Technologies for biodiesel and bio-ethanol production

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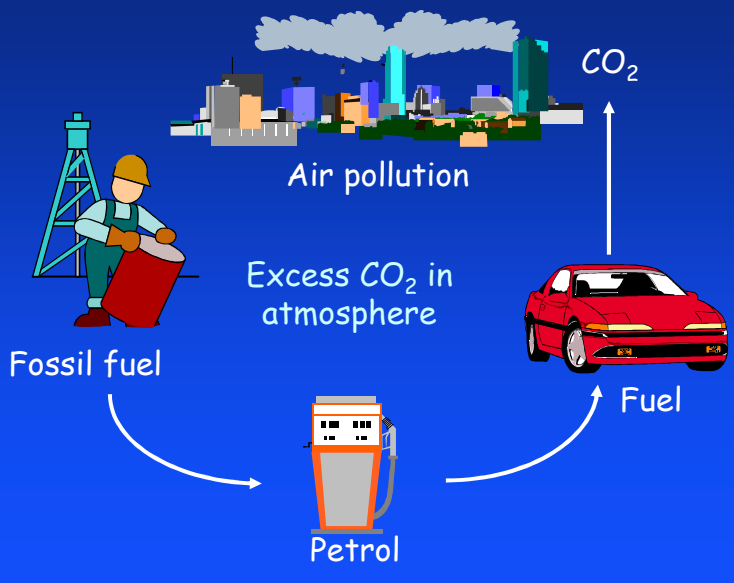
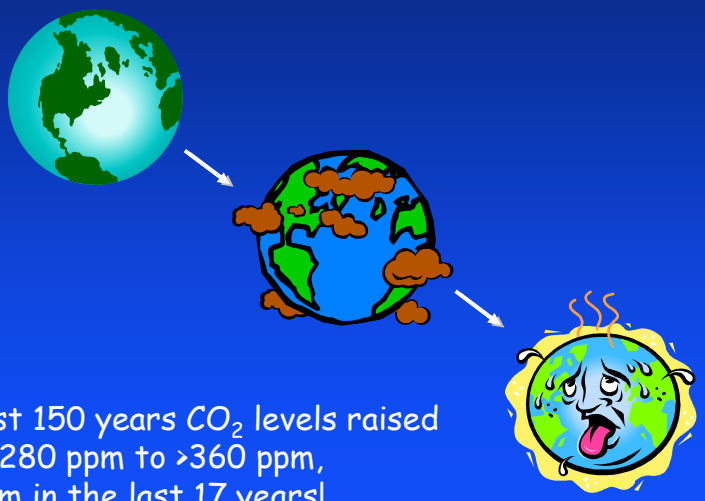
1
Why consider biofuels?

Fossil fuel

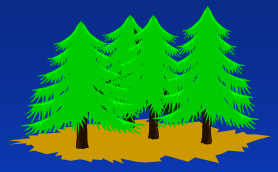


Greenhouse effect



In past 150 years CO_2 levels raised from 280 ppm to >360 ppm, 30 ppm in the last 17 years!

Alternative fuel



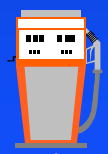
Renewable resource

CO_2

Closed carbon cycle !

Sugar, starch, lignocellulose
Vegetable oils

Fuel



Biodiesel and bio-ethanol

2
Biodiesel and bio-ethanol as renewable fuels

Biofuels as renewable energy

1. Biodiesel and bio-ethanol recently gained much attention with the soaring crude oil prices
2. Biofuels has to date hardly made a dent in the use of petroleum fuels. Approx 2% of USA transport fuels, similar in EU
3. This is bound to change in the future with limiting oil resources, the treat of greenhouse gas production as well as global security risks associated with limiting oil resources = government interventions
4. EU and USA have +2025 targets of ≈ 25% biofuels
   RSA 2013: 8% ethanol, 2% biodiesel, 4.5% total
   (ASGISA and BEE government program)

First generation (conventional) biofuels			
Biofuel type	Specific name	Biomass feedstock	Production process
Bioethanol	Conventional bioethanol	Sugar beets, grains	Hydrolysis & fermentation
Pure vegetable oil	Pure plant oil (PPO)	Oil crops (e.g. rape seed)	Cold pressing/extraction
Biodiesel	Biodiesel from energy crops Rape seed methyl ester (RME), fatty acid methyl/ethyl ester (FAME/FAEE)	Oil crops (e.g. rape seed)	Cold pressing/extraction & transesterification
Biodiesel	Biodiesel from waste FAME/FAEE	Waste/cooking/frying oil	Transesterification
Biogas	Upgraded biogas	(Wet) biomass	Digestion
Bio-ETBE		Bioethanol	Chemical synthesis

