Knowledge import from outside the European Union

Koen Meesters (AFSG)

Introduction

Review of knowledge from outside the EU

Very large amount of information

- From websites, conference proceedings and literature
- From workshop with lecturers from Brazil, Japan and the USA

Selection Criteria

- Biorefinery (multiple products)
- Integration (connection with other industries)

Bio Ethanol

Problems:
- Low value products (ethanol, DDGS)
- High input of capital and (fossil) energy

Focus of biorefinery and integration research often on:
- production of **more** ethanol from lignocellulosic feedstocks (corn stover)
- use of stover as a fuel to **reduce** fossil energy demand

Problems not solved / heat integration only

Other solutions will be presented

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EnerGenetics

Process:
- Start with genetic crop that produces nutraceuticals
- Use wet micro-milling
  - Producing protein isolate
  - Leaving fibres in solid phase
- Ethanol is a by-product
- Use membranes instead of distillation

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EnerGenetics

5 problems tackled:

- High added value products
  - Nutraceuticals
  - Protein isolate (sold @ 6 USD/kg)
  - Fibres in solid phase (no DDGS)
- Ethanol is a by-product
- Less energy demand (through membranes)
- No need for large scale processes
  - Less transport costs

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Centre for Crops Utilization Reseach (CCUR, Iowa State University)

Use wet milling technology

Produce multiple products from corn:

- Zein (a high value protein)
- Oil
- Protein
- …and ethanol

Instead of only ethanol and DDGS

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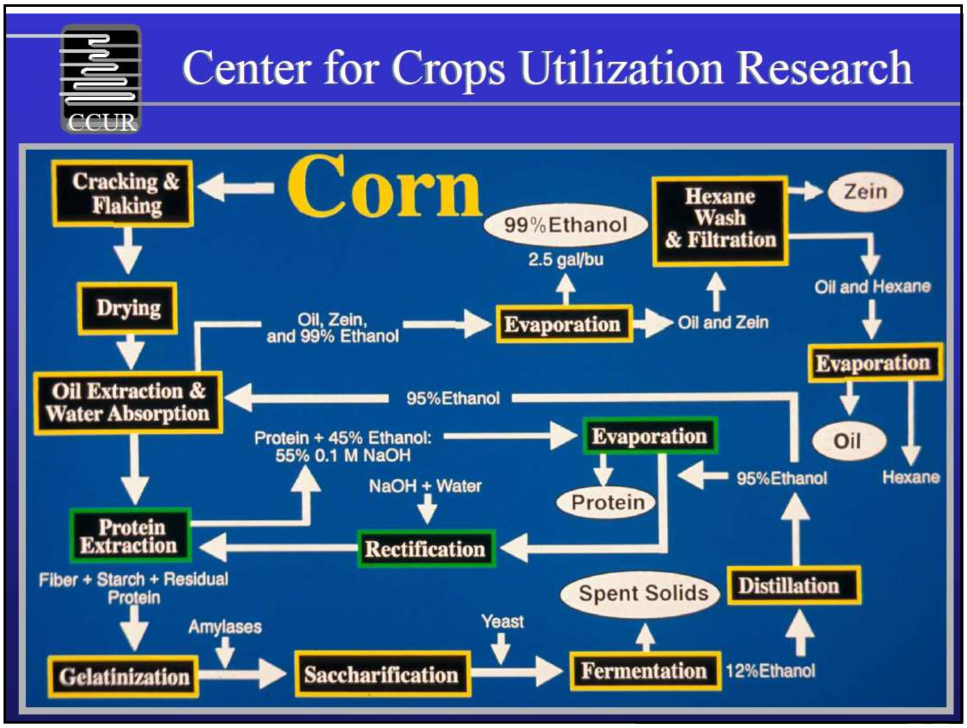

Lignocellulose as a substrate

Lignocellulose consists of mainly 3 components:

- Lignin
- Cellulose
- Hemi cellulose

Separation is difficult:

- Often rough conditions applied (side products formed)
- Low yields (high impurities)
- High demand for chemicals (large waste streams)

