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Effect of Slurry Concentration on Biogas Produced From Cow Dung Substrate

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Original Research Article

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Abstract: The effect of four different cattle dung slurry concentration (1:1 1:4 1:5 and 1:6) at 28 days retention time was studied at chemical laboratory of the Sokoto Energy Research Center. The result shows that biogas yield in 1:4 and 1:5 ratios were significantly higher than those at 1:1 and 1:6 concentrations for a given retention time. The outcome of this research suggest that the biogas production is in the order of 1:4> 1: 5 > 1: 6 > 1: 1 which means that further increase in substrate concentration results in the decrease of the specific growth rate. Therefore, for optimum biogas production the slurry should not be concentrated or too diluted. The water to substrate ratio should be about 1:4.
Keywords: Cow dung, biogas, slurry, Sokoto Energy Research Center, mix ratio.

INTRODUCTION

Since the beginning of the last century fossil fuels had become the major source of global energy. In the last 110 years, large quantities of oil, gas and coal were removed from their underground deposits. These fuels are generally used as sources of energy in combustion engines, and in some instances as raw materials for the petrochemical industries. Although, fossil fuels play a key role in the global economic and political situations, their numerous challenges accounted for a shift to more sustainable energy sources [1-6]. Environmental pollution is the major issue of concern associated with exploitation of these fuels. There are currently about 750 Giga tones of CO_2 in the atmosphere, a greenhouse gas that was identified as the major contributor to the current global warming problem.

Reports by Intergovernmental Panel on Climate Change [7] revealed that, the world is experiencing severe consequences ranging from drought, melting of sea ice, diminishing of important plant and animal species to overspread of diseases especially in the developing countries. Oil spill and gas flaring are another environmental threat associated with exploitation of fossil fuels. Between 1970 and 2004 more than 700 tons of oil were accidentally spilled from tankers across the globe, the consequences of which include economic loses and destruction of marine plants and animals [8]. Another major challenge with these fuels is their un-sustainability and projected depletion over the years. While the total reserves would only last for the next few decades, the consumption was projected to double in many centuries. For example, analysis by Energy Information Administration (EIA) of USA showed the US energy demands to rise by 62 % for natural gas, 33 % for oil, and 45 % for electricity by the year 2020. To address the various energy challenges associated with these fuels, many countries have indicated commitment to bio-fuels production such as biogas, bio fuel, bio diesel, etc.

Biogas is produced when bacteria degrade biological materials in the absence of oxygen, in a process known as anaerobic digestion. Anaerobic treatment is the use of biological processes, in the absence of oxygen, for the breakdown of organic matter and the stabilization of these materials by conversion to methane and carbon dioxide gases and a nearly stable residue [9]. It is used for cooking, crop drying and soil fertilizing [10]. In addition to energy security and waste management, biogas has strong potentials for jobs creation and source of revenues to the government [11].

Biogas in particular, had become an important source of energy even in the rural communities. For example, there are currently about 135,000 biogas plants in Nepal [12]. In the year 2007, there were 26.5 million biogas plants in china, producing 10.5 billion m^3 of biogas to mostly the rural people [13]. In African countries such as South Africa, Zimbabwe, Egypt e.t.c. there are numerous of biogas producing units used daily by the local inhabitants [14]. However, despite international commitments to sustainable energy development, the Nigerian government and the local communities have only indicated a partial concern.

In fact, very few biogas units, operating mainly on a significantly low level of technology are available in Nigeria. The local manure from animal herds, other agricultural and industrial wastes that are largely produced daily in the country could be employed as raw-materials for both small and largescale biogas production. Animal wastes are abundant all over the world with Nigeria producing about 227,500 tons of fresh waste each day [15].

In this paper analysis has been made on the effect of retention time and slurry concentration on biogas produced from cow dung substrate.

MATERIALS AND METHODS

The materials used in this work are: cow dung (both fresh and dried) serving as the samples/substrates. Empty tins (400g capacity each) serving as the digesters, 1000 cm^3 measuring cylinder serving as the gas holder, Araldite adhesive and candle wax. Apparatus used include retort stand, basin, tin can, measuring cylinder (1000 cm^3), a top loading weighing balance (Model BH 600) with a capacity of 600 g and resolution of ± 0.01 g, digital pH meter (Hanna Model PH-211), tap water, mortar, pestle, and hose pipe. The volume of gas produced was taken on a 24-hour basis and the average for each week was also noted.

Sample collection

The cow dung used was obtained (both fresh and dried one) from cattle flock of Sokoto Energy Research Center. All samples were collected and kept in a polythene bag.

Sample processing

The cow dung collected (only the dried one) was further sun dried and thereafter crushed mechanically using a mortar and pestle to ensure homogeneity.

Preparation of slurry

Three batches of one hundred grams of dried cow dung was weighed and poured into three empty tins which serve as the digesters. This was followed by the addition of 400 cm^3, 500 cm^3, and 600 cm^3 of tap water. For the fresh cow dung, one hundred grams was weighted, put into an empty tin and then followed by addition of 100 cm^3 of water. Four digesters were therefore obtained. The digesters are labelled as A, B C and D respectively. The concentration ratios are referred to as 1:1, 1:4, 1:5 and 1:6 for digesters A, B, C and D. All the mixtures wire stirred to obtain homogeneity; the slurry was obtained when a saturated solution is formed. Hose pipe was inserted via a small hole followed by sealing the hose pipe with araldite adhesive. All the digesters were sealed with candle wax to obtain and ensure anaerobic environment for the set up.

Mixing ratio/dilution ratio

The dilution ratio of waste to water or the concentration for each of the samples were varied for the dried cow dung are 1:4, 1:5, 1:6, and for the fresh cow dung 1:1 respectively.

