BIOeconomy

The Second Bioeconomy Course
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Biomass based Chemicals Production – Grass Silage Biorefineries in rural Areas

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Straubing Center of Science

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Region of Renewable Resources

Straubing in Europe

federal state:	Bavaria
population:	ca. 45.000
area:	67.61 km²
altitude:	330 m

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Center of Excellence for Renewable Resources
located in
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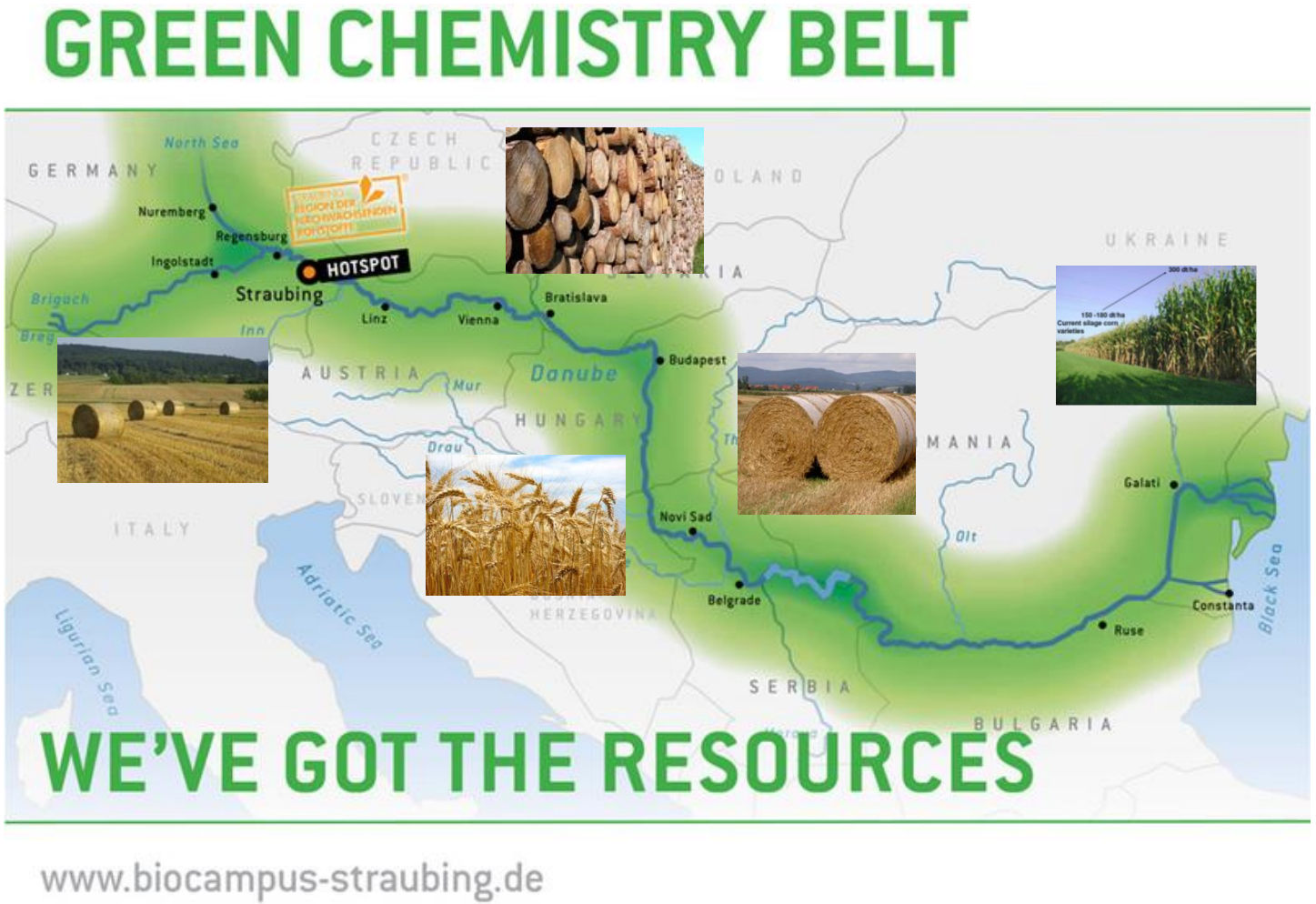
Region of Renewable Resources



