Wissenschafts Zentrum STRAUBING

Technische Universität München

Novel biorefinery concepts for a biobased economy

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Chair of Chemistry of Biogenic Resources
TU München

Agenda

Biorefinery concepts

Drop in solutions

- Novel biorefinery concepts – one pot enzymatic cascades
- Gaseous fermentations – novel synthetic routes

Valuable new natural products

- Microbial polysaccharides

Summary

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Definition of a biorefinery



Biomass resources

- Oil
- Starch
- Sugar
- Ligno-cellulose
- …

Biorefinery

Based on different conversion technol-ogies/processes

- Bio-chemical
- Thermo-chemical
- Physico-chemical
- …

Energy

- Transportation fuels (liquid/gaseous)
- Electricity/heat
- Solid fuels
- …

Biopased products

- Fine chemicals
- Bulk chemicals
- Animal feed
- Materials
- Fertilizers
- …

Various biorefinery concepts

- **Whole crop biorefinery** (grains and maize) “whole grop”
- **Green biorefinery** (wet green feedstocks– gras, clover, alfalfa)
- **Lignocellulosic feedstock** biorefinery (dry feedstocks wood and straw)
- **Two platform concept** (sugar and syngas platform)
- **Algy based biorefinery** (CO_2, sunlight)

1. Generation

- Classical use of agricultural biomass
- Biomass rich on sugar
  - Bioethanol
- Biomass rich on oil
  - Biodiesel

