Straw Fermentation Technology Sharing

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SF-Soepenberg GmbH

- Produces more than 300.000 t/a fertilizers from waste
- Produces customized organic and mineral fertilizers
- Operates a waste water treatment facility with industrial biogas plant and nutrient revovery for more than 3,000 t Struvite (P) and K per year.

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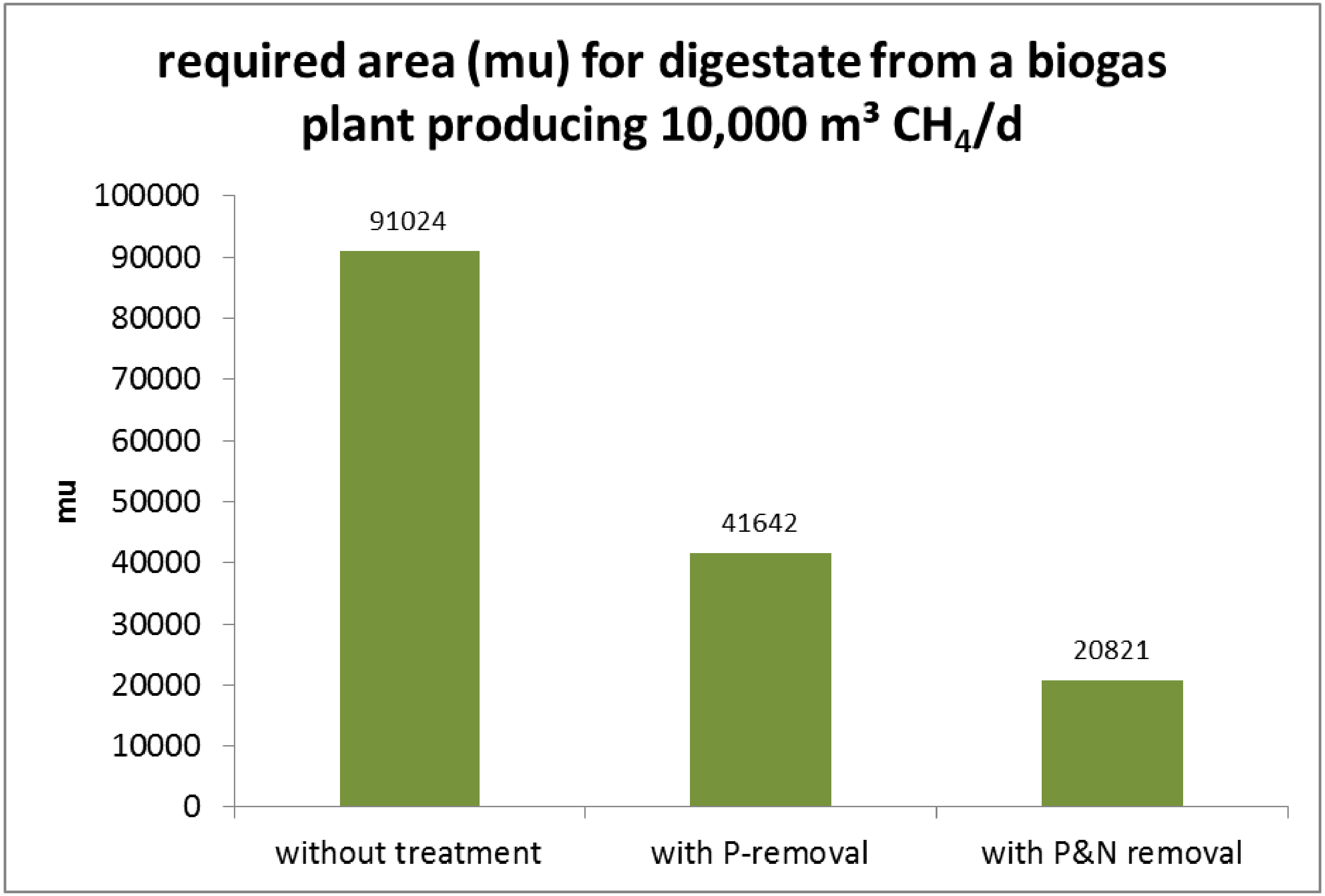
Nutrient Management Plans



