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Original Article

Optimum Organic Loading Rate in the Biomethanation of a Mixture of Cow Dungs and Poultry Droppings

Jeje Julius Olatunji[1], Oluwaseun Ruth Alo[1] and Tomiwa Oke Akadiri[1]*

[1]Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.
*Author for Correspondence Email: jemails2000@yahoo.co.uk.

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Organic Loading Rate, Cow Dung, Poultry Droppings, Methanation, Biogas and Biomass.

ABSTRACT

The effect of varying the organic loading rate in the digester volume using a mixture of poultry droppings and cow dung as biomass was studied. The study was aimed at determining the optimum organic loading rates, which would produce the maximum volume of biogas from a mixture of poultry droppings and cow dung. The pH was maintained between 6.8 and 7.2. All other parameters affecting the production of gas were kept constant except the organic loading rate. The wastes, poultry droppings and cow dung was mixed in the ratio 60:40 and maintained at a sludge concentration of 700g/l. It was observed that biogas produced from the digester with the organic loading rate of 2.8 kg vs/m^3/day gives the highest proportion of methane and the digester with organic loading rate of 3.2 kg vs/m^3/day produced the highest proportion of carbon dioxide.

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INTRODUCTION

Energy is the soul of motion without which everything will stand still. Energy comes in various forms and is present in nearly all matters. Out of these substances is fuel which is a combustible matter that could be converted to power or heat. Sources of fuel include coal, wood, oil and gas. Crude oil has been the only source of energy serving at least 60% of the world energy demand to date (Loftness, 1984). The increasing number of industries and energy-consuming lots have brought about high demand for crude oil. It is believed that the world's crude oil reserve will be exhausted if its exploitation continues at the present rate (Anderson, 1979; Alvarez & Liden, 2008). Millions of cubic yards of associated and non-associated gas are flared away every day all over the world in the course of tapping crude oil. With the use of high technology, associated gases are liquefied and stored for use.

In considering the alternative energy sources, certain things had to be borne in mind; the energy has to be cleaned, renewable and economical in production. The biomass produced every year if converted to energy amounting to ten times the annual world energy requirement (Hall, 1978). Thus, if the energy stored in biomass is converted through microbial fermentation can help solve part of the world energy problems. This option is chosen instead of using energy stored in plants in order not to contribute to global warming and erosion resulting from deforestation. Biogas is the gas obtained from the microbial fermentation of biomass; the waste generated by animals especially livestock. It comprises of methane and carbon dioxide and other gases in trace amount such as nitrogen and hydrogen sulphide (Mattocks, 1984; Adak *et al.*, 2011).

The quest for alternative sources is an issue that needs to be seriously considered more so due to the ever-increasing cost of petroleum-based fuel and contribution to climate change. Pollution resulting from the use of fossil fuel is another problem. Pollution of air from the by-products resulting from the combustion of fossil fuel is as serious as that produced from domestic, industrial and agricultural wastes. Since one of the useful and beneficial ways of disposing wastes is to generate fuel from it; biogas production thus alleviates the energy problem. It also stabilizes waste thereby reducing pollution (Braun & Wellinger, 2016).

MATERIALS AND METHODS

The materials that were used for the study included swine wastes and cow dung (collected from an abattoir in Ile – Ife, western Nigeria), poultry droppings, block polyethene bags (to prevent algae photosynthesis and contamination during transportation), retort stands, cans used as digesters, conical flasks, measuring cylinders, glass and rubber tubing. A 2-litre hydrochloric acid solution was prepared by adding 820 ml of distilled water to 180 ml of concentrated HCl. Also, hydrochloric acid solution, hydroxide, distilled water, concentrated HCl, phenolphthalein and methyl orange were used.

Proportion of Substrate

The substrate for digestion was a mixture of swine waste, cow dung and poultry droppings. For the first experiment, 200 g of each waste was diluted to a concentration of 700 g/l; i.e. 2/7 litre of distilled water was added to each sample which was then thoroughly mixed. For the second experiment, a mixture of cow dung and poultry droppings was used. The wastes were combined in the ratio 40:60 respectively and diluted to a concentration of 700 g/l using distilled water. All substrates subsequently added on a daily basis was diluted to 700 g/l.

Loading Rate for Digester

The loading rate is the amount of volatile solid, in kilograms, added to the digester volume per unit of time.

$$Volume\ of\ digester = A\ cm^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ 1$$

$$Organic\ loading\ rate, OLR = B\ kg\ vs/m^3/day/ \quad \ldots\ldots\ldots\ldots\ 2$$

$$OLR\ in\ g\ \frac{\frac{vs}{cm^3}}{day} = C \quad \ldots\ldots\ldots\ldots\ldots\ 3$$

$$\therefore Waste\ loading\ rate/day\ = (C \times A)\ g\ vs/day \quad \ldots\ldots\ldots\ldots\ 4$$

