Disintegration Technologies – Impacts on Biogas Process and Profitability
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IBBA-Workshop ‘Pretreatment of lignocellulosic substrates for biogas production‘
Malmö/Sweden, 10th of September 2015
DBFZ – Development, Mission, Structure

Development:
• Founded on 28th February 2008 in Berlin as gemeinnützige GmbH
• Sole shareholder: Federal Republic of Germany, represented by the Federal Ministry of Food and Agriculture (BMEL)

Mission:
The key scientific mission of the DBFZ is to provide wide-ranging support for the efficient integration of biomass as a valuable resource for sustainable energy supply based on applied scientific research.

Structure:
About 200 employees until 12/2014 in the administration and the four research departments.

General Management:
Prof. Dr. mont. Michael Nelles (scientific)
Daniel Mayer (administrative)
Research focus areas and structure

The four research focus areas
• Systemic contribution of biomass
• Anaerobic processes
• Processes for chemical bioenergy sources and motor fuels
• Intelligent biomass heating technologies
• Catalytic emission control

Organizational structure: the four research departments
Applied class research along the entire supply chain
Biochemical Conversion Department

Research focus areas /working groups
• Characterization and design of anaerobic processes
• Process monitoring and simulation
• Biogas technology
• System optimization
• UFZ Working Group „MicAS“

Research services (selection)
• Discontinuous and continuous AD-Test up to full scale
• Process development for special substrates
• Consulting
• Model-based process simulations
• Acquisition of data on biogas plants in Germany
• Emission measurements and leak detection
• Ecological and economic assessment
• Policy advice for the biogas sector

Head of Department
Dr. -Ing. Jan Liebetrau
Jan.Liebetrau@dbfz.de
Equipment – lab-/full-scale digesters
Small but efficient – Cost and Energy efficient BioMethane Production

- Supported by: German Federal Ministry of Food and Agriculture (BMEL) (FKZ 22028412)
- Partners: Ventury GmbH Energieanlagen (Germany), Poland, Sweden
- Duration: 02/2013 – 04/2016
- Focus: auto-hydrolysis, thermal-pressure-hydrolysis, plug flow digestion of straw, dung, gas purification
Disintegration Technologies
Disintegration – Goals & Challenges

- increase of the degradation kinetics and/or biogas potential caused by disintegration of cells and reduction of the particle size
- → efficient capacity use of the digester (small plants, high loading rate)
- avoiding of floating and sinking layers
- enhancement of the management and automation of the feed-in (stirring, pumping)
- change of viscosity and change of mixing properties
- challenge for designer, manufacturer and operator of disintegration units is the proof of the efficiency changes in cost and energy under full scale conditions
Disintegration on Agricultural Biogas Plants

Options for Disintegration

Silo

Energy crops

Stable
Liquid manure tank

Digester

Combined Heat and Power Plant (CHP Unit)

Heat
Power

Biogas

Storage tank (digestate)

Field

Digestate’s application

Options for Disintegration

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Disintegration – Methods´ Overview

Physical Methods

• disintegration by size reduction or milling
• thermal treatment with hot water, steam or hydrolysis with heat and steam
• microwaves and ultrasound treatment

Chemical Methods

• utilization of acids or bases, oxidation

Biological Methods

• utilization of microorganisms as additives for ensiling (substrate’s conservation) to minimize storage loss
• hydrolytic microorganisms or enzymes e.g. for substrates with high content of proteins or ligno-cellulose
Dis-/Advantages of Disintegration

- Enhanced biogas production
- Utilization of excess heat (e.g. CHP unit) is positive for energy balance
- Optionally the energy consumption of agitators and pumps can be reduced
- Additional demand on thermal or/and electrical energy
- Additional costs (investment, costs of operation)
- Additional risk of technical failure
- The risk of acidification could appear, if the feed-in frequency of pretreated substrate is too low
- Disintegration + shortened hydraulic retention time /increased organic loading rate → changes have to be made carefully and parameters of the effluent should be analyzed to avoid process failure or capacity overload
- Experiences in practice are often limited to a few biogas plants, except for macerators
Disintegration Technologies in Germany

Operator’s survey – biogas sector;
DBFZ: Stromerzeugung aus Biomasse, 03MAP250, 06/2013 (data 2012)

- Appr. 7500 biogas plants were operated in Germany in 2012
- 6909 biogas plants got a questionnaire of DBFZ
- 980 operators gave a feedback
- 148 disintegration technologies were stated for 123 biogas plants
Disintegration Technologies Impacts on Biogas Process
Discontinuous AD
Acceleration or Enhancement

acceleration is not interesting for biogas plants with long hydraulic retention time or easy degradable substrates
Continuous AD
Enhancement – losses – process failure

substrate specific methane yield - continuous trial

- treated (enhanced yield)
- untreated
- treated (diminished yield)
- treated (process failure)
Interaction of disintegration and mixing

lab-scale CSTR
completely mixed

full-scale CSTR
partially mixed

Major impact of disintegration in imperfect system?
Lab experiments show limited effect?

HRT
OLR

dead zone +/- 30%?

▲ viscosity <-> ▲ volume dead zone?

