Deutsches Biomasseforschungszentrum

Höhere Wertschöpfung aus Biogasanlagen durch die Produktion von Plattformchemikalien

Maria Braune, Heike Sträuber, Arne Gröngröft

Bioeconomy e.V. Branchentreff - „Grüner Kohlenstoffkreislauf“ | 20.10.2021

Projektträger Jülich
Forschungszentrum Jülich

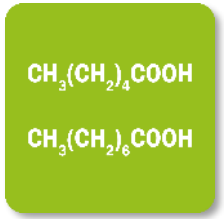
Bundesministerium
für Bildung
und Forschung

Background

Motivation

≈ 9,500
biogas plants

Amendments
German Renewable
Energy Act



n-Caproic acid (C6)
n-Caprylic acid (C8)

Protection and
securing resources

Background

Applications

Caproic and caprylic acid,
a wide range of applications …

- Lubricants
- Detergents and cleaners
- Care and cosmetic products
- Food and feed additives
- Pharmaceutical products
- Bio-plastics
- etc.

Feed additives

Lubricants

Specialty chemicals

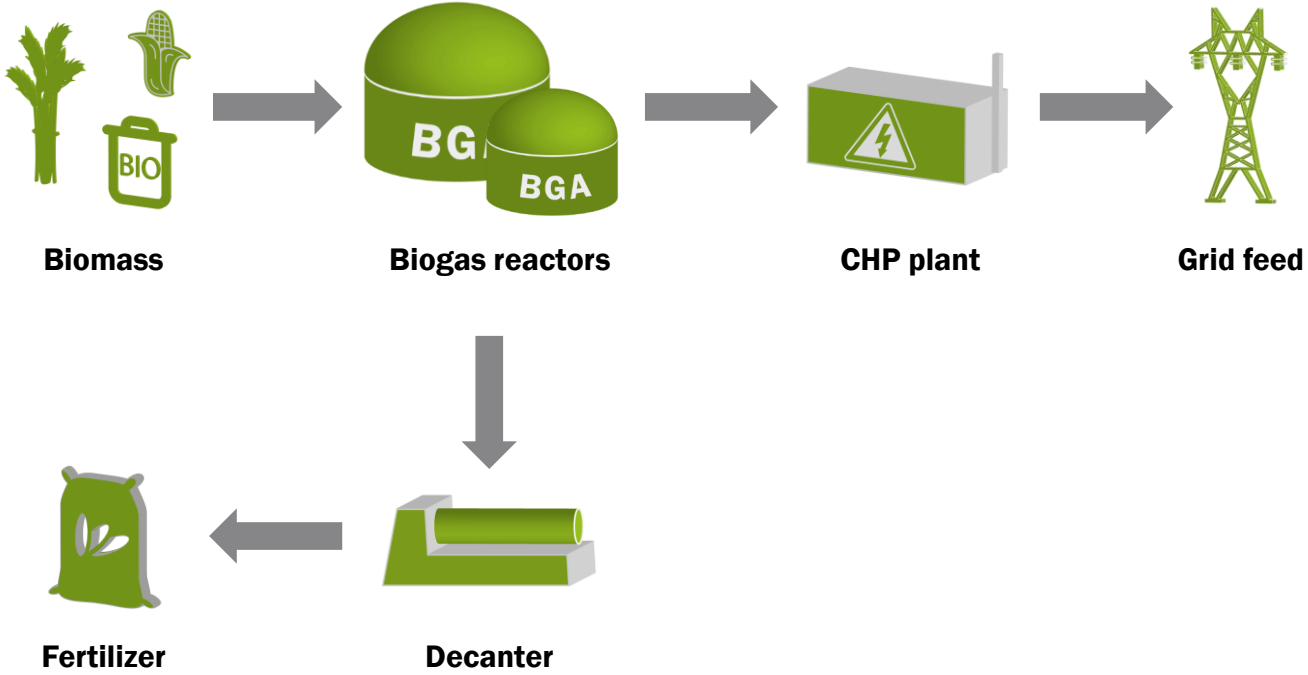
Bio-plastics

Detergents

Pharmaceutical products

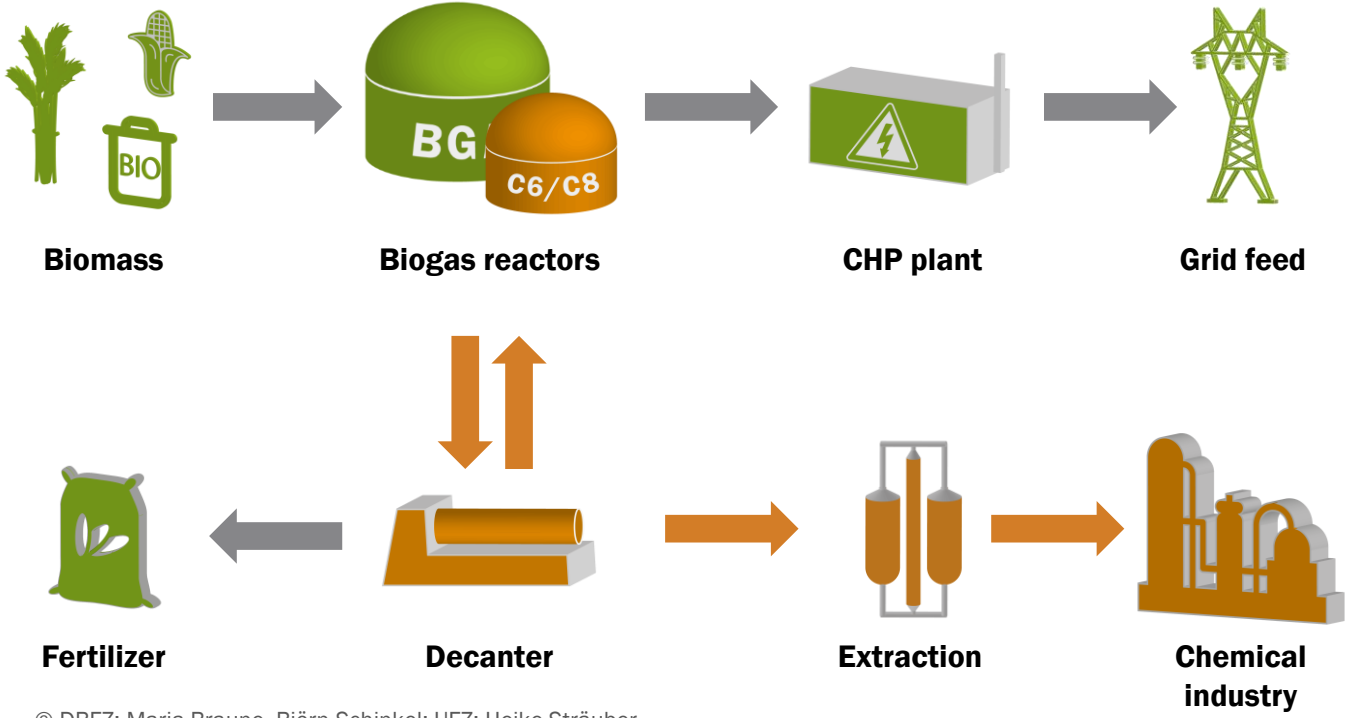
Retrofitting existing biogas plants – a vision

Typical agricultural biogas plant



Retrofitting existing biogas plants – a vision

Upgrade to a biorefinery



Anaerobic Fermentation

Continuous process CAPRAFERM®

- Continuous production of C6 and C8 by anaerobic fermentation with a microbiome
- Complex substrates (crops, residual and waste biomass) without costly pre-treatment
- Biogas production is suppressed by certain process control
- Microbial chain elongation in acidogenesis (short-chain fatty acid + electron donor)

Anaerobic Fermentation

Products

Product	Chain length	Yield in g kg^{-1} VS
Acetic acid	C2	168
Propionic acid	C3	7
iso-Butyric acid	C4	3
n-Butyric acid	C4	82
iso-Valeric acid	C5	4
n-Valeric acid	C5	8
***n*-Caproic acid**	**C6**	**90**
n-Enanthic acid	C7	8
***n*-Caprylic acid**	**C8**	**26**

- **C6 – C8**
  124 ± 4 g kg^{-1} VS
- C2 – C4
  261 ± 7 g kg^{-1} VS
- Productivity in a 15 L reactor
  1.2 kg MCFA m^{-3} d^{-1}

