Cow dung: An effective substrate for biogas production

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Abstract

In this study, cow dung was evaluated as substrate for the production of biogas under anaerobic conditions. Fermentation slurry was prepared by the addition and vigorous mixing of dried cow dung and dried poultry droppings separately with an equivalent amount of water needed for maximum yield in the ratio 1:1. 2 batch-type anaerobic digesters of 25 L each were equipped with pH probe, stirrer, thermometer and sampling port. Digestion was carried out for 30 days at room temperature. The substrates were characterized using X-ray fluorescence (XRF) according to the method of AOAC and Proximate analysis of the substrates was carried out according to the method of AOAC. The pH value of the cow dung substrate was found to be mainly alkaline which favored digestion and biogas production. The retention time of the substrate cow dung in the bio-reactor affected the quantity of biogas produced. This results of this study established cow dung substrate as an effective feedstock for biogas production.

Keywords: Biogas, Cow dung, Substrate, Digestion, Anaerobic, pH, Retention time

Introduction

Animal waste management is becoming an interesting area in renewable energy research and development. It is cheap and cost effective and many countries are finding it suitable and environmentally friendly. In Nigeria today, the problem of poor waste management and inadequate power supply has remained a daunting task. As was observed by Abubakar and Ismail, poor disposal methods for animal waste manure like cow dung can lead to adverse environmental and challenges such as odor and green house gasses [1].

Though, abundant organic waste like cow dung and other agricultural wastes exist in Nigeria, harnessing its inherent potentials for sustainable energy supply has not yielded the desired result. Nigeria still battles with power problems. Onwuliri et al, viewed energy demand of a nation as an index that measures its development and standard of living. In a nation like Nigeria, energy demand and utilization cuts across different industries ranging from domestic to industrial [2].

Anaerobic Digestion (AD) is considered as a natural process in which the action of bacteria helps in the digestion of organic matter to generate biogas. Thomsen et al, noted that biological digestion of organic matter in absence of oxygen remain a major process in the natural metabolism of an ecosystem [3]. Uzodinma et al, are of the view that AD process generates gases made up of mainly methane (CH₄) and carbon (IV) and that the process impacts positively on the environment as it reduces CO₂ and CH₄-that are responsible for global warming [4]. Corroborating the work of Uzodinma et al, Clements et al, and Zahariev et al, expressed the opinion that anaerobic digestion of livestock wastes has a tripartite effects viz.: takes care of unpleasant odour management, creates new source of bioenergy and lowers of green house gases emission [4-6].
Anaerobic process as was stated by Chinwendu et al, involves three stages (hydrolysis, acidification and methanogenesis) of biochemical processes with release of energy rich biogas [7]. Ukpabi et al, explained that in the first stage, extra cellular enzymes externally catabolizes the organic matter [8]. Jantsch et al, reported that during the third stage, methane producing bacteria decomposes low molecular weight compound to produce CH₄ and CO₂ [9]. The methanogenesis and microorganisms growth is mainly dependent on different parameters like pH, temperature, carbon/nitrogen ratio, organic loading rate and digester design, inoculums, Hydro Retention Time. According to Hashimoto and Varriel, the produced biogas is typically composed of 50-70% methane, 30-40% carbon dioxide, 1-10% hydrogen, 1-3% nitrogen, 0.1% oxygen and carbon monoxide and trace of hydrogen sulphide [10]. Biogas can Balsam and Ryan, stated can be used for cooking, heating, cooling, lighting, generating electricity among other uses [11].

In this research, an attempt was made to study the effect of parameters like pH, temperature, on the generation of biogas using cow dung manure.

Materials and Methods

Materials

The cow dung used in this research was obtained from Mami Market in (82 Division Enugu) in Enugu state. About 20 kg of cow dung was collected for the purpose of this study. The cow dung served also as inoculums as it contained the required microorganisms for anaerobic digestion. Other equipment used includes test-tubes, beakers, conical flasks; syringes; measuring cylinder (Pyrex); crucible; Buchner funnel; oven; muffle furnace; hose pipe; water trough; graduated (transparent) bucket.

