Tropical biorefineries for energy and bio-products

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The world we live in...

Increasing scarcity (cost) of oil

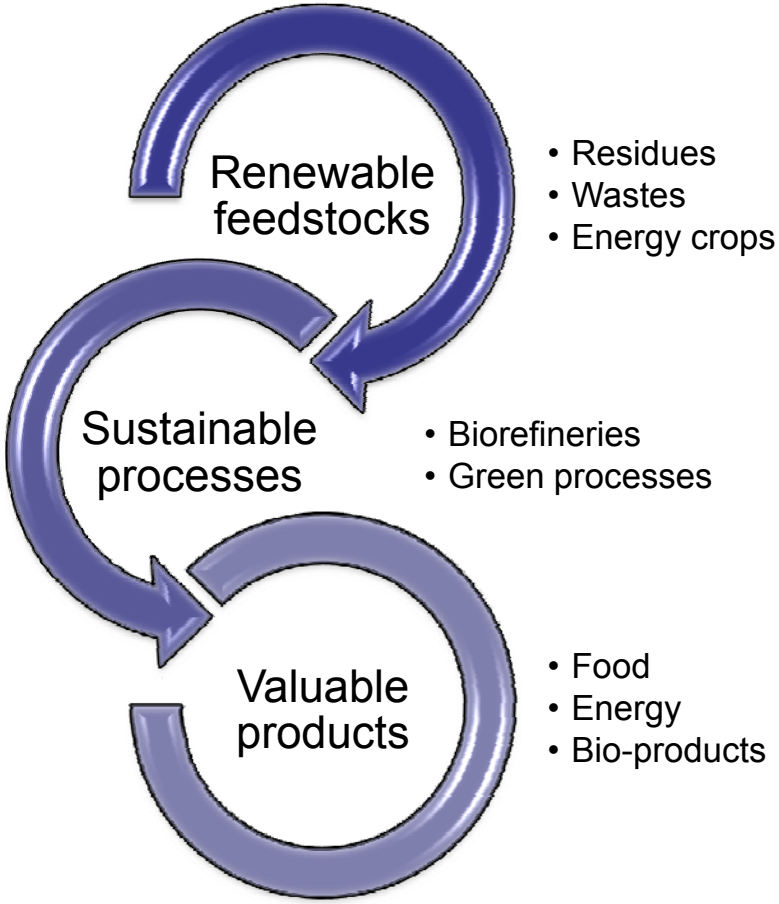
Global warming

Consumer demand for 'green' products

Rapid advances in biotechnology

The bio-economy…

- Bio-based products to a Bio-economy…
- Sustainable production and conversion of biomass to products including:
  - Food
  - Health
  - Fibre
  - Industrial
  - Energy

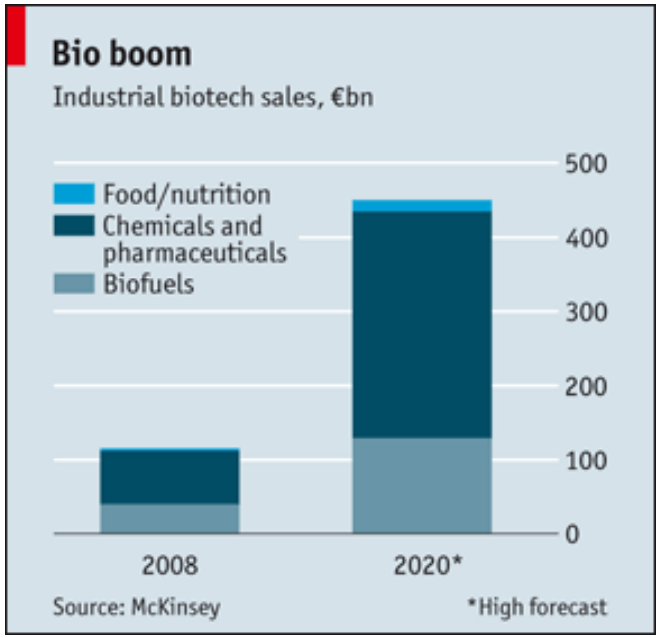


Key elements of the bio-economy

http://www.csiro.au/Organisation-Structure/Divisions/Ecosystem-Sciences/The-Bioeconomy.aspx

New industries...

