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Experimental Investigation on the Effects of Digester Size on Biogas Production from Cow Dung

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ABSTRACT : *This paper presents the experimental investigation on the effect of digester size on biogas production. Experiments were carried out to produce biogas from different sizes of digester. 1.4 kg of cow dung was used to carry out the experiments. The temperature throughout the period of experimentation was within ambient temperature of 25^{0}C to 35^{0}C. It was observed that the pH values of the Digesters fluctuate between 5.4 and 7.6. This may be due to the activities of acid. Digesters A, B, C, D and E, with volumes of 250 ml, 500ml, 1000ml, 2000ml and 3000ml, produced a total biogas of 625 cm^3, 715cm^3, 1635cm^3, 2082cm^3 and 2154cm^3 respectively. Digester size is an important factor which has a direct effect on the quantity of gas produced. For the total biogas produced per litre of digester size, Digesters A, B, C, D and E, produces 2500 cm^{3}l^{-1}, 1430 cm^{3}l^{-1}, 1635 cm^{3}l^{-1}, 1041 cm^{3}l^{-1} and 718 cm^{3}l^{-1} respectively.*

KEYWORDS : *Biogas, Cow dung, digester size, temperature, pH.*

I. INTRODUCTION

Anaerobic digestion of animal waste on farms involves the breakdown of organic matter by bacteriological action to produce biogas and digested effluent (digestate). The pollution potential of digestate is lower, has fewer odours, contains fewer viable weed seeds, has fewer pathogens than the input slurry and is an excellent biofertiliser [1].The manorial value of the biomass is not diminished in this process, rather, it is enhanced. Biogas plant helps in obtaining both fuel and manure from the same quantity of biomass [2].Biogas is a clean and cheap fuel in the form of gas which contains mixture of gases: methane (50–75%); carbon dioxide (25–50%); nitrogen (0–10%); hydrogen (0–1%); hydrogen sulphide (0–1%); and oxygen (0–2%).The calorific value of biogas varies between 20-26 MJ/m^3 (5.6-7.2 kWh/m^3) depending on the methane content. In terms of heating oil, it is equivalent to approximately 0.5–0.7 litres oil/m^3 biogas. Biogas is thus an excellent source of renewable energy [1].

Anaerobic digestion requires a gastight tank with draw-off points for biogas in the headspace, a heating system to maintain optimum digester temperature (35^{0}C-40^{0}C), a method of loading inputs and unloading digestate. Mixing of digester contents is necessary to prevent settling of solids and crust formation, as well as to ensure an even temperature within the digester. Typically, mixing is carried out by mechanical stirrers or by biogas recirculation [1].During anaerobic digestion, various organic materials are degraded to biogas (methane, carbon dioxide and other traces of gases such as nitrogen, ammonia and hydrogen sulphide) [3]. The process is of great significance and also in many well-known habitats such as marched sediments and rumen. Methane fermentation has been known since long and methane formation in sediments was discovered in the 18th century, while anaerobic digestion has been used by man since the end of the 19th century [3].

The present and potential application of anaerobic digestion requires a detailed understanding of the process. Considerable research and development efforts are necessary on many aspects of the process varying from basic microbiology and biochemistry to engineering and economics. Knowledge on microbiology, biochemistry and anaerobic digestion control of methane production has increased considerably during the last decade but still far from sufficient-mainly due to the complexity of the process. The production of biogas happens only under strict anaerobic conditions.

The bacteria prefer to use oxygen to produce their energy intermediate because of the higher efficiency of the anaerobic process with oxygen as final electron acceptor in the breathing chain and electron transport phosphorylation. The fermentation is a reaction in which oxidation and reduction reactions are internally balanced, while some atoms of the energy source become more oxidized.

