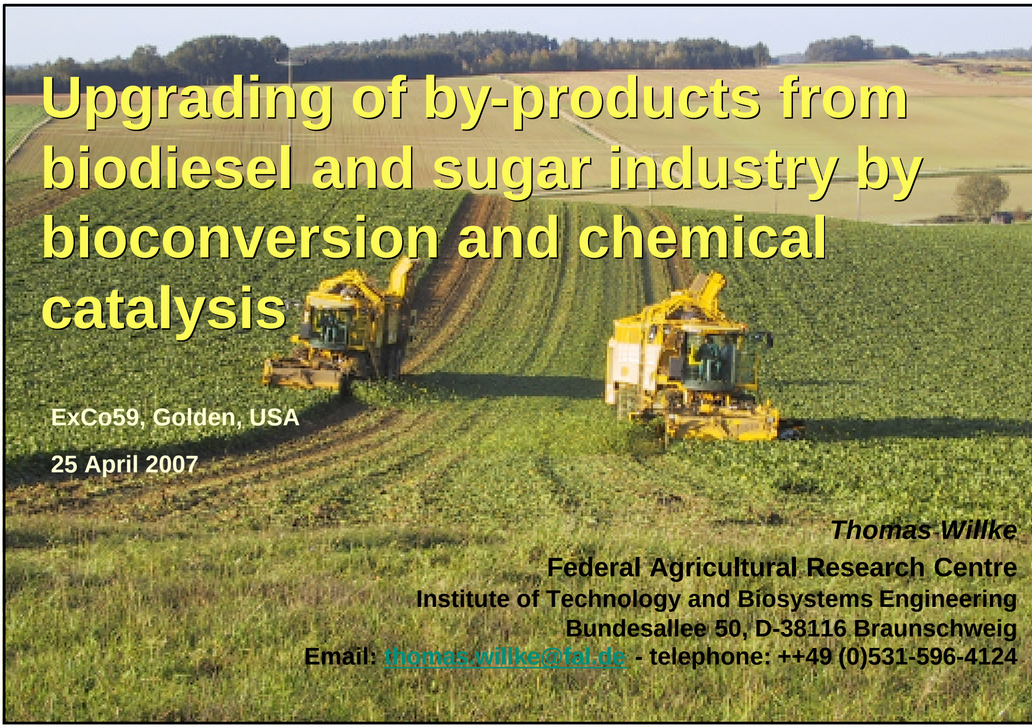

Upgrading of by-products from biodiesel and sugar industry by bioconversion and chemical catalysis

ExCo59, Golden, USA

25 April 2007

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Institute of Technology and Biosystems Engineering
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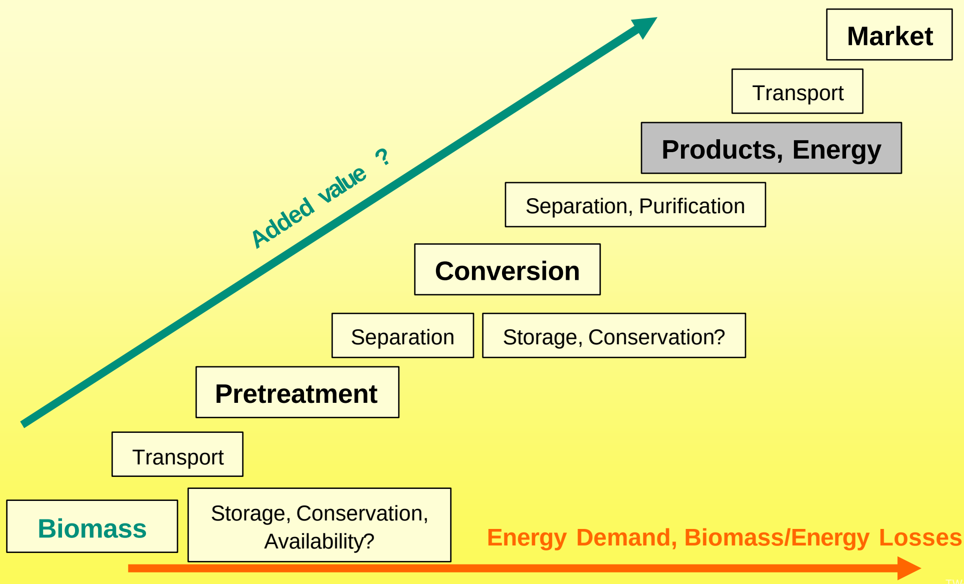
Biorefinery
Chain links

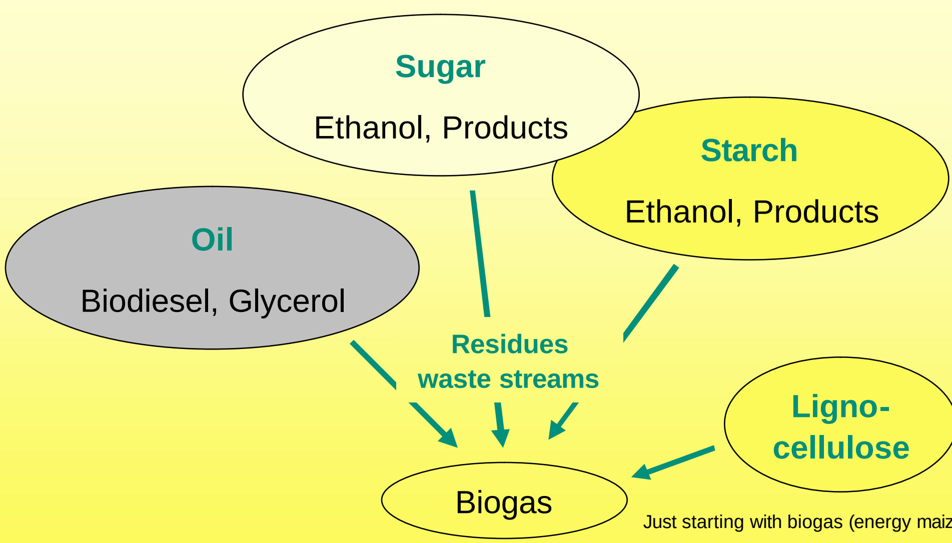


Some Important Steps in Biorefineries

The whole process combines physical, chemical and biotechnological steps

- **Pretreatment, Conservation, Separation**
  - Physical, mechanical (destructure, milling, sieving)
  - (Thermo)chemical (heat, acid, base, …)
  - Biological (enzymes, microorganisms)
  - Combination of all
- **Conversion**
  - Biotechnological (bacteria, fungi, enzymes)
  - Chemical-catalytic (e.g. noble-metal-catalysis)
  - (Thermo)chemical (pressure, heat, …)
  - Combination of all