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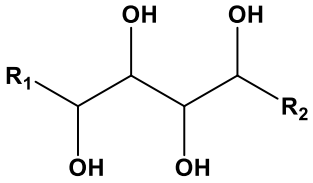
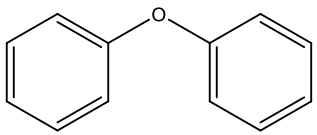
Nature´s Diversity for the Diversity of Chemical Products

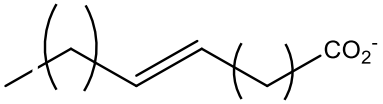
Biomass

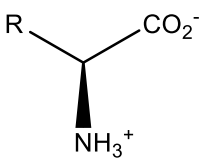
$C_{13}H_{21}O_{10}$

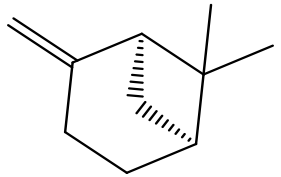
natural product



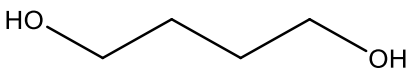


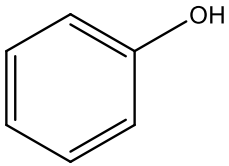


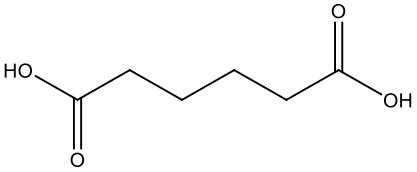


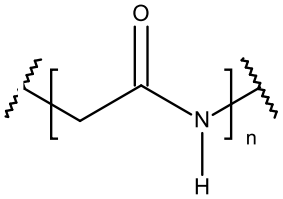


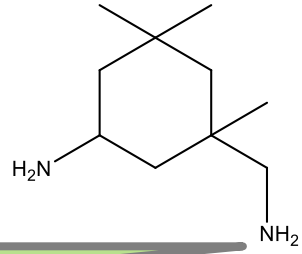
processing











applications

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Main Research Fields

Raw materials

Residual materials

Energetic use

Chemical-material use

Economic aspects

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- chemical and biological conversion of renewable resources
- biotechnological production of bulk chemicals/chemical precursors from carbohydrates and plant oils
- “Green Chemistry“ – processes:

  multi-stage cascade reactions combining chemical and enzymatic catalysis
- optimization and engineering of enzymes:

  development of new high-throughput screening methods
- biosynthesis and production of microbial biopolymers

