Improvement Anaerobic Digestion performance of Sewage Sludge by Co-digestion with Cattle Manure

Raouf Hassan

Department of Civil Engineering, Faculty of Engineering, Aswan University, 81542 Aswan, Egypt; Contact: e-mail: eng_r_m@yahoo.com, tel.: 01120727227

Abstract. Biogas energy production from sewage sludge is an economically feasible and eco-friendly in nature. Sewage sludge is considered nutrient-rich substrates, but had lower values of carbon which consider an energy source for anaerobic bacteria. The lack or lower values of carbone-to-nitrogen ratio (C/N) reduced biogas yield and fermentation rate. Anaerobic co-digestion of sewage sludge offers several benefits over mono-digestion such as optimize nutrient balance, increased cost-efficiency and increased degradation rate. The high produced amounts of animal manures, which reach up to 90% of the total collected organic wastes, are recommended for the co-digestion with sewage sludge, especially with the limitations of industrial substrates. Moreover, cattle manures had high methane production potential (500 m³/t vSprod). When mixed with sewage sludge the potential methane production increased with increasing cattle manure content. In this paper, the effect of cattle manure (CM) addition as co-substrates on the sewage sludge (SS) anaerobic digestion performance was investigated under mesophilic conditions (35°C) using anaerobic batch reactors. The batch reactors were operated with a working volume 0.8 liter, and a hydraulic retention time of 30 days. The research work focus on studying pH values inside the reactors.

Keywords: Anaerobic digestion, Sewage sludge, Cattle manure, Mesophilic, pH.

1. INTRODUCTION

Sludge stabilization and utilization are a priority issue due to the high quantity generated and to the rigid legislation related to safeguarding human health and its environment (Mahvi, 2008). The existing wastewater treatment plants in Egypt produce an estimated quantity of dry sludge of 950 000 tons per year and are expected to increase to 2 million tons by 2020. At the same time, animals wastes increasing, the magnitude of the problem. The costs of the present methods of wastes disposal are increasing rapidly and without beneficial return (Baghapour et al., 2011, Zhao and Kugel, 1997). In recent times, the worldwide energy shortage has furthered consideration and improvement of such non-fossil sources of energy.

Biogas production of anaerobic digestion has been widely practiced, particularly with respect to digestion of sewage sludge organic waste. This invention relates to a process for improved methane production from anaerobic digestion (Rubia et al., 2005 and 2002). The methane in biogas can be burned to produce both heat and electricity. Anaerobic digestion has many economic and environmental benefits apart for those associated with energy production (Brooks et al., 2008 and Hutnan et al., 2001a, 2001b).

The purpose of the anaerobic process is to convert sludge to end products of liquid and gases while producing as little biomass as possible. The process is much more economical than aerobic digestion.

Anaerobic digestion process has been described by the following four steps:

1) Hydrolysis: large polymers are broken down by enzymes.
2) Acidogenic: are most important, acetate is the main end product. Volatile fatty acids are also produced along with carbon dioxide and hydrogen.
3) Acetogenesis: Breakdown of volatile acids to acetate and hydrogen.
4) Methanogenesis: Acetate, formaldehyde, hydrogen and carbon dioxide are converted to methane and water.

Co-digestion is considering a good solution, which composting different wastes types, by this way the treatment cost is reduce, moreover increasing of biogas yield (Álvarez and Liden 2000; Lehtomäki et al., 2007; Álvarez et al., 2010; Kangle et al., 2012).

The objective of this work was to study the production of methane by the anaerobic co-digestion of sludge and animals wastes. The effect of adding cattle manure is conducted in the stability of digester in term of pH, and also in the operation efficiency as biogas yield.

2. MATERIALS AND METHODS

2.1. Collection of substrates and inoculums

Sewage sludge taken from a full scale municipal wastewater treatment plant operated on the activated sludge method, and cattle manure was collected at a
farm in the rural area. The samples were received in one batch, mixed thoroughly and distributed in a 5.0 liter plastic bottle. It was kept at −20 °C for the whole period of experiment. The frozen samples were thawed and kept at 4 °C for 2–3 days before use. Pervious fermentation anaerobically treated sewage sludge was used as inoculums. The characteristics of substrates were analyzed as shown in Table 1.