(-) only starch/only oil

2. Generation

- Lignocellulosic bio-mass as raw material
- Utilization of the whole feedstock

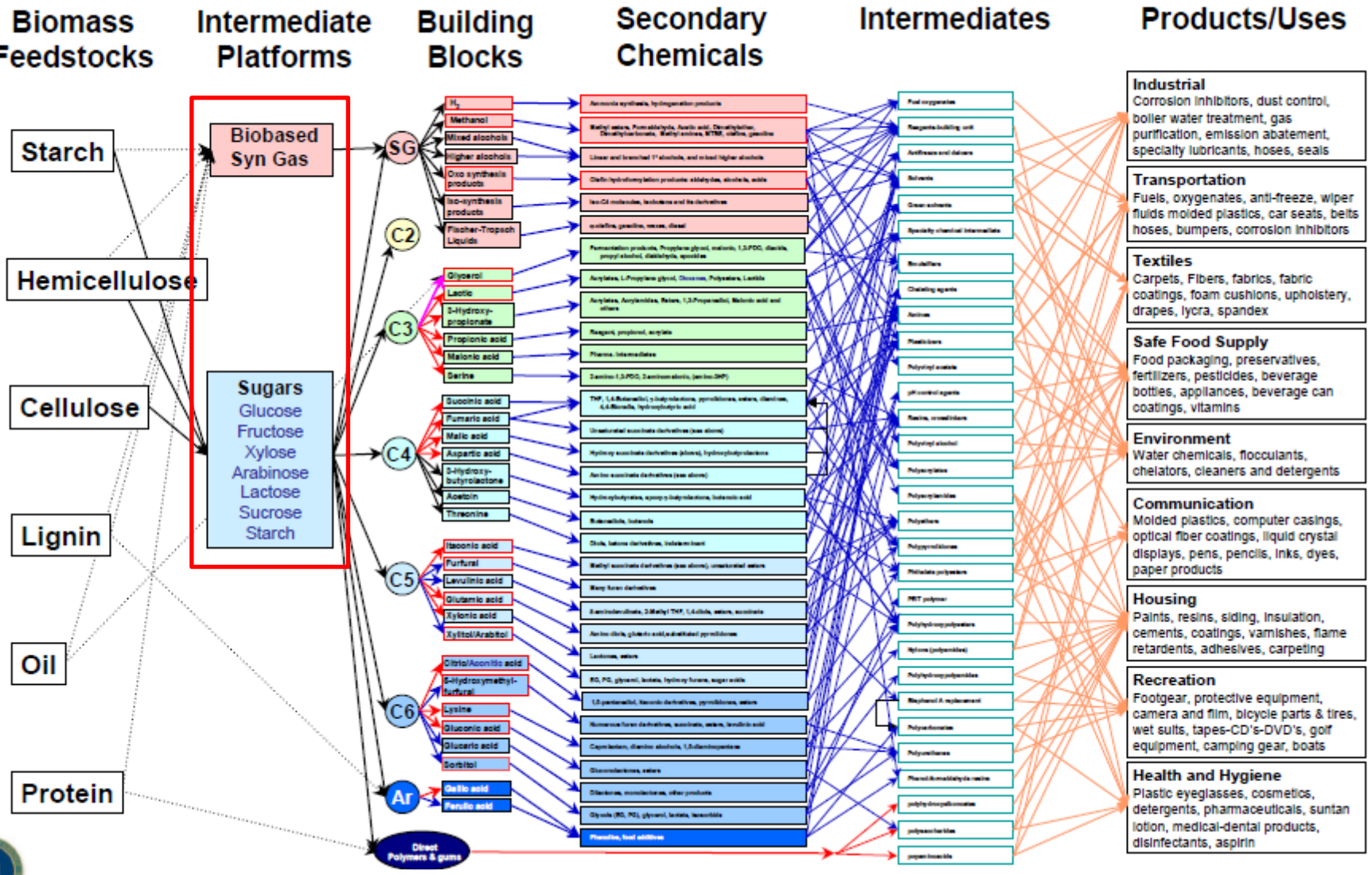
(+) holistic utilization

3. Generation

- Use of agricultural waste streams, as well as (biogenic) urban waste
- Algae biorefinery

(+) various sorts of clean energy
(+) technical solution of waste management

Various principles, various ways to go…..



Source: Top Value Added Chemicals from Biomass Volume I—Results of Screening for Potential Candidates from Sugars and Synthesis Gas, PNNL, NREL, EERE, 2004

… and still various challenges left …

Substrates
- Inhomogeneous composition
- Variable quality and composition
- Seasonable production
- Limited storage stability

Pre-treatment and Fermentation
- Individual pre-treatment requirements
- High costs energy/chemicals
- Inhibitory and toxic components
- Reduced yield by conversion

Down-stream processing
- Aqueous solutions
- Complex mixtures
- Cost intensive
- Intermediates and final products

Products
- Limited production depending on the market situation
- Instable quality
- Logistics

Down-stream: product separation from aqueous solutions

Separation of soluble products requires much energy
→ More favorable are: gaseous or insoluble products

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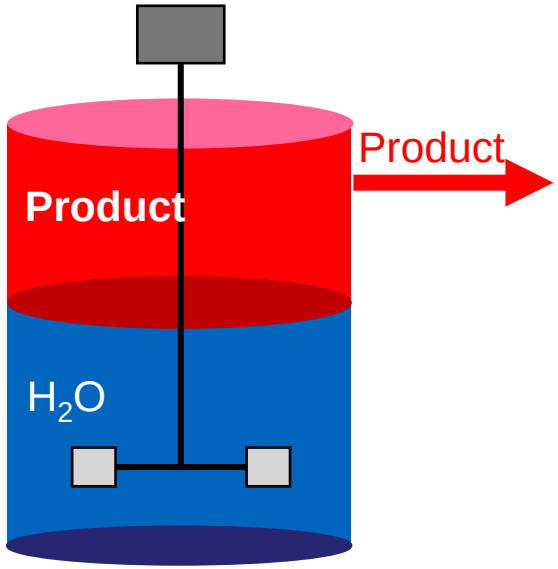
Liquid/liquid