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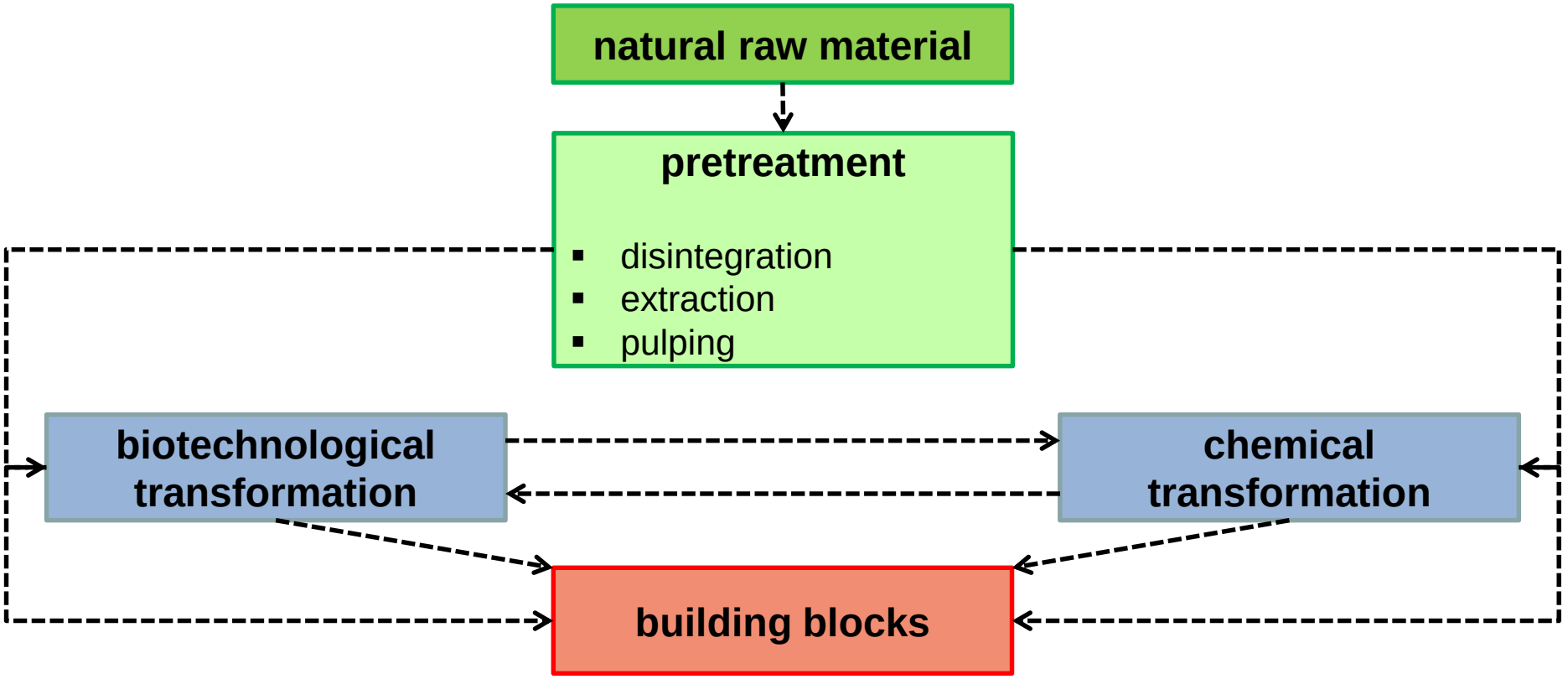
Biomass based Chemicals Production – Grass Silage Biorefineries in rural Areas

Grass Silage Biorefineries in rural Areas

Biorefinery

"A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power and chemicals from biomass"