Experimental set up of biogas

Hose pipe was connected at the top of each digester which was then inserted into a measuring cylinder of 1000 cm^3 capacity which serves as the gas holder filled with water and placed in an inverted position was held firmly by a retort stand in a basin filled with water. The gas produced from the digesters will pass via the hose pipes to the measuring cylinder which as a result displaced the water down ward. The volume of gas produced is measured by the amount of water displaced from the measuring cylinder and the daily ambient temperature was also noted throughout the retention period. Plate 1 shows the experimental set up in the laboratory.

Plate-1: Experimental Set up

RESULTS AND DISCUSSION

From the results obtained, cumulative biogas yields for different substrate concentration were calculated. Thus, the results of biogas production from both fresh and dried cow dung are shown in table 1. It has been observed that Biogas production was slightly slow at the beginning of observation. This is predicted because biogas production rate is directly proportional to specific growth rate of methanogen bacteria in the bio digester [16].

Table-1: Average Gas Produced Per Week

WEEK	Digester A (cm^3)	Digester B (cm^3)	Digester C (cm^3)	Digester D (cm^3)	TEMP ^0C
1	NGP	100	NGP	100	32^0c
2	NGP	580	740	180	31^0c
3	NGP	2030	1900	730	31^0c
4	610	1060	560	270	30^0c
TOTAL	610	3770	3200	1280	

NGP: No Gas Produced

The biogas produced in the entire retention time of the experiment yield a total of 8860 cm^3. it was observed that in the first week of the experiment digesters B and D (with a dilution ratio of 1:4, 1:6) containing dried cow dung produced a certain amount of gas while digester A containing the fresh cow dung yield no gas which may be associated with the biodegradable material found in the cow dung [17]. In second week of the experiment, digesters B, C, D, produced a significant amount of gas while digester A produced no gas at all.

However, digester B was found to produce the highest amount of gas in the third week of the experiment followed digester C and then D and no amount of gas was produced by digester A. It may be low temperature that affected gas production in digester A because it needs an optimum temperature of 30^0c to 40^0c for the bacterial growth found in it, any value of temperature below that level can probably lead to slow growth of the methanogen bacteria which leads to gas production [18]. Furthermore, in the last week of the experiment both the digesters containing the slurry produced a certain amount of gas.

pH is an important factor that affects biogas production. The pH of the slurry in all the four digesters varies. This is not surprising as the decrease in pH may be as a result of anaerobic fermentation taking place. It was reported that anaerobic bacteria required a natural environment [19] and thus, pH ranging from 6.4 to 7.2 is required for optimum biogas production. Also, a decrease in pH may be due to the action of acetogenic methanogens as they break down sulphur containing organic and inorganic compounds as well as the formation of fatty acids. It was reported [15] that biogas produced at pH of 5 is greater than that of pH 10.

Figure 1 shows the relationship between volume of gas produced and the slurry concentration with the retention time. It can be seen that the biogas produced by the digester B with a dilution ratio of 1:4 at the total retention time of the experiment has the highest yield of gas produced as similarly reported by [20]. It can be seen clearly from the Figure that biogas production in the experiment is in order of B> C> D> A, which means that slurry containing the dilution ratio of 1:4 is higher than that of 1:5 followed by 1:6 and then 1:1 of the fresh cow dung. It was said that further increase of substrate concentration result in decrease of the specific growth rate [21]. Suggested that the specific growth rate decreases almost linearly at high concentration of the substrate.

Moreover, for optimum biogas production the slurry should not be highly concentrated or too diluted, the water to substrate ratio should be about 1:4 [22] so that the slurry should be at optimum level for the growth of methanogen bacteria which is responsible for biogas production.

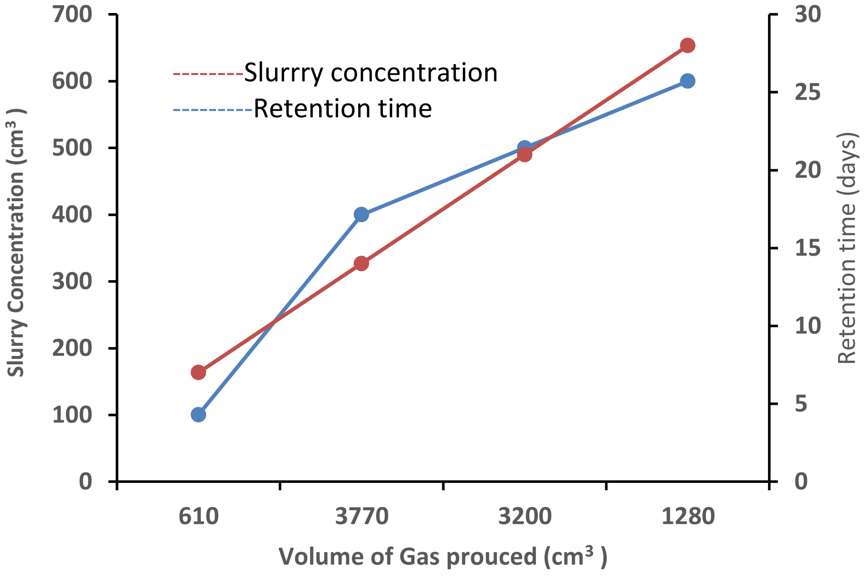

Fig-1: Volume of gas produced against slurry concentration and retention time

CONCLUSION

The outcome of this research suggest that the biogas production is in order of 1:4> 1: 5 > 1: 6 > 1: 1, which means that further increase in substrate concentration result in the decrease of the specific growth rate which result in lower gas production. Therefore, for optimum biogas production the slurry should not be concentrated or too diluted, the water to substrate ratio should be about 1:4.

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