Abstract template for 3rd IBBA workshop, in Malmö, Sweden, September 10th 2015.

Co-digestion of sewage sludge and municipal biowaste with thermal hydrolysis pre-treatment.

Mats Edström

1. Introduction

The city of Växjö

The city of Växjö is working to develop sustainable technical solutions for reduction of greenhouse gases and efficient management of waste and sludge. Due to that, Växjö’s waste water treatment plant (WWTP) Sundet started to co-digest sewage sludge and municipal biowaste (called “food waste” in this abstract, due to that is mostly containing source sorted food waste from households) for a couple of year ago. The quantities of digested food waste at Sundet have increased the last couple of years and have during some periods contributing with approx. 50% of the biogas production. The gas production has periodically (average during a month) in year 2013 reach 3600 m$^3$ CH$_4$/day [1]. The digesters (total active volume of 3400 m$^3$ operated at 37 °C) had then a substrate inflow of 175 ton/d, hydraulic retention time of 19 days, an organic load exceeding 3 kg VS/m$^3$&d and a volumetric gas production of 1.1 m$^3$ CH$_4$/m$^3$ digester volume and day, which is double the average volumetric methane production at Swedish WWTP [2]. Växjö’s estimation was that the plant Sundet had reached it maximum biogas production capacity.

Växjö made an analysis of future prospect that showed that the digestion capacity was not large enough. The substrate for digestion year 2016 was estimated to increase to 203 ton/day and methane production of 3900 CH$_4$/d. The substrate for digestion would continue to increase and would year 2030 be 330 ton/d with a predicted gas production of 6900 m$^3$ CH$_4$/d. Further on, the judgement was that demand on improved hygienisation capacity soon would appear. When Växjö was planning to multiply the digester volume and improve the hygienisation capacity, Cambi offered a solution with thermal hydrolysis pre-treatment of the substrates before digestion. For Växjö, the concept fulfils the hygienisation requirement and increased digestion capacity without building new digesting volume.

The Cambi installation at Sundet has been in operation since late 2014. In the same time as the commissioning started, corrosion was discovered in Sundets two digesters. The repair work of the digester has delayed the tests of the evaluation of Cambi’s installation at Sundet. In September 2015 the last digester is repaired make normal operation possible again and the warranty evaluation of the Cambi installation can be started.

Thermal Hydrolysis

Cambis installation at Sundet includes:

- Centrifuge dewatering of sewage sludge at Sundet from approx. 6% DM to approx. 16% DM reducing sludge quantity from approx. 150 ton/day to less than 60 ton/day, resulting in
prolonged retention time in the digester.

- Co-treatment of dewatered sludge and food waste in Thermal Hydrolysis Process (THP) at 165 °C followed by rapid pressure drop, resulting in cell destruction by steam explosion (www.cambi.com).

The THP treatment improves the biodegradability of the organic material [3]. According to Cambi, the centrifuge and THP installation together, makes it possible to more or less double the digesters volumetric methane production at Sundet WWTP.

2. Method

Digestion tests

The purpose of the digestion test was to investigate:

- the effect of THP treatment on substrates digested at the WWTP plant Sundet in laboratory CSTR processes.
- how difference in hydraulic retention time (HRT) effected the methane production.
- the process stability and microbiology

Process A is a reference process operated at organic loading rate (OLR) of 3 g VS/l&d (table 1) and represents the time at WWTP Sundet with maximum methane production before investment in Cambi technology. Process B digest the same substrate mixture as Process A, but at OLR of 5 g VS/l&d. Process B represent the future prospect of operation at Sundet, if no investment was realized to increase the plants digestion capacity. Process C operate with a THP treated substrate with higher DM due to pre-centrifugation of sewage sludge also with OLR of 5 g VS/l&d. Process D has approx. the same DM, HRT and OLR as process C but the substrate has not been treated in a THP.

In all 4 processes (table 1) sewage sludge is contributing with 67% of the dry matter content in the substrate mixture and food waste with 33%.

Table 1. Four CSTR digesters (A-D) with 5 L active volume operated at 37 °C.

<table>
<thead>
<tr>
<th>Process</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>THP</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>HRT</td>
<td>18</td>
<td>11</td>
<td>16</td>
<td>17</td>
<td>Days</td>
</tr>
<tr>
<td>DM</td>
<td>6.5</td>
<td>6.5</td>
<td>9.4</td>
<td>10.0</td>
<td>%</td>
</tr>
<tr>
<td>OLR</td>
<td>3.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>g VS/l&amp;d</td>
</tr>
</tbody>
</table>

Heat demand calculation

The heat demand (E) calculations, connected to Cambi’s thermal hydrolys, is prepared by JTI is simplified and based on the general thermo-dynamic equation: E=m*c_p*△t.

m is the mass of substrate
c_p-water: 4.2 kJ/kg °C
c_p-dry matter: 1.6 kJ/kg °C
△t is the temperature rise.