Reactor

Example
Long chained alcohols

Gaseous products

Reactor

Example
Hydrogen

Liquid/solid

Reactor

Example
Lactic acid salts

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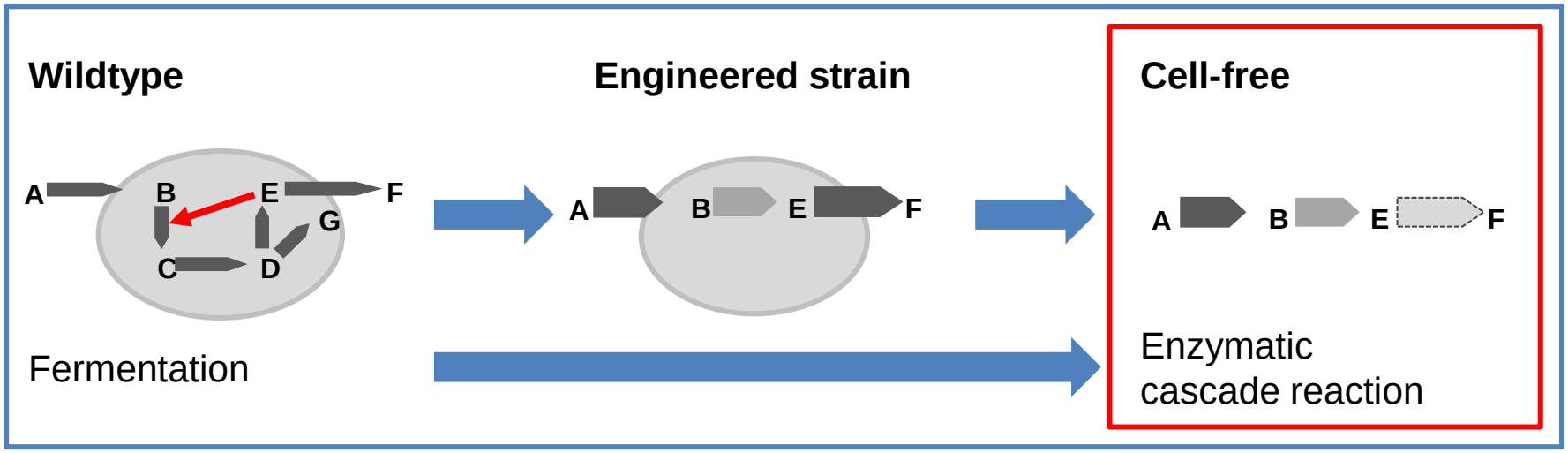
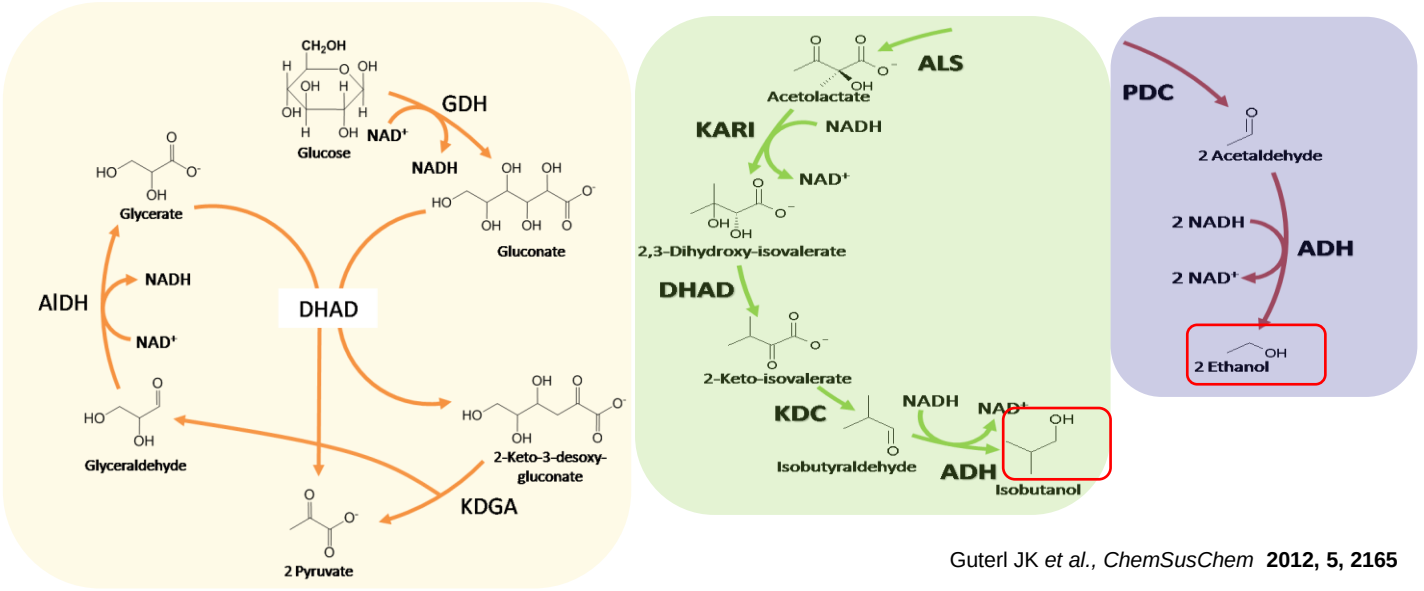
Novel biorefinery concepts – one pot enzymatic cascades

