Pre-Treatment Technologies for Increasing the Biogas Potential of Agricultural Wastes

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CE 521
30 November 2006
Introduction of AD

- Widely Used in Municipal Systems
  - Fewer Applications in Agriculture

- Microbes Consume Substrate Producing
  - CH$_4$ and CO$_2$
    - Stabilizes and Reduces Solids
    - Conserves Nutrients
    - Produces Renewable Energy
    - Controls Odors
AD Limitations in Agriculture

• Compared to Traditional Manure Systems
  – High Capital Investment
  – Maintenance and Operation
  – Limited Economic Return
  – Safety Concerns

• Economical Solids Loading ~ 5%
  – Ag Waste Total Solids 2% - 10%
Pretreatment Technologies

- **Maceration**
  - Chopping, Grinding, Blending, etc.
  - Reduce Particle Size, Break Fibers

- **Chemical Treatment**
  - Addition of Caustics (NaOH, NH₄OH, H₂SO₄)
  - Destruction of Lignin Bonds

- **Liquefaction**
  - Forced Explosion of Cellular Structure
  - Disassociation of Fibers and Colloids
Pretreatment Technologies

- **Thermal Hydrolysis**
  - Heating: 100-200°C for 30-120 minutes
  - Disrupts Cells, Destroys Lignin Bonds

- **Sonication**
  - Low Frequency Ultrasound Waves
  - Cell Lysis, Solids Solubilization

- **Ozonation**
  - Oxidation of Organic Matter

- **Biological**
  - Aerobic Digestion
  - Cellulose and Hemicellulose Degrading Bacteria
Case Study 1
Bourgrier et al. 2006a

- Non-Newtonian Liquid
- Treatment Provides
  - Shift Towards Newtonian Fluids
  - Reduced Apparent Viscosity

- Increased Biogas Production
- Increased Production Rate
- Thermal and Sonication Provide Best Results
Case Study 2
Ardic and Taner 2005

Thermal vs. Chemical vs. Thermochemical

- Increases Solubility of Organics
  - All Treatments
- Reduced Particle Size
  - Thermal and Thermochemical
- Increased Biogas Production
  - Thermal
- Methanogenic Inhibition
  - High Dose Chemical Treatments
## Case Study 3

Angelidaki and Ahring 2000

Maceration vs. Liquefaction vs. Chemical vs. Biological

<table>
<thead>
<tr>
<th>Treatment</th>
<th>CH$_4$ potential increase (%)</th>
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<tbody>
<tr>
<td>Maceration 2 mm</td>
<td>16</td>
</tr>
<tr>
<td>Maceration &lt; 0.35 mm</td>
<td>20</td>
</tr>
<tr>
<td>Decompression explosion</td>
<td>17</td>
</tr>
<tr>
<td>NaOH 20 g/kg VS</td>
<td>13</td>
</tr>
<tr>
<td>NaOH 40 g/kg VS</td>
<td>23</td>
</tr>
<tr>
<td>NH$_4$OH &lt; 20 g/kg VS</td>
<td>0</td>
</tr>
<tr>
<td>NH$_4$OH 40 g/kg VS</td>
<td>23</td>
</tr>
<tr>
<td>NaOH:KOH:Ca(OH)$_2$ 40 g/kg VS</td>
<td>20</td>
</tr>
<tr>
<td>Hemicellulose degrading bacterium B4</td>
<td>30</td>
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</table>
Case Study 4
Valo et al. 2000; Bourgrier et al. 2006b

Chemical vs. Thermochemical
– Two Waste Sources
– Semi-Continuous System

<table>
<thead>
<tr>
<th>Sludge</th>
<th>Methane Yield, L/kgVS</th>
<th>130°C, KOH</th>
<th>150°C</th>
<th>170°C</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>128 +/- 5</td>
<td>220 +/- 4</td>
<td></td>
<td>228 +/- 5</td>
</tr>
<tr>
<td>2</td>
<td>145 +/- 5</td>
<td></td>
<td>238 +/- 4</td>
<td>256 +/- 7</td>
</tr>
</tbody>
</table>
Full Scale Applications

Municipal Systems Most Common

- **Prague → Maceration**
  - 7.5% Increased Biogas Production
  - Supports Energy Demand

- **UK, Sweden, USA, Australia → Sonication**
  - Improved Solids Destruction
  - Substantial Increase in Biogas Production
  - Enhanced Dewatering
  - Reduced Sludge Production
  - 2-Year Payback Period
Full Scale Applications
Muhler et al. 2004

Maceration vs. Sonication vs. Ozonation

• Economic Assessment
  – Increased Solubilization
  – Improved AD Performance
  – Economic Viability Dependant upon Sludge Disposal Costs
Agricultural Applicability

• Maceration
  – Simple System Operation
  – High Maintenance and Operating Costs

• Liquefaction
  – Complex System
  – High Capital Investment
  – Safety with High Pressure System
Agricultural Applicability

- **Chemical**
  - Simple Application
  - High Chemical Costs / Low Capital Cost
  - Safety Concerns with Storage and Handling of Caustics
- **Ozonation**
  - Simple Application
  - Moderate Operating and Capital Cost
  - Least Effective Method
Agricultural Applicability

• Thermal
  – Flexible System
  – Capital Costs are Minimal
  – Energy Economics are Critical

• Sonication
  – New Technology
  – High Capital Costs
Agricultural Applicability

• Biological
  – With Proper Management
    • Low Energy Consumption
    • Low Maintenance
    • Limited Capital Expenditures
  – Technological Advancements
    • Enhanced Performance and Reliability
    • Unrealized Potential
Conclusion

- Pretreatment Enhances AD
- Provides Benefits in Ag Systems
- Full Potential Realized with Economic Benefits
- Thermal, Sonication, and Biological are Most Feasible Pretreatment Systems
Questions?