Effects of Pretreatment Technologies on Maize Straw for Biogas Production

Andreas Gronauer
Javier Lizasoain
Challenge for a technical implementation and management

- Crop cultivation
- Harvest
  - Main products: food, feed
  - Crop residues retrieval & size reduction
- Preservation & storage
- Preparation & pretreatment
- Fiber & fuel production

Sustainable soil management (humus)
- fertilizer
- crops
Challenge for a technical implementation and management

Harvesting technologies

- Adaptation of existing harvesting systems
- Short chopping lengths (compaction at the silo) or dried straw bales
- Avoidance of substrate contamination

Crop cultivation

Harvest

Main products

Crop residues retrieval & size reduction

Preservation & storage

Preparation & pretreatment

Fiber & fuel production

Sustainable soil management (humus)

Crop residues retrieval & size reduction

food, feed

fertilizer

crop residues retrieval & size reduction

food, feed

fertilizer

Sustainable soil management (humus)
Challenge for a technical implementation and management

Preservation and storage

Crop cultivation
Harvest

Main products
Crop residues retrieval & size reduction

food, feed
Preservation & storage

fertilizer
Preparation & pretreatment
Fiber & fuel production

Sustainable soil management (humus)
Challenge for a technical implementation and management

Preservation and storage

Maize straw ≠ Maize straw

- Highly dependent on biomass type, maturity, harvest time, etc.
- Ensiling or
- Storage as dry material
Ensiling:
- 28-45% DM → Early harvesting time → Post-drying corn grains
- Improvement of ensiling ability by combination with catch crops and green wastes
Ensiling:
- 28-45% DM → Early harvesting time → Post-drying corn grains
- Improvement of ensiling ability by combination with catch crops and green wastes

Dry storage:
- Low water content → later harvesting time
- Big storage volumes
- Strong lignification → need of pretreatment for biogas production
Challenge for a technical implementation and management

Pretreatment of biomass

Crop cultivation

Harvest

Main products

Crop residues retrieval & size reduction

Preservation & storage

Preparation & pretreatment

Fiber & fuel production

Sustainable soil management (humus)

food, feed

fertilizer

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Strong lignification prevents degradation of biomass

Additional process step (pretreatment) is necessary in the process chain
Challenge for a technical implementation and management

Pretreatment: background I

- Strong lignification prevents degradation of biomass
- Additional process step (pretreatment) is necessary in the process chain
Challenge for a technical implementation and management

Pretreatment: background II

Possible problems
- Reduction of usable reaction space
- High energy requirement
- Operational disturbances

Improvements
- Viscosity / pumping hability
- Stirability and homogeneisability
- Degradability

Source: Björn Schwarz, Fraunhofer IKTS, Dresden 2012
Pretreatment of biomass

- Pretreatments
  - Biological
    - Enzymatic
    - Fungal
  - Physical
  - Mechanical
  - Thermal
  - Ultrasound
  - Electrokinetic
  - Chemical
    - Acid
    - Alkali
    - Oxidative
  - Combined
    - Steam explosion
    - Extrusion
    - Termochemical
Pretreatment of biomass

Pretreatments

Biological
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Physical
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Pretreatment of biomass

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Pretreatment of biomass

**Pretreatments**

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- **Chemical**
  - Acid
  - Alkali
  - Oxidative

- **Combined**
  - Steam explosion
  - Extrusion
  - Thermochemical
Pretreatment technologies:

**Mechanical pretreatment**

Mainly related to surface reduction

- Grinding (pressure, impact)
- Cutting (shear)
- Extrusion (pressure, friction, defibration)
Pretreatment technologies:

Mechanical pretreatment

Methane production ($L_N / Kg VS$)

untretreated
Pretreatment technologies:

**Mechanical pretreatment**

![Graph showing methane production over days for mechanical and untreated samples](image)

- **Methane production** ($L_N/ Kg VS$)
- **days**
- **Lines:**
  - **Orange line:** mechanical
  - **Green line:** untretreated
Pretreatment technologies:

Mechanical pretreatment

- **Mechanical pretreatment**
- **Untretreated**

![Graph showing methane production over days with mechanical pretreatment increasing by +20%](image)

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Mechanical pretreatment

Differences in gas yields (40 days)

- Untretreated
- Mechanical 1 (cutting)
- Mechanical 2 (grinding)
- Mechanical 3 (extrusion)

Methane production ($L_N / Kg VS$)
Mechanical pretreatment:

Energy requirement

- Extruder
- Grinding mills
- Dissolver
- Cutting mills
- Perforated discs

Energy required (kWh/t silage)

