ANAEROBIC DIGESTION
FOR CLOSING THE LOOP OF A
BIOREFINERY FOR ORGANIC FARMING:
PRODUCTION OF BIOGAS AND ORGANIC
FERTILIZER FROM PROCESS RESIDUES

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AD and fertilizer of residues from Organofinery

Outline

• Organofinery – a green biorefinery concept for organic farming.
• Biogas production from residues – press cake and brown juice.
• Batch tests of press cake and brown juice.
• Co-digestion reactor tests press cake + brown juice.
• UASB reactor for mono-digestion of brown juice.
• Nutrient balance for mechanical fractionation and biogas process.
• Conclusions.
The OrganoFinery - From organic green biomass to protein feed, energy and fertilizer

**GREEN BIOMASS** → **Screw press** → **GREEN JUICE** → **Fermentation 38°C LAB**

**PRESS CAKE** → **Separation**

**ORGANIC PROTEIN CONCENTRATE** → **Biogas plant** → **BROWN JUICE** → **ORGANIC FERTILIZER** → **BIOGAS**

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Batch tests of press cake and brown juice

Methane yield in different mixture ratios

- Brown juice
- 15PC:85BJ
- 30PC:70BJ
- 50PC:50BJ
- Press cake
CSTR reactor tests

Press cake and co-digestion of press cake and brown juice

- Co-digestion press cake and brown juice
- Press cake alone

Methane yield (mL-CH4/gVS) vs. Time (days)
UASB reactor – Mono-digestion of brown juice

Brown juice, mesophilic (37°C), pH adjusted, HRT: 1-3 days

- Methane Yield
- Average Methane Yield
- OLR
- Average OLR

Time (days)

Methane Yield (LCH₄ KgCOD⁻¹)

OLR (gCODL⁻¹d⁻¹)
Main results for biogas production

**Press cake (PC)**

- Batch tests (mesophilic, after 38d)
  - Methane yield was 307 mL-CH$_4$/g-VS.

**Brown juice (BJ)**

- Batch tests (mesophilic, after 38d)
  - Methane yield was 456 mL-CH$_4$/g-VS.

**Co-digestion PC + BJ**

- Batch tests (mesophilic, after 38d)
  - Methane yield was 426 mL-CH$_4$/g-VS for the 15%PC:85%BJ mix.

**Reactor tests**

- CSTR, HRT = 20d, TS-adjusted by H$_2$O
  - Stable process
  - Average methane yield was 202 mL-CH$_4$/g-VS.

- UASB, HRT = 3d, pH-adjusted
  - Stable process
  - Average methane yield was 307 mL-CH$_4$/g-VS.

- CSTR, HRT = 20d, no adjustment
  - Stable process
  - Average methane yield was 236 mL-CH$_4$/g-VS.
Nutrient recovery in press cake and brown juice

After mechanical fractionation
Nutrient conc. x mass of PC/BJ

<table>
<thead>
<tr>
<th></th>
<th>Press cake</th>
<th>Brown juice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>% of input</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Red clover</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>52%</td>
<td>15%</td>
</tr>
<tr>
<td>P</td>
<td>53%</td>
<td>30%</td>
</tr>
<tr>
<td>K</td>
<td>43%</td>
<td>38%</td>
</tr>
<tr>
<td>S</td>
<td>52%</td>
<td>13%</td>
</tr>
<tr>
<td><strong>Clover grass</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>60%</td>
<td>11%</td>
</tr>
<tr>
<td>P</td>
<td>56%</td>
<td>27%</td>
</tr>
<tr>
<td>K</td>
<td>39%</td>
<td>31%</td>
</tr>
<tr>
<td>S</td>
<td>55%</td>
<td>26%</td>
</tr>
</tbody>
</table>
Nutrient recovery in press cake and brown juice

Before and after AD process
Co-digestion PC+BJ, or BJ alone

<table>
<thead>
<tr>
<th></th>
<th>AD digestate</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg</td>
<td>% of input</td>
<td></td>
</tr>
<tr>
<td><strong>Co-digestion PC+BJ, CSTR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>3.42</td>
<td>94%</td>
<td></td>
</tr>
<tr>
<td>NH$_4^+$</td>
<td>2.11</td>
<td>62% of N</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>1.35</td>
<td>&gt;100%</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>3.96</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.52</td>
<td>&gt;100%</td>
<td></td>
</tr>
<tr>
<td><strong>Mono-digestion BJ, UASB</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>0.39</td>
<td>68%</td>
<td></td>
</tr>
<tr>
<td>NH$_4^+$</td>
<td>0.06</td>
<td>16% of N</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.11</td>
<td>59%</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>2.03</td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.06</td>
<td>56%</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

**Biogas production from residues PC and BJ:**

- **42-68%** of the biogas potential is recovered in the **PC** while only **10-15%** is recovered in the **BJ**.

- Both **co-digestion of PC+BJ** and **mono-digestion of BJ** in UASB showed stable process performance.

- **Co-digestion of PC+BJ** in the ratio coming from the fractionation **does not need** pH, nutrient or TS adjustment.

**Nutrient recovery:**

- **52-60%** of **N, P, S** is recovered in **PC** and **11-30%** in **BJ** while **39-42%** of **K** is recovered in **PC** and **31-38%** in **BJ**.

- In the **co-digestion** process a **high share of** total-N is converted into **NH$_4^+$**, while this is only limited in the UASB process of **BJ**.

- **Nutrient conc. in digestate from mono-digestion of BJ** is **too low** for practical application on the field.
THANKS FOR YOUR ATTENTION