Biogas is used at all times and does not cause smoke in the kitchen which may affect the human lungs and also cause irritation of the eyes. Due to high methane thermal output (37 MJ/m^3); biogas cooks quicker and enhances village sanitation if latrines are attached to these biogas plants [4]. Most Agricultural, Industrial and Municipal wastes are used for the production of biogas and the final wastes are used as manures in the farm. It has been experimentally observed that the nitrogen, phosphorus and potassium content of the biomass were higher after anaerobic digestion [2]. This shows that digested animal or plant waste should be better manure than ordinary farm yard nature. This is because the waste material is in more finely divided state after digestion as the complex organic molecules like cellulose and semi celluloses would have been broken down. Digesters vary widely with regardto complexity and layout. No simple design can be considered as ideal, since many factors affect their arrangement and construction, and these needs to be considered for an optimum to be achieved for each particular set of circumstances and environmental conditions. There are however, some essential differences in digesters principles and for conveniences, digesters types have been loosely categorized into four sections; batch, continuous, high rate and others [5]. This order generally follows a pattern of ascending sophistication, the simpler designs usually falling into the description of a batch digester and the more complimented falls into the description of heated and stirred digester, two stage layout at the other of the spectrum. In this study, the effect of digester size will be investigated.

II. METHODS

2.1 Sample Collection and Preparation

Fresh cow dung samples used for the study were obtained in a large clean plastic container from a Cattle farm in Minna, Niger State, Nigeria. The samples were mixed with water at 40°C in a ratio of 1.4kg of the cow dung to 1 litre of water into slurry. The slurry was screened to remove unwanted materials before being introduced into the digester.

2.2 Physiochemical Parameters

Moisture Content

The moisture content of the cow dung was determined as follows: 2.0g of cow dung was weighed in a pre-weighed aluminium dried dish. The sample was then placed in an oven and dried to constant weight at 105^{0}C for 24 to 36 hrs. The weight of the aluminium dish, cow dung and dried cow dung were recorded and the moisture content of the sample was calculated using equation (1).

$$\%\ Moisturecontent = \frac{M_1 - M_2}{M_1 - M_0} \times 100 \qquad \textbf{(1)}$$

Where, M_0 is the weight of aluminum dish (g), M_1 is the weight of fresh sample and dish (g) and M_2 is the weight of dried sample and dish (g).

Ash Content

5.0 g of cow dung sample was weighed into a crucible previously ignited and weighed organic matter was charred by igniting the material on a hot plate in the fume cupboard. The crucible was placed in the muffle furnace and maintained at 600^{0}C for 6hrs. It was then cooled in a desiccator and weighed immediately. The recorded weights were used to calculate the ash content of the cow dung using equation (2).

$$\%\ Ashcontent = \frac{W_{a+c} - W_c}{W_s} \times 100 \qquad \textbf{(2)}$$

Where, W_s is the weight of cow dung (g), W_{a+c} is the weight of crucible and ash (g) and W_c is the weight of empty crucible (g).

Nitrogen Content

1.0 g of cow dung sample was introduced into the digestion flask. Kjedahl catalyst (5 selenium tablets) was added to the sample. 20 ml of concentrated acid was added to the sample and fixed to the digester until a clear solution was obtained. The cooked digest was transferred into 100ml volumetric flask and made up to mark with distilled water. 20 ml of 4% boric acid was pipetted into the conical flask. 5 drops of methyl red was added to the flask as indicator and latter diluted with 75ml of distilled water. 10ml of the digest was made

Alkaline with 20ml of 20% NaOH and distilled. The filtrate was then titrated against HCl normalcy of 0.1N. The percentage total Nitrogen was calculated using equation (3).

$$\%\ Total N_2 = \frac{(V_2 - V_1) \times N \times 0.014}{W_s} \times 100 \qquad \textbf{(3)}$$

Where, V_2 is the sample titre, V_1 is the Blank titre, W_s weight of cow dung and N is the Normality.