Biorefineries in Germany
Existing



Just starting with biogas (energy maize)

Biorefinery in Germany

The main problem: costs

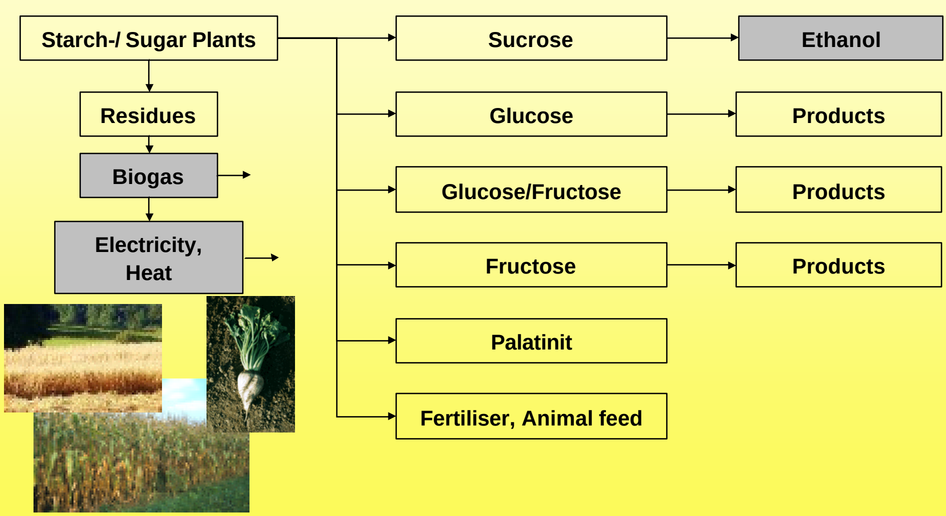
Cost reduction in Biorefinery

- **Transportation efficiency**
  - Energy-density of feedstock and products
  - Infrastructure, distances
- **More efficient processes**
  - Biocatalysts, chemical catalysts
  - Productivity
  - Product concentration
- **Cheaper and more efficient feedstocks**
  - Agricultural/industrial residues
  - Lignocellulose
  - Additional use of wase water/-air

Processes

Starch, Sugar

Sugar-Refinery (for example: Südzucker, crop energies)



Top 12 Platform Chemicals From Biomass

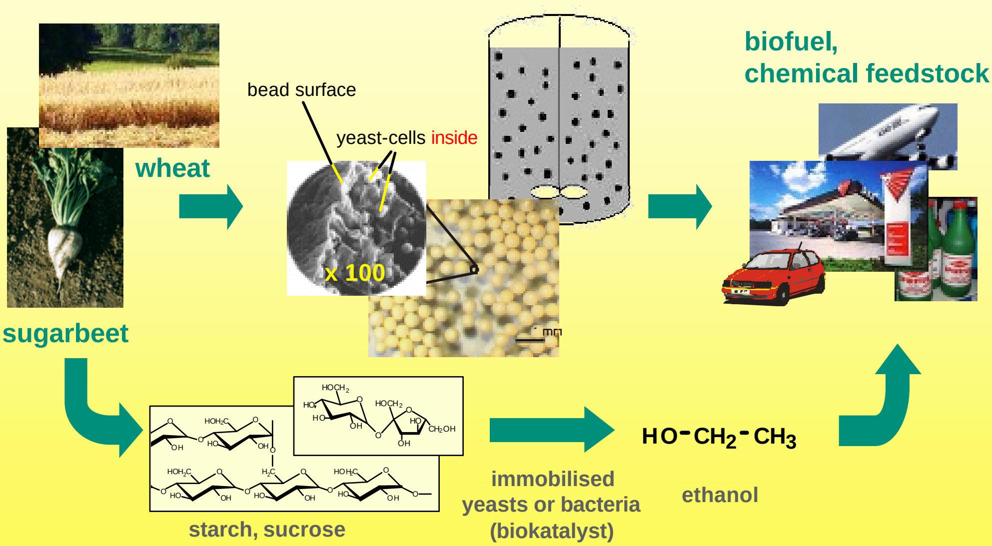
- 1,4-Succinic, fumaric and malic acids
- 2,5-Furan dicarboxylic acid
- 3-Hydroxypropionic acid
- Aspartic acid
- Glucaric acid
- Glutamic acid
- **Itaconic acid**
- Levulinic acid
- 3-Hydroxybutyrolactone
- **Glycerol (1,3-propanediol)**
- Sorbitol
- Xylitol/arabinitol

Ethanol ?

