The effect of temperature on biogas production by co-digestion of cattle manure with poultry manure and cheese whey

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ABSTRACT

In this study effect of temperature on biogas production from co-digestion of cattle manure is evaluated. For this purpose glass bottles with 1 liter volume was used as reactors. Reactors was fed with %50 cattle manure and %50 other substrates at different mixing ratios. Agitated water baths was used to heat the reactor at specified temperatures. The study was carried out at batch mode and at 30 days hydrolc retention time (HRT). 10 set reactor was studied at the same time and reactors was studied at mesophilic (38±2 °C) conditions and thermophilic conditions (50±2 °C). Results showed that more biogas production was obtained by co-digestion of cattle manure with poultry manure and cheese whey at thermophilic conditions. However the highest methane content of biogas was obtained at thermophilic conditions.

Keywords: Biogas, Cattle Manure, Co-digestion, Temperature
1. INTRODUCTION

The use of fossil fuels as energy sources affects people and the environment in a negative way and also fossil fuel sources are exhaustible resources. Therefore, the use of renewable energy sources increasing. Biogas is one of the most used renewable energy sources. Biogas is a byproduct of anaerobic digestion process that mainly consist of 60% methane, 40% carbon dioxide, hydrogen sulphide, trace gas compounds and vapor [1]. Biogas production with anaerobic process is a useful process that provides energy production while also providing waste disposal. And almost all wastes with organic matter content can be used for biogas production. There are many studies about biogas that used different substrates to biogas produce. But recent studies aim to enhance the biogas production from available substrates and there are many methods. For this purpose, one of the most using method is co-digestion of substrates. Co-digestion is anaerobic digestion of two or more substrates at the same time to overcome of disadvantages that mono-digestions of substrates [2]. Anaerobic co-digestion of different substrates provides some benefits, increase biogas production and methane yield, utilise new substrates, increase organic loading rate, more appropriate carbon to nutrient ratio, dilute inhibitors or toxic compounds [3–6].

Poultry manure and cheese whey are problematic substrates for anaerobic digestion because of their organic matter contents. Poultry manure has high nitrogen compounds content, low C/N ratio and high total solids content [7,8]. Cheese whey has easily biodegradable organic matter content this cause rapid acidification that drop in pH and cause VFA accumulation so can failure anaerobic digestion [9–11]. All of this problems of substrates can be solved with co-digestion at proper operational conditions and mixing ratios.

In this study effect of temperature on biogas production by co-digestion of cattle manure with poultry manure and cheese whey was investigated. For this purpose, cattle manure and other substrates were mixed at different ratios and biogas productions were observed for 30 days at mesophilic (38±2 °C) conditions and thermophilic conditions (50±2 °C).

2. MATERIAL AND METHODS

2.1. Substrates

Cattle manure was taken from a slaughterhouse, poultry manure was taken from a chicken farm that produces eggs and cheese whey was taken from a dairy. All the substrates were taken fresh and used fresh. In all experiments inoculum was used that taken from pilot scale biogas plant at Karabük University Biogas Research Laboratory. Biogas plant has a digester with 6 m³ volume and cattle manure is used to produce biogas at mesophilic temperatures.
2.2. Experimental setup

In all experiments glass bottles with 1 litre volume was used as reactor. All reactors were covered with aluminium foil to prevent from the light and agitated water bath was used to heat the reactors (Figure 1).

Reactors were loaded with 50% cattle manure and 50% other wastes. Cattle manure ratio was kept constant at 50% and other wastes was loaded at different ratios (Table 1). All reactors were studied at batch conditions and inoculum was added to all reactors to shorten the methane production period. Pure nitrogen gas was passed through all the reactors in order to provide the anaerobic environment completely in the reactor media.

Table 1. Reactor mixing ratios

<table>
<thead>
<tr>
<th>Reactors</th>
<th>Cattle Manure (%)</th>
<th>Poultry Manure (%)</th>
<th>Cheese Whey (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R2</td>
<td>50</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>R3</td>
<td>50</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>
3. RESULTS AND DISCUSSION

The reactors R2 and R3 were fed according to the substrate mixture ratios given in the Table 1 and digested at mesophilic and thermophilic conditions simultaneously. Also only cattle manure was digested in mesophilic and thermophilic conditions in order to compare the results. Reactors operated in mesophilic conditions are named R(1), reactors operated in thermophilic conditions are named R(2).