- A rapidly growing industry…
  - US$170 billion in 2008
  - US$660 billion by 2020



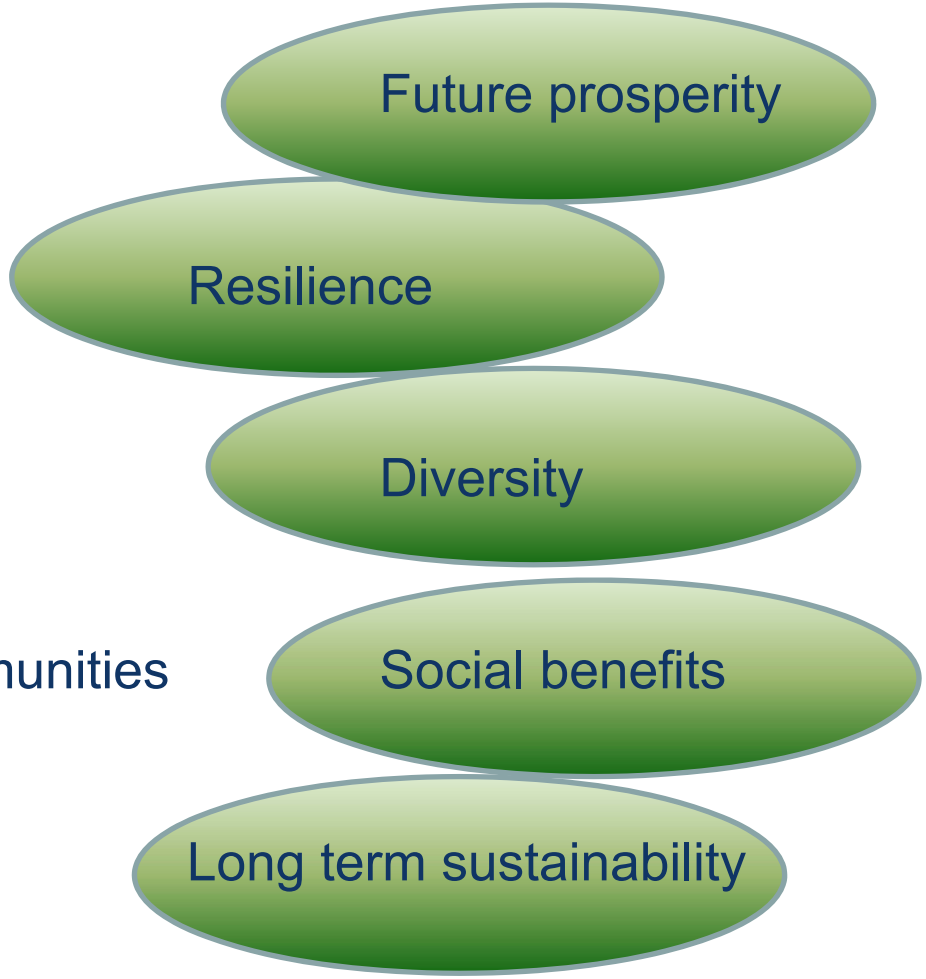
- High levels of consumer demand…

	USA	China
Familiar with green products?	40%	40%
Confidence that green product is better for the environment	60%	70%
Would preferentially buy green product at a similar price	80%	75%

McKinsey analysis from 2010 reported in The Economist http://www.economist.com/node/16492601?story_id=16492601
Survey conducted by Dupont Industrial Biosciences: Consumer attitudes on Renewable and Sustainable Chemicals. Industrial Biotechnology. April 2013

Building resilient regions…

- Economic growth
- Low carbon industries
- Manufacturing base
- Opportunity for regional communities
- Profitable agriculture



Tropical biorefinery feedstocks

Sugarcane…

- Sugarcane (*Saccharum* spp.)
  - Global sugarcane industry
  - Huge resource – 1.6 billion tonnes
  - Established industrial crop
  - Sugar and electricity

  – Excellent biorefinery crop
    - Biomass - Sustainable, large resource
    - Crop residue already at factory
    - Low value component of crop
    - Proven sustainability performance