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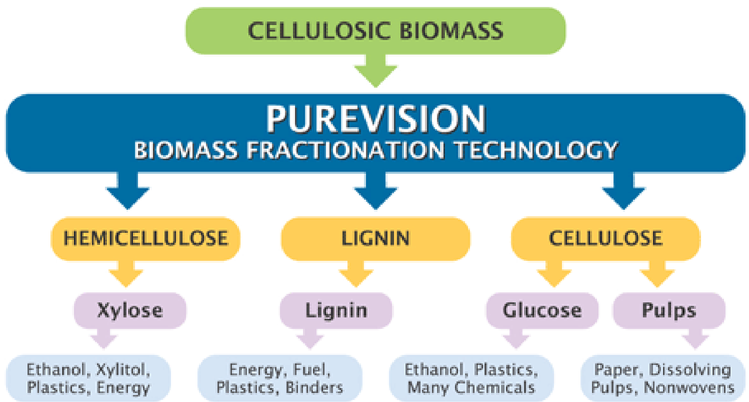
PureVision

Fractionation of lignocellulosic biomass:



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PureVision:

- Fractionation via Counter Current Extraction
  - Hot water → hemi celluloses
  - High pH → lignin
  - Left → cellulose
- Patent: WO 2008/019228jhg

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PureVision tackles 5 general problems

- Unwanted side products

→ Mild conditions

- High usage of chemicals
- Low yields
- Low concentrations
- Low purities

→ Counter current extraction

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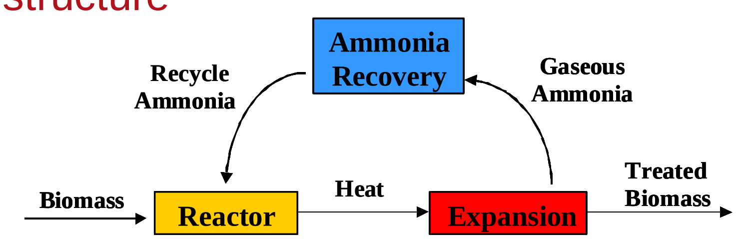
AFEX (Workshop presentation by Bruce Dale)

- **A**mmonia **F**ibre **EX**plosion
- High temperature treatment with ammonia followed by expansion opens up biomass structure



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Process

Conditions:

- 20 - 30 bar
- 70 - 140 ºC
- 5 - 10 minutes

- Dry process:
  - No extra water involved (no dilution)

- Ammonia is a gas:
  - Easy recovery of chemicals

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2 general problems are tackled

Lignocellulosic biomass is:

1. not accessible to cellulolitic enzymes
2. very bulky (120 kg/m^3 after baling of straw)

AFEX:

1. opens up lignocellulosic complex: 90% glucan yield from cellulose after 72 hours of enzymatic treatment
2. product is easily pelletized to 400 kg/m^3 (lignin serves as glue)

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Advantages of AFEX

Densified biomass allows:

- Long distance transport
- Centralized large scale biorefinery

Problems tackled without running into new problems:

- Loss of chemicals (ammonia is a gas)

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Ames

Biodiesel production (transesterification):

Plant oil + methanol → biodiesel + glycerol

2 problems:

- Low added value product (fuel)
- Glycerol waste

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Glycerol to 1,3-propanediol

1,2,3-propanetriol + H_2

→ 1,3-propanediol + H_2O

- R_3Si-H as a reductant
- F_3C-COOH as a catalyst

Propanediol is interesting building block for co-polymers (also 1,2-PDO, 3-HPA)

More valuable side product makes production of biodiesel profitable

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Paper pulping (American Process Inc.)

AVAP (American Added Value Pulping)

Pulping with:

- Ethanol
- Sulfur dioxide

C_5 sugars used for ethanol production

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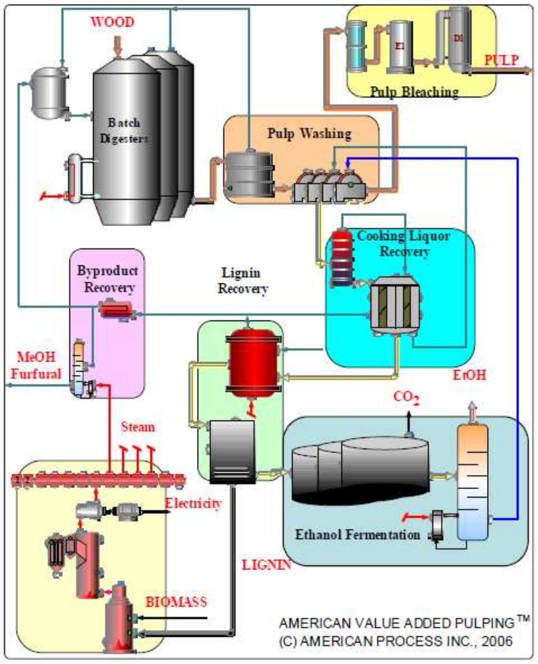