Source: Top Value Added Chemicals From Biomass, PNNL & NREL, 2004

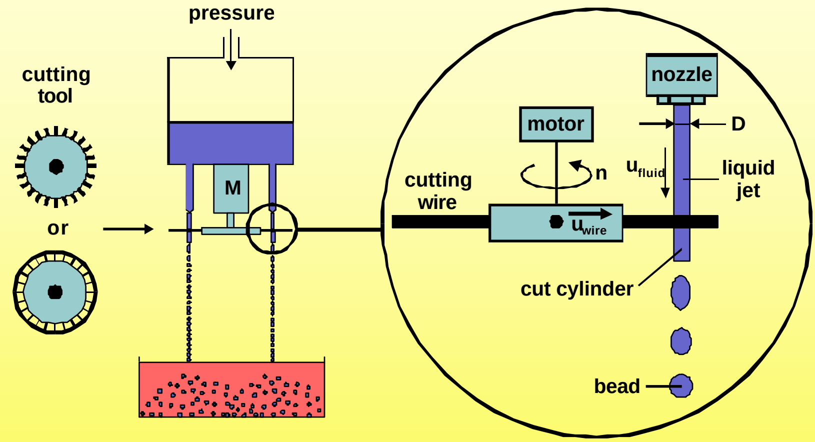
Immobilisation in Biotechnology

Example: ethanol-production with immobilised yeasts



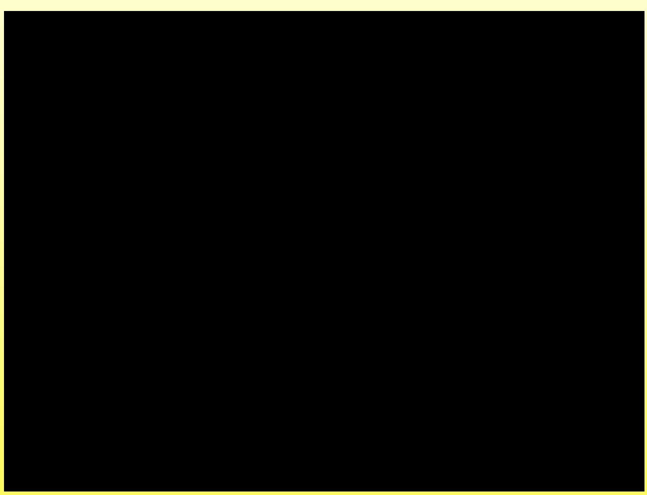
Bead Production with JetCutter

Scheme and operation



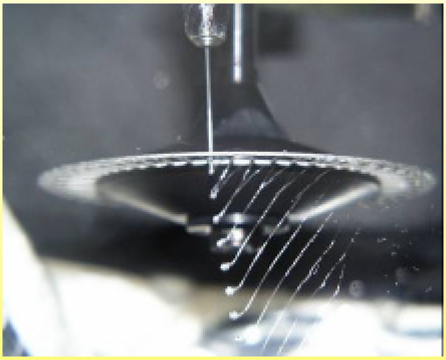
u_{fluid} = fluid velocity	m = motor	D = diameter of
u_{wire} = wire velocity	n = rotations	the nozzle

Animation of the Cutting Process



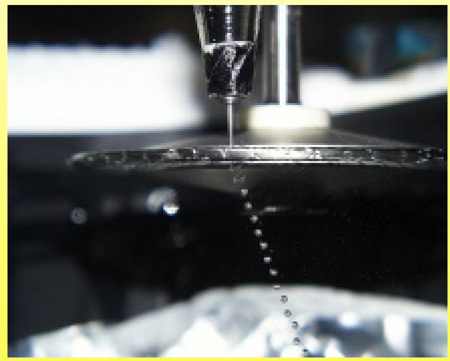
JetCutter

optimisation of settings for low spray losses



unsuited adjustments
→ high losses

suited adjustments
→ almost no losses



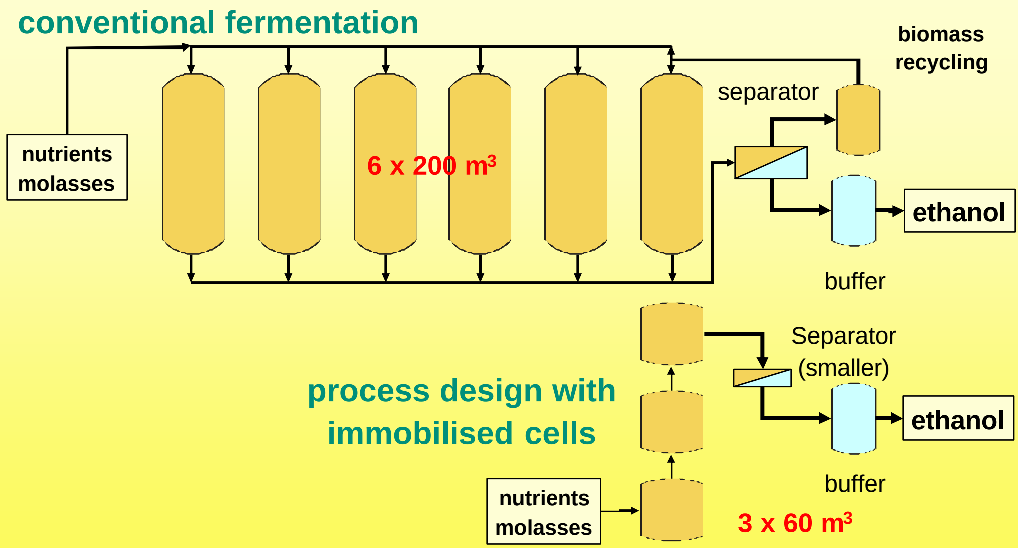
Bioethanol Production

Advantage of immobilisation

	free cells	immobilised cells	
microorganism	**activity** [kg EtOH/(kg BDM·h)]	**activity** [kg EtOH/(m^3 cat·h)]	**productivity** [kg EtOH/(m^3·h)]
yeast ***Saccharomyces cerevisiae***	**0.5 – 1.4**	**25 - 70**	**10 - 30**
bacterium ***Zymomonas mobilis***	**4 - 5**	**190 - 230**	**50 - 80**

Ethanol Fermentation: Production Plant

Conventional or with immobilised cells



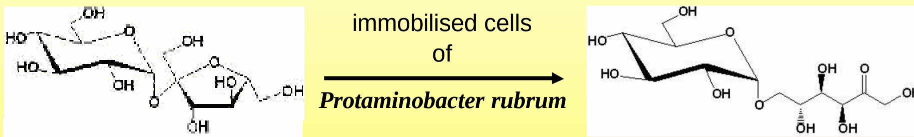
BMA Braunschweig, capacity: 60,000 litres EtOH / 24 h