Methods

Substrate preparation

The substrate collected was sun dried and thereafter crushed mechanically using a mortar and a pestle to ensure homogeneity. The substrate was weighted using a digital scale 5354M. The prepared substrate was stored at 6°C prior to use. Fermentation slurry was prepared by the addition and vigorous mixing of dried cow dung separately with an equivalent amount of water needed for maximum yield in the ratio 1:1 [12]. Fresh rumen content of a freshly killed cow was retrieved anaerobically and 0.23 kg of the rumen content was measured and used to inoculate the medium in the biogas digester as a source of methanogens. The waste sample was weighed and poured into the digester based on the experimental design.

Experimental procedure

The digestion of waste was undertaken by batch-type anaerobic-digester. Cow dung was used as substrate in the experiments. 25 L digester equipped with pH probe, stirrer, and sampling port were also used in this study. A thermometer model 00384RM was inserted in the digester to measure temperature. A U-tube was used to measure the gas pressures, while the pH of the mixture was measured with a digital pH meter model 2221.

The working volume of the bioreactor was maintained at 18.75 L and ran under uncontrolled pH, which is without acid or base solution. The experiment was carried out at ambient temperature and the mixing was aided by a mechanical stirrer. The reactor was seeded with sample of cow dung and stirred for 5 minutes at interval of 3 hrs thrice daily to enable digestion to take place in the entire medium. After 3 days retention time biogas evolved from the reactor was measured and collected in a gas holder by water displacement and analyzed with gas analyzer PAC2 model. Also small quantities of the sample was withdrawn from the reactor and sent for analysis. The experiment was carried out at the Energy Center, University of Nigeria, Nsukka.

The bio-digester was covered with black polythene sheet to prevent light penetration which can stimulate algae growth and also to trap the heat that has been absorbed in the day. Leakages in the bio-digester system were checked by immersing the bio-digester into water-bath to check for air bubbles at intervals to prevent loss of medium and the gases generated.
Results and Discussions

Biogas production

The biogas production during the period of the study is shown in Figure 1. The anaerobic bio-digester was charged on 5th of May, 2017 and the retention time was 30 day. It was observed that biogas production actually started after the 3rd day for the substrate cow dung. This was predicted because biogas production rate in batch condition is directly equal to specific growth of methanogenic bacteria corroborating the work of Nopharatana et al. [13]. This could be likened to the alkaline nature of cow dung which allows the growth of methanogenic bacteria in the first 3 days. During the first 8 days of observing the sample, there was slow biogas production and this is mainly due to the lag phase of microbial growth. Whereas in the range of 9 to 21 days of observation biogas production increased substantially due to exponential growth of methanogens. The pH of cow dung substrate was found to be basic and later became neutral as the retention days increased. The unregulated pH region can lead to increase/decrease in concentration of ammonia nitrogen and might be assumed to inhibit the process. As could be in Figure 2, a decrease in the process pH for the cow dung substrate was observed and this could be due to higher volatile fatty acid (VFA) formation caused by fermentation of the substrate. It was reported by Chen et al. that high concentration of ammonia nitrogen is toxic to anaerobes, which will decrease the efficiency of the digestion and upset the process [14]. The biogas production started decreasing after 15th day of production for the cow dung and this could be as result of decrease in the total soluble solid of substrate as degradation process continued. It was obvious from Table 1 that cow dung is an effective feed stocks for anaerobic digestion with a good yield of biogas and this could be attributed to the higher total soluble solid (TSS), volatile solid (VS) and carbon content of the cow dung in Figure 3 and is in line with the works of Umar et al. and Sadaka and Engler for sample (cow dung) [15,16].

Figure 1. Graph biogas yield versus retention time (days) from cow dung
Figure 2. Graph of pH profile during anaerobic digestion of cow dung

**Table 1.** Gas content of biogas produced

<table>
<thead>
<tr>
<th>Substrate Yields (%)</th>
<th>Cumulative Methane CH₄ gas (%)</th>
<th>Cumulative CO₂ (%)</th>
<th>Cumulative CO (%)</th>
<th>Others (%)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (%) Cow dung</td>
<td>58</td>
<td>23</td>
<td>10</td>
<td>9</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 3. Total solid of cow dung substrate

**Conclusion**

This study investigated the effectiveness of cow dung for biogas production using domed shape biogas digester and presented the performance characteristics of the anaerobic digestion in batch and semi-continuous operation. Biogas (methane gas) yield of 58% was achieved. Also, the alkaline nature of cow dung helps in the growth of methanogenic bacteria responsible for the decomposition of the cow dung. pH variation and retention time affect the quantity of produced biogas.
References