- American National Renewable Energy Laboratory -

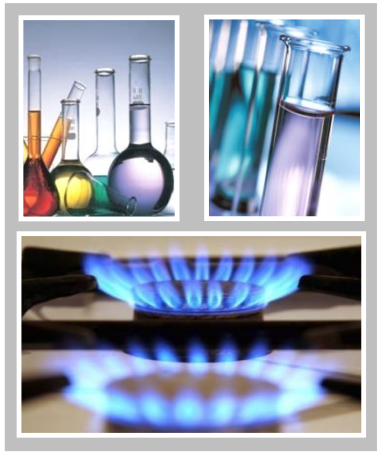


Grass Silage Biorefineries in rural Areas

Key note and objective

agric. biomass

farm-based biorefinery

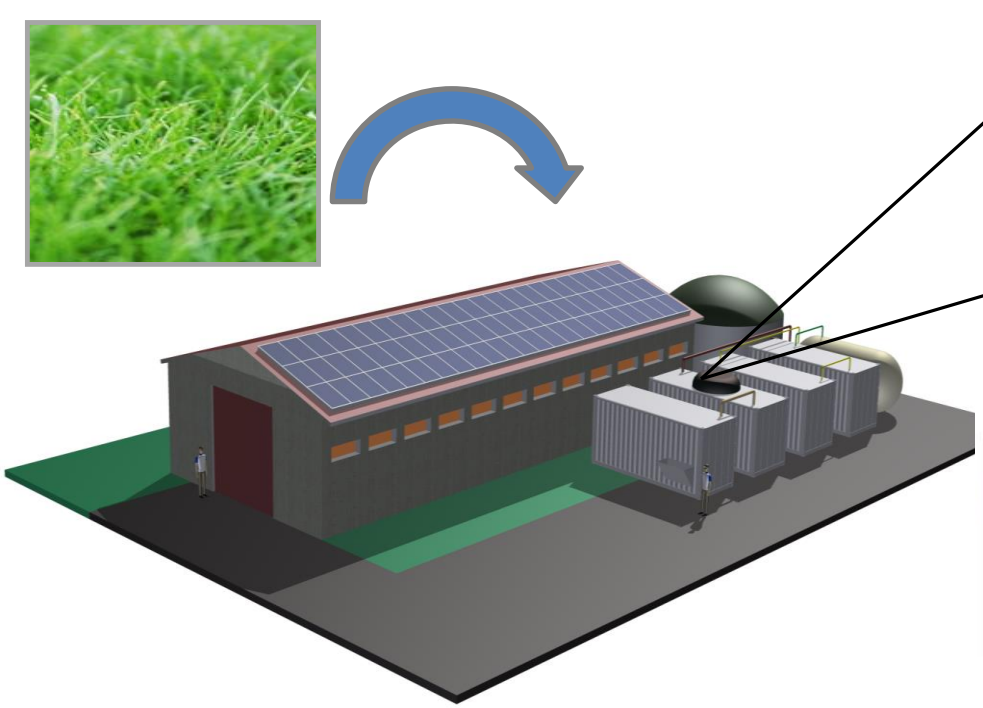


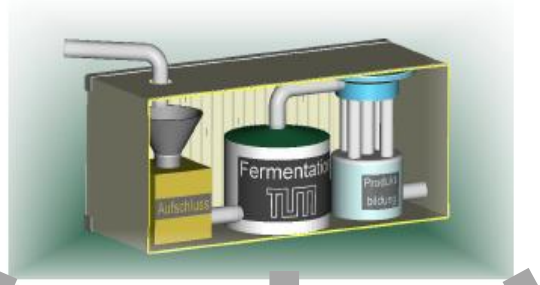
bulk chemicals

" … sustainable supply of bulk chemicals by refining of agricultural biomass in modular sized farm-based biorefineries …"

Grass Silage Biorefineries in rural Areas

Modular concept

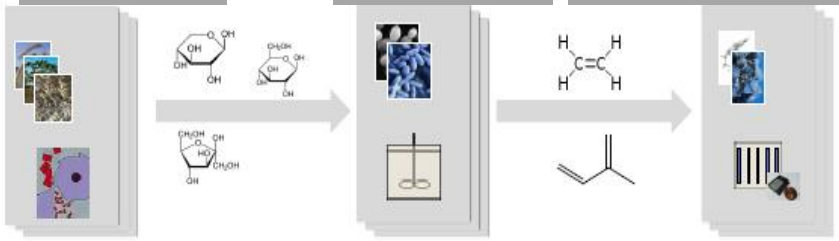




module 1 **pulping**

module 2 **conversion**

module 3 **product synthesis**



- local, inexpensive small plants
- modular, flexible structure
- (bio-)chemical cascade reaction
- new and innovative (bio-)catalytic processes
- processing of various substrates
- independent of season and region

- fermentative modification towards gaseous olefins
- conversion of variable intermediates in micro reactors

- provide different products
- flexible adaption to commercial and political conditions
- products with high energy density

Grass Silage Biorefineries in rural Areas

Interdisciplinary research project

Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst

Fraunhofer BioCat

Prof. Dr. Volker Sieber

Universität Regensburg

Chair of Organic chemistry and micro reactor systems

Prof. Dr. Olga Garcia Mancheno

HOCHSCHULE WEIHENSTEPHAN-TRIESDORF UNIVERSITY OF APPLIED SCIENCES

Chair of Bioinformatics

Prof. Dr. Dominik Heider

Technische Universität München

Chair of Chemistry of Biogenic Resources

Prof. Dr. Volker Sieber

Bioinformatic analysis

Biomass treatment

Olefin conversion in micro reactors

Interest of farmers

Fermentative production of olefins

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Chair of Marketing and Management of Biogenic Resources

Prof. Dr. Klaus Menrad

Technische Universität München

Chair of Chemistry of Biogenic Resources

Prof. Dr. Volker Sieber

Technische Universität München

Chair of Biogenic Polymers

Prof. Dr. Cordt Zollfrank

Material utilization of residuals

Olefin conversion

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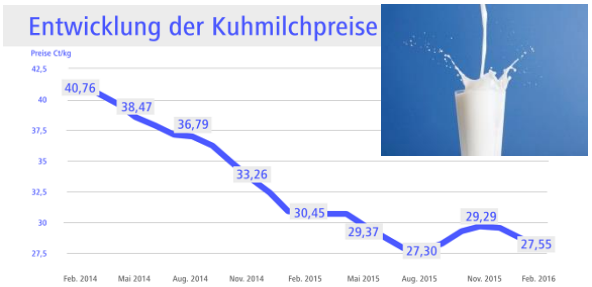
Chair of Organic and Analytical Chemistry