Sweet sorghum…

- Sweet sorghum (*Sorghum bicolor*)
  - Highly productive, short rotation crop
  - Stalk syrup is used as a food sweetener
  - Grain used to produce gluten-free flour
  - Grain sorghum
    - 5th largest cereal crop globally
  - Compared to sugarcane, sweet sorghum:
    - Higher tolerance to salt and drought
    - Requires less water and fertiliser
    - Produces similar levels of biomass
    - Similar levels of total fermentable sugars

Left: sweet sorghum, Right: grain sorghum
Source: Louisiana State University crop trials 2007-2008

Agave…

- *Agave tequiliana*
  - Sugar and fibre rich crop
  - Sugar rich pina – up to 80 kg
  - Pina – sugar content up to 24%
  - High in fructans
  - Leaf – up to 18 kg
  - Min 5 years from planting to harvest

  – Drought proof perennial
    - Reliability over 5 year growth
    - High water use efficiency

  – Grown on low value land

Cassava…

- Cassava (*Manihot esculenta*)
  - Good yields
  - High starch contents 20 – 30%
  - Third highest carbohydrate yield of crop plants

  – Multi-product
  - Starch to fuels / chemicals
  - Flour can be used in gluten free products
  - Fibrous stem
  - Foliage – stock feed

Oil Palm…

- Oil palm (*Elaeis guineensis*)
  - Multi-product crop
    - Oil rich fruit – oleochemicals, fuels
  - Cellulosic waste residues
    - EFB and plantation wastes
    - Electricity and bio-products
  - Well established crop of significant importance in many tropical countries

Energy grasses…

- Napier grass (*Pennisetum purpureum*)
  - Perennial – annual harvest
  - Minimal pests and diseases
  - Rapid growth and high biomass yields
  - Moderate sugar content but high in fibre

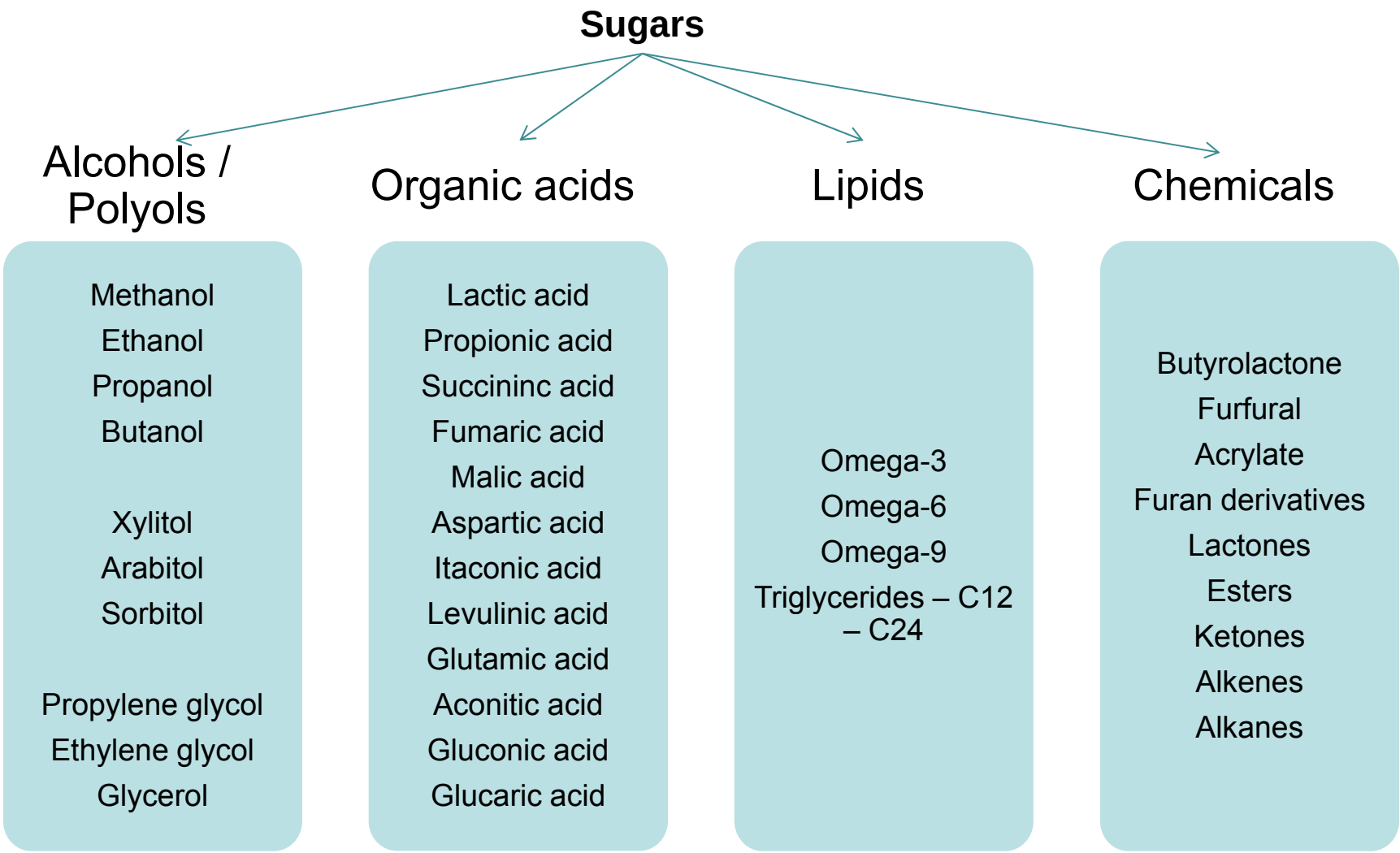
  – Use conventional sugarcane equipment for planting, harvesting, etc