→ **12 % of the substrate VS converted into MCFA**

→ 88 % of the substrate VS available for subsequent biogas production

Product separation and purification

Challenges

Characteristics of the fermentation broth:

- $c_{C6} \approx 5\ g\ L^{-1}$, $c_{C8} \approx 1\ g\ L^{-1}$
- Total solids content = 7.7 %

Solid-liquid separation as requirement for effective product separation

→ Removal of solids

Selective product separation

→ Removal of water

→ Separation of C6/C8 from short-chain acids

→ Low product loss

Product separation and purification

Separation cascade

Fotos: Maria Braune/DBFZ

FERMENTATION BROTH

SOLIDS

LIQUID PHASE

PERMEATE

EXTRACT

CAPROIC-/ CAPRYLIC ACID

FILTER PRESS/DECANTER

MEMBRANE FILTRATION

EXTRACTION

DISTILLATION

Braune, Yuan, Sträuber, McDowall, Nitzsche, Gröngröft (2021) A Downstream Processing Cascade for Separation of Caproic and Caprylic Acid from Maize Silage-Based Fermentation Broth. Front. Bioeng. Biotechnol., doi.org/10.3389/fbioe.2021.725578

Product separation and purification

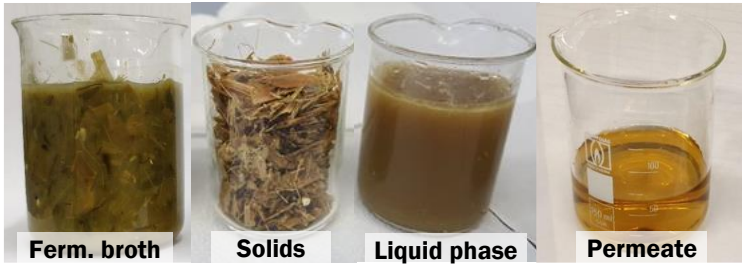
Solid-liquid separation

Separation method	Total solids content in %	Turbidity in NTU
Untreated	7.7	-
Filter press	3.8	-
Decanter centrifuge	2.9*	> 600[1]
Microfiltration	2.4	-
Ultrafiltration	2.3	< 40[2]

*Processing with filter press and decanter centrifuge
[1]above the upper detection limit, [2]below the lower detection limit

✓ **Removal of solids**

? **Product retention**



Product separation and purification

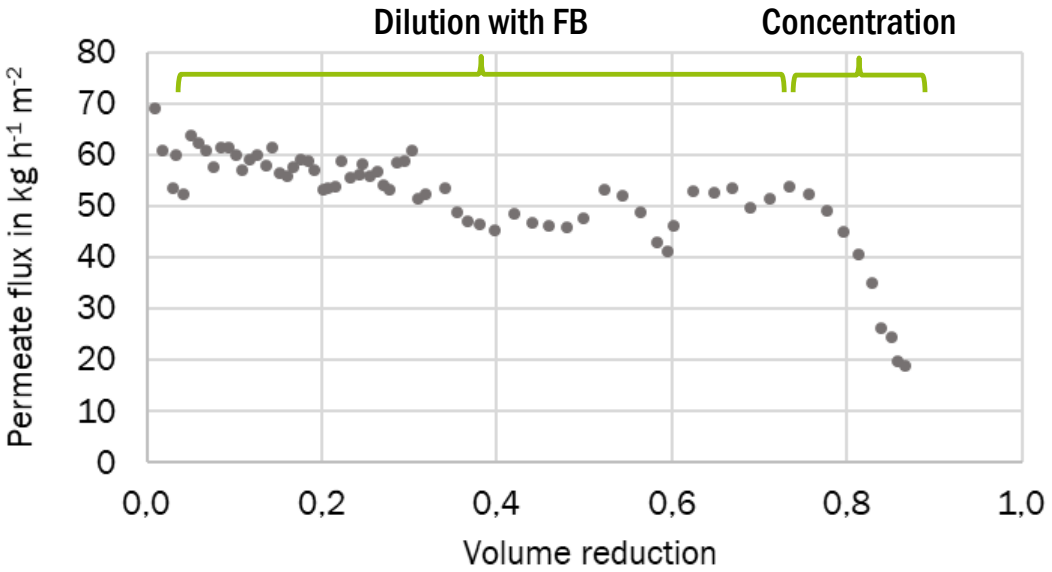
Solid-liquid separation

Membrane filtration

- Ceramic multichannel membrane
- Ultrafiltration (15 kDa)
- Flux value up to 60 kg h^{-1} m^{-2}