2.3 Digester Experimental Procedure

Digester sizes made of conical flask was used in carrying out the digestion operations. The different sizes of conical flask used were 250ml, 500ml, 1000ml, 2000ml and 3000ml and labelled Digester A, B, C, D and E respectively. The sample as prepared above was measured into the conical flask. Rubber stopper of various sizes were plugged into the mouth of the conical flasks with two openings: one for the gas and the other for placing thermometer on top of the stoppers. The gas outlet was connected to a water displacing section. From each of the digester A, **B,** C, D and **E** the following parameters were monitored: pH (hydrogen ion concentration), temperature and volume of gas produce (cm^3).The pH of the sample was monitored on a daily basis for 26 days using the pH meter after the initial standardization of the pH with buffer 4.0 and 7.0. The temperature of the digester was monitored twice daily (morning and afternoon) with a mercury in glass thermometer placed in the digester for 26 days. The volume of gas produced by each of the digester under investigation was monitored on a daily basis through the displacement of water in the measuring cylinder. The quantity of water displaced expressed in cm^3 is a direct effect of gas produced. The experiment was monitored over a period of 26 days.

III. RESULTS AND DISCUSSION

The results of the experiments carried out to determine the effect of digester size on biogas production are presented in Figures 1 to 6 below.

3.1 Physiochemical Parameters

The physiochemical parameters, such as the percentage Moisture content, Ash content and Nitrogen of the fresh cow dung were calculated using equations (1) to (3) and shown in Figure 1. The values for the moisture content, Ash content and Nitrogen content were 75%, 3.8% and 2.5% respectively. The physiochemical parameters affect the quantity of biogas produce [6].

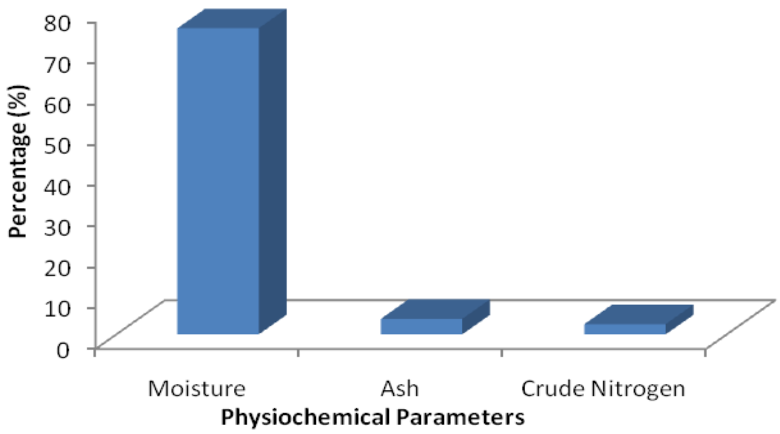

Figure 1. Physiochemical parameters of Cow dung

3.2 Temperature and pH of Digesters

Investigations reveal that in all the digesters under investigation, the pH value is a little neutrally within the first three days of operation (Figure 2), and then a fall from 6.0-6.8 was experienced. The fall might have been due to the activities of the acid forming bacteria involved in the digestion process for gas production. However, towards the end of the digestion process pH increased again to neutrality. This might have been due to the activities of the methanogenic bacteria, which were able to convert the product of acid forming bacteria to methane gas. This result is in agreement with the work of Fernando and Dangoggo (1986) and Maishanu et al. (1990)[7,8].

The effect of temperature reveals that throughout the period of experimentation it was within an ambient temperature of between 25^{0}C to35^{0}C (Figure 3).This range of ambient temperature allows for proper digestion of the waste by the activities of microorganism within the digester and helps to enhance the smooth operations of the biogas digester. However, critical observation on the temperature effects reveals that lower amount of gas are produced in the morning until the temperature is increased above 30^{0}C.The effects of both the pH and temperature are initial factors that affect the level of Biogas.