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Volatile solid content

This is the biodegradable portion of the biomass. It is given off as volatile organics if biomass is subjected to a temperature above 550 ºC. 100 g of waste was dried in an oven for 24 hours at over 105ºC.the dried sample was then subjected to a temperature of 550ºC for 35 minutes in a furnace. The ashes left are the fixed solids while the volatile organics are the volatile solids. The percentage of the volatile solids is calculated using the equation

$$Vs\ (\%) = \frac{a-b}{a} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. 5$$

Preliminary Experiment

For this filtration study, a pilot filter unit made from a circular cross polyvinyl chloride pipe with 4 inches diameter and cross-sectional area of 8,108 mm^2 was used. The head of water above the filter bed was kept constant by the overflow mechanism. This was done by making a hole of about 10.0 mm in the pipe which prevented water rising beyond a particular level. An underdrain was provided at the bottom of the pilot unit to support the medium and to allow the effluent from the unit pass to the effluent storage unit. The filter unit was supported at the base and braced properly for stability and possible leakage. Along the height of the pipe were installed three manometer ports to record the headloss at different levels of the bed.

Determination of Carbon Dioxide Contained in Biogas

Carbon dioxide contained in the biogas generated in the digester read with sodium hydroxide solution in the conical flask giving sodium trioxocarbonate IV. Two samples of the mixture, 20 ml each, were titrated each day against a standard solution of hydrochloric acid by using phenolphthalein as an indicator. To the resulting reaction mixture was added methyl orange; thus, the volume of acid required to neutralise $NaHCO_3$ is determined by titrating further to a second endpoint. The volume of CO_2 in the reaction was calculated as shown in equation 2.6.

$$V_{CO_2} = \frac{2240 \times X \times T}{273 \times P} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Where X = number of moles of CO_2; T = room temperature (30ºC); P = atmospheric pressure

Determination of Methane Content of the Biogas

The design of the experimental setup was based on the production of biogas containing 60-80 % methane with carbon dioxide and other traces amount of hydrogen sulphide, oxygen and nitrogen making up the rest. After the absorption by caustic scrubbing of CO_2 in the conical flask, the rest of the gas, predominantly methane, was collected by downward displacement of water in the inverted measuring cylinder where the volume was read.

RESULTS AND DISCUSSION

Volatile Solid Content

Poultry droppings had a higher volatile solid content compared to cow dung with a volatile solid content of 68.40 %. The lower volatile solid content value of cow dung was attributed to the kind of feed the cow was given, i.e. high cellulolytic ration consisting of a high percentage of fibre. The mixture of cow dung and poultry droppings in the ratio 60:40 gave a volatile solid content of 75.4 %.

Biogas Production from Poultry Droppings and Cow Dung

The methane production from poultry droppings was observed to be higher than that of cow dung. This is because cow dung consisted of non-biodegradable fibres in high proportions (Olowoyeye, 2013). The methane production from poultry dropping increased on the second day from 0.09 ml/g to 0.52 ml/g, corresponding to the peak of methane production. Production rate decreased to 0.34 ml/g on the third day and then increased to 0.42 ml/g after which it decreased gradually until it reached 0.00 ml/g on the ninth day. Cumulatively, 1.81 ml/g of CH_4 was produced in the span of ten days.

However, for cow dung, methane production decreased from 0.01 ml/g on the first day to 0.00 ml/g on the second day. Production on the third day steadily increased till the eighth day when methane production was 0.06 ml/g. it decreased again till the tenth day when it increased.

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Biogas Production from different Organic loading Rates

Based on the cumulative amount of methane produced, the digester with the organic loading rate of 2.8 kg vs/m^3/day gave the highest methane production of 1.09 ml/g cumulatively. The results of biogas production from organic loading rates are as shown in Figures 1 and 2.

Figure 1: Daily biogas production from a mixture of cow dung and poultry droppings

