**SUMMARY**

Anaerobic digestion tests were performed to evaluate the biogas potential of different waste streams from two different bioethanol process configurations. The initial substrate, wheat straw was in both configurations pre-treated with acetic acid. Biogas potential for different waste streams, separately and co-digested, different biogas process temperatures, co-digestion with other external substrate (food waste) were assessed. Results show that in general the ethanol residues have substantial methane potentials, but the resulting amounts are varying depending on the different process steps preceding the biogas step.

**INTRODUCTION**

This project focuses on bio-ethanol and biogas production from 2\textsuperscript{nd} generation feedstocks (i.e. lignocellulosic materials such as wood or straw). The focus of the study was wheat straw-based bio-ethanol production and the waste streams of interest are marked as substrate 1-5 in the process scheme (Fig. 1). Two different process configurations are possible; either fermentation of the whole slurry or fermentation of the solid fraction only, where the liquid fraction goes directly to a treatment system of some sort. Biogas potentials of waste streams were assessed.

**Figure 1.** Scheme of the bioethanol process with substrates for biogas production marked as Substrates 1-5.
METHOD

The work included lab-scale pre-treatment (with acetic acid) and processing of wheat straw according to the scheme in Figure 1 to establish the Substrates 1-5. Characterization of substrates concerning organic content, eventual inhibiting substances and content of nutrients was done by HPLC analysis, spectro-photometrical analyses and other standardized methods. Anaerobic digestion tests including separate digestion of waste streams, digestion at different temperatures (mesophilic and thermophilic) as well as co-digestion with food waste were performed according to the BMP-method (Fig. 2) described in Hansen et al (2003).

RESULTS

Previous to the initial anaerobic tests, the following parameters were analyzed on substrate 1-5 : TS, VS, Ntot, Ptot, NH₄-N, TOC, COD, pH, VFA (acetic+ propionic acid) and alkalinity. Additionally, the usual bioethanol production parameters were provided by HPLC measurement: cellobiose, glucose, XyGaMa, arabinose, lactic acid, glycerol, formic acid, acetic acid, ethanol, HMF (hydroxymethyl furfural) and furfural. The most interesting results are found in Table 1 and Figure 3. The results show that the waste streams contains a lot of water (88-97%). The organic content in terms of VS is varying from 70-97% and that the nitrogen content in some streams (1-3) and phosphorus content in one (3) are rather low and might lead to lack of nutrients in the anaerobic digestion process. The optimal nutrient relation for the anaerobic digestion process is 250:5:1 (COD:N:P) (Henze & Harremoes, 1983).

![Figure 2. 2-litres-reactors used for anaerobic digestion tests](image)

**Table 1. Substrate characteristics**

<table>
<thead>
<tr>
<th>Substrate</th>
<th>pH</th>
<th>COD (mg/l)</th>
<th>TOC (mg/l)</th>
<th>NH₄-N (mg/l)</th>
<th>Ntot (mg/l)</th>
<th>Ptot (mg/l)</th>
<th>TS (%)</th>
<th>VS (% av TS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5,04</td>
<td>166400</td>
<td>50200</td>
<td>133</td>
<td>560</td>
<td>249</td>
<td>12</td>
<td>89%</td>
</tr>
<tr>
<td>2</td>
<td>5,02</td>
<td>63500</td>
<td>21800</td>
<td>96</td>
<td>288</td>
<td>162</td>
<td>6,1</td>
<td>70%</td>
</tr>
<tr>
<td>3</td>
<td>3,47</td>
<td>79600</td>
<td>29000</td>
<td>26</td>
<td>196</td>
<td>44</td>
<td>6,2</td>
<td>97%</td>
</tr>
<tr>
<td>4</td>
<td>4,89</td>
<td>101800</td>
<td>33000</td>
<td>48</td>
<td>700</td>
<td>202</td>
<td>6,9</td>
<td>87%</td>
</tr>
<tr>
<td>5</td>
<td>4,96</td>
<td>30400</td>
<td>10100</td>
<td>12</td>
<td>161</td>
<td>104</td>
<td>2,6</td>
<td>71%</td>
</tr>
</tbody>
</table>

Abbreviations : COD= Chemical Oxygen Demand ; TOC=Total Organic Carbon ; TS=Total Solids ; VS=Volatile Solids (ignition loss)
Methane potential tests were prepared with the aim of determining the methane potential of the waste streams present and evaluating possible inhibitory problems and/or nutrient deficiency that could disturb biogas production. The substrates were tested individually and substrate 3 was also combined with 4 and 5 to investigate any potential co-digestion effects. The results show significant methane potentials in most of the waste streams, but also that there are some differences, see Figure 4. The combinations of waste streams 3+4 and 3+5 gave reasonable methane production, but no additional co-digestion effect was seen. Digestion at different temperatures (Figure 5) resulted in about the same methane potentials for both substrates tested (1 and 2), with slightly higher potential for substrate 2 at thermophilic temperature. Co-digestion of Substrate 3 together with food waste (source separated and pre-treated food waste originating from households) was assessed and resulted in a methane potential that corresponded to the expected value from calculations (based on single-substrate digestion of food waste and Substrate 3 respectively).

Figure 4. Methane potential for substrates 1-5 and combinations (3+4 and 3+5), 50:50 on VS-basis, in mesophilic digestion for 45 days.

Figure 5. Methane potential for substrates 1 and 2 in both mesophilic and thermophilic digestion for 48 days.
CONCLUSIONS

- Significant but varying amounts of biogas production from bioethanol waste streams were seen. Some solids are not degraded in anaerobic digestion. Therefore lower potential was seen from unfiltered substrates 1 and 4.
- Co-digestion of substrates generated in Case 2 (separation before SSF) resulted in lower biogas production than expected.
- Both mesophilic and thermophilic digestion were successful for substrates 1 and 2.
- Digestion of Substrate 2 (liquid phase) resulted in slightly higher methane production at thermophilic temperature.
- Thermophilic digestion could be favourable since the bioethanol process involves high temperatures.
- Co-digestion of bioethanol residue (Substrate 3) and food waste slurry was successful and resulted in the same methane potential as expected from calculations.
- Considering the fact that the optimal nutrient relation for the anaerobic digestion process is 250:5:1 (COD:N:P), bioethanol residues should be co-digested with nitrogen rich substrates to avoid nutrient deficiency.

ACKNOWLEDGMENTS

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REFERENCES