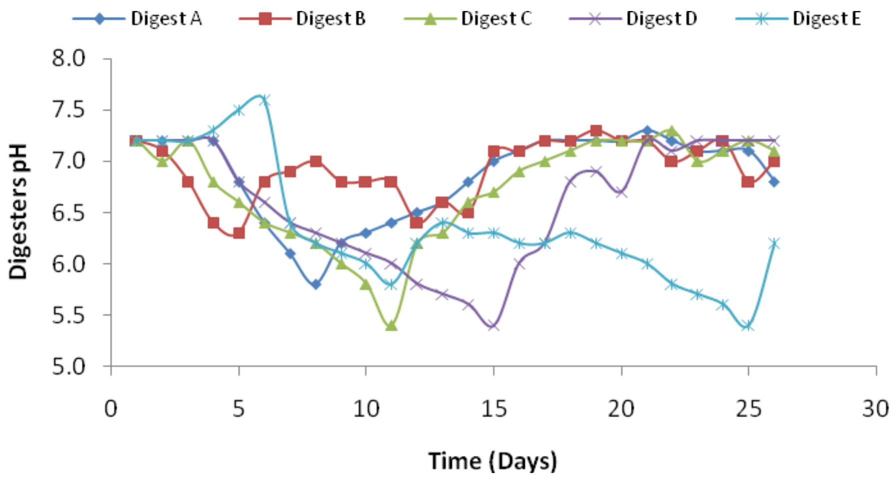

Figure 2. Changes in the pH of Digester materials during Digestion

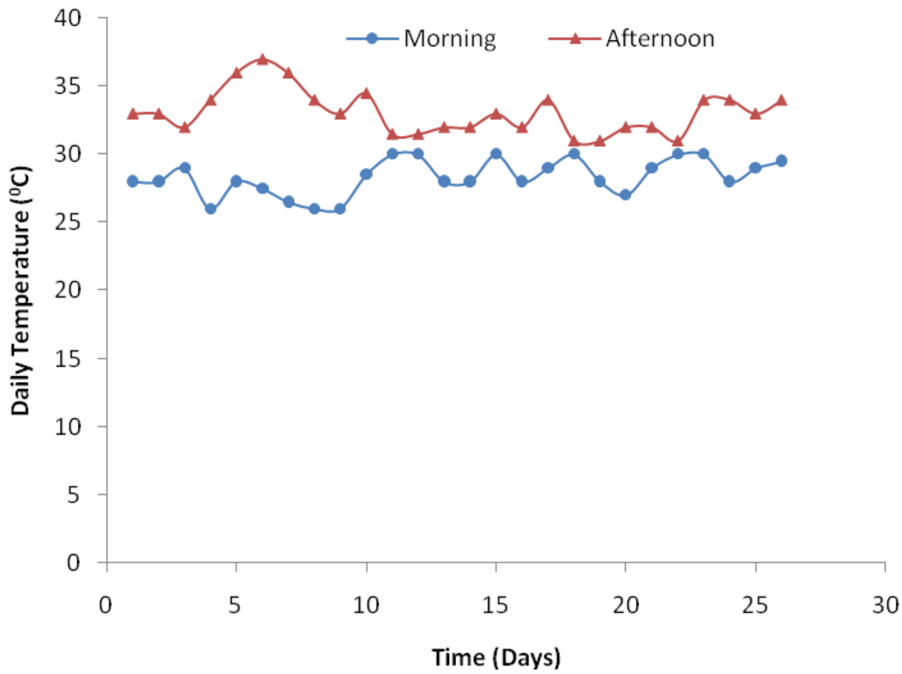

Figure 3. Daily Digester Temperature

3.3 Effect of Digester Size on Biogas Produced

Investigation revealed that in all digester sizes, during the first 6 days of operations, no gas was produced as shown in Figure 4. This might be as a result of the fact that the microorganism were in their formative stage for digestion process. However, from the 7thday, digesters C, D and E started producing some quantity of biogases (Figure 4). Thereafter gas produced was observed to increase with digester sizes. The peak for biogas production occurs between days 14 and 20 for Digesters D and E. While Digesters A and B maintained an average production of biogas. The maximum daily biogas production of 190 cm^3 occurred in Digester E on days 14 and 16. Digester A recorded the lowest biogas production of 5 cm^3 on day 25.