Second generation biofuels			
Biofuel type	Specific name	Biomass feedstock	Production process
Bioethanol	Cellulosic bioethanol	Lignocellulosic material	Advanced hydrolysis & fermentation
Synthetic biofuels	Biomass-to-liquids (BTL) Fischer-Tropsch (FT) diesel Synthetic (bio)diesel Biomethanol Heavier (mixed) alcohols Biodimethylether (Bio-DME)	Lignocellulosic material	Gasification & synthesis
Biodiesel (hybrid between 1st and 2nd generation)	NExBTL	Vegetable oils and animal fat	Hydrogenation (refining)
Biogas	SNG (Synthetic Natural Gas)	Lignocellulosic material	Gasification & synthesis
Biohydrogen		Lignocellulosic material	Gasification & synthesis or Biological process

Biofuels energy balance

Ratio between energy produced as biofuel compared to fossil energy inputs

Biodiesel: 3.2:1

Bio-ethanol from starch: 1.34:1

Bio-ethanol from sugarcane: 8:1

Bio-ethanol from lignocellulose 4-20:1

3
Biodiesel production

Feedstocks for biodiesel

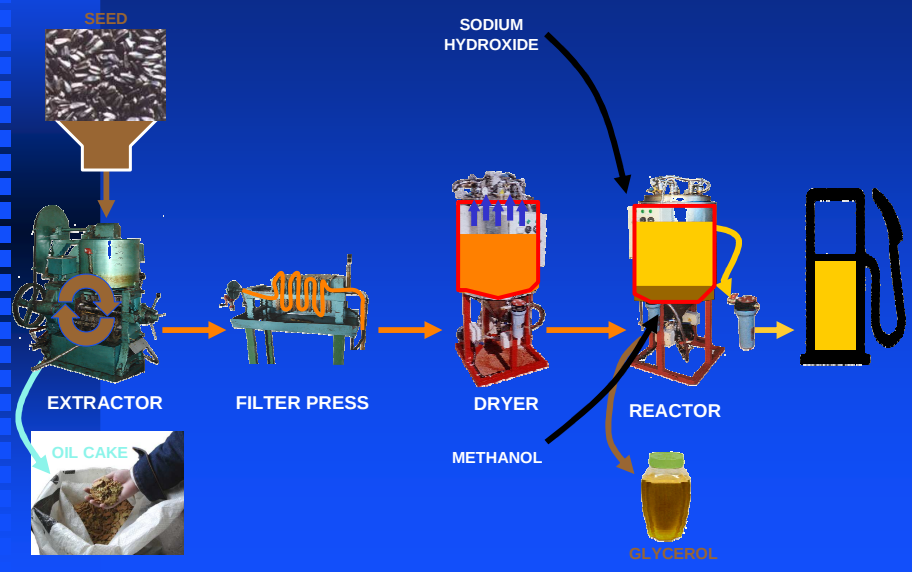
Conventional:

- Sunflower seeds
- Soyabeans
- Cottonseed
- Waste vegetable oil

Unconventional:

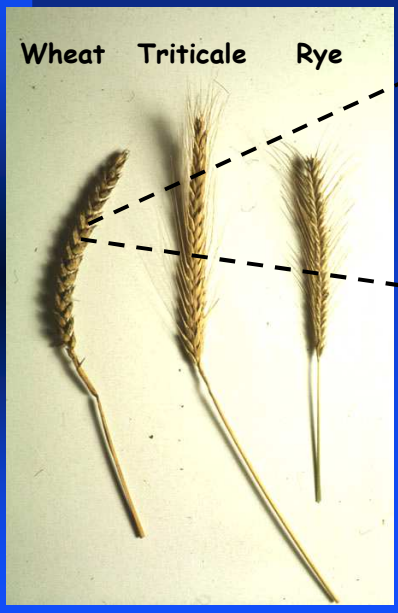
- Jatropha
- Indigenous plants
- Micro algae
- Animal oil