Quelle: Björn Schwarz, Fraunhofer IKTS, Dresden 2012
Mechanical pretreatment:

Advantages and disadvantages

Advantages

• Easy integration in biogas plant
• Reduction of floating layers
• Improving mixing properties (stirring ability)
• Faster degradation
• Increased gas yield
Mechanical pretreatment:

Advantages and disadvantages

Advantages

• Easy integration in biogas plant
• Reduction of floating layers
• Improving mixing properties (stirring ability)
• Faster degradation
• Increased gas yield

Disadvantages

• High electrical demand
• Milling tools are usually sensitive to contaminants (stones, metal parts, etc.)
• Corrosion or abrasion by organic acids and minerals (sand)
Pretreatment technology:

Combined - Steam explosion

- Treatment of biomass for a defined time with hot water under high pressure
- Pressure suddenly drops $\rightarrow$ Water evaporates suddenly
- Thermochemical and mechanical digestion of the biomass (Steam Explosion)
Pretreatment technology:

Combined - Steam explosion
Pretreatment technology:
Combined - Steam explosion
Combined pretreatment – Steam explosion

Differences in gas yields (45 days)

Methane production ($L_N / Kg VS$)

days

untretreated
Combined pretreatment—Steam explosion

Differences in gas yields (45 days)

Methane production (L\textsubscript{N} / Kg VS)

- Steam explosion
- Untretreated

+ 20%
Combined pretreatment—Steam explosion

Differences in gas yields (45 days)

- steam explosion
- mechanical
- untretreated

Methane production ($L_N / Kg VS$)

+ 20%
## Combined pretreatment – Steam explosion

### Power requirements

<table>
<thead>
<tr>
<th>Electricity demand</th>
<th>&lt; 25 kW</th>
<th>2.5 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>580 kWh/d</td>
<td></td>
<td>35 kWh/t VS</td>
</tr>
</tbody>
</table>
## Combined pretreatment – Steam explosion

### Power requirements

<table>
<thead>
<tr>
<th></th>
<th>Electricity demand</th>
<th>Heat demand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demand</strong></td>
<td>&lt; 25 kW</td>
<td>250 – 300 kW</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td>2,5 %</td>
<td>25 - 30 %</td>
</tr>
<tr>
<td><strong>Input</strong></td>
<td>580 kWh/d</td>
<td>6600 kWh/d</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td>35 kWh/t VS</td>
<td>392 kWh/t VS</td>
</tr>
</tbody>
</table>
### Combined pretreatment – Steam explosion

#### Power requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Demand</th>
<th>Percentage</th>
<th>Reference Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electricity</strong></td>
<td>&lt; 25 kW</td>
<td>2.5%</td>
<td>1 MW electrical capacity (Economizer SE, BiogasSystems)</td>
</tr>
<tr>
<td></td>
<td>580 kWh/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Heat</strong></td>
<td>250 – 300 kW</td>
<td>25 - 30%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6600 kWh/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>30% DM input</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13,500 to 15,000 m³/year</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Advantages and disadvantages

More biogas and faster degradation due to higher surface area and a change in the chemical composition

Advantages

- Possibility to use waste heat from CHP
- Potential to speed up digestion
- Suitable for hygienisation (sludge, slaughterhouse residues, ...)

Thermal pretreatment– Steam explosion
Thermal pretreatment—Steam explosion

Advantages and disadvantages

More biogas and faster degradation due to higher surface area and a change in the chemical composition

Advantages

• Possibility to use waste heat from CHP
• Potential to speed up digestion
• Suitable for hygienisation (sludge, slaughterhouse residues, ...)

Disadvantages

• Partially complex integration into the biogas plant
• Suitable for large biogas plants (> 1 MW)
• Waste heat must be sufficient for the process (no additional heating)
Key points

Consistent and effective pre-treatment is imperative to avoid operational problems in biogas plants
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→ Consistent and effective pre-treatment is imperative to avoid operational problems in biogas plants

→ Selection of pretreatment
  • Economical
  • Effective degradation of the feedstock
  • Adapted to the installed technology (feeding systems, pumps, agitators)
Key points

→ Consistent and effective pre-treatment is imperative to avoid operational problems in biogas plants

→ Selection of pretreatment
  • Economical
  • Effective degradation of the feedstock
  • Adapted to the installed technology (feeding systems, pumps, agitators)

→ The adaptation and optimization of the pretreatment technologies require the performance of individual studies for every specific biogas plant
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