Base of calculation: Demand of nutrients: 22.5 kg N/(mu a)**; 3.7 kg P/(mu a)**; 12.800 LU produce 1,400 kg DM/(LU a)*; 1 kg DM produces 12 m^3 CH_4 ***; 1 LU= 500 kg, P-removal 80%, N removal 50%, (Data from Schuchard et al. 2012*, according to Roelcke 2016**, database Lfl***)

What is to share?

- The European biogas sector is only beginning to use pure straw as feedstock for biogas plants
- So far straw has not played a role with the exception as cosubstrate in Farm Yard Manure and liquid animal manure.

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Full Scale Pretreatment in China – Alkaline Pretreatment

- NaOH-pretreatment
- CSTR-technology
- Designed capacity: 10,000 m^3 CH_4/d

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http://yuanyibiogas.com/

Challenges for Straw

Challenges

- Technical
  - Harvesting
  - Pretreatment
  - Mixing in the fermenter
- Biological
  - Additional nutrients
- Financial
  - Price (60- 120 €/t FM)

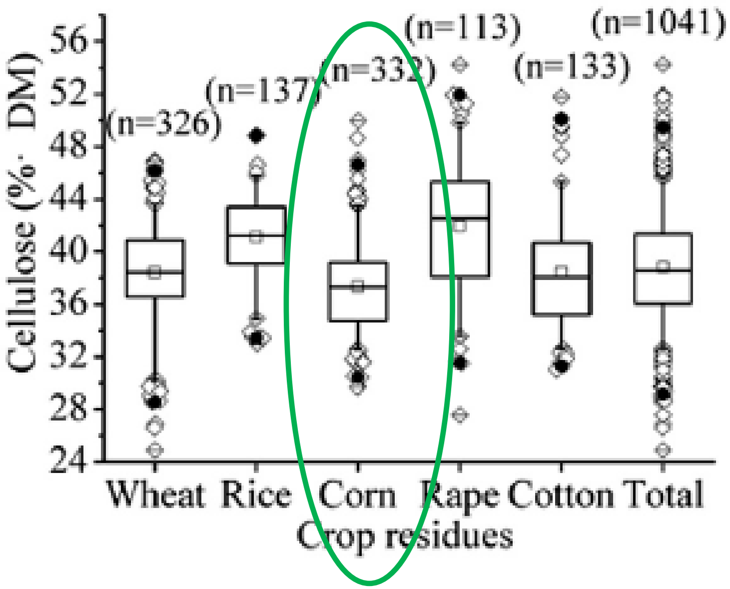
Advantages

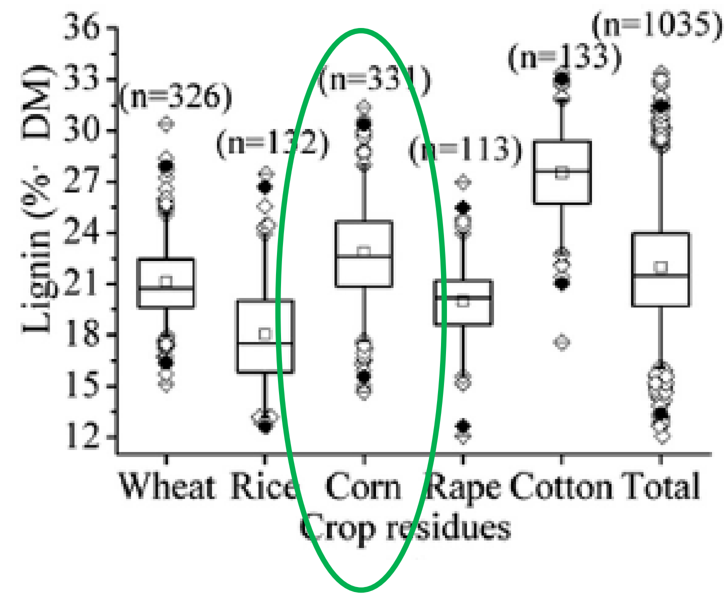
- Additional energetic value from arable land in Germany:
  8- 13.2 Mio t/a
- Energetic use via biogas is a low emission technology