Prof. Dr. Herbert Riepl

Grass Silage Biorefineries in rural Areas

Grass silage as alternative raw material





- high annual biomass yields per hectare (Ø 8 t DM ha^{-1})
- no direct competition to food
- rarely used in industry
- labile commercial and political framework (cross compliance etc.)

alternative utilization ?



air-tight compacting of wet biomass

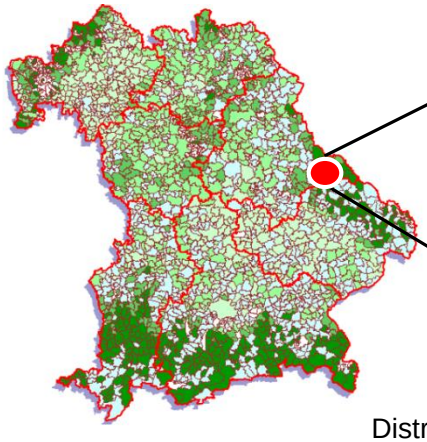
in silos or bales

conservation due to anaerobic conditions and auto-fermentative acidification (pH ↓)

- biomass modification
- simplified logistics
- cost-efficient storage
- all-season availability

Grass Silage Biorefineries in rural Areas

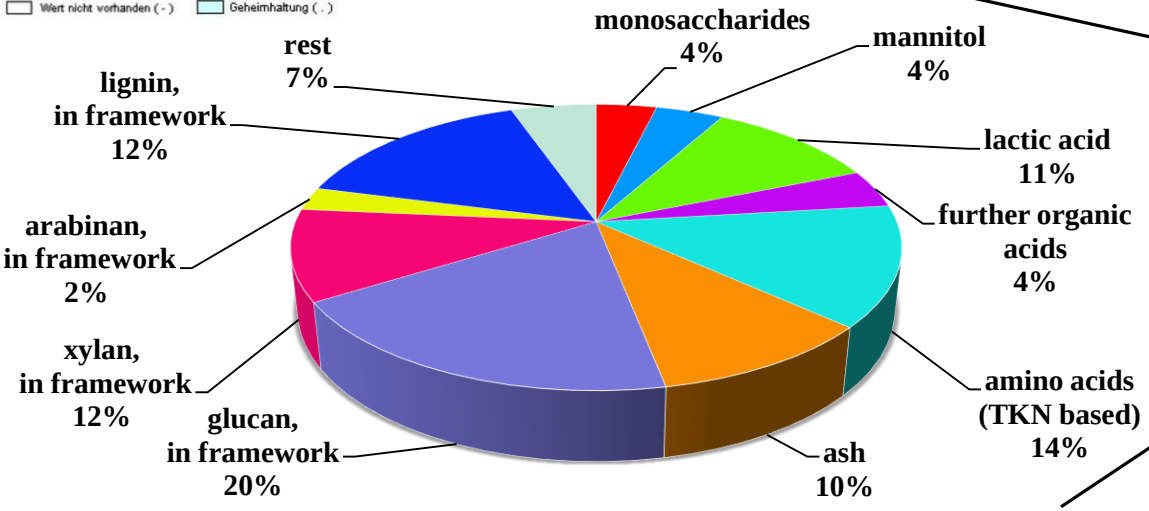
Composition of grass silage



Distribution of greenland in the Federal State of Bavaria

- *Poaceae* (dominant!)
  - *Lolium perenne*
  - *Dactylis glomerata*
  - *Alopecurus pratensis*
- *Asteraceae*
- *Fabaceae*
- *Plantaginaceae*
- *Ranunculaceae*
- …

Sort spektrum of the examined grassland located in the East-Bavarian mountain range.



Dry matter composition of the examined grass biomass after ensiling.