Ethanol-Fermentation: Pilot Plant

Immobilised yeast, continuously, 3-step

Palatinose-Production

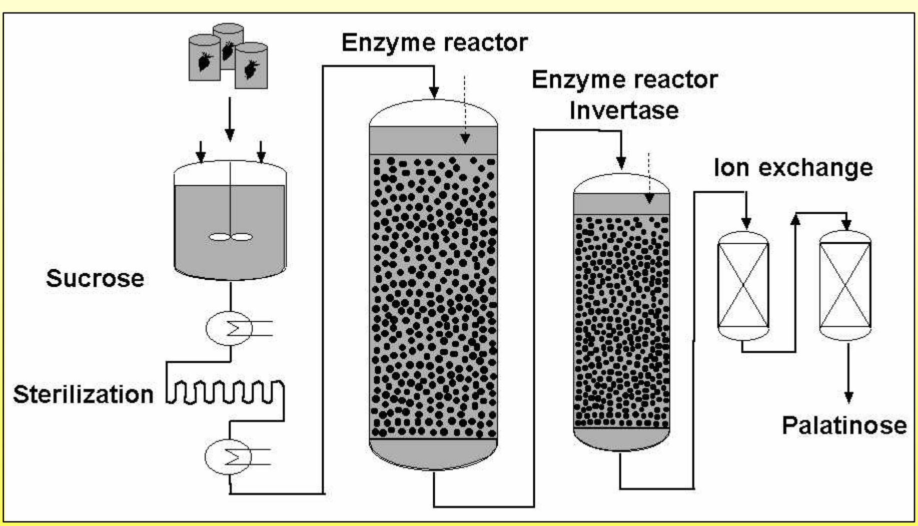
Example for immobilisation on an industrial scale



saccharose **palatinose**

Palatinose-Production

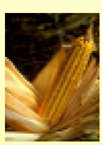
Bioconversion



Industrial Production of Palatinose with Immobilised Microorganisms

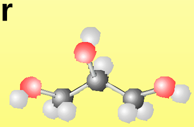
Itaconic Acid Production

The process



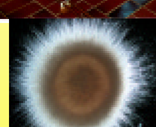
Sugar

or



glycerol 10%

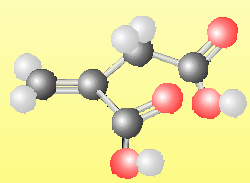
(byproduct of biodiesel production)



Fungi, aerobic

Yeast, aerobic

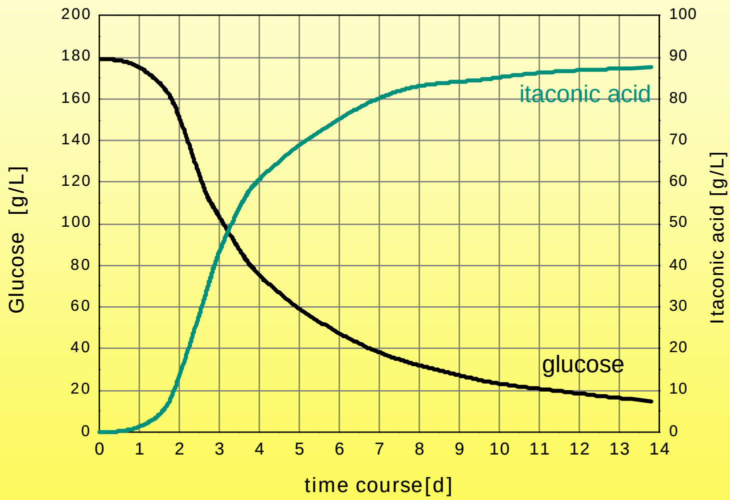
Itaconic acid



chemical feedstock

Itaconic Acid Production

Fermentation from glucose



conditions

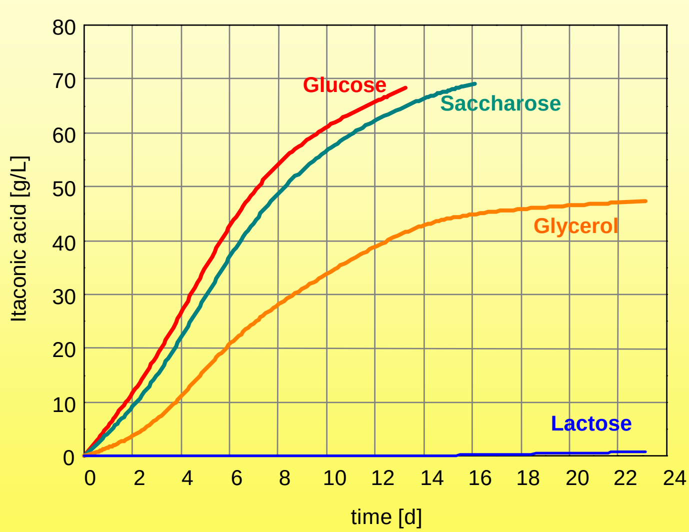
- batch (without pH-controll)
- mineral-salt medium, P-limitation
- pH 1,7
- 33°C

result

- ➔ final concentration > 80 g/L IA
- ➔ max. productivity > 1 g/(L·h)
- ➔ Yield: 0,6 g/g = 83% of Theory

Itaconic Acid Production

other substrates?