Biorefinery products

Bio-based products…

- Biofuels
  - Alcohols - ethanol, methanol, butanol
  - Direct (drop-in) hydrocarbons
  - Oils & fatty acid based fuels
- Bioenergy
  - Combustion
  - Gasification
- Human and animal feed products
  - Livestock, feedlot, aquaculture
- Chemicals
- Biomaterials and biopolymers

Chemicals from sugars…



The rise of green packaging…

- Green polyethylene
  - Made from sugarcane ethanol in Brazil
  - HDPE, LDPE
  - eg Proctor & Gamble, Tetra Pak, Danone

- Coca-cola plantbottle™
  - PET from 30% renewable component
  - Monoethylene glycol (MEG)
  - MEG currently made from sugarcane ethanol
    Developing technology for green TPA

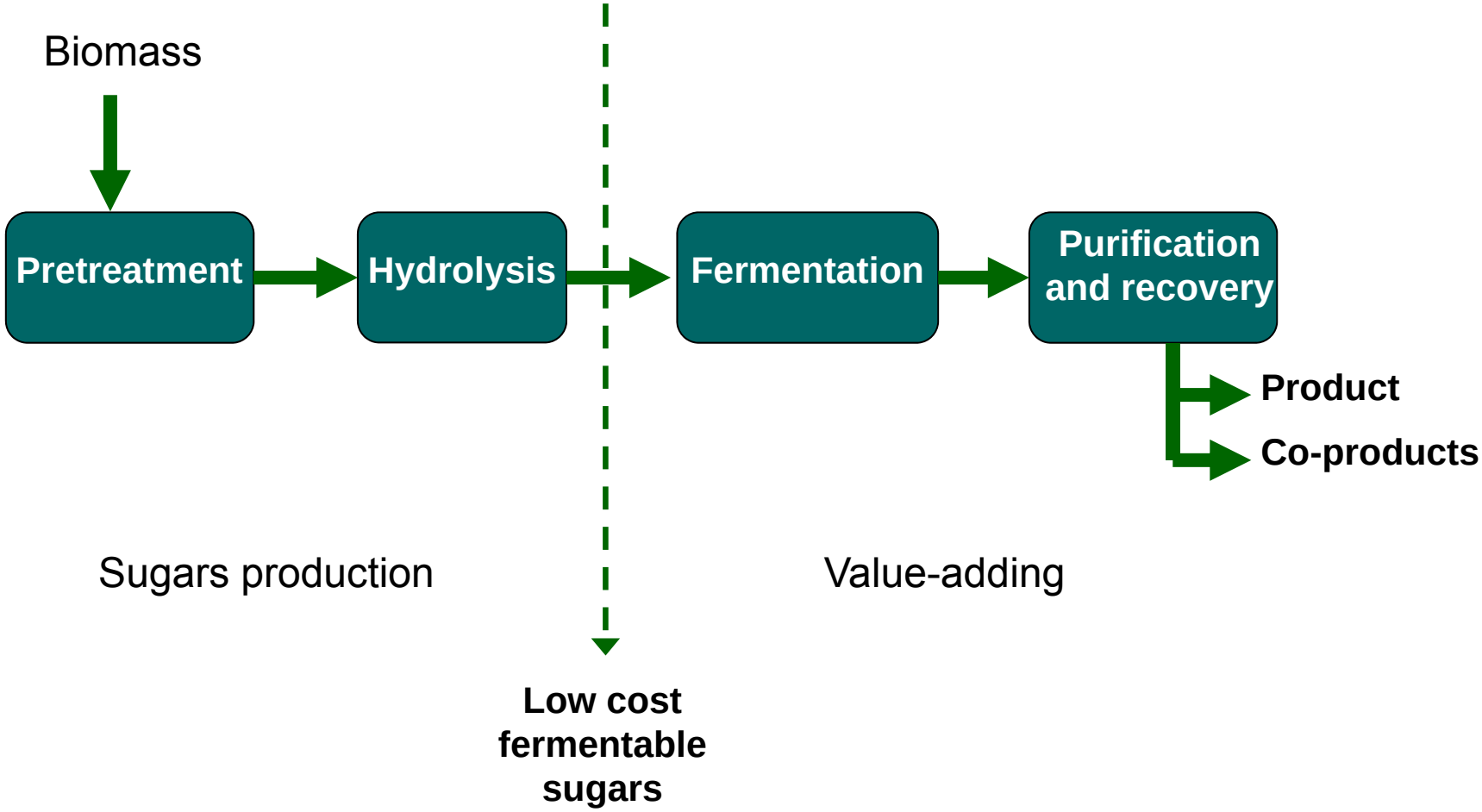
- PepsiCo - Frito-lay Sun Chips
  - Renewable polylactic acid (PLA)