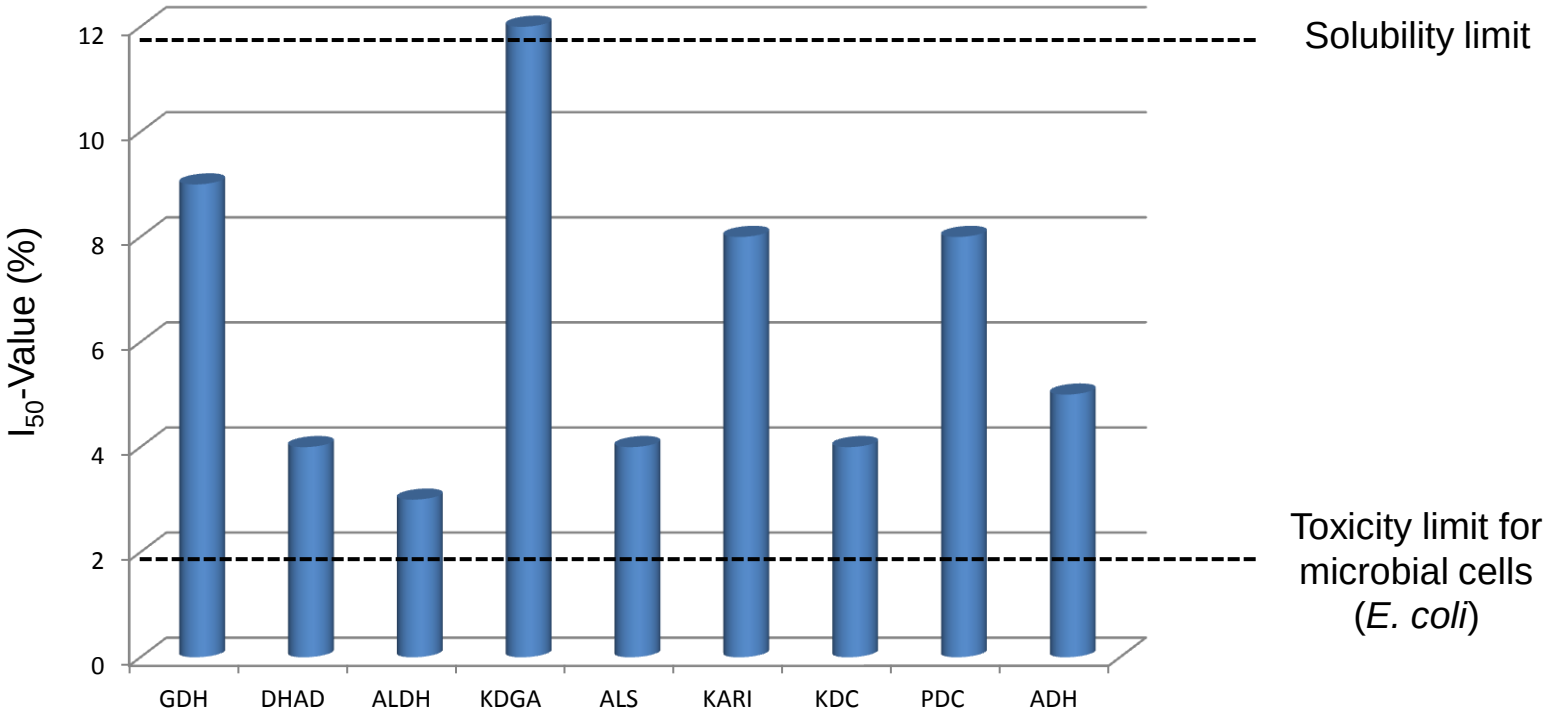


Example
Isobutanol



Guterl JK *et al.*, *ChemSusChem* **2012, 5, 2165**

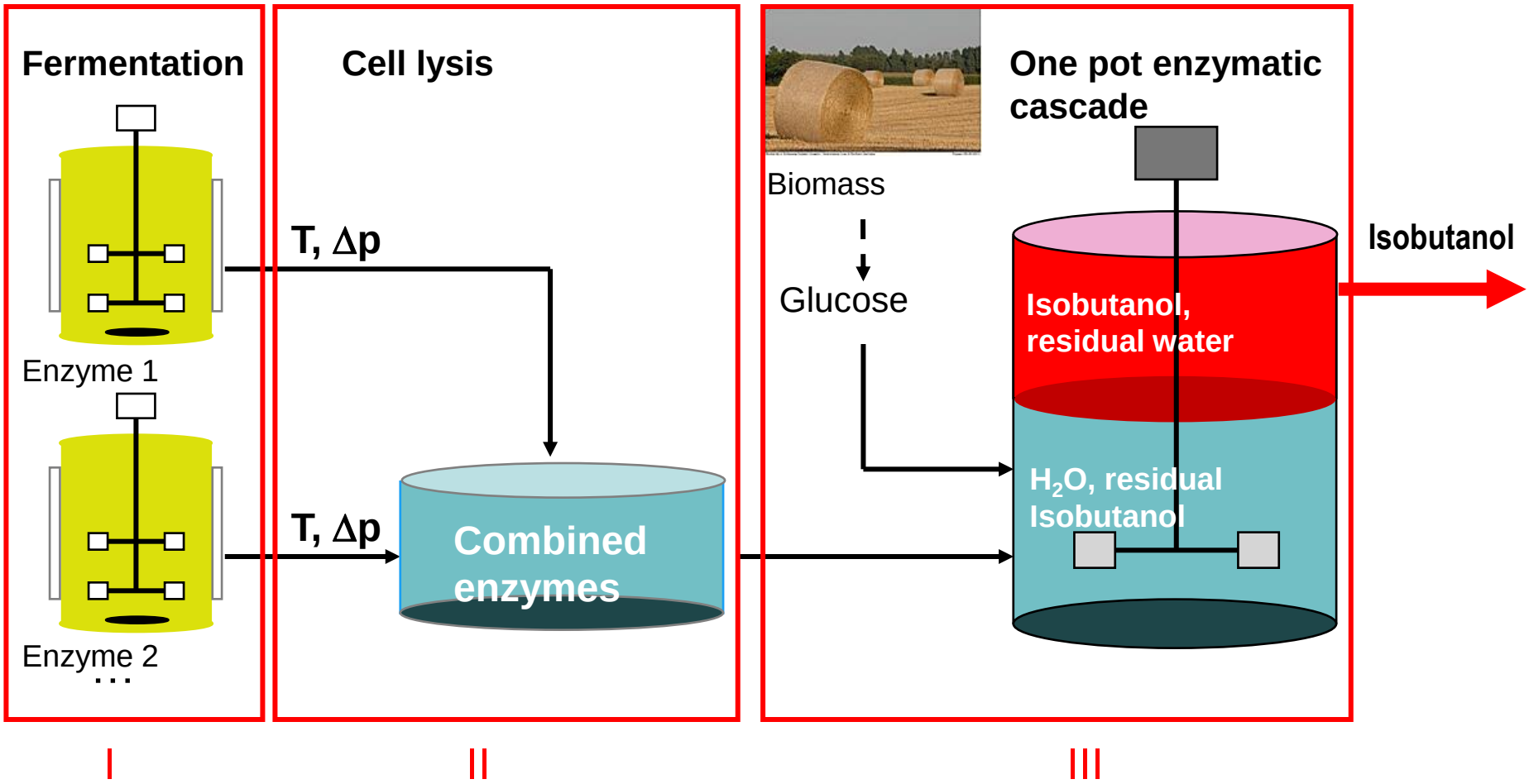
Tolerance of the cascade enzymes towards isobutanol



I_{50} = Isobutanol concentration (% in water) where enzyme displays 50% of its initial activity