Grass Silage Biorefineries in rural Areas

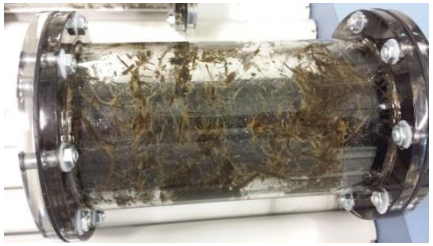
Integrated biorefinery concept for grass silage










grass silage
separation (A)
press juice, *Al*
water
press juice fermentation
product
press cake, *As*
liquid phase
mechanically supported saccharification (B)
solid-liquid separation
hydrolyzate, *Bl*
fermentation
product
solid fraction, *Bs*
water + enzymes
water/ethanol
organosolvation (C)
solid-liquid separation & solvent recovery
liquid fraction
lignin recovery
liquid fraction, *Cl*
anaerobic digestion
high-grade lignin, *C, precipitated lignin*
heat & power generation
steam & electricity
solid fraction, *Cs*
water + enzymes
subsequent hydrolysis (D)
solid-liquid separation
hydrolyzate *Dl*
residual solid phase, *Ds*

Schwarz *et al*. 2016

Grass Silage Biorefineries in rural Areas

Combined saccharification and downstream lignin extraction

grass silage

press cake

mechanically supported saccharification (**B**)

solid-liquid separation

hydrolyzate, **B***l*

solid fraction, **B***s*

water + enzymes

water/ethanol

organosolvation (**C**)

solid-liquid separation & solvent recovery

liquid fraction

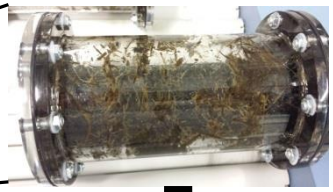
solid fraction, **C***s*

water + enzymes

subsequent hydrolysis (**D**)

solid-liquid separation

Schwarz *et al*. 2016



high dry matter loading (25% DM)