http://cargocollective.com/homeschool#Plant-Bottle-Logo
http://us.industrysourcing.com/articles/49800.aspx
http://www.heinz.com/csr2011/economic/innovation.aspx

The need…

…low cost fermentable sugars…

A biochemical approach to value-added products from biomass



Pretreatments…

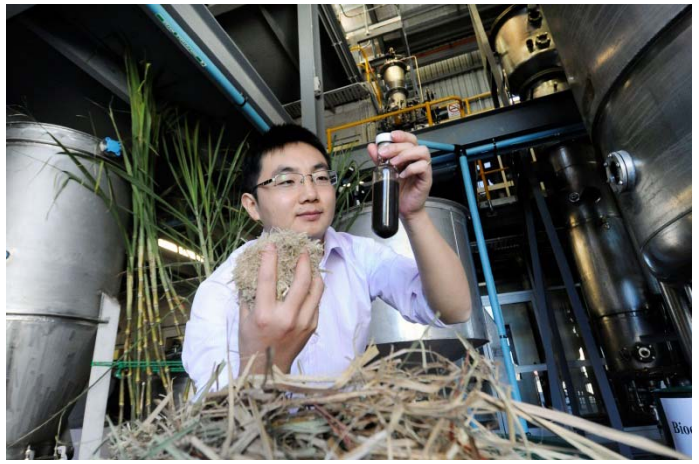
- Dilute acid
- Concentrated acid
- Steam explosion
- Autohydrolysis
- Alkaline delignification
- Lime treatment
- Wet oxidation
- Ammonia fibre explosion
- Organosolv
- Ethanol, methanol, organic acids
- Compressed liquid hot water
- Ionic liquid processes
- Inorganic salts
- Mechanical processes
  - Grinding, milling, extrusion
- Ultrasound
- Microwave
- Irradiation
- Microbiological processes
- Pulsed power
- Solid acid catalysts
- CO2 explosion

Hydrolysis...