Guterl JK *et al.*, *ChemSusChem* **2012, 5, 2165**

Novel cell free biorefinery concept - example isobutanol



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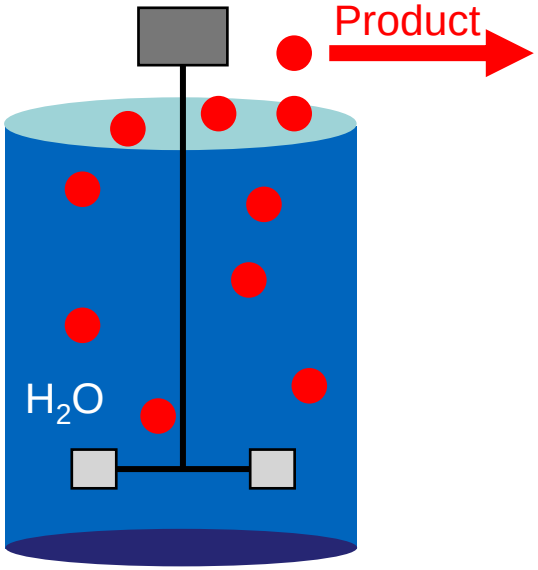
→ More favorable are: gaseous or insoluble products

Gaseous products



Reactor

Example
Hydrogen

Liquid/liquid

Reactor

Example
long chained alcohols

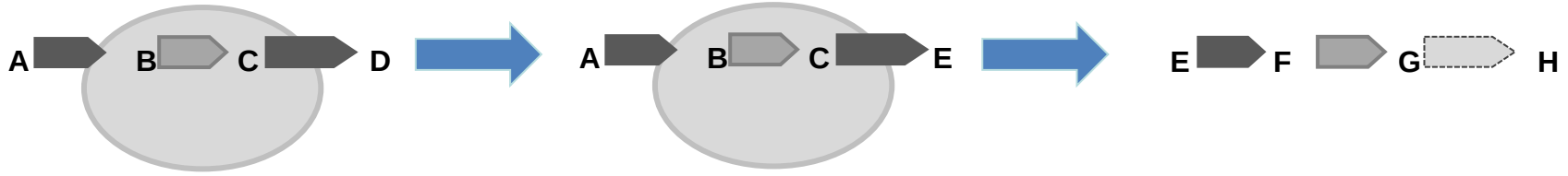
Liquid/solid

Reactor

Example
lactic acid salts

Gaseous fermentations – novel synthetic routes

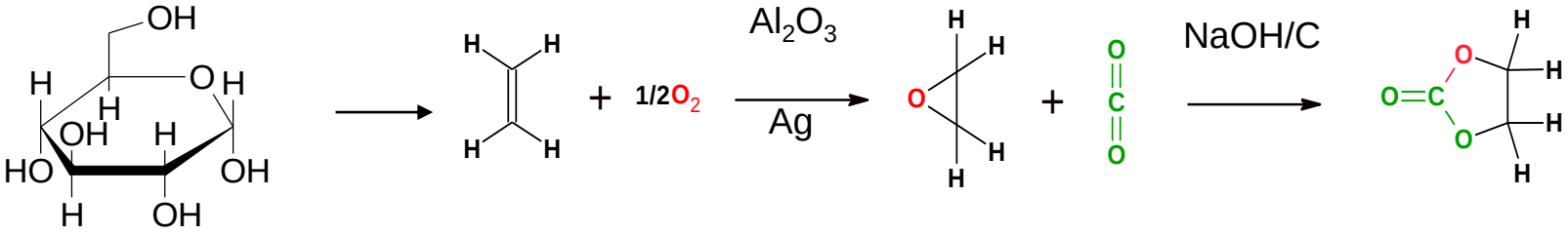
Novel synthetic routes → **Gaseous products** → **Chemical synthesis**



Engineered strains → Bio(chemical) cascades

Example:

Ethylencarbonat



Glucose — **Etylen** — **Etylenoxid** — **Etylen-carbonate**

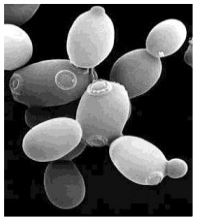
Principle of a novel biorefinery – gaseous fermentation