conditions

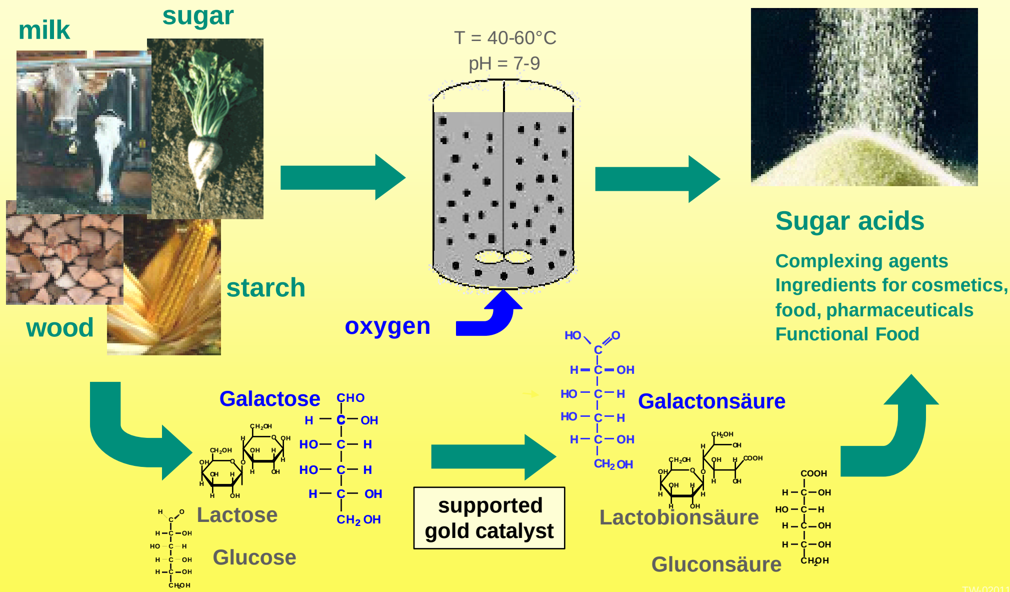
- batch (without pH-controll)
- mineral-salt medium, P-limitation
- pH 1,7
- 33°C

Result (for Glucose)

- ➔ final concentration > 80 g/L IA
- ➔ max. productivity > 1 g/(L·h)
- ➔ Yield: 0,6 g/g = 83% of Theory

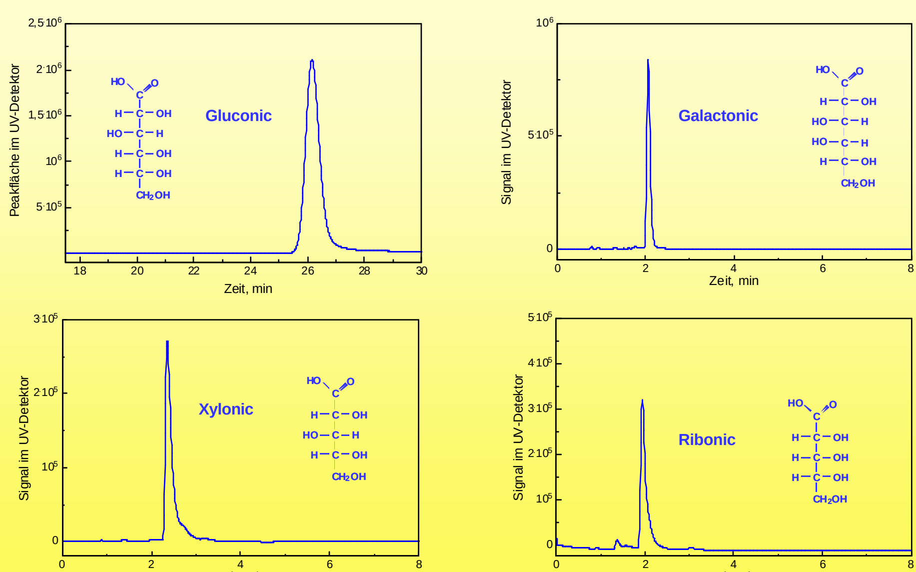
Innovative Technologies

Chemical catalysis with gold catalysts



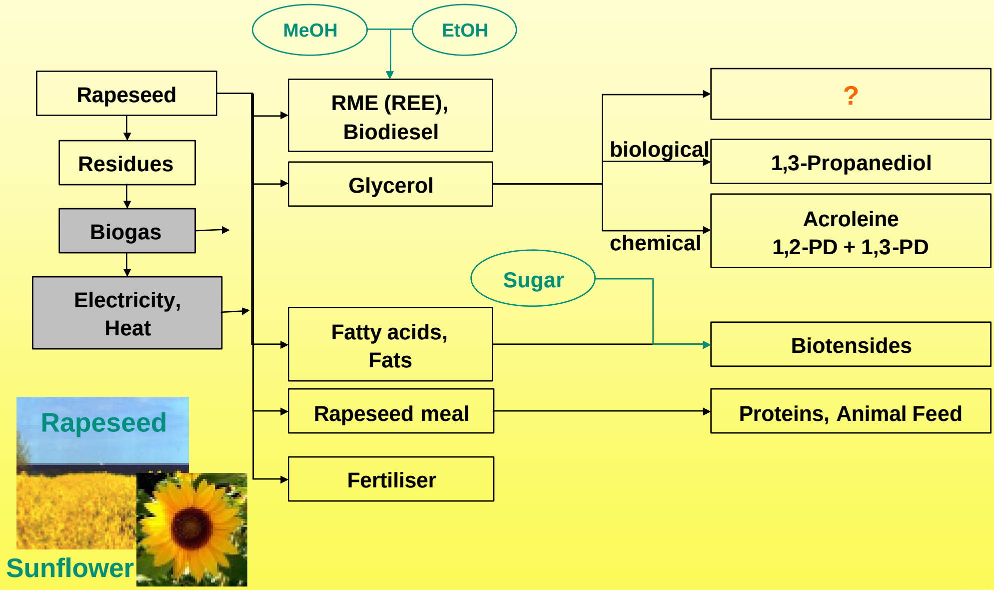
Oxidation of Monosaccharides

Selectivity of the gold catalyst (HPLC-data)