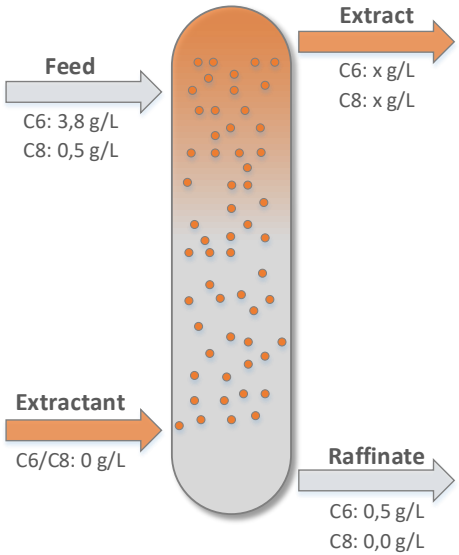
Removal of solids

No product retention



Product separation and purification

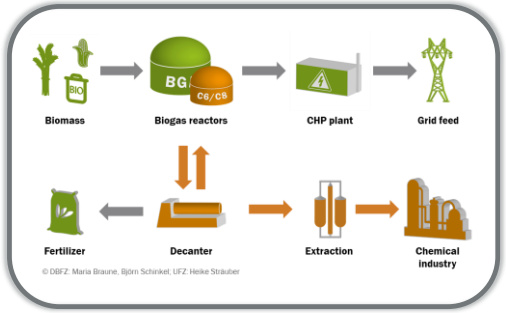
Liquid-liquid separation

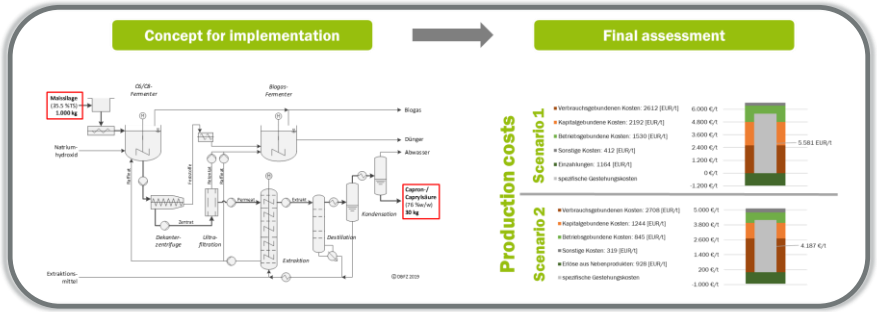


- **Water removal**
- **Short-chain acids remain in fermentation broth**
- **Selective separation of C6/C8**

Conclusion

- **Process for combined material and energetic use of biomass** in biogas plants for the production of C6 and C8 as well as biogas and fertilizer
- **Continuous fermentation process** was developed and tested in lab scale
  - various biomasses were tested
  - 12 % of maize silage VS can be converted into C6 and C8
- **Downstream cascade** was developed and tested in lab scale
  - filter press, ultrafiltration: complete removal of solids
  - liquid-liquid extraction: removal of water, selective separation of C6 and C8
  - purification by distillation
- **Techno-economic evaluation**
  - plant concept compiled
  - mass and energy balance
  - calculation of product costs





Outlook

- Upscaling (pilot plant)
- Validation of process data
- GHG balance and cost calculation

Thank you for your attention!

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Smart Bioenergy – Innovations for a sustainable future

Contact

Maria Braune
maria.braune@dbfz.de
+49 341 2434-368

Heike Sträuber
heike.straeuber@ufz.de
+49 341 2434-563

DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH

Torgauer Straße 116
D-04347 Leipzig
Tel.: +49 (0)341 2434-112
E-Mail: info@dbfz.de
www.dbfz.de