- Cellulolytic enzymes from bacteria and fungi
- Three functional classes
  - Endo-glucanases
    - Hydrolyse β(1→4) bonds at random in the amorphous regions of cellulose
  - Cellobiohydrolases
    - Progressive unidirectional hydrolysis of crystalline cellulose liberating cellobiose
  - β-glucosidases
    - Hydrolyse cellobiose to glucose
- Large quantities of enzymes in complex mixtures generally required

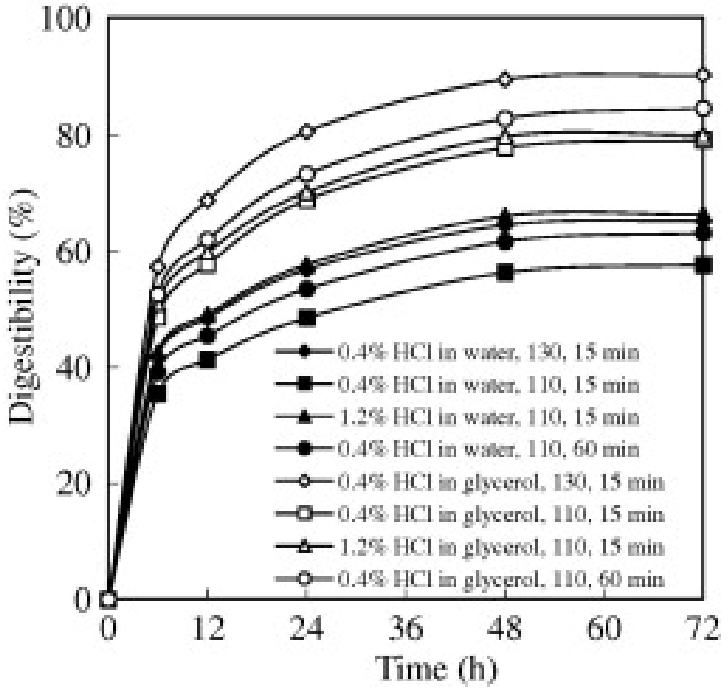
Glycerol pretreatment...

- Developing lower cost biomass conversion processes
  - Lower energy, simple processes
  - Less expensive construction
  - Higher efficiencies
- New process based upon waste glycerol
  - Glycerol waste from biodiesel production
  - 2 wastes – many valuable products
- Being commercialised in Australia (and certain other territories) by Leaf Energy

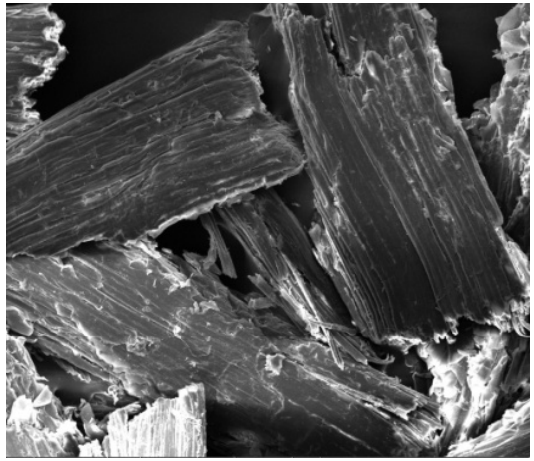


Pretreatment with acidified glycerol solutions...

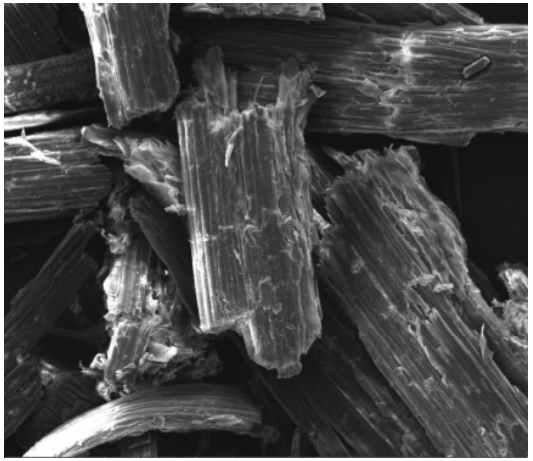
- Acidified glycerol solution
  - Temperature 90 – 130 °C
  - Reaction time 15 – 90 min
  - Water content 2.5 – 40%
  - Acid conc 0 – 1.2%
- Better performance
- Lower temperatures
- Lower enzyme dosage
- Cheaper equipment materials
- Lower cost sugars