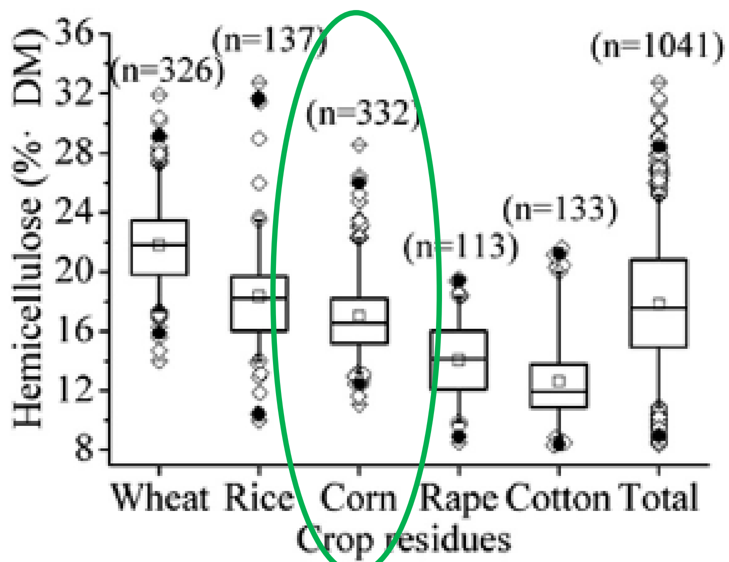
http://www.proplanta.de/Markt-und-Preis/Agrarmarkt-Berichte/Aktuelle-Strohpreise-und-Heupreise-2016-KW-42_notierungen1476799985.html

Straw in China

Straw in China (data from 1,076 samples)