Table 1: Characteristics of sewage sludge and cattle manure

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sewage sludge</th>
<th>Cattle manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.32</td>
<td>8.11</td>
</tr>
<tr>
<td>TS (%)</td>
<td>4.80</td>
<td>16.85</td>
</tr>
<tr>
<td>VS (%)</td>
<td>3.60</td>
<td>13.92</td>
</tr>
<tr>
<td>VS/TS</td>
<td>0.75</td>
<td>0.83</td>
</tr>
<tr>
<td>Carbon, C (% TS)</td>
<td>37.62</td>
<td>27.30</td>
</tr>
<tr>
<td>Nitrogen, N (% TS)</td>
<td>4.85</td>
<td>4.90</td>
</tr>
<tr>
<td>C/N ratio</td>
<td>7.76</td>
<td>5.57</td>
</tr>
</tbody>
</table>

2.2. Batch experiments

According to (Igoni et al., 2008), there are different types of reactors used for biogas recovery from wastes co-digestion, including batch reactors, which are commonly preferred in the world due their easier and simpler designs and low investment cost. In batch reactors, wastes are fed into the system and all the degradation steps are allowed to follow sequentially. Batch experiments were performed in a glass bottle with total and working volumes equal to 1.0 and 0.8 liter respectively. Digesters were maintained at a constant temperature of (35 ± 1 °C) by placing in the heating bath. Their content was mixed periodically by using magnetic mixer (300 rpm). The system of experiments set-up is shown in Figure 2.

The digestion was carried out for sewage sludge exclusively (R1 – blank sample) as well as co-digestion with the cattle manure. In co-digestion, the amount of sewage sludge in each digester was kept constant (8.25 g-VS/L), while varying the amount of cattle manure added of digestion R2, R3, R4 as 6, 4, and 2 g-VS/L respectively. In digestion R5, cattle manure was designed alone at the load of 6 g-VS/L. The characteristics of the different experiments are shown in Table 2.
After set-up the reactors were flushed for two minutes with pure nitrogen ($N_2$) to ensure anaerobic environment in the head space of the batches.

2.3. Measurements and analyses

Both quantitative and qualitative analyses of the biogas produced were carried out during the experiment. Biogas was collected by water displacement method and the volume was calculated daily and stopped after biogas was insignificantly produced. The produced biogas was passed through a glass bottle contain 5% NaOH solution before collecting and measuring the volume in order to remove CO$_2$ (Wellinger and Lindberg, 1999). The biogas samples were taken by using 0.1 ml glass syringe at two positions as shown in Figure 2. The first position is at the top of the digester to give the total volume of gas production. The second one is from the top of the bottle of NaOH solution in order to know the volume of methane (after the absorption of CO$_2$). Biogas samples periodically were examined by gas chromatography to determine the CH$_4$ and CO$_2$ content.

The pH, Total solids (TS) and volatile solids (VS) of sewage sludge and cattle manure samples were determined according to standard methods (APHA, 1998).

### 3. RESULTS AND DISCUSSIONS

#### 3.1. The pH within the digester

The production of biogas is depended on the optimum biodegradation process. pH is a process parameter which plays an important role in the anaerobic process, that affected the growth of microorganisms worked in organic degradation anaerobically. Bacteria actively work in the range of specific pH and shows maximum activity in the optimum pH. The optimum pH needed by acidogenic bacteria is in 5-6.5, whereas the optimum pH for methanogenesis bacteria is higher than 6.5 (Igoni et al., 2008).

Figure 3 shows the variation in pH within the digester during the process. The acidity of the digester tends to decreased from the first 12 days from pH of 6.9 to 5.8 and rose again to neutral condition. This result shows that the digester worked mostly in pH value lower than the optimum pH for anaerobic digestion process (6.8-7.4). The decrease of pH represented that there was acid accumulation caused mostly by high concentration of volatile fatty acid in the digester. When the acidogenic bacteria have worked, the organic acid was produced and decreased the digester pH (Igoni et al., 2008).

![Fig. 3: The pH values within the digester during anaerobic process.](image-url)
The stable and neutral pH was not easy to reach within the digester. By decreasing of pH value, both the methane production rate and the overall anaerobic digestion process are reducing. Basically, the optimum pH should be maintained in the anaerobic digestion process, which is the optimum range for methanogens growth. If the pH could not be controlled, the appearance of volatile organic acid and carbonic acid will increased the acidity of digester.

4. CONCLUSION

Anaerobic co-digestion of sewage sludge and cattle manure could enhance the biogas production and the methane yield. Addition of cattle manure enhanced the buffer capacity in the digesters, allowing high organic loads in batch digestion with pH control.

REFERENCES


Journal of Agricultural Science and Research 2: 53-60.