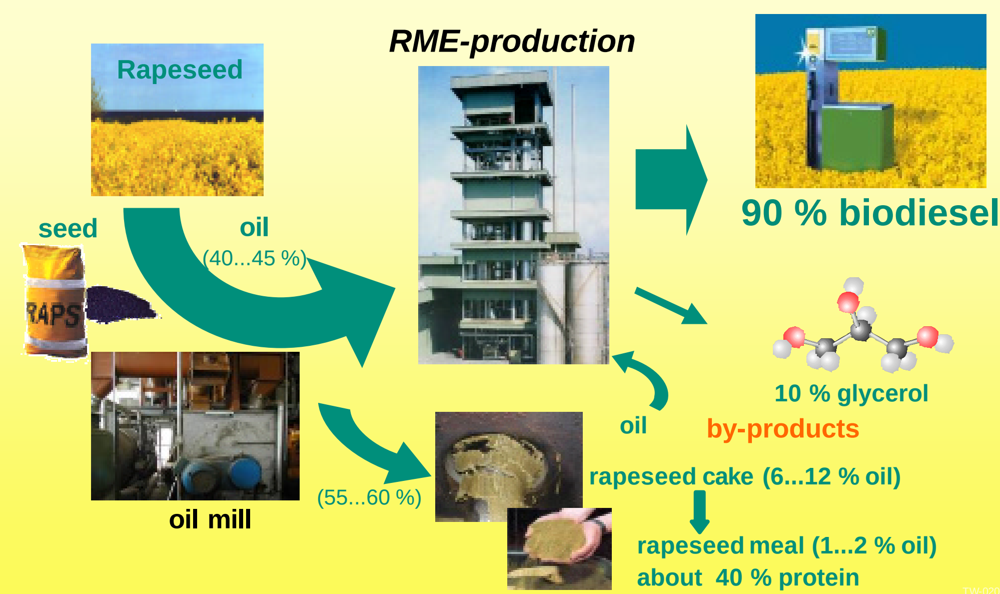
Processes

Oil mill, biodiesel plant



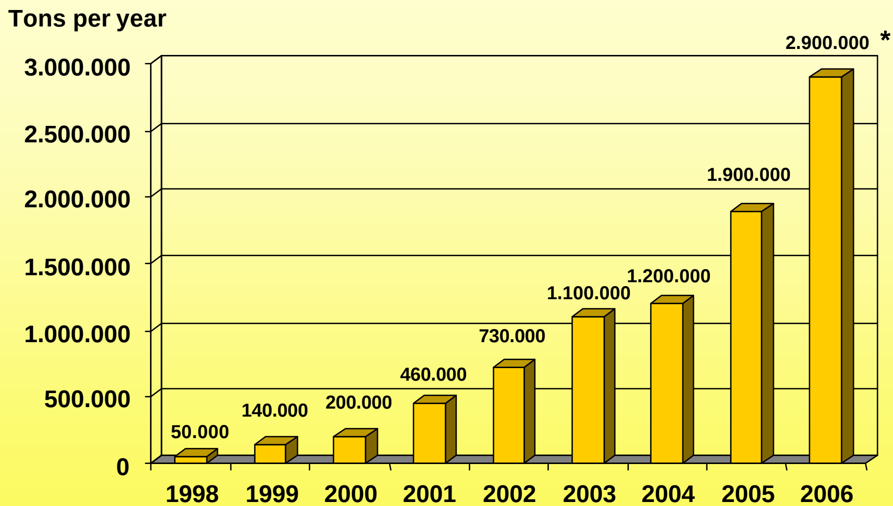
Biodiesel from Rapeseed

Production



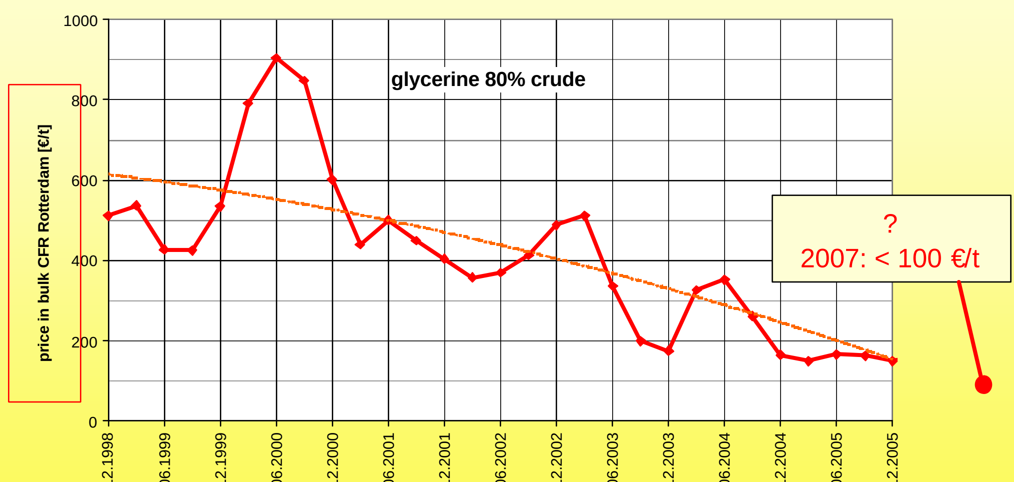
Biodiesel

Production capacity in Germany



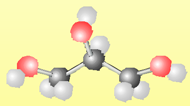
Data: UFOP, *estimated

Price of Raw Glycerol



1,3-Propandiol from Glycerol

FAL Federal Agricultural Research Centre

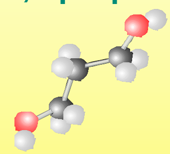


glycerol 10%

(byproduct of biodiesel production)

bacteria, anaerobic

1,3-propanediol



chemical feedstock

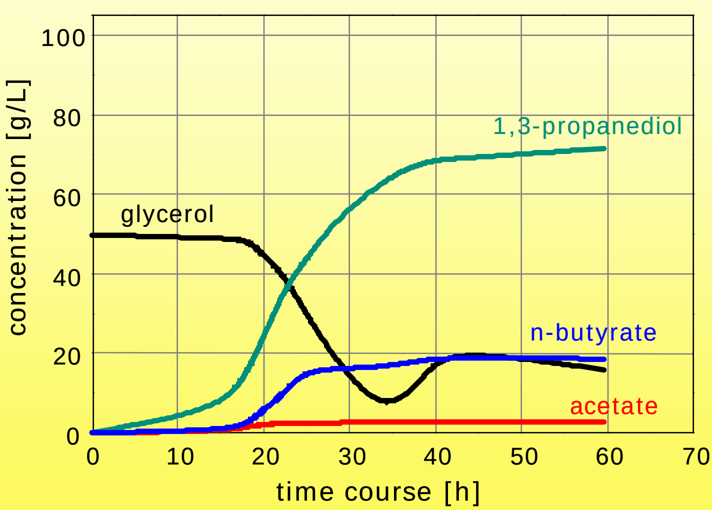
(polymers)

