Determination of the Mesophilic Temperature for Optimum Continuous Process Biogas Production from Anaerobic Digestion of Animal Wastes.

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ABSTRACT

The production of biogas, an alternative source of energy, from animal wastes, was investigated at the laboratory scale using simple single-state digesters of 4000 ml working volumes. The digesters were fed on a continuous basis with the slurry of Cow Dung (CD) and Poultry Droppings (PD) blended in the ratio of CD:PD 1:3 and operated at ambient temperature (30°C) as baseline and temperatures of 35°C to 47°C for 30 days. This experiment was carried out to assess the influence of temperature on mesophilic anaerobic digestion of animal wastes and the optimum temperature for biogas production from the blends of the animal wastes. Controlled heat was supplied to the digester and observed. Biogas production from the waste blends was monitored at the mesophilic temperature ranges. Results obtained indicate maximum biogas yield of 3.603 liters was achieved from the digestion of the animal wastes at temperature of 37° C in the continuous digestion process using simple single-state digesters.

(Keywords: biogas, mesophilic temperature, continuous digestion process)

INTRODUCTION

Biogas, the gas generated from organic digestion under anaerobic conditions by mixed population of microorganisms, is an alternative energy source which has been commenced to be utilized both in rural and industrial areas at least since 1958 (Stuckey, 1984). It is the naturally occurring emission of bacteria that thrive without oxygen, and occurs in three steps. First is the decomposition, or hydrolysis, of the biodegradable material into molecules such as sugars. Next, these molecules are converted into acids. Lastly, the acids are converted into biogas.

Anaerobic digesters harness the bacteria's natural processes to capture and utilize the biogas, all in a safe, controlled environment. Biogas produced in anaerobic digesters is burned to generate clean, renewable energy. The main components of biogas are methane (50-75%), carbon dioxide (25-50%), nitrogen (0-10%), hydrogen (0-1%), and hydrogen sulphide (0-3%) which, if released in uncombusted form, is harmful to the environment as a particularly potent greenhouse gas (Milono et al., 1981).

Anaerobic digestion helps manage two of the biggest sources of manmade methane: livestock manure and landfills. Livestock manure, since it is the main ingredient for the digesters, and landfills, since food waste can be digested rather than dumped. Certainly, methane can be extracted from landfills, but anaerobic digestion is far more efficient for the same waste source. By preventing the emission of methane while producing clean energy, anaerobic digesters make a twofold contribution to climate protection: the usual unchecked discharge of methane into the atmosphere is prevented, and the burning of fossil fuels is replaced with an unlimited supply of clean, renewable energy (biogas).

There are two conventional operational temperature levels for anaerobic digesters, which are determined by the species of methanogens in the digesters (Song et al., 2004). The *Mesophilic* which takes place optimally around 35°- 45°C or at ambient temperatures between 20°- 45°C where mesophiles are the primary microorganism present and the *Thermophilic* which takes place optimally around 50°-52°C at elevated temperatures up to 70°C where thermophiles are the primary microorganisms present (Mackie et al., 1995). However, the thermophilic process has some disadvantages. For example, it is not so stable and produces somewhat low quality effluent compared with mesophilic process (Duran and Speece, 1997).

There are a greater number of species of mesophiles than thermophiles. These bacteria are also more tolerant to changes in environmental conditions than thermophiles (Carbone et al, 2000). Mesophilic systems are therefore considered to be more stable than thermophilic digestion systems (Song et al., 2004).

Several kinds of waste materials have been reported to be exploited (Bardiya et al., 1996; Cuzin et al., 1992; Kalia et al., 2000; Zhang et al., 1999).

Cow dung and poultry droppings, the cheap and abundant animal wastes in Nigeria, are investigated to be applied as a raw material for the bio-energy production in this study. In this study, the *Mesophilic* temperatures for maximum production of biogas from the blend of animal wastes were investigated in laboratory scale using the simple single-state digesters. Two different feeding processes can be used: Batch Feeding Process and Continuous Feeding Process. Batch digesters are filled and then emptied completely after a fixed retention time. Continuous digesters are fed and emptied continuously. They can be empty automatically through the overflow whenever new material is filled in. Therefore, the substrate must be fluid and homogeneous. In this study, continuous feeding process digesters are used.

MATERIALS AND METHODS

Three identical conical flasks were used. A conical flask of 4000 ml capacity with the top corked, was used as the digester, and placed in a water bath. The cork was drilled in two places for an opening to fix a thermometer and a plastic tube for gas collection. A thermostat with heater line system was used to control biogas temperature of production. The digester setup was made air tight as illustrated in Figure 1.