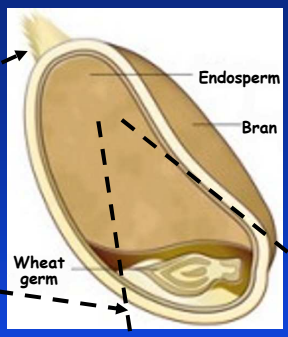
Process for Biodiesel Production

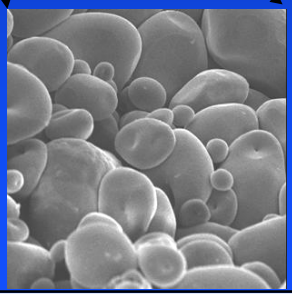


4
Bio-ethanol production from starch

Starch composition







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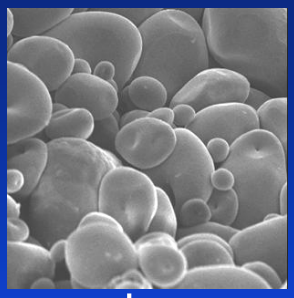
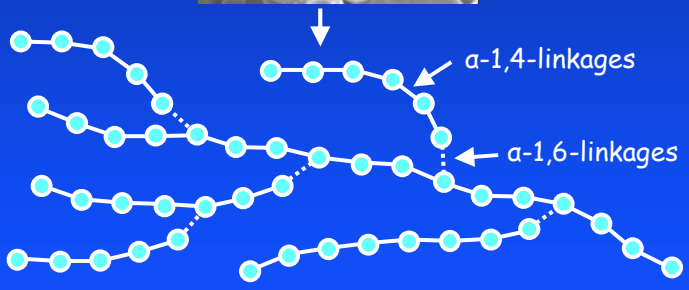
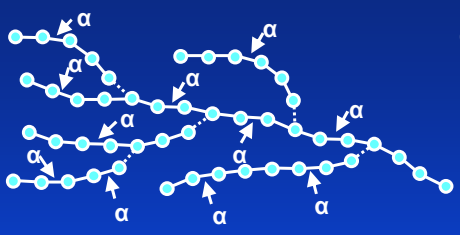




Structure of amylopectin in raw starch

Starch degradation

Amylo-pectin

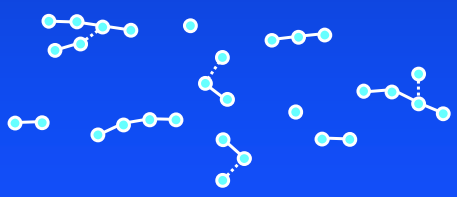


α = α-amylase

[pH 6.0; 95-105ºC; 90 min]

Liquefaction step

Small starch oligo-saccharides



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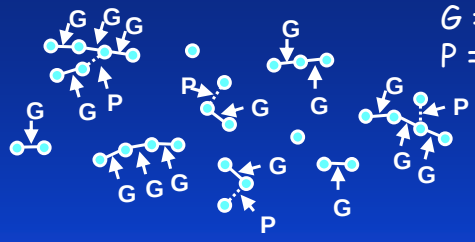
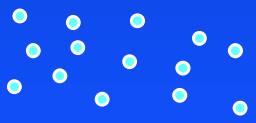


G = glucoamylase
P = Pullulanase

[pH 4.5; 60-62ºC; 12-96 h]

Saccharification step

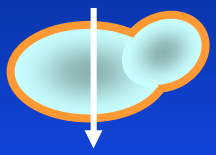
Glucose



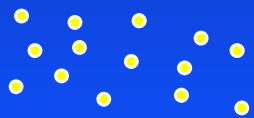
Sugar fermentation

Glucose

Yeast



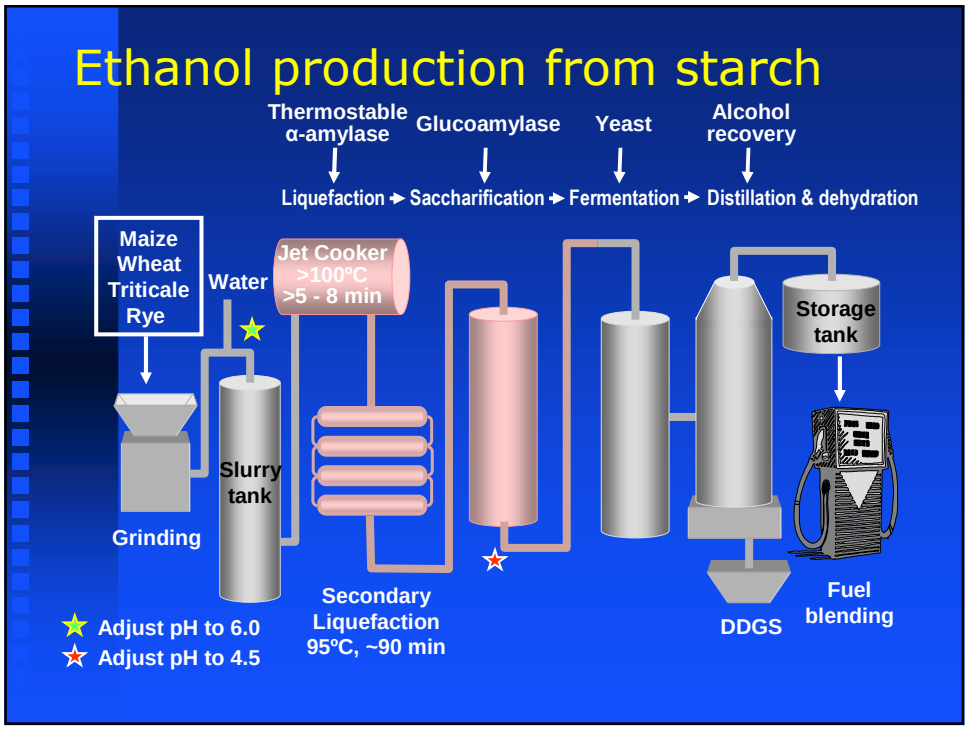
Ethanol



$C_6H_{12}O_6 \longrightarrow 2x\ C_2H_6O + 2x\ CO_2$

Glucose [180] Ethanol [2x 46] [2x 44]

Ethanol Yield = 92/180 x 1.1 = 0.56