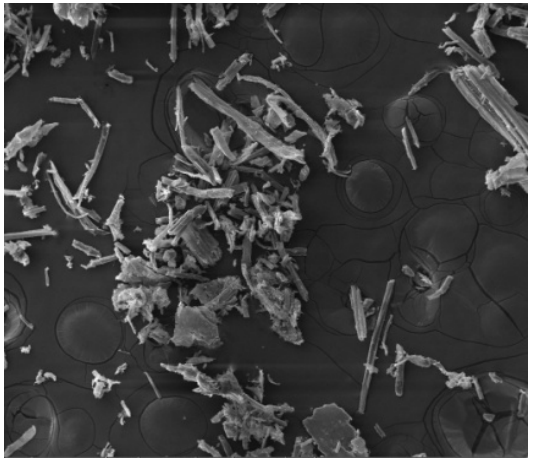
SEM images of glycerol pretreated sugarcane bagasse



Untreated bagasse



Water, 1.2% HCl



Glycerol, 1.2% HCl, 10% water

Pretreatment conditions: 130 ° C for 60 min. Samples were magnified 200 times.

Zhang et al. Laboratory and pilot scale pretreatment of sugarcane bagasse by acidified aqueous glycerol solutions. Bioresource Technology 2013. 138.14-21

Pilot plant trials of the glycerol process

Mackay Renewable Biocommodities Pilot Plant

An Australian Government Initiative
National Collaborative Research Infrastructure Strategy
Queensland Government
QUT
MACKAY SUGAR

Pilot plant pretreatment process

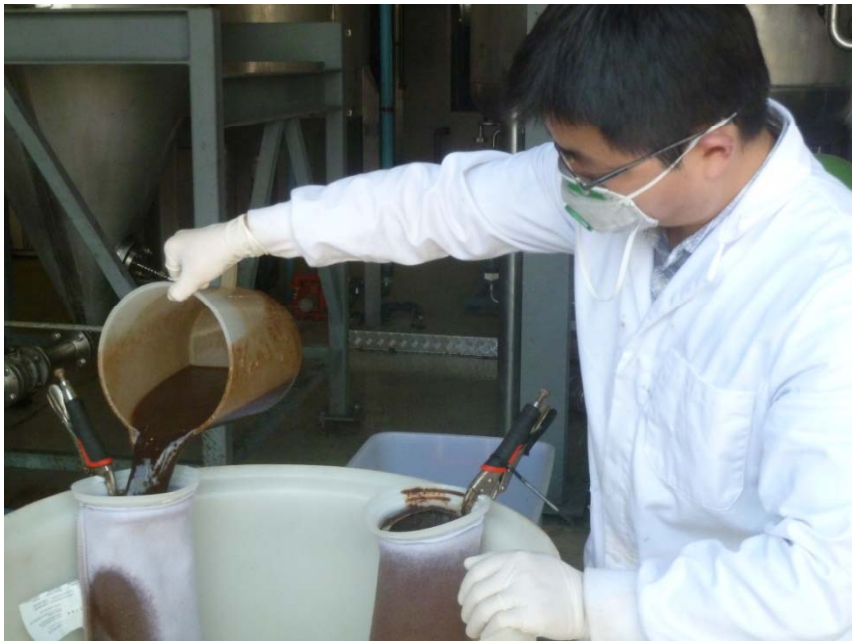
Pentose rich hydrolysate

Pretreated fibre

Fermentable sugars

Pilot trials of glycerol pretreatment process…

Solid residue



Hydrolysate

Zhang et al. Laboratory and pilot scale pretreatment of sugarcane bagasse by acidified aqueous glycerol solutions. Bioresource Technology 2013. 138.14-21

Key messages...

- Significant opportunities exist to establish new biorefinery industries
- Tropical regions with biomass potential will be at the forefront of this new industry
- Optimise the cost and sustainability of delivered feedstock
- Increasing demand for renewable energy and bio-products
- Novel processes will continue to drive down technology costs
- Rapid advances in microbial biotechnology are changing the way fuels and chemicals will be produced in the future

Acknowledgements

- Australian Government
  - National Collaborative Research Infrastructure Strategy
  - Super Science Fund
- Queensland Government
  - Smart State Research Facilities Fund
  - Research Infrastructure Partnerships Program
  - National and International Research Alliances Program
- Partners
  - Syngenta Biotechnology
  - Leaf Energy
  - Sugar Research and Development Corporation
  - Sugar Research Australia
  - Mackay Sugar Ltd
  - Sugar Research Institute
  - AgriFuels Ltd

- Colleagues, staff and students at QUT / CTCB

Centre for Tropical Crops and Biocommodities

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Further information: **www.ctcb.qut.edu.au**