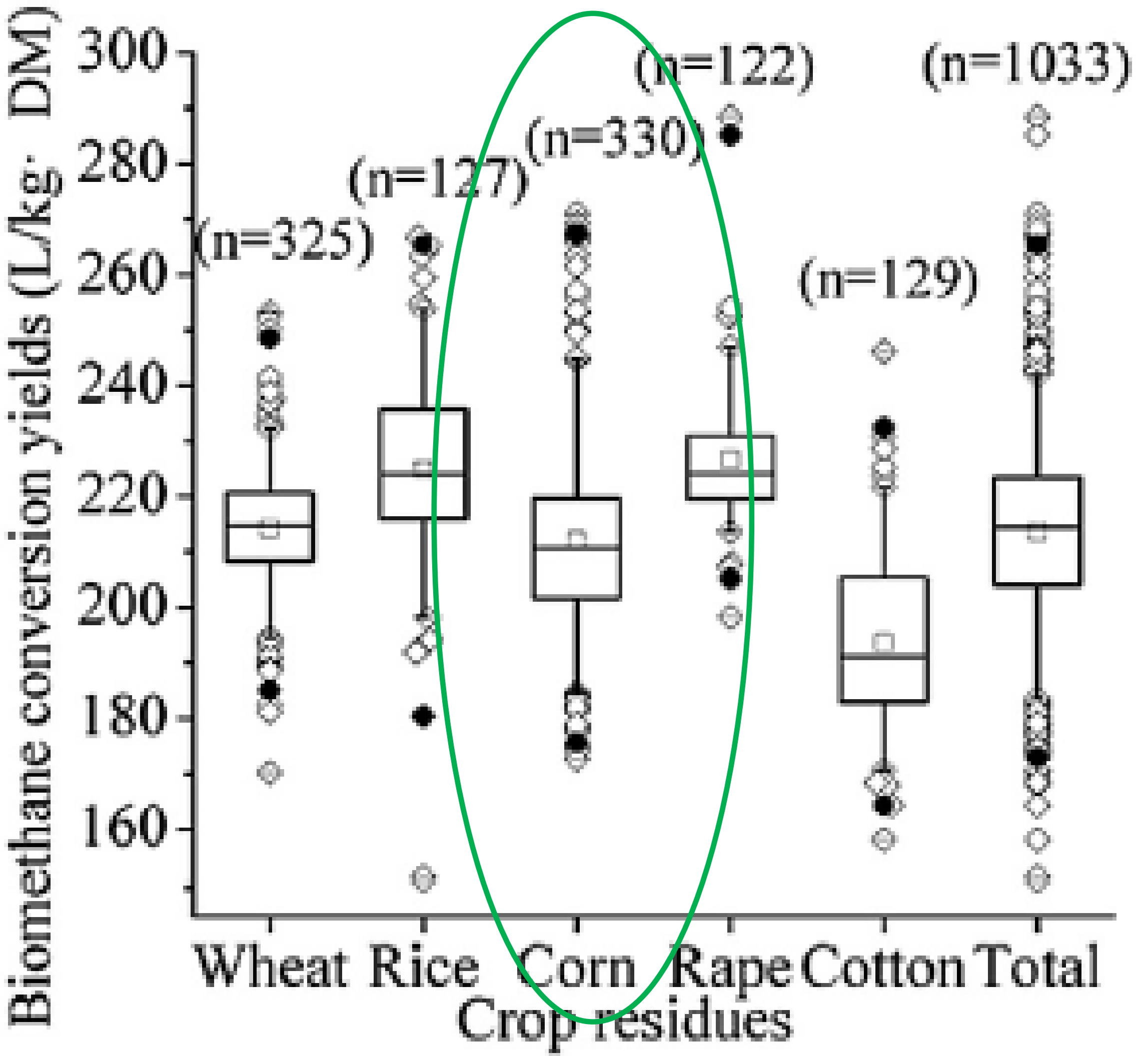






Niu et al. 2016

Straw in China



The equation used to calculate BMP needs perhaps adjustments

Pretreatment technologies

- "Pretreatment of feedstock for enhanced biogas production"
  - Published by: International Energy Agency Bioenergy 2014
- In general, all pretreatment technologies aim to use a CSTR for AD
- Following technologies can be used alone or combined for pretreatment