TW-020117

1,3-Propanediol Fermentation

Strain NRRL1024 (from culture collection)

FAL Federal Agricultural Research Centre



conditions

- fed-batch (pH-controlled)
- mineral-salt medium + YE
- pH 7.0
- 35°C

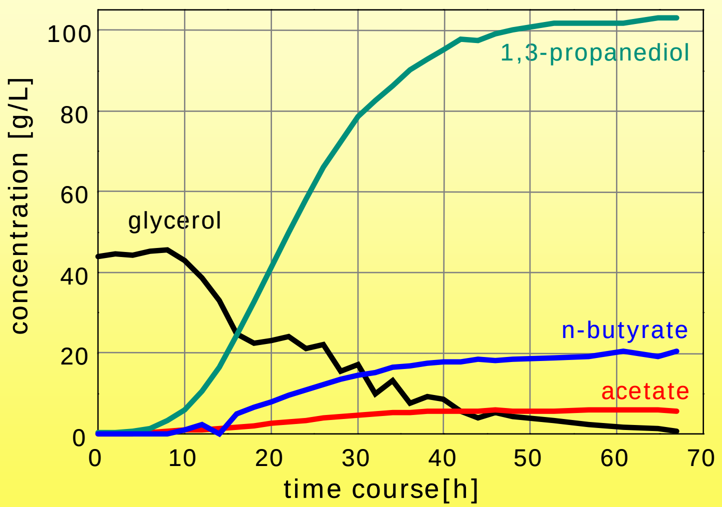
results

- final concentration > 72 g/L 1,3-PD
- productivity: > 1.7 $g_{PD}/(L \cdot h)$

TW-020117

1,3-Propanediol Fermentation

Strain IK123 (from screening)



conditions

- fed-batch (pH-controlled)
- mineral-salt medium + YE
- pH 7.2
- 32°C

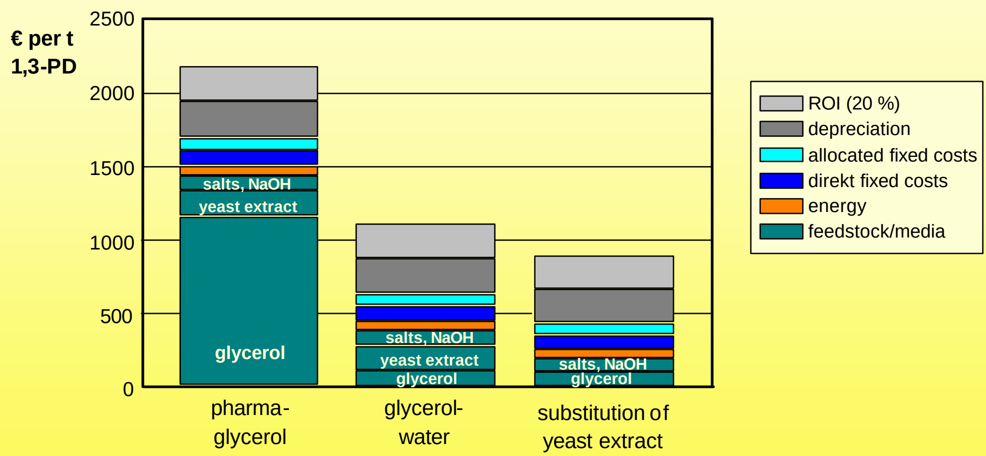
result

- ➔ final concentration > 100 g/L 1.3-PD
- ➔ productivity: > 2 g_{PD}/(L·h)

