31.5	32.9	32.5	14.3
Poultry dropping (dm^3)	21.7	29.8	30.5	31.3	12.8
Domestic waste (dm^3)	22.2	33.8	34.5	34.4	7.2

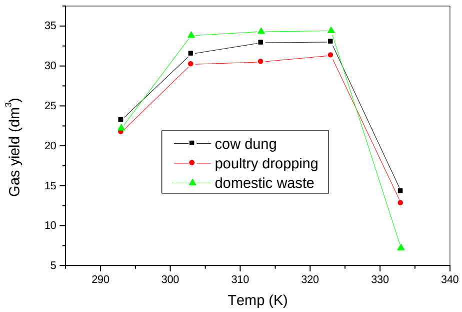
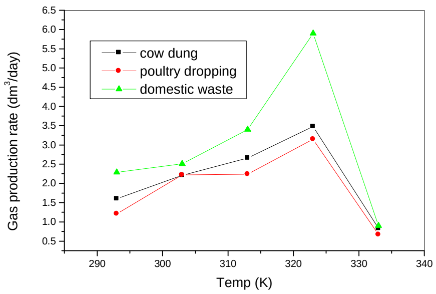


Fig.3 Effect of temperature on gas yield



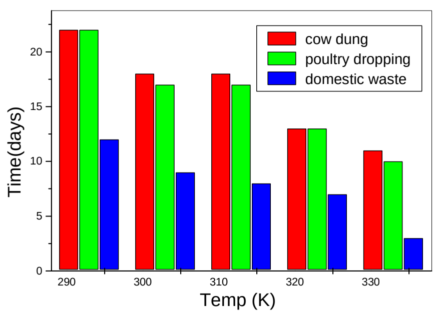


Fig 4: Effect of temperature on rate of gas production Fig. 5 Effect of temperature on commencement of gas production

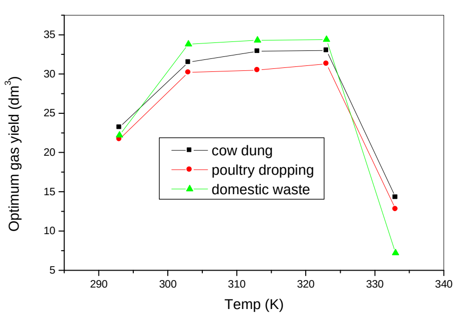


Fig. 6 Effect of temperature on the attainment of peak of gas production Gas generation kinetics

From the volume of gas produced after every 24 hours, it was observed that the anaerobic digestion reaction followed a first order kinetics as comparatively close values were obtained for the rate constants, k, using the first order integrated rate equation;

$$k_1 = \frac{2.303}{t} \log \frac{a}{a-x} \qquad (2)$$

where t = time (days), a = vol. of gas produced from the first day of gas production a – x = vol. of gas produced at any other stated time. The activation energy for gas generation from each was evaluated using the Arrhenius equation [3];

$$k = Ae^{\frac{-E_a}{RT}} \qquad (3)$$

where, k = rate constant, A = exponential factor, E_a = activation energy,

R = gas constant and T = temperature (K).

Taking natural log of each side of the Arrhenius equation gives;

$$\log k = -\frac{E_a}{2.303RT} + \log A \qquad (4)$$

and

$$\ln k = -\frac{E_a}{RT} + \ln A \qquad (5)$$

The calculated values of the activation energies obtained are presented in Table 3.

Table 3: Activation energies of the various wastes

substrate	Activation energies (E_a) $kJmol^{-1}$
Cow dung	37.82
Poultry droppings	37.23
Domestic waste	30.08

The trend of E_a (Cow dung > Poultry > Domestic) corroborates the earlier findings with respect to gas yield from the different waste materials. The system with the lowest E_a (domestic waste) gave the highest yield.

Conclusions

A critical look at the results of this study gives an assurance that if the technology of anaerobic digestion is applied in waste management, it will in addition to preventing environmental pollution, arrest the uncertainty of sustenance surrounding fossil fuel. Economic efficiency of this anaerobic digestion depends on adequate control of the parameters affecting gas yield since maximum production will be expected from any feedstock. The study shows that it is possible to optimize/control biogas production rate and gas yield by adequate control of the environmental condition of the anaerobic digestion systems. The test results show that the maximum gas production was obtained at a temperature of 323K and at a pH range of 6 -8.

***Corresponding author:**
+2348030886970
e-mail: mrs_ngoziolehi@yahoo.ca

References

1 Anthony, L..J (1988). **Information in Energy Technology**. London: Butterworth and Co (Publishers) Ltd, P 3.
2 Novazek, Irene (2007): Canada's Fossil Fuel Dependency. Posted on the internet. **http://www.elements.nb.ca/theme/fuels/Irene novazek.htm.**
3 Rai, G.D (1988). **Non–Conventional Sources of Energy**. Delhi: S. Chand & Coy. Pp35- 39
4 Goswasni, Y. D. (1986). **AlternativeEnergy I n Agriculture.** (Vol. II) Florida: CRC press Inc, p58.
5 Higgins, I. J & Burns, R. G. (1975). **The Chemistry and Microbiology of Pollution.** London: Academic Press, p125
6 Jackson, F. R., (1974). **Energy from Solid Waste**. U.K Noyes publishers. p 110
7 Grontmij, M. (2004). **Municipal Solid Waste Mechanical Separation and Biological Treatment Plant.** Netherlands: Vagron publishers. pp 7-8.

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