The effect of Digester sizes shows that Digester A with a volume of 250ml produced the least volume of 625cm^3 of biogas and Digester D and E, which has a volume of 2000 ml and 3000 ml, produced 2082 cm^3 and 2154cm^3 respectively as shown in Figure 5. The high volume of gas production in bigger digesters might be as a result of the fact that the materials were able to expose the greater surface area for rapid multiplications of the methaprogen for maximum utilization of the waste material for greater gas production.

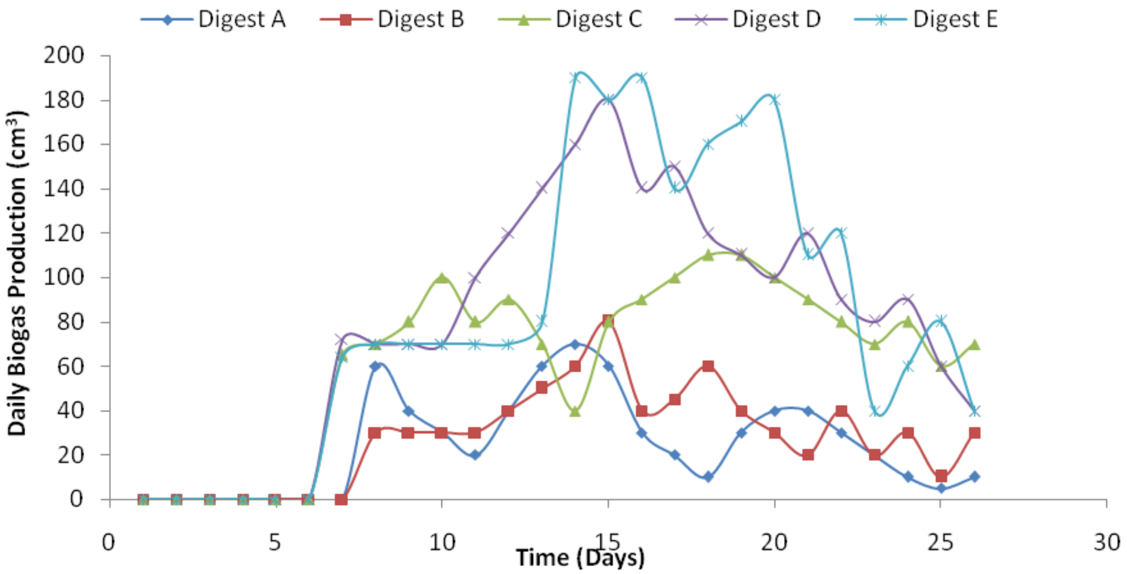

Figure 4. Daily Biogas Production

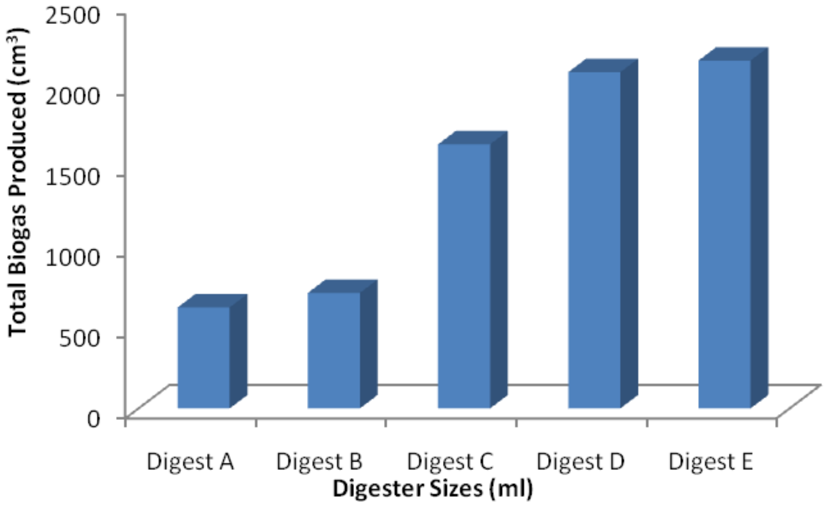

Figure 5: Total volume of gas produced by each digester

3.4 Optimal Biogas Production

Figure 6 shows the optimal biogas production for the digesters used. It can be seen that though the total volume of biogas produced increases with increase in digester sizes (Figure 5), the biogas produced per litre shows a different trend. The smallest Digester size of 250 ml produces the highest total biogas produced per litre of digester size of 2500 cm^{3}l^{-1}, while the largest digester size of 3000ml produces the smallest total biogas produced per litre of digester size of 718 cm^{3}l^{-1}. Digester C with a size of 1000 ml produces 1635 cm^{3}l^{-1}. The volume of total biogas produced per litre was higher for Digesters A and B, but lower for Digesters D and E. Digester C is the optimal digester size, above which the volume of total biogas produced per litre will fall below the total biogas produces (Figure 6). Depending on the cost of Digesters, if a higher total biogas production is required, Digester E should be used.

