New technologies towards net-zero/negative emissions in integrated biorefineries

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Vision „Negative-Emissions“

Industry and emissions

Biorefineries – new products, new pathways, possibly integrated to industrial complexes

Biorefinery concepts with net zero / negative emissions

energy and resource efficient

How can Net-Zero/Negative Emissions be reached in biorefineries?

Source: AEE INTEC
Can new biorefinery products enhance the pathway towards net-zero/negative emissions?
Spent grain valorization as new biorefinery concept

Protein Hydrolysis

Proteases

PROTEIN HYDROLYSATES, AMINO ACIDS, PEPTIDES
Need for: **Process intensification (PI)** of cost-/time- and scale- limiting bioprocess steps

- **Direct biomass use**
- **Application of high solid loadings**
- **Efficient extraction of products**
- **Appropriate conditions for high yields**
- **Limitations such as insuff. enzyme-substrate binding and product inhibition effects**
- **Cost effectiveness (resources and energy)**

Source: Judith Buchmaier

Proteins valuable biorefinery product

Stankiewicz, 2009
Process Intensification by Oscillatory Flow Bioreactor OFB

→ decoupling flow velocity and residence time

Objective:

Energy- and resource efficient reactor set-up for continuous processing with high solid loadings and efficient mass transfer rates (effect on conversion rates) with the possibility of in-situ product removal.

Sugar, Proteins

Double jacketed turbular reactor with helical baffles

Biomass

Enzymes, IL, DES

Oscillatory motion (Hz, mm)

Turbulent flow regime

Source: Judith Buchmeier
### Results – Amino Acids/Proteins

Total free AA: 22.4 – 25.8 mg AA/ml

Peptide-based protein identification by mass spectroscopy

<table>
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<th>AA</th>
<th>mg AA / ml</th>
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<tbody>
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<tr>
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![Peptide Mass Spectroscopy](image-url)
Oscillatory reactors potential key enabling technology for bioprocessing

Promising protein solubilisation rate
→ 72 – 85 % protein yield
21 - 26 mg\textsubscript{protein}/ml hydrolysate

→ Specific methane yield per kg oTS rather unchanged
→ mass balance effects need to be accounted
→ Rather faster biogas process after hydrolysis (washed spent grain)
Current digestate pathway includes losses
Solid/liquid separation
Liquid – production of liquid ammonium fertilizer
Liquid – production of liquid ammonium fertilizer

Operating conditions 27°C
Atmospheric pressure
Stable operation (Nov – March)
>99% N-NH4 removal
Product concentration
61,3 g/l ASL
Solids – peat substitute / humus substrate

Peat substitution

Spent grain

Carbon
Nitrogen - N
Phosphorous - P
Potassium - K

Agriculture

Bio - plants
Pflanzversuche mit Torfersatzstoff im Profigartenbau

- Torfersatz → keine bis geringe Qualitätsminderung durch Reduktion des Torfanteils und der Beimengung von Torfersatzstoffen
- Untersuchung der Ausbildung der Wurzelkörper bei unterschiedlichen Beimischungen

- Rund 1.500 Pflanzen für Versuche eingetopft
Solide substrates – plant testing

without digestate substrate

with digestate substrate

with digestate substrate
Substrates have potential for emission reduction

- Peat is the main component of growing media (commercial horticulture) and garden soils.

- Peatlands cover only 3% of the earth's surface, but bind a third of terrestrial carbon in their peat layers - twice as much as the earth's forests.

- Drained peatlands in the EU emit ≈220 Mt CO2eq per year (≈5% of total EU emissions), mainly from agriculture on drained peat soils.

- The emission of peat for horticultural purposes amounts to about 7 million tonnes of CO₂ equivalents for Europe → New growth 1 mm per year

Goldstein et. al., 2020
Tannenberger et. al., 2020
Combined resource and energy concept – climate positive vision

- Brewery: Currently no fossil CO₂ emissions (100% renewable energy)
- Protein production process quantification necessary (thermal energy demand, however excess heat from biogas production useable)
- Avoided emissions ammonium-fertilizer dependence on bio-fertilizer possibilities
- Avoided emissions peat generation: > 4000 t CO₂ equiv./a
- Binding potential humus substrate: > 1000 t CO₂ equiv./a
Which system boundaries do we allow?
Closing the loop: Towards a self-sufficient biorefinery
Carbon capture and utilization

... A question of the system boundary and the binding time

- The energy and material requirements for CO2 capture must be considered.
- Since CO2 from point sources is most likely a "by-product", the results depend on the allocation and expansion of the system boundary.

Quelle: Energieinstitut an der JKU basierend auf Zimmermann, A. et al. (2020)
Conclusions

• New biorefinery pathways and products are highly important

• Material use of biomass can lead to challenges for energy supply: energy efficiency tools and renewable energy are needed; holistic process view required to account for energy, resource, waste, water, emissions, product yields…

• Use of secondary raw materials is important in biorefineries to reach circular economy and carbon circularity

• Negative Emission concepts require interdisciplinarity, looking beyond company borders - a question of system boundaries and CO₂ binding time

• Framework conditions, market mechanisms and existing infrastructure can influence technological choices/energy supply which are all attributes towards net zero

• Net-zero emission concepts in biorefineries will be elaborated and collected in the future – they might rely on different pillars:
  • **Key technologies** to increase intrinsic process efficiency and/or render secondary raw materials into products (CCU)
  • **Intelligent system concepts** linking diverse process routes
  • **RES-based energy supply** when biobased material is converted into material-products
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