additional mechanical treatment of the fibrous fraction

saccharide-containing hydrolyzate
glucose 42 g/L
xylose 17 g/L

increased lignin content

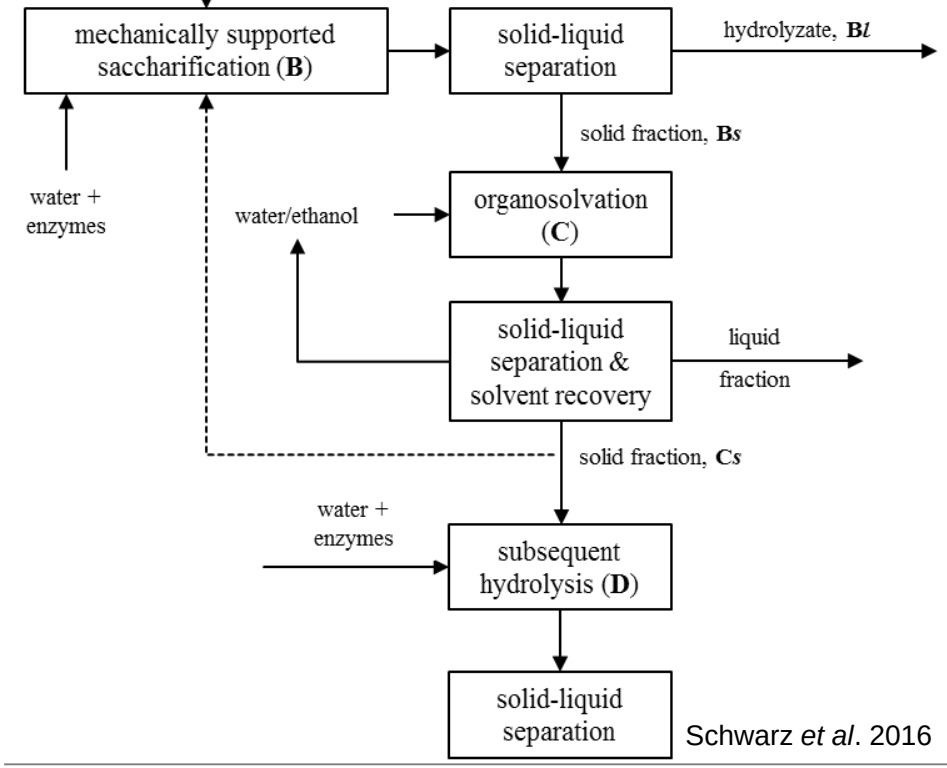
lignin extraktion

Grass Silage Biorefineries in rural Areas

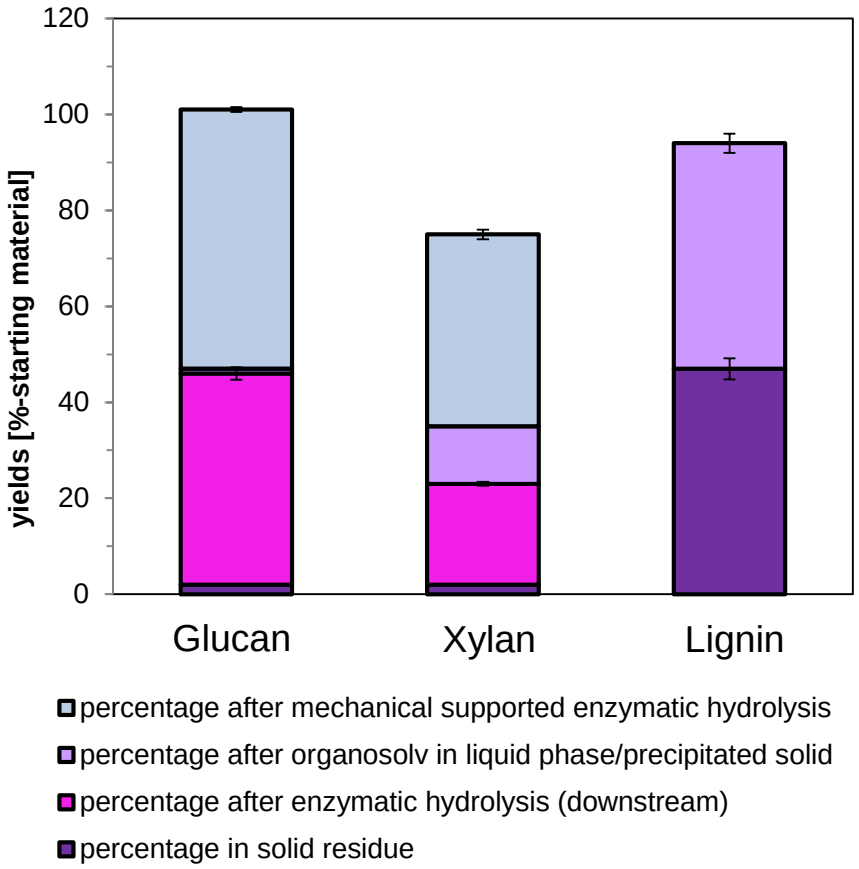
Combined saccharification and downstream lignin extraction

grass silage

press cake



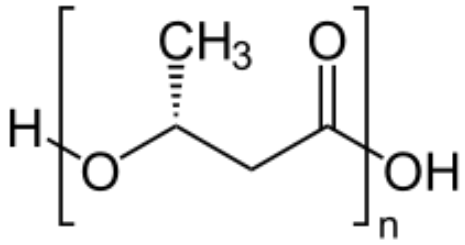
Schwarz *et al*. 2016



Yields of the main components of the grass silage after different treatment steps.