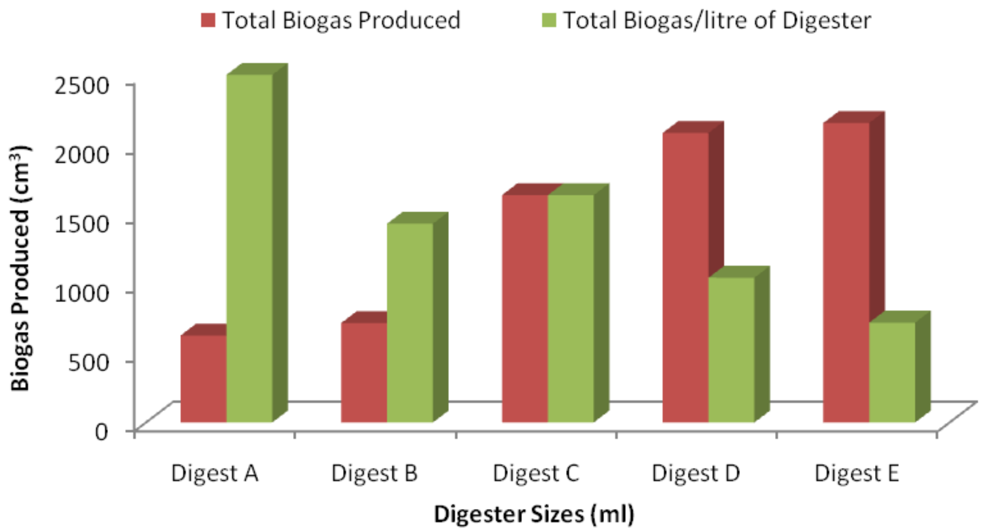

Figure 6.Biogas produced per litre of digester size

IV. CONCLUSION

The experimental investigation of the effect of digester size on biogas production has been carried out. Experiments were carried out to produce biogas from different sizes of digester. 1.4 kg of cow dung was used to carry out the experiments. The temperature throughout the period of experimentation was within ambient temperature of 25 ^{0}C to 35 ^{0}C. It was observed that the pH values of the Digesters fluctuate between 5.4 and 7.6. This may be due to the activities of acid. Digesters A, B, C, D and E, with volumes of 250 ml, 500 ml, 1000 ml, 2000 ml and 3000 ml, produced a total biogas of 625 cm^3, 715 cm^3, 1635 cm^3, 2082 cm^3 and 2154 cm^3 respectively. Digester size is an important factor which has a direct effect on the quantity of gas produced. For the total biogas produced per litre of digester size, Digesters A, B, C, D and E, produces 2500 cm^3l^{-1}, 1430 cm^3l^{-1}, 1635 cm^3l^{-1}, 1041 cm^3l^{-1} and 718 cm^3l^{-1} respectively. Digester C is the optimal digester size, above which the volume of total biogas produced per litre will fall below the total biogas produces (Figure 6). Depending on the cost of Digesters, if a higher total biogas production is required, Digester E should be used.

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