The gas production was monitored with a water displacement gas collector. The water in the gas collector was acidified with thin sulfuric acid and saturated with brine (NaCl) to prevent CO_2 from dissolving in the biogas. In the continuous digestion process, 300 ml slurry was constantly added weekly to the digester using a syringe during the 30 days retention time. An equal volume was first removed before the addition.

Gas production was also measured daily. Samples were also taken for analysis after the 30 days detention time. Stirring was done by hand shaking the digester to break the scum. To obtain the consistency of the raw material for biogas production experiments, cow dung (CD) and poultry droppings (PD) were prepared by blending 100g of fresh Cow dung (CD) with 300g of fresh poultry droppings (PD) that is a ratio of 1:3. Tap water was stirred into the mixture and then sieved to make slurry. The digesters were operated at ambient temperature, 30°C for 30 days.

The digesters were then setup to determine the biogas yield for temperatures of 35°C, 36°C, 37°C, 38°C, 39°C, 40°C, 41°C 42°C, 43°C, 45°C, and 47°C. The temperatures 35°C, 36°C, 37°C, 38°C, 39°C, 40°C, 41°C 42°C, 43°C, 45°C, and 47°C for the study being close indicate that for increased and steady biogas, the mesophilic temperature for optimum continuous process biogas production can only be determined by investigating each of the *Mesophilic* temperatures which takes place around 35°-45°C.

The pH could be maintained by adding sodium bicarbonate to increase digester alkalinity. In this study, sodium bicarbonate was added four times during the first week of digestion. Afterwards the digesters could maintain themselves.

The composition of biogas collected over water, was analyzed using the Gas Analyser (Shimadzu, Class-GC14B, Japan) equipped with a thermal conductivity detector (TCD) and 1-M Porapak Q (80-100 mesh) column. Total solid (TS) and volatile solid (VS) were 15.5% and 88.6% respectively, and pH values were 7.1-7.3.

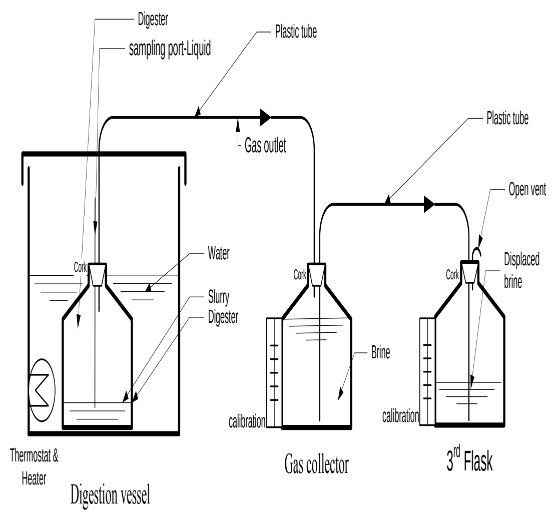

Figure 1: Schematic of Digester Setup.

RESULTS AND DISCUSSIONS

Biogas Yield

The biogas production at temperatures of 30 °C; 35 °C; 37 °C: Figure 2 shows the superimposed relative biogas production from continuous production temperatures of 30^{0}C, 35^{0}C, and 37^{0}C, respectively. Within the ambient range of 30°C temperature, gas production was minimal.

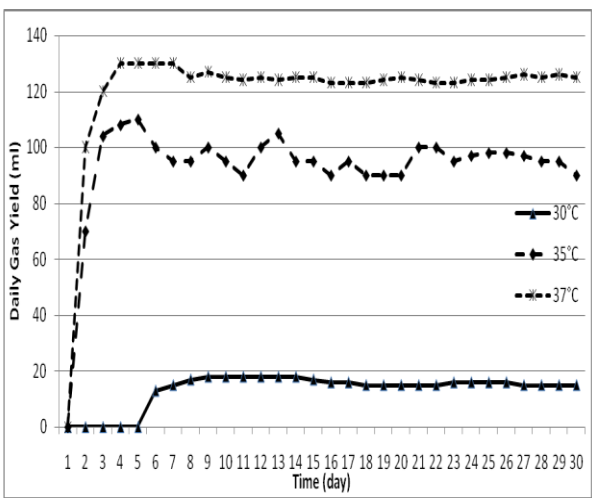

Figure 2: The Superimposed Continuous Production Process at Temperature 30 °C, 35 °C, and 37 °C.