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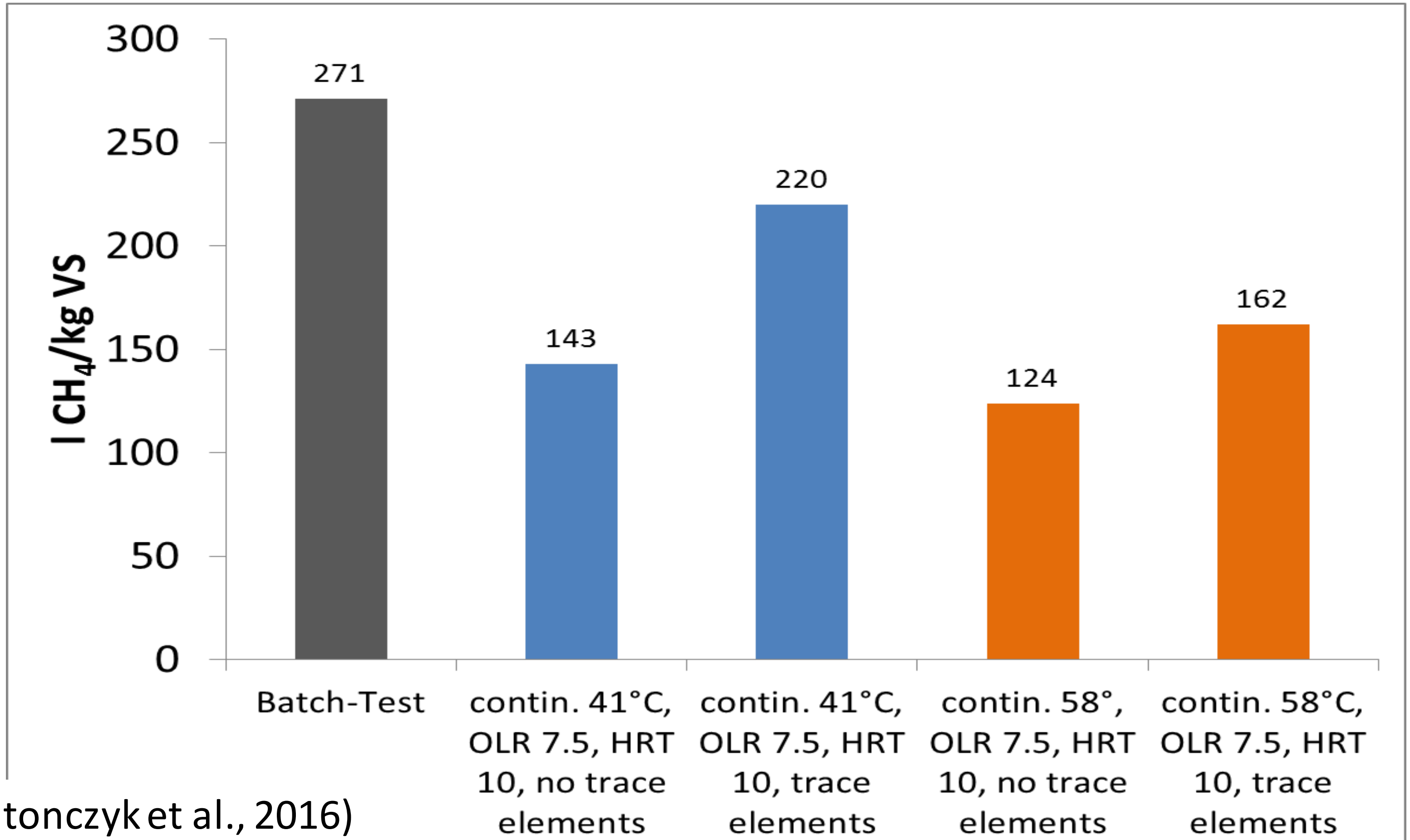
	Advantage	Disadvantage
Milling	increases surface area makes substrate easier to handle often improves fluidity in digester	increased energy demand high maintenance costs / sensitive to stones etc.
Hot water (TDH)	increases the enzyme accessibility	high heat demand only effective up to certain temperature
Alkali	breaks down lignin	high alkali concentration in digester high cost of chemical
Acid	solubilises hemicellulose	high cost of acid corrosion problems formation of inhibitors, particularly with heat
Microbial	low energy consumption	slow no lignin breakdown (?)
Enzymatic	low energy consumption	continuous addition required high cost of enzymes
Steam explosion	breaks down lignin solubilises hemicellulose	high heat and electricity demand
Extrusion	increases surface area	high maintenance costs / sensitive to stones etc.