3. Results

Digestion tests

The process C with Cambi THP-treated substrate had a specific methane production of 417 l CH_4/kg VS (see table 2). Compared with the other processes the specific methane production was approx. 15 % higher.

Table 2. Four CSTR digesters (A-D) operated according to table 1. Spec. CH_4 means specific methane production. Vol CH_4 means volumetric methane production.

<table>
<thead>
<tr>
<th>Process</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>THP</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>HRT</td>
<td>18</td>
<td>11</td>
<td>16</td>
<td>17</td>
<td>Days</td>
</tr>
<tr>
<td>Spec. CH_4</td>
<td>366</td>
<td>360</td>
<td>417</td>
<td>365</td>
<td>L/kgVS</td>
</tr>
<tr>
<td>Vol. CH_4</td>
<td>1.14</td>
<td>1.80</td>
<td>2.08</td>
<td>1.83</td>
<td>L/L&amp;d</td>
</tr>
</tbody>
</table>

In table 2, the stated methane production is measured at 22 °C and at 1 atm. Further
on, the VS in substrate is given without compensation of VFA content in substrate mixture, analysing VS.

**Heat demand calculation**
The heat demand has been calculated for two cases:
- Business As Usual (B.A.U.) year 2016 digesting 203 ton substrate/day (13.9 ton DM/day) with an estimate production of 3900 m$^3$ CH$_4$/day (38 MWh/year). The total substrate flow is pasteurised at 70 °C.
- Cambi year 2016 digesting 96 ton substrate/day (also 13.9 ton DM/day) with an estimate production of 4500-5000 m$^3$ CH$_4$/day (44-49 MWh/year). The total substrate flow is heat-treated at 165 °C.

### Table 3. Heat demand for the two cases.

<table>
<thead>
<tr>
<th>Process</th>
<th>B.A.U.</th>
<th>Cambi</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate</td>
<td>203</td>
<td>95.8</td>
<td>ton/d</td>
</tr>
<tr>
<td>Δt</td>
<td>10-&gt;70</td>
<td>97-&gt;165</td>
<td>°C</td>
</tr>
<tr>
<td>Heat demand, substrate</td>
<td>13.6</td>
<td>6.92</td>
<td>MWh/d</td>
</tr>
<tr>
<td>Hot water by the boiler$^x$</td>
<td>-</td>
<td>15.3</td>
<td>ton/d</td>
</tr>
<tr>
<td>Δt</td>
<td>-</td>
<td>10-&gt;165</td>
<td>°C</td>
</tr>
<tr>
<td>Heat demand, hot water</td>
<td>0</td>
<td>2.77</td>
<td>MWh/d</td>
</tr>
<tr>
<td>Total heat demand</td>
<td>13.6$^z$</td>
<td>9.69</td>
<td>MWh/d</td>
</tr>
</tbody>
</table>

$^x$ The inflow to the reactor tank including recovered steam flow from flash tank. After steam recovery, the temperature in this mixture is 97 °C.

$^z$ This is the heat demand excluding heat recovery by heat recovery.

$^w$ The steam boiler provides the total external heat demand calculated to 9.69 MWh/d to the THP. The boiler uses wood pellets as fuel.

The repairing of Sundets both digesters has resulted in rather large variation in operation parameters, difficult to evaluate. Hopefully it’s possible to verify the actual heat demand at the Sundet during this fall before the project deadline.

### 5. Conclusions and remarks
- The laboratory digestion tests resulted in 15% higher specific methane production with a Cambi THP treated substrate mixture.
- Extended HRT for digestion process without thermal hydrolysis, by increased DM in substrate mixture (Process D), did not result in a higher specific methane production.
- Process B without heat pretreated operated at 5 g VS/l&d OLR and 11 days HRT was remarkable robust.
- Thermal hydrolysis seems to be a rather energy competitiveness pretreatment method, compared with traditional hygienisation at 70 °C. Key factor: a) the reduction of sludge amount & b) the steam recovery from flash tank preheating the next batch in the pulper tank to approx. 97 °C.
- The project also includes 2 additional CSTR- processes and more than 20 BMP-tests.

The evaluation project is a joint activity between SLU (Anna Schnürer, project leader) and JTI (Maria del Pilar Castillo, Johnny Ascue, Gustav Rogstrand & Mats Edström). The project is co-financed by The Swedish Energy Agency, The Swedish Water & Wastewater Association, Växjö, Cambi AS, SLU and JTI.

### 6. References