Kinetics of volatile fatty acids and hydrogen production during anaerobic digestion of organic waste material

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Abstract. This short paper describes the changes in VFA and hydrogen production in time, during an anaerobic microbial digestion where the organic waste material was given as a substrate. The experiment showed that the reaction ran most efficiently between 6 and 10th hour of the reaction time. This can be an indicator for future experiments on VFA and hydrogen production optimisation.

Keywords: biopolymers, anaerobic digestion, VFA, hydrogen.

Introduction

Every year the disposal of municipal solid wastes (MSW) creates serious environmental and economic problems, especially in fast developing countries. These problems, together with price increases and supply disturbances affecting petroleum products and natural gas, have led to research into alternative fuel sources. One of the biotechnologies recently developed to utilize the organic fraction of MSW for useful energy and materials recovery is anaerobic digestion [1]. The organic compounds are decomposed in a microbial chain to volatile fatty acids (VFA) as a first stage and then, in a second stage, the acids are decomposed to methane and carbon dioxide. These acids could be used to produce biogas in a second stage of anaerobic digestion (two-phase anaerobic digestion) [2]. In addition to that, under anaerobic conditions, hydrogen is produced as a by-product during conversion of organic wastes into organic acids (first phase anaerobic digestion) [3]. Some photo-heterotrophic bacteria utilize organic acids such as acetic, lactic and butyric acids to produce H$_2$ and CO$_2$. The advantages of the later method are higher H$_2$ gas production and utilization of waste materials for the production. However, the rate of H$_2$ production is low and the technology for this process needs further development [4]. The fatty acids can also be utilized and polymerized into polyhydroxyalkanoate (PHA) by bacteria under unbalanced growth conditions such as nitrogen limitation. PHA is a type of promising thermoplastic material which may replace synthetic polymers such as polypropylene (PP), polyethylene (PE) and polystyrene (PS) for short-life applications because of their similar mechanical properties and true biodegradability of PHA in the environment. The main obstacle to PHA application is its high production cost [5]. Production of PHA from organic wastes may significantly reduce the production cost because of the negative raw material cost and less sludge produced when it is integrated into a biological waste treatment system [6].

The aim of this work was to examine the kinetics of VFA and hydrogen production in time, during anaerobic degradation of the organic waste material. This is to find out the conditions for the VFA production to be served as a substrate for biodegradable polymers.

Materials and Methods

Substrate used in this experiment was the expired food. As the inoculum it was served the digested sludge from the local wastewater treatment plant. The experiment was conducted under anaerobic conditions in the temperature of 37°C for 24 hours. During that period samples were taken and the amount of VFA, the pH, total organic carbon, total solids, total volatile solids and gases (CH$_4$, CO$_2$, H$_2$) was monitored. Two sets of the experiment were done: 1. only with the sludge and 2. sludge + 8.8 g dry weight/L of a substrate. Each was performed in duplicate and the average data was then discussed.

Results and Conclusions

In current paper the data of VFA and gas analysis will be presented.

To measure the fluctuation of VFA in time, samples were taken every 3 hours, e.g.: at 0h, 3h, 6h, 9h, 12h and after 24 hours. Collected data are shown in Table 1.

Table 1: Total Volatile Fatty Acids amount produced in two different sets of the experiment at various experimental time. Set 1: no added substrate and set 2: 8.8 g/L OFMSW was added at 0h.

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>Set 1 (mgCH$_3$COOH/dm$^3$)</th>
<th>Set 2 (mgCH$_3$COOH/dm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1284</td>
<td>1410</td>
</tr>
<tr>
<td>3</td>
<td>1368</td>
<td>1548</td>
</tr>
<tr>
<td>6</td>
<td>1548</td>
<td>1680</td>
</tr>
<tr>
<td>9</td>
<td>1332</td>
<td>1486</td>
</tr>
<tr>
<td>12</td>
<td>1020</td>
<td>1296</td>
</tr>
<tr>
<td>24</td>
<td>5604</td>
<td>5604</td>
</tr>
</tbody>
</table>

The numbers clearly show that in both series the amount of VFA is raising along with the duration of the experiment. Nevertheless, the second set represents higher VFA concentrations, reaching up to 5605 mgCH$_3$COOH/dm$^3$ after 24 hours of the reaction, which is almost three times more than the amount detected at the same time in the first set of the experiment. This observation confirms that the addition of organic material to the samples containing the inoculum (sludge) is very important in the matter of VFA microbial production. Obtained data allow the evaluation of the actual VFA production reached after the microbial digestion of organic wastes.

Second parameter measured in the current experiment was the production of gases: CH$_4$, CO$_2$, H$_2$ during the reaction time. Figure 1. shows that there was no production of gases in
the first experimental set, where no substrate was added. In the second set, $H_2$ and $CO_2$ were detected, whereas $CH_4$ was not produced. This observation confirms that most active at the first hours of the fermentation are acetogenic bacteria and methanogens activity is stopped at that ‘early’ stage. In the scope of volatile fatty acids production, presented analysis show that crucial is whole 24-hour period of the experiment, whereas hydrogen is most dynamically produced up to the 10th hour of the anaerobic reaction.

![Figure 1: Gas fluxes (CH$_4$, CO$_2$ and H$_2$) measured at different reaction time, e.g. after 0h, 6h, 9h, 24h in both series of the experiment.](image)

**BIBLIOGRAPHY**


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