Adapted from IEA, 2014

Milling

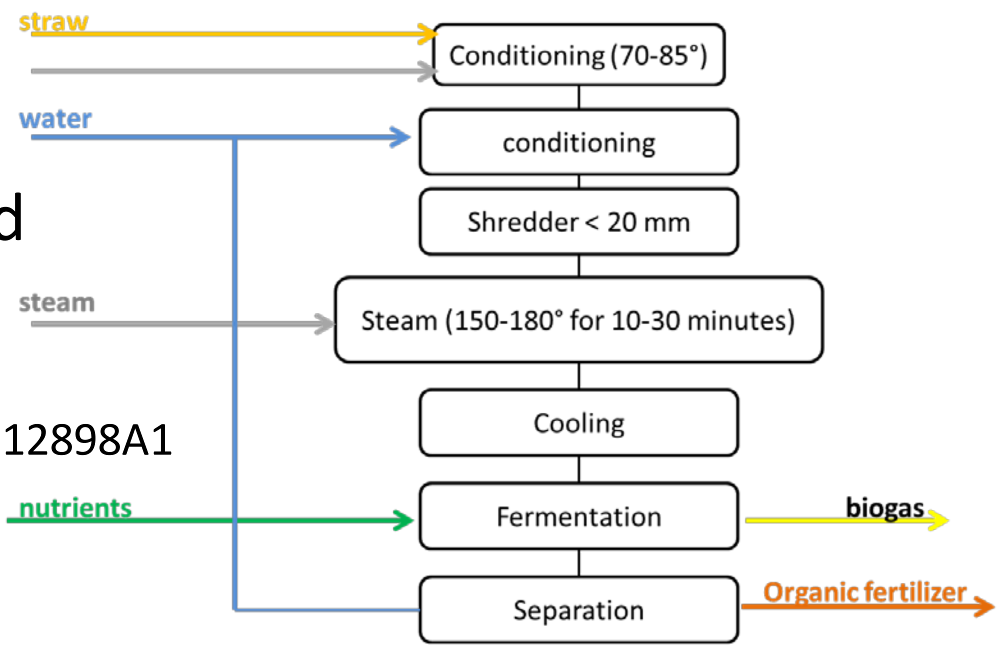
- milled wheat straw 0.13 mm
- 630 days continuous operation of a lab fermenter



(Antonczyk et al., 2016)

Hot water (Thermo Druck Hydrolyse)

