SENSE AND NO-SENSE OF PRETREATMENT FOR INCREASING BIOGAS YIELDS

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Pretreatment for increasing biogas production

Overview

• Lignocellulosic biomass resources for biogas production
  - where pretreatment may be relevant to increase biogas production

• Effects of biomass pretreatment

• Costs vs. benefits of pretreatment

• Different pretreatment methods

• Implementation of pretreatment
  - in combination with solid-liquid separation
  - before and after the biogas reactor

• Conclusions
Lignocellulosic biomass for biogas

- Manure
- Manure fibers
- Agricultural residues
- Organic fraction of municipal solid waste
- ...

Waste Biomass

BioGAS

Energy crops

- Maize
- Miscanthus
- Catch crops
- ...

Digestate
Biogas from straw – focus in DK

Seminar on straw for biogas 2 weeks ago:
Lignocellulosic biomass for biogas – potential in DK
Pretreatment for increasing the biogas yield

Effects:

1) **Biomass is easier to handle**
   -> smaller particle size, lower viscosity

2) Increasing the biodegradability by addition of cellulolytic activity
   -> **Higher conversion rate**

3) Increasing the release of cellulose and hemicellulose from lignin
   -> **Higher final methane yield**
Pretreatment for increasing the biogas yield

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Pretreatment for increasing the biogas yield – depending on biomass and desired product

Depending on the biomass

Depending on the desired product(s)

Manure → Manure separation → Fiber fraction → Pretreatment

Energy crops → Agricultural residues

Maize → Catch crops → Straw

Anaerob digestion

Bioethanol

Enzymatic hydrolysis

Fermentation

Downstream processing

Biochemicals
Costs vs. benefit of pretreatment

Limit of treatment costs depends on revenue from biogas production
Pretreatment methods for lignocellulosic biomass

- Physical/mechanical
  - Grinding, milling, maceration, ultrasound etc.

- Thermal
  - Steam explosion, Wet oxidation @ 150-180°C, +/- O₂

- Chemical
  - Addition of acid, base etc.

- Biological
  - Fungi, hydrolytic bacteria and their enzymes
Mechanical pretreatment/maceration

for increasing the biogas potential of manure fibers

Biogas Potential [lCH4/kgVS]

<table>
<thead>
<tr>
<th>Biogas Plant</th>
<th>before mac.</th>
<th>after mac.</th>
<th>after 2nd mac.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab-Mac.</td>
<td></td>
<td>+16%</td>
<td></td>
</tr>
<tr>
<td>Blåbjerg</td>
<td></td>
<td>+25%</td>
<td></td>
</tr>
<tr>
<td>Sinding</td>
<td></td>
<td>-5%</td>
<td></td>
</tr>
<tr>
<td>Snertinge</td>
<td></td>
<td>+24%</td>
<td></td>
</tr>
<tr>
<td>Studsgård</td>
<td></td>
<td>+23%</td>
<td></td>
</tr>
<tr>
<td>Thorsø</td>
<td></td>
<td>+5%</td>
<td></td>
</tr>
<tr>
<td>Århus N</td>
<td></td>
<td>+15%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+2%</td>
<td></td>
</tr>
</tbody>
</table>

Change of Biogas Potential

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Mechanical pretreatment/maceration
for increasing the biogas potential of manure fibers

Change in biogas potential after maceration (%)

Biogas potential of influent (L-CH$_4$/kg-VS)
Mechanical pretreatment/maceration for increasing the biogas potential of manure fibers
Mechanical pretreatment/maceration
for increasing the biogas potential of manure fibers
Dry matter concentration and pretreatment effect

Increase of biogas yield by pretreatment in combination with TS increase

- Wet explosion
- Pressure cooking
- Prolonged retention time
- Raw manure

Biogas yield (m$^3$ biogas/t) vs. %TS in concentrated manure

- 0.29 m$^3$CH$_4$/kg-VS$_{part}$
- 0.27 m$^3$CH$_4$/kg-VS$_{part}$
- 0.23 m$^3$CH$_4$/kg-VS$_{part}$
- 0.20 m$^3$CH$_4$/kg-VS$_{part}$
Pretreatment of raw manure and manure fibers

- Increasing the biogas yield by wet explosion

<table>
<thead>
<tr>
<th></th>
<th>Raw manure</th>
<th>Separated Manure fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cow</td>
<td>pig</td>
</tr>
<tr>
<td>Methane yield</td>
<td>287 587</td>
<td>286 125</td>
</tr>
<tr>
<td>(L-CH₄/kg-VS) before</td>
<td></td>
<td></td>
</tr>
<tr>
<td>after</td>
<td>362 426</td>
<td>256 177</td>
</tr>
<tr>
<td>increase</td>
<td>26%</td>
<td>-26%</td>
</tr>
</tbody>
</table>
Most efficient concept

- Pretreatment of the digested fiber fraction

**Manure**

- Mixing tank

**Biogas plant**

- BioGAS

- 35 m$^3$/ton$\text{feed}$

**Manure fibers**

- WEx treated digested fibers

- Wet explosion (WEx)

- 51 m$^3$/ton$\text{feed}$

- + WEX treatment

- 43 m$^3$/ton$\text{feed}$

- + recirculation

**Liquid fertilizer**

- Digested fiber fraction
Increasing the biogas production from manure

Pretreatment of the digested fiber fraction

• Wet explosion (WEX) @ 150-180°C, +/- O₂

• Reactor experiments:
  - Increase by factor 2.36
  - Increase by factor 1.72

• Batch tests:

⇒ Increase by factor 2.36

⇒ Increase by factor 1.72
Further optimization of the concept

The Re-injection loop (EU project BIOMAN)
Effect of enzyme addition on biogas yield

BMP of digested manure fibers (DMF) and of wheat straw (WS) with addition of enzymes
Increasing the biogas production from manure

Pretreatment of feedlot manure

• Wet explosion (WEX) @ 170ºC, 4 bar O₂, 25 min.
Conclusions (1)

The choice of the most suitable pretreatment for a viable concept depends on several factors:

• The **ADDITIONAL biogas yield** (or other benefits) have to be higher than CAPEC and OPEC of the pretreatment -> The increase in biogas yield by the pretreatment should be significantly higher than the variation in biogas yield of the biomass.

• It has to be distinguished if the pretreatment should just **increase the CONVERSION RATE or the FINAL YIELD** of the biogas production
  -> In the 1st case a larger reactor volume or a shift to thermophilic process operation may be just as effective
Conclusions (2)

The choice of the most suitable pretreatment for a viable concept depends on several factors:

• The **volume of the biomass to be pretreated should be reduced** as much as possible
  - For example by combination with solid-liquid separation

• The **pretreatment should be specifically applied only to the biomass (fractions), which actually needs pretreatment**
  - Specific pretreatment of biomass (fractions) with a high lignin content; treatment of the fiber fraction after the first digestion in a biogas plant

• **Economy of scale!** Pretreatment will be in most cases only feasible for large biogas plants