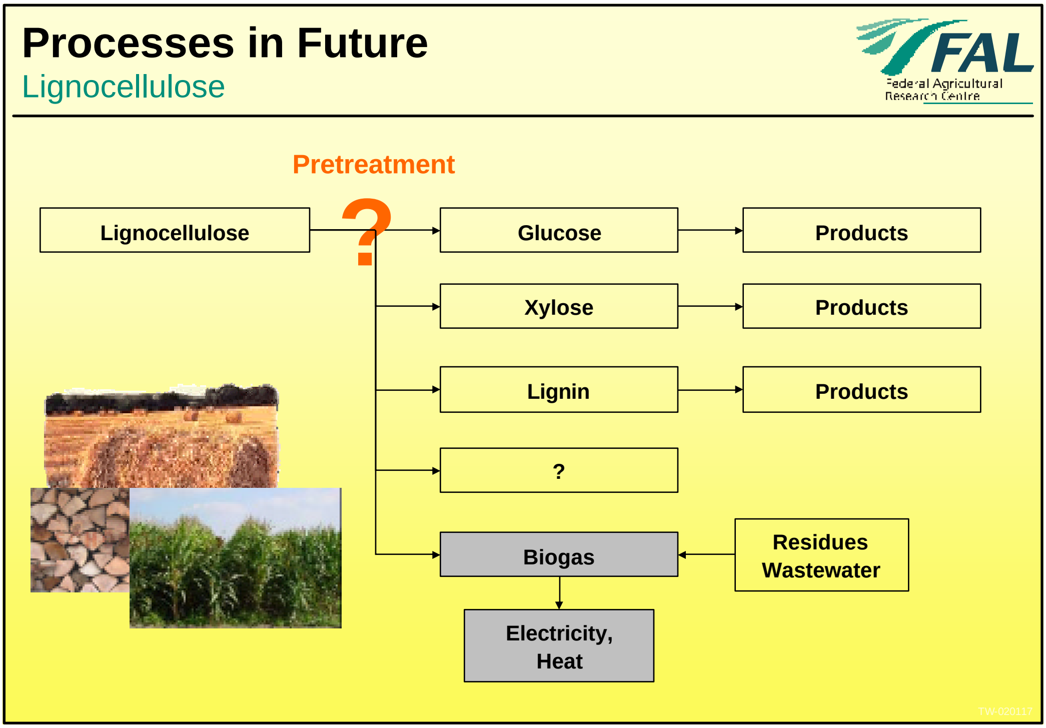
TW-020117

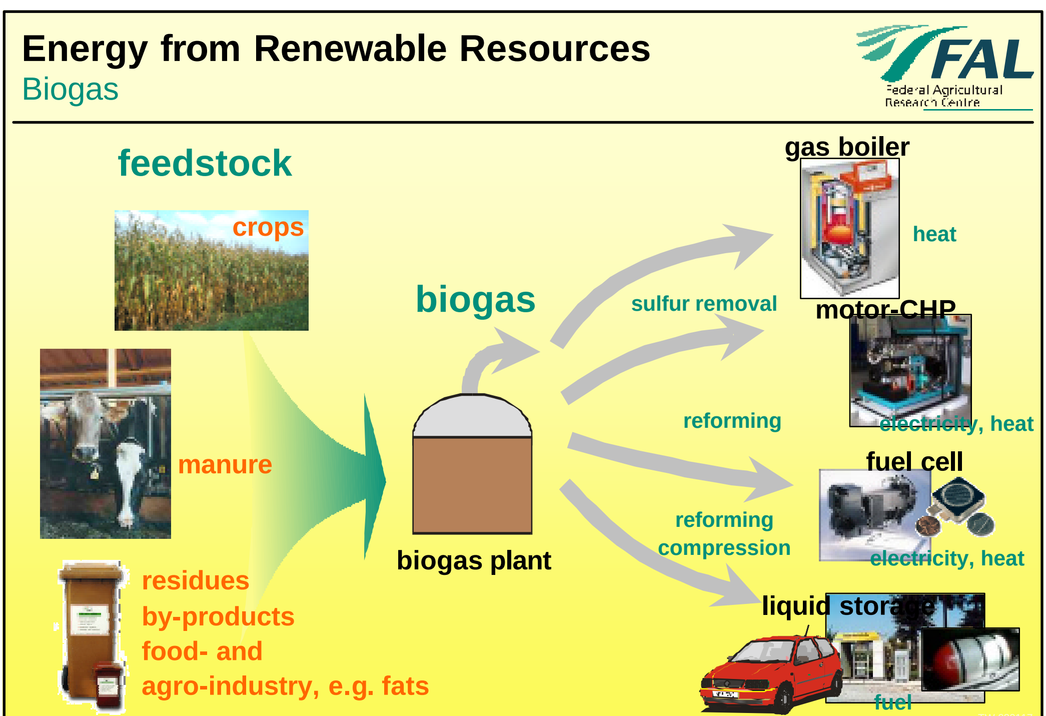
1,3-Propandiol-Fermentation: Cost Reduction

Influence of glycerol and nutrients price

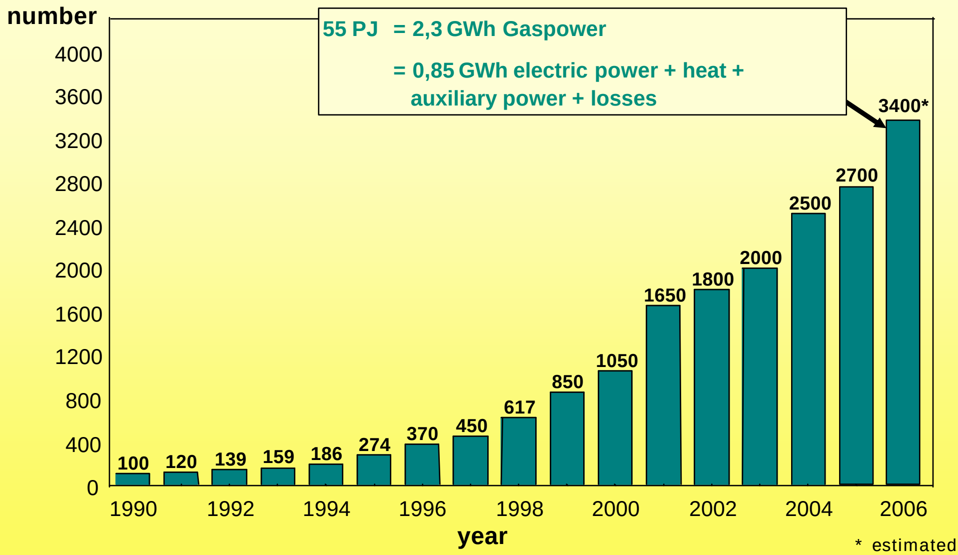


TW-020117


Processes in Future
Lignocellulose
FAL
Federal Agricultural Research Centre
Pretreatment
Lignocellulose
?
Glucose
Products
Xylose
Products
Lignin
Products
?
Biogas
Residues Wastewater
Electricity, Heat


Energy from Renewable Resources
Biogas
FAL
Federal Agricultural Research Centre
feedstock
crops
manure
residues
by-products
food- and
agro-industry, e.g. fats
biogas
biogas plant
sulfur removal
reforming
reforming
compression
gas boiler
heat
motor-CHP
electricity, heat
fuel cell
electricity, heat
liquid storage
fuel

Biogas Plants in Germany



Source: German Biogas Association and own Data

Electricity from Biogas

fuel-cell pilot plant located at the FAL

Biorefineries

Manifold interactions

FAL Federal Agricultural Research Centre

Locality
Climate, Soil, Water
Infrastructure, Logistic
Industry

Market
Consumer, Products
Heat & Power

Policy
Directions, Rules
Subsidies, Tax Benefits

Technology
Methods
Processes
Transport

Biorefinery
Products
Heat, power
Fuels
Materials
Feed & Food?

Economy
Energy Situation
Prices,
Globalisation
Foreign Trade
Feedstocks

Auxilaries
Energy, Seed, Fertilizer
Pest Management

Biomass
Yield, Quality, Price
Seasonal Availability

Man
Needs
Population development
Social aspects

Thank you for your attention!