After 30 days HRT daily and total biogas productions and comparison of R2 and R3 with R1 are given at Figure 2-5. At first days of study, biogas production rate at R2 was similar with R1 but after 5 days, biogas production of R2 at 50 °C was completely stopped and biogas production could not be observed. Biogas production of R2 at 38 °C was slowed down after 9 days. After reduction of biogas production, pH measurements were done at all reactors and pH adjustment was done by using NaOH (Table 2).

![Figure 2](image-url)

**Figure 2.** Comparison of daily biogas productions of R1 and R2 at mesophilic and thermophilic conditions

No increase in the biogas production of R2(1) and R2(2) was observed after PH adjustment while the biogas production of R1(1) and R1(2) was increased. After 20 days although not too much, some biogas production was observed at both R2(1) and R2(2). Average daily biogas productions of R2(1) and R2(2) were 49.7 ml/L.d and 47.7 ml/L.d and total biogas production were 1547 ml and 1541.9 ml, respectively. Biogas yields were obtained as 221.7 ml/gVS and 201 ml/gVS and the methane content of biogas was obtained as 47.2 % and 46.3 % from R2(1) and R2(2), respectively.
The daily biogas productions of R1(1) and R1(2) were 107,3 ml/L.d and 116 ml/L.d and total biogas productions were 3222,6 ml and 3506 ml, respectively. Biogas yields of R1(1) and R1(2) was 261,2 ml/gVS and 298,4 ml/gVS and the methane content of biogas was obtained as 52,8 % and 51,6 %.

Table 2. pH changes of reactors

<table>
<thead>
<tr>
<th>Reactor</th>
<th>Initial pH</th>
<th>pH at 10th day</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1(1)</td>
<td>7,99</td>
<td>6,14</td>
</tr>
<tr>
<td>R1(2)</td>
<td>7,84</td>
<td>5,94</td>
</tr>
<tr>
<td>R2(1)</td>
<td>6,55</td>
<td>4,51</td>
</tr>
<tr>
<td>R2(2)</td>
<td>6,51</td>
<td>4,48</td>
</tr>
<tr>
<td>R3(1)</td>
<td>7,07</td>
<td>5,83</td>
</tr>
<tr>
<td>R3(2)</td>
<td>7,16</td>
<td>5,54</td>
</tr>
</tbody>
</table>

Figure 3. Comparison of total biogas productions of R1 and R2 at mesophilic and thermophilic conditions
The biogas production rates at R3(1) and R3(2) were very similar to each other. Biogas production rates of R3(1) and R3(2) were almost stable and sudden ups and downs were not observed. The pH adjustment was also done to R3(1) and R3(2) because of the pH drop. The biogas production rates at R1(1), R1(2) and R3(1) were very close 10 days after pH adjustment but the biogas production rate was the highest at R3(2). Average daily biogas production rates were 136.7 ml/L.d and 163 ml/L.d and total biogas productions were 3952.1 ml and 4499.8 ml at R3(1) and R3(2), respectively. Biogas yields were obtained as 460.2 ml/gVS and 508.27 ml/gVS and the methane content of biogas was obtained as 72.3 % and 75.6 % from R3(1) and R3(2), respectively.
4. CONCLUSION

It was observed that the temperature in the anaerobic fermentation of the R2, which has high whey content and low poultry manure content, does not have much effect on biogas production. Also it was observed that biogas yield of R2 was approximately 15% less at mesophilic conditions and %32 less at thermophilic conditions than R1. However, the highest biogas production rate, the highest biogas yield and highest methane content of biogas were obtained at R3, both mesophilic and thermophilic conditions. When compared to the control reactors, it was observed that biogas yields were 43% higher at mesophilic conditions and 41% higher at thermophilic conditions. The highest methane content was observed at R3(2) at thermophilic conditions. Results showed that, co-digestion of cattle manure with poultry manure and cheese whey is applicable at thermophilic conditions and low cheese whey contents.

REFERENCES