When the temperature of the slurry in the digester was raised to 35°C, a fairly constant production of biogas after the initial rise in biogas yield was observed. 2782ml of biogas was recorded. At 37°C, a steadier rate resulting in approximately constant biogas production was observed. The plots showed optimum increase in biogas production when running on 37^{0}C production temperature indicating that a digester should be maintained at 37°C for most favorable continuous process production. The higher methane yield at this temperature was probably due to more metabolisms of methanogenic bacteria caused by favorable temperature and pH. Optimum yield of 3603ml was observed at temperature of 37°C.

The biogas production at temperature 30 °C; 40 °C; 42 °C: Figure3 shows the superimposed relative biogas production from batch production temperatures of 30^{0}C, 40^{0}C, and 42^{0}C respectively. When the temperature was further increased, biogas production decreased, indicating that biogas production was highly influenced negatively by the temperature increase. The plots showed very significant decrease in production when operating at 40°C. The increase of operating temperature to 42°C showed further decrease in biogas production. This can be attributed to inadequate metabolism of the methanogenic bacteria caused by temperature sensitivity of the bacteria.

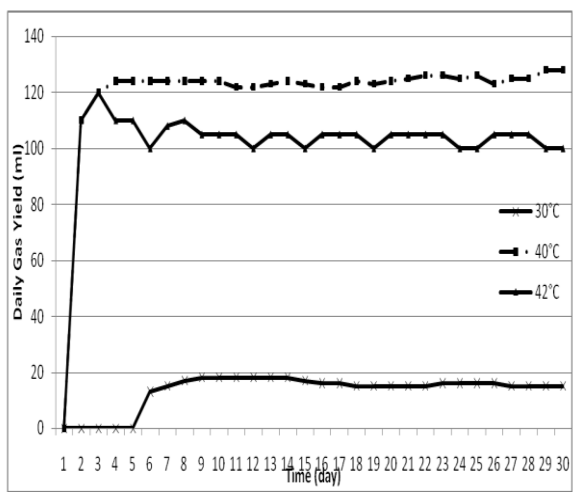

Figure 3: The Superimposed Continuous Production Process at Temperature 30°C, 40 °C, and 42°C.

The biogas production at temperature 30 °C; 45 °C; 47 °C: Figure 4 shows the superimposed relative biogas production from batch production temperatures of 30°C, 45°C, and 47°C respectively. The test results showed that biogas production at 45°C significantly increased as compared to the biogas produced at 42°C shown in Figure 3.

The biogas yield further increased significantly at production temperature of 47 °c. This trend was perhaps due to the biogas-producing bacteria entering into the thermophilic temperature range. The higher temperature of production may have provided better environmental condition leading to efficient metabolism process for the bacteria to function. However, excessively high temperatures may harm the bacteria, and ultimately kill off the biogas-producing bacteria in the digester.

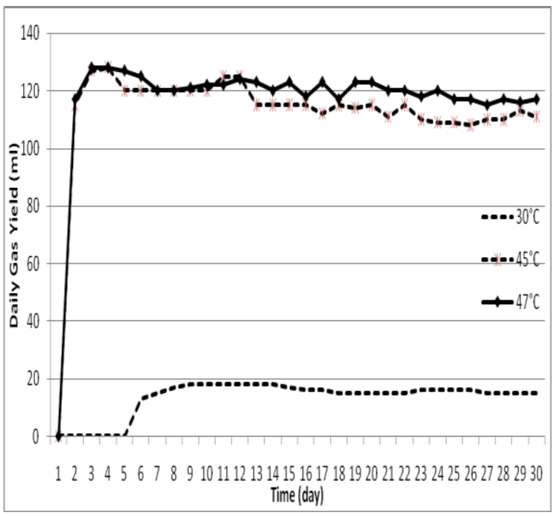

Figure 4: Superimposed Continuous Production Process at Temperature 30°C, 45°C, and 47 °C.

CONCLUSION

These results indicate that in continuous digestion process, gas production is constant, and higher than in batch digesters due to the continual replacement of the active ingredients. Temperature of 37°C has proven most efficient for stable continuous digestion process. This indicates that gas production can be accelerated and made more consistent by continuously feeding the digester with small amounts of animal-waste daily or weekly. Regularly feeding and empting the digester at temperature of 37°C will result in regulating digester failures. Continuous process systems are therefore considered to be more stable and better digestion systems. Gas production is constant and higher.

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