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## Dis-/Advantages of different scales & tests

<table>
<thead>
<tr>
<th></th>
<th>Lab batch</th>
<th>Lab conti</th>
<th>Full scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time requirement</td>
<td>~ 35 d</td>
<td>month</td>
<td>month</td>
</tr>
<tr>
<td>Amount of substrate</td>
<td>low</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>Substrate´s quality</td>
<td>high</td>
<td>high/varying</td>
<td>varying</td>
</tr>
<tr>
<td>Costs</td>
<td>low</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>Parallels</td>
<td>easy</td>
<td>manageable</td>
<td>seldom</td>
</tr>
<tr>
<td>Process stability/ synergistic effects</td>
<td>no</td>
<td>yes, partially</td>
<td>yes</td>
</tr>
<tr>
<td>Rheology (Impact of mixing detectable)</td>
<td>no</td>
<td>??</td>
<td>yes</td>
</tr>
<tr>
<td>Lack of nutrients/ inhibition detectable</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Mono-fermentation</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>...changes in gas yield are detectable</td>
<td>small</td>
<td>small/medium</td>
<td>large</td>
</tr>
<tr>
<td>Relevance of results?</td>
<td>low</td>
<td>medium</td>
<td>high</td>
</tr>
</tbody>
</table>
Conclusion – Impacts on Biogas Process

- Two effects of disintegration: acceleration and/or enhancement of the conversion of substrate
- Losses or process failure are also possible
- The effects are dependent on the composition of the substrate and the disintegration method
- Acceleration is not interesting for biogas plants with long hydraulic retention time or easy degradable substrates, because non-treated substrates might reach the same degree of degradation
- Acceleration might be interesting for biogas plants with short hydraulic retention time or hardly degradable substrates and/or the wish of capacity expansion
- A real enhancement of the biogas yield is hardly to achieve
- Due to varying mixing, lab- and full-scale trials might show different results
Disintegration Technologies
Impacts on Profitability
### Various samples for German biogas plants

<table>
<thead>
<tr>
<th>Sample</th>
<th>Capacity (kWel)</th>
<th>Operating Hours</th>
<th>Maize (%)</th>
<th>Manure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>50</td>
<td>8000</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>II</td>
<td>75</td>
<td>8000</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>III</td>
<td>75</td>
<td>8000</td>
<td>65</td>
<td>35</td>
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<tr>
<td>IV</td>
<td>75</td>
<td>8000</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>V</td>
<td>190</td>
<td>7700</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>VI</td>
<td>190</td>
<td>8000</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>VII</td>
<td>600</td>
<td>7700</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>VIII</td>
<td>600</td>
<td>8000</td>
<td>65</td>
<td>35</td>
</tr>
<tr>
<td>IX</td>
<td>600</td>
<td>7700</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>X</td>
<td>600</td>
<td>8000</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>XI</td>
<td>biomethane plant 1333 m³ i.N./h</td>
<td>43.30%</td>
<td>29.63%</td>
<td>21.19%</td>
</tr>
<tr>
<td>XII</td>
<td>biowaste plant 600kW, 8000h</td>
<td>32.13%</td>
<td>54.92%</td>
<td>11.45%</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
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Investment for Disintegration Technologies (D)

Investment depends on the manufacturer and the throughput (m³/h or t/h)

- **ultrasound**: 2 m³/h
- **extrusion**: 1-7 t/h
- **electrokinesis**: 25 - 80 m³/h
- **cutting mill**: 5 - 750 m³/h

Exemplary calculation - assumptions

1. 500kWe CSTR, new constructed biogas plant (01.01.2016)
2. Calculation of production costs of electricity/investment calculation (annuity method VDI 2067)
3. Invest cutting mill: 2*15.000€ = 30.000€
4. Invest thermal-pressure-hydrolysis (TPH): 500.000€
5. Lightweight construction depot for straw: 200.000€
6. Costs cattle manure: 0€/t FM
7. Costs straw: 80€/t; 100€/t; 120€/t FM
8. Revenue of surplus heat from CHP: 3 €ct/kWh th
9. Utilization of rejected heat of CHP for TPH, rise in heat demand for the whole biogas plant from 20% to 40% for TPH.
10. Marketing of surplus heat: 50%
Exemplary calculation - assumptions

11. Gas yield cattle manure (KTBL): 16,8 m² CH4 N/t FM
12. Gas yield straw (KTBL) cutting mill: 162,54 m² CH4/t FM
13. Gas yield straw TPH: 180,42 m² CH4/t FM (enhancement compared to cutting mill: 11% (Schumacher et al.))
14. Mix of substrate (fresh matter related): 7% straw, 93% cattle manure

KTBL: Faustzahlen Biogas, 2013
CSTR – continuous stirred tank reactor
CHP – combined heat and power plant
FM – fresh matter
th- thermal
Exemplary calculation

Economical Assessment - Production costs
500kWe biogas plant

Production costs [ct/kWhel]

Cutting Mill
- straw price: 80€/t
- straw price: 100€/t
- straw price: 120€/t

Thermal-Pressure-Hydrolysis
- straw price: 80€/t
- straw price: 100€/t
- straw price: 120€/t

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Conclusion – Impacts on profitability

• Mechanical pre-treatment is State-of-the-Art, but energy demand as well as operational costs are dependent on the substrate and should be reduced

• High expectations in Thermal-Pressure-Hydrolysis (TPH) etc., but the high energy demand, high invest and technical design are challenging
Conclusion

• disintegration: can lead to accelerated and/or enhanced conversion of substrate or losses of substrate

• case-by-case calculations have to be made for every biogas plant, to reveal the limits of profitability

• variables are e.g.:
  • composition of substrate/substrate’s mixture,
  • substrate’s costs (logistics),
  • available treatment units (e.g. invest, its energy consumption, wear and tear),
  • reactor design (including mixing),
  • hydraulic retention time,
  • usage of digestate (logistics) etc...
Thank you for your attention!

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