Problems solved

Not only pulp; also ethanol, methanol and furfural

Hemi cellulose is not wasted (higher yield)

Possibility for added value products from lignin

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Thermal processes

Advantages:
- fast

Disadvantages:
- loss of quality
- loss of mass
- high capital costs
- operational problems

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Iowa State University

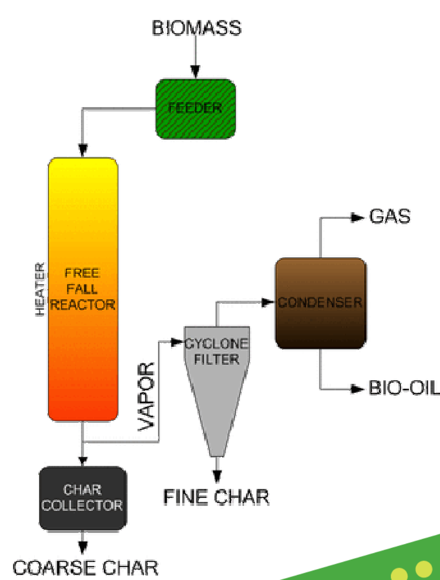
Problems solved:

Clogging

No FT needed

Solid (densified) fuel produced

Smaller scale = less transport



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Conclusions

Biofuel production:

- High capital costs, difficult DSP, low added value

Biorefinery:

- High added value products

Integration:

- Other main products
  - Can reduce biofuel DSP costs
  - Can prevent by-products

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Thanks for your attention

- Questions?

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Lignocellulosic biomass

General problems:

- Low yields
- Low purities
- Low concentrations
- Rough pretreatment → unwanted side products
- High usage of energy and chemicals
- Bulky

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WP leadership

- Mladjan Stojanovic has left AFSG
- Koen Meesters will take over the WP leadership

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DOW

3.1 Analysis of conference, seminar, workshop proceedings and websites on biorefinery related information

3.2 Gathering information from the IEA bioenergy implementing agreement

3.3 Organising an internal workshop

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Finished

- Workshop (WP 3.3)

Today

- Analysis of knowledge from outside EU
  - Koen Meesters
  - Work executed by Mladjan Stojanovic and Laura Bermudez
- Knowledge from EIA
  - René van Ree

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Knowledge import from outside EC

- A list of symposia, websites etc. was generated
- This list is rather boring; it will be made available to you all
- Today: A ‘Pick of the day’, some trends, some insights, not a complete review
- Put into European perspective

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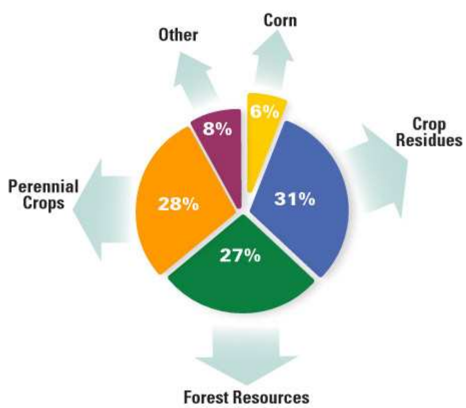
Biofuel Resourses USA



Projected U.S. Biofuel Sources
Source: Biomass as Feedstock for a Bioenergy and Bioproducts Industry: Technical Feasibility of a Billion Ton Annual Supply. 2005. DOE and USDA.

- Large focus on ethanol from corn today
- This will change!
- Lignocellulosic biomass will be used

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Developments on ethanol production

- Use of wood as fuel for distillation
- Use of straw or corn cobs as fuel for distillation
- Around 15% of straw is needed for distillation
- Distillation energy is high, a renewable resource for this energy leads to large improvement of GHG-efficiency

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Ethanol from cellulosic materials

- More ethanol from corn cobs and corn fiber (POET)
- C_5 to ethanol
  - Zymomonas Mobilis (DuPont)
  - ABNT
  - Escherichia Coli (Mexico, Japan)
- Cellulose to ethanol ‘bug’
  - Isolated from forest (Massachusetts, USA)
- Ethanol from lignocellulosic wastes (Range Fuels, Verenium)