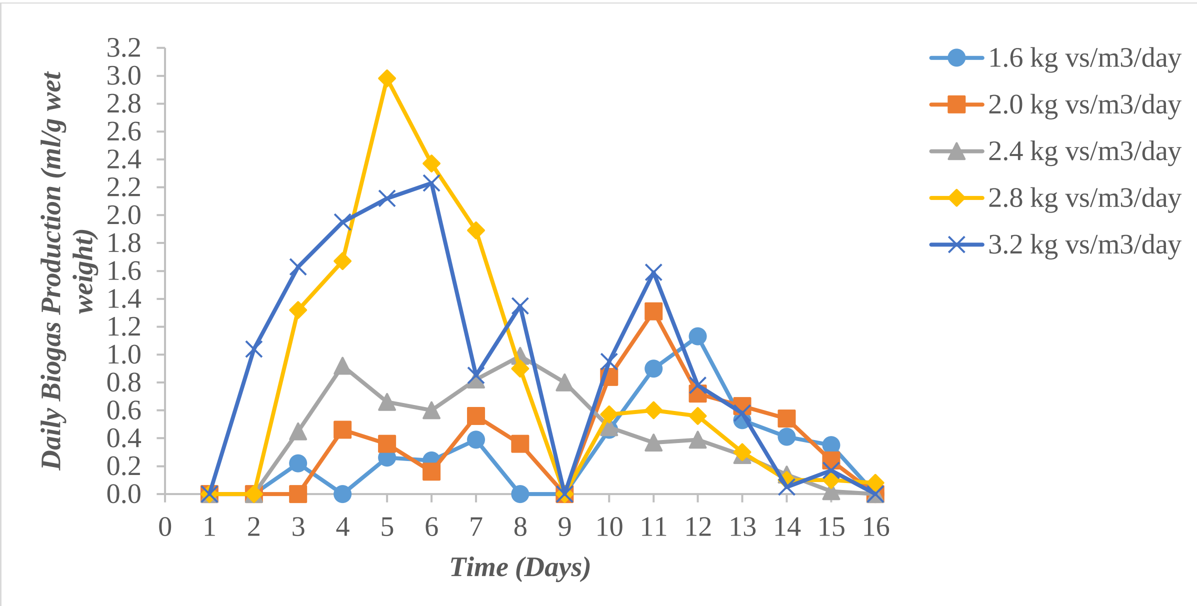
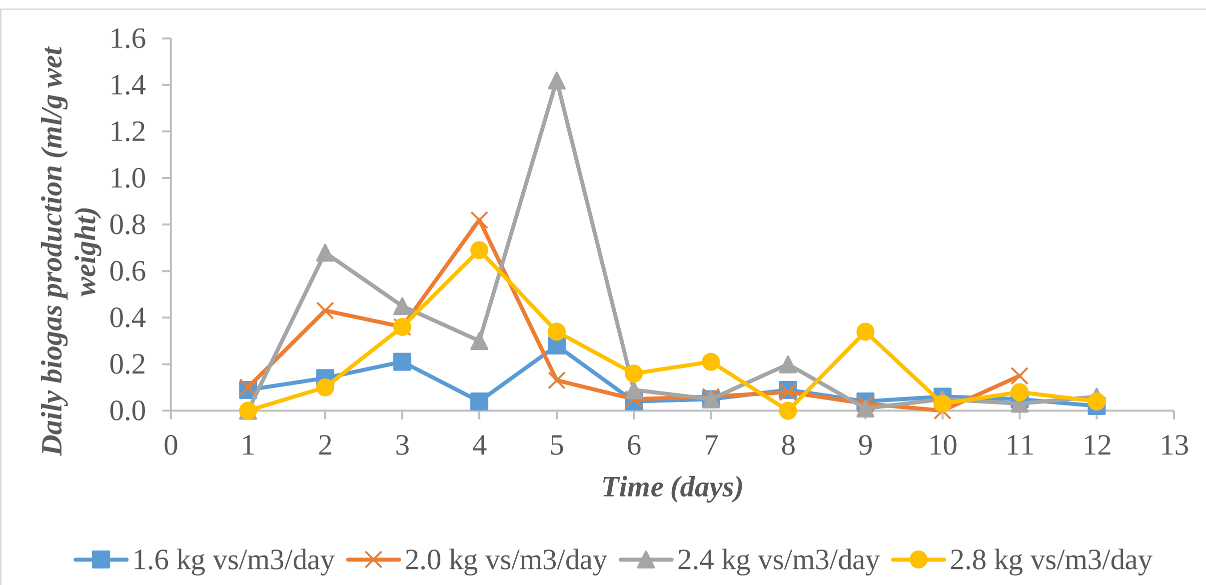


Figure 2: Daily biogas production from a mixture of poultry waste and cow dung without effective removal of CO2



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From the analysis of the results of methane produced, as a component of biogas from different organic loading rates for a mixture of poultry droppings and cow dung with a mix ratio of 60:40 respectively and a concentration of 700 g/l, the digester with the organic loading rate of 2.8 kg vs per m^3 of digester volume per day gives the highest. Since all the loading rates within the range 1.6 – 3.2 kg vs/m^3/day produced biogas of considerable volume as established by Merkel (1981) thus the organic loading rate of 2.8 kg vs/m^3/day was considered to be the optimum.

The volatile solid content of poultry waste was found to be higher than that produced from cattle wastes. The carbon dioxide content of the biogas generated from the digester with the organic loading rate of 3.2 kg vs/m^3/day found to be 14.56 ml/g was the highest, indicating the lowest reduction of carbon dioxide by bacteria to methane. Since this loading rate is the highest, and from the study of the sequence of increment in carbon dioxide produced from the various digesters, it could be deduced that the efficiency of the reduction of carbon dioxide by CO_2-reducing bacteria is the bio-methanation process.

CONCLUSION

Based on the results of the study, the following conclusion was drawn; biogas production due to the synergistic effect of combining waste is improved using a combination of poultry droppings and cow dung using a mix ratio of 60:40 at a concentration of 700 g/l. The organic loading rate of 2.8 kg vs/m^3/day using a mix ratio of 60:40 for poultry droppings and cow dung respectively produces the highest methane content from the range of 1.6 to 3.2 kg vs/m^3/day. The cumulative carbon dioxide produced using organic loading rate of 3.2 kg vs/m^3/day gives the highest value and consistent increase in biogas production, but at a lower rate, as shown in the experiments, using an organic loading rate of 2.4 kg vs/m^3/day.

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