Module 1
Pre-treatment

Module 2
Fermentation

Module 3
Chemical synthesis

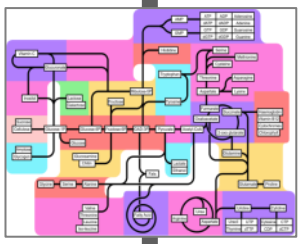
Glucose



Ethanol

Chemically catalyzed

Ethylen



- Pre-treatment via biorefiner
- Strain engineering (Ethylen production and lactate tolerance)
- Microreaction technology

Source: www.mpg.de

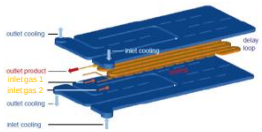
Principle of a novel biorefinery – cascade product formation

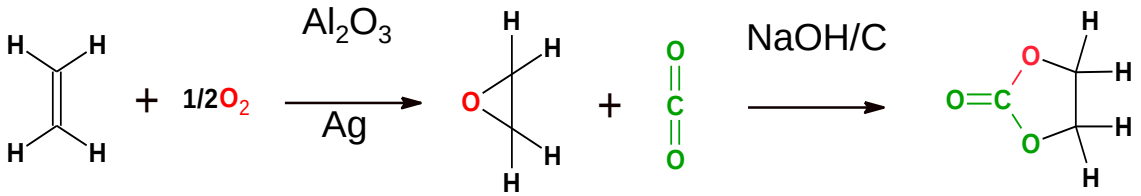
Module 1
Pre-treatment

Module 2
Fermentation

Module 3
Chemical synthesis

Microreaction-technology



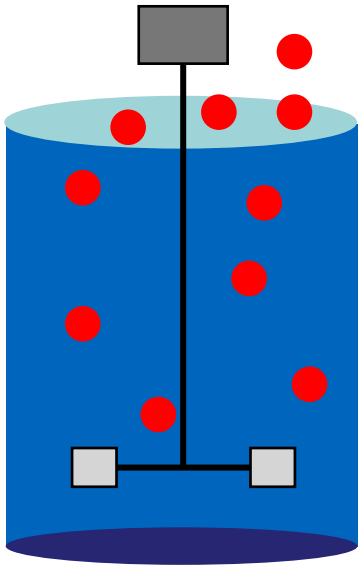


Example:
Etylencarbonate

Source: Industrial design, scale-up, and use of microreactors, **Chemistry Today • vol 27 n 4 / July-August 2009**

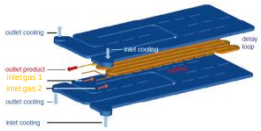
Scale-up of gaseous fermentation - scalability by numbering-up

Gaseous fermentation

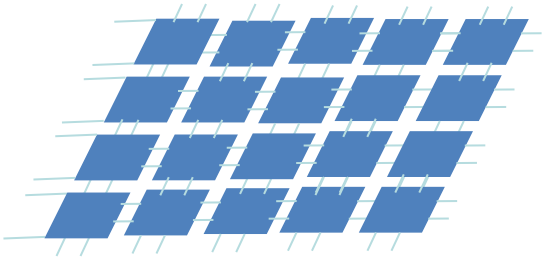


Ethylen

Micro-reactors



Numbering-up



Ethylen-carbonate

Module 2

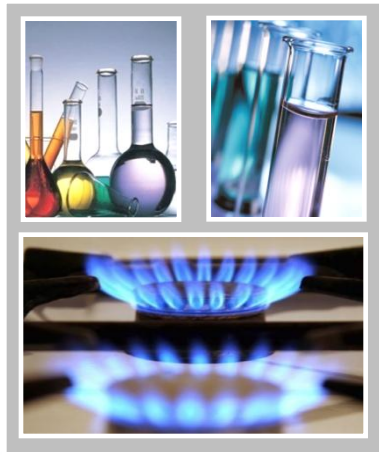
Module 3

Source:: Industrial design, scale-up, and use of microreactors, **Chemistry Today • vol 27 n 4 / July-August 2009**

Local small scale biorefinery concept – Farmestead bioerfinery

Agricultural biomass

Farmstead-biorefinery



Chemical base materials

„ … sustainable resourcing of chemical base materials by refining agricultural biomass in modular farmstead biorefineries …“