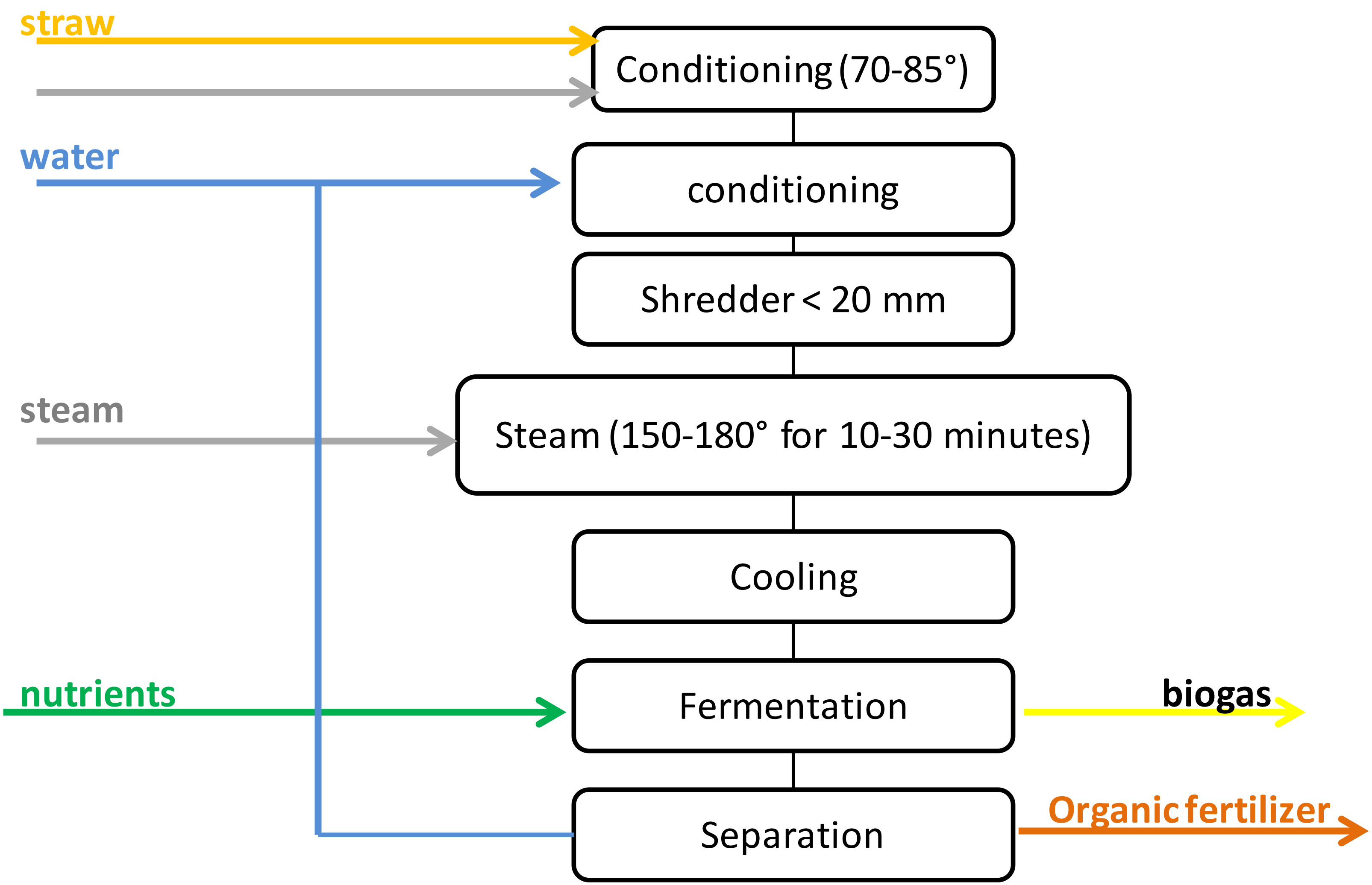
- Plant from Verbio AG in Schwedt, Germany
  - from 2019 on
  - 40,000 t of straw per year*
  - 120-140 GWh biomethan*
  - Biomethane Yield: 300 m³ CH_4/ t straw (or some addittional substrate)
  - Around 37.000 m³ CH_4/d



*www.verbio.de

Simplified, according to patent DE102012112898A1

Verbio Straw Process?



Simplified, according to patent DE102012112898A1

Microbial Pretreatment of Straw

- BMT-System from MWK Bionic GmbH operates a pilot system
- Separated liquid digestate is heated
- Additive is used
- Straw is added
- After reaction the material is pumped to the fermenter

www.mwk-bionik.de/de/systeme/bmt.html

Steam Explosion

- ECONOMIZER SE from BIOGAS SYSTEMS GmbH
- Material is heated up to 180°C in two steps
- Pressure up to 1 MPa
- Final rapid pressure drop disintegrates material

- large scale pilot plant in operation since 2014
- capacity: up to 1 ton straw / hour
- first client projects under realisation

(www.biogas-systems.com)