Grass Silage Biorefineries in rural Areas

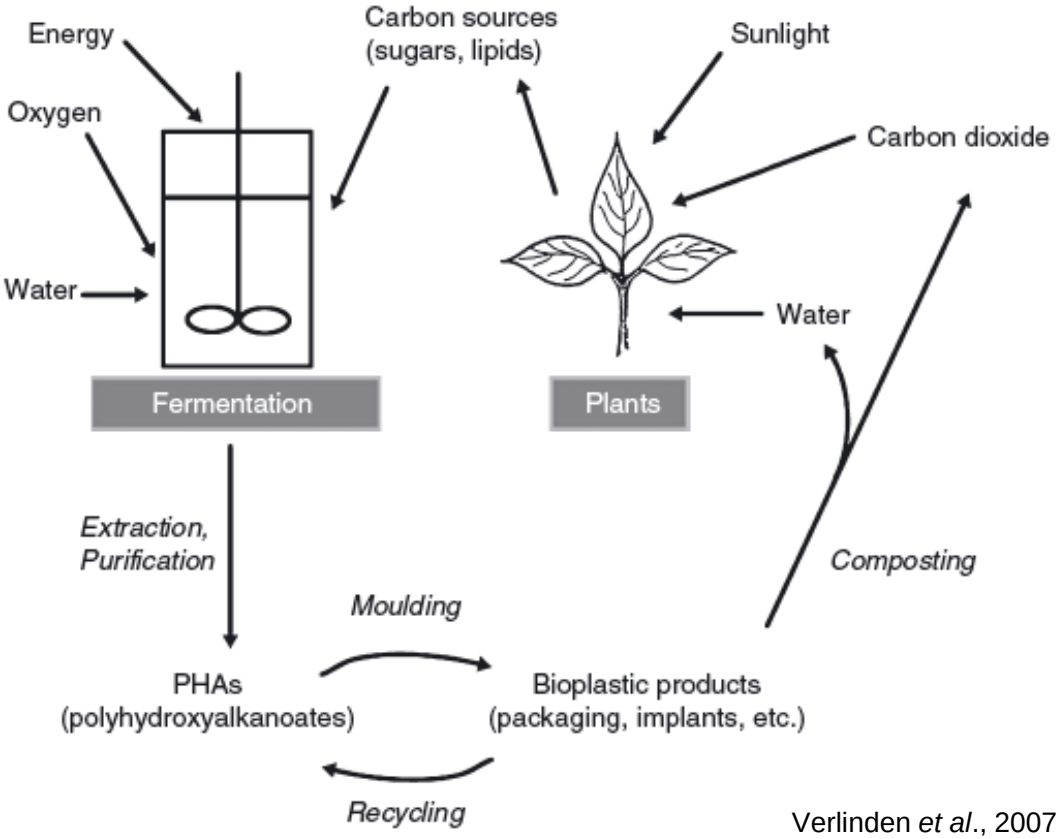
Biosynthesis of polyhydroxybutyrate from grass silage



structure of Poly-(3)-hydroxybutyrate

- biodegradable and renewable polyester
- accumulates as granules in bacteria cells
- alternative to common plastic materials produced from mineral oils
- applications:
  - packaging (containers and films)
  - hygiene articles (diaper)
  - agricultural sector (encapsulation of fertilizers)
  - medical sector (sutures, repair patches, stents, bone scaffolds etc.)

Lifecycle of Polyhydroxyalkanoates



Verlinden *et al*., 2007

Grass Silage Biorefineries in rural Areas

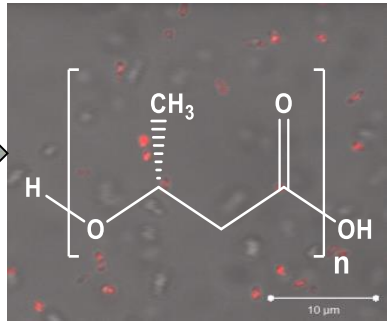
Biosynthesis of polyhydroxybutyrate from grass silage

nutrient- and carbon source

substrate from renewable resources

conversion in bioreactor

intra-cellular polyester inclusion



fluorescence image of the intra-cellular inclusion of PHB in bacteria cells

Features

- strain: *Cupriavidus necator*
- fed-batch fermentation system:
  - application of grass silage press juice and hydrolyzate from presscake saccharification as nutrient and C-source
- accumulation of cell mass by adapted cell recycle systems
- no evaporation energy required for concentration of feeds
- current fermentations:
  PHB content of about 40% (w/w) cell dry mass

Tab.: Composition of grass silage press juice

compound	concentration [g/L]
lactic acid	35.3
acetic acid	10.0
monosaccharides	12.9
mannitol	15.6
further organic acids	7.0

Grass Silage Biorefineries in rural Areas

Conclusion and review

- grass silage:
  - complex composition → nutrient-rich
  - modified under anaerobic conditions → storable
  - wet biomass → processing in local facilities
  - high potential as raw material for biorefineries
- biorefinery: multi-product system
  - integrated utilization of the raw material
  - combination of pulping methods → access to saccharides and lignin from grass silage
  - biotechnological conversion to bio-polymers and hydrocarbons
- employment and profit for farmers in rural areas
- preservation of urban-rural areas

bio-based chemicals production at local facilities

Acknowledgment

- Project Funding

Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst

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- Feasibility study

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- Team CBR

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