Challenges and benefits of novel biorefinery concept

Pre-treatment
- Inhomogeneous composition
- Gras and silage
- Modular
- Various substrates

Fermentation
- Strain engineering
- Enzyme optimization
- Reactor design for gaseous products
- Cheap down-stream processing

Chemical synthesis
- Evaluation of different proceedings (air/O2)
- Design of microreactor
- Catalyst development
- Cascade optimization
- Up-scale by numbering

Interfaces
- Process development for
- Optimization of safety-relevant process parameters
- Regulation of gas flows
- Modular

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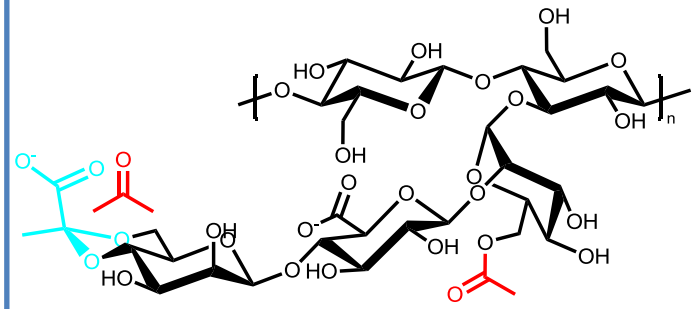
Valuable natural biopolymers – microbial exo-polysaccharides

Xanthan

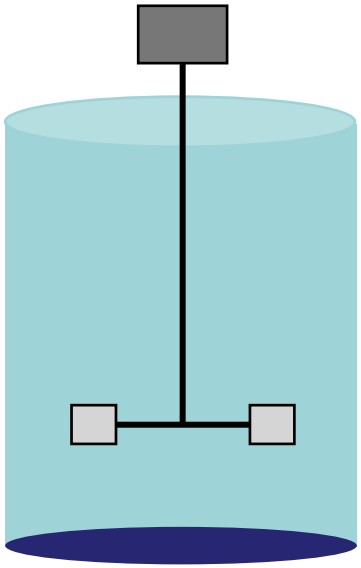
- M*w*: 1.5 x 10^6
- Different substituent´s
- Various applications
- Viscosity ~2 Pa*s



- Food
- Feed
- Lacquers
- technical applications
- …..

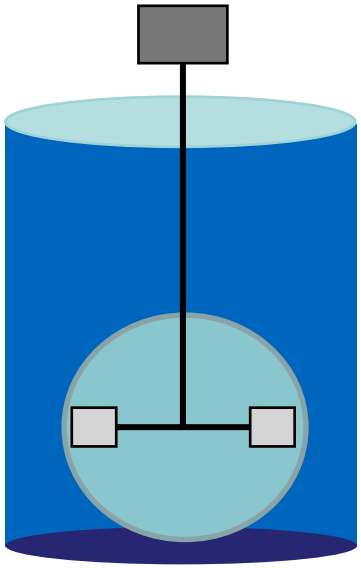
Viscosity – one of the main problems

Start of fermentation



Newton behaviour

End of fermentation



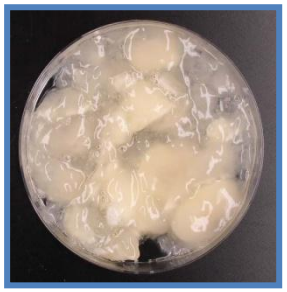
Non-Newton behaviour, shear thinning

Area with well mass and oxygen transfer

Area with low mass and oxygen transfer

Further challenges - especially for production on hydrolysates

- Mass transfer
- Mixing
- Different reactor designs available – no special one for EPS production
- **Down-stream processing**
- Alternatives to precipitation with alcohols
- Screening for novel microbial exopolysaccharides



Fermentation broth

Final product

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Summary

- Cell free cascades might be superior to fermentation processes
- Chemo enzymatic cascades will enhance product portfolio
- Engineered strains will led to synthetic fermentation products
- Drop in chemicals and biofuels
- Valuable novel natural products
- Biopolymers will be produced by competitive costs

And you for your attention!

Thanks to:

FG Ind. Biocatalysis
Prof. Thomas Brück

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