Extrusion

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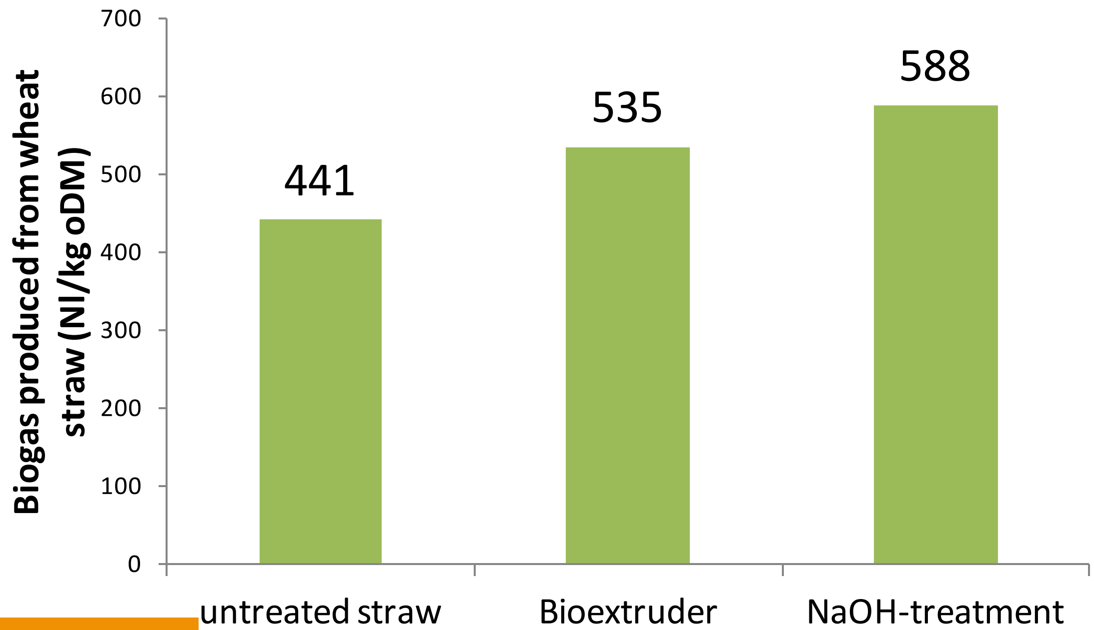
- Extrusion is a process where material is subjected mechanically to high shear, temperature, pressure and desintegration.
- „Bioextruder“ from Lehmann-UMT GmbH combines short time-hydrolysis & extrusion: 5-12 kWh/t material, low maintenance
- Installed at different plants, but non for monofermentation of straw



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Data from Lehmann & Friedrich 2012, picture from Lehmann-UMT GmbH

New Reactor Design for Straw?

- IEA Bioenergy:

  "Current pretreatment systems are useful to transform a very fibrous substrate into something resembling manure or maize.
  This allows lignocellulosic substrates to be used in existing *(CSTR)* reactors. However, …., there is much evidence that a different reactor design may be more suitable for lignocellulosic substrates."

- The Vertical Plug Flow Reactor used in China…?

Vertical Plug Flow Fermenter for Straw Digestion in China

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Pictures from 2012

Vertical Plug Flow Fermenter for Straw Digestion in China

- Straw forms swimming layer
- Digested material settles down and can be removed
- Straw surface is rewetted with digestate pumped from the bottom to the top

- Design/operating considerations:
  - Is it possible to supply the swimming layer with enough nutrients and water?
  - Is the gas sufficiently released to the top of the fermenter?
  - A too thick swimming layer is not favorable
  - The ratio of surface area to volume should be rather high

A CSTR/VPF-like fermentation system

- No agitator & no heating system in the fermenter
- Operation as CSTR or as Vertical Plug Flow Reactor

Nozzle System

- Heat and mass transfer by a pump/nozzle system
- Three nozzles that can be turned for 120°
- By electronic frequency converter the nozzle can splatter digestate from the fermenter wall to the center
- The digestate is pumped from the bottom to the nozzle.

www.ecogas-gmbh.de

Characterists of the CSTR/VPF system

- Little maintenance
- 11 plants up to 7,200 m^3 CH_4/d or 1.2 MW_{el})
- Operating hours more than 95% in a year
- Electricity consumption of the plant:
  < 5% of the produced electricity
- System is suited for earth basin fermenter

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Conclusions

- Various technologies for straw pretreatment exist.
- In Europe the straw fermentation is about to start.
- The only running biogas plants for straw fermentation are in China: CSTRs with pretreatment and Vertical Plug Flow Fermenter
- Without pretreatment CSTRs may not be the first choice of reactor design
- So far a sound analysis of the methane yield and mass balance from full scale plants is missing.

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Thank you for your attention

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