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Straw refinery/prehydrolysis

- Consecutive extraction of straw with hot water with dilute acid (@210 ^{o}C) and alkaline solution
- Hemicellulose and lignin extracted, cellulose remains
  - ABNT
  - Simulated Moving Bed extraction (PureVision)
- Concentrated sulfuric acid treatment (BlueFire), focus on reduction of sulfuric acid

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Europe

- Primary goal of biofuels is GHG mitigation
- Food/feed discussion
- Concern about indirect land use change
- Therefore GHG efficiency (expressed in tonCO_2/(ha·yr)) is crucial
- Lignocellulosic materials and wastes: no land use change: far better GHG efficiency than plant cultivations

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‘Novel’ products

- FAEE
- Alkenes
- PHA
- Adhesives, elastomers and foams

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Ethanolysis

- Use of ethanol instead of methanol for transesterification
- Production of FAEE instead of FAME
- Case in Brazil

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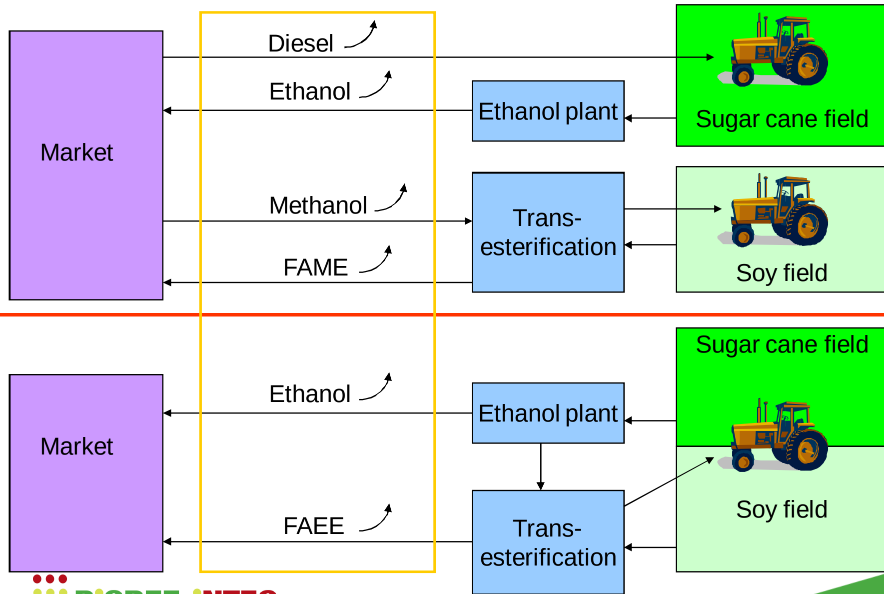
FAME vs. FAEE (transport)



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Advantages

- Less transport of diesel
- No transport of methanol
- Less transport of ethanol
- Less transport of biodiesel,
- 100% renewable biodiesel

In Europe methanol is very cheap, transport distances are shorter → not as interesting

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Ethenolysis

Conversion of FAME to alkene and methylalkene-ester

$H_3(CH_2)_7CH{=}CH(CH_2)_7COOCH_3 + CH_2{=}CH_2$

$\rightarrow$

$H_3(CH_2)_7CH{=}CH_2 + CH_2{=}CH(CH_2)_7COOCH_3$

- Cargill, Caproleic acid production
- Other high value products
- In Europe only attractive if renewable chemicals are rewarded

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Others

- Kernel, germ, fiber and endosperm fractionation (ICM)
- Corn oil from DGS (VeraSun)
- PHA from corn starch (Metabolix/ADM)
- Adhesives, elastomers and foams (Rohm & Haas Company)

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Thermal processes

- Combustion
- Pyrolysis
- Thermo-chemical liquefaction (HTU)
- GTL (Gasification, FT synthesis)

- Thermo-chemical processes might complement biological pathways (lignin)

- These processes might overtake biological pathways (especially looking at fast developments of electric car technology)

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Densifying of straw

- Transport of bulky materials (straw) is expensive
- Densifying at the spot
  - Briquetting (China)
  - Torrefaction (production of char)
  - Pyrolysis (production of oil)

- Europe: also valid for thinnings, tops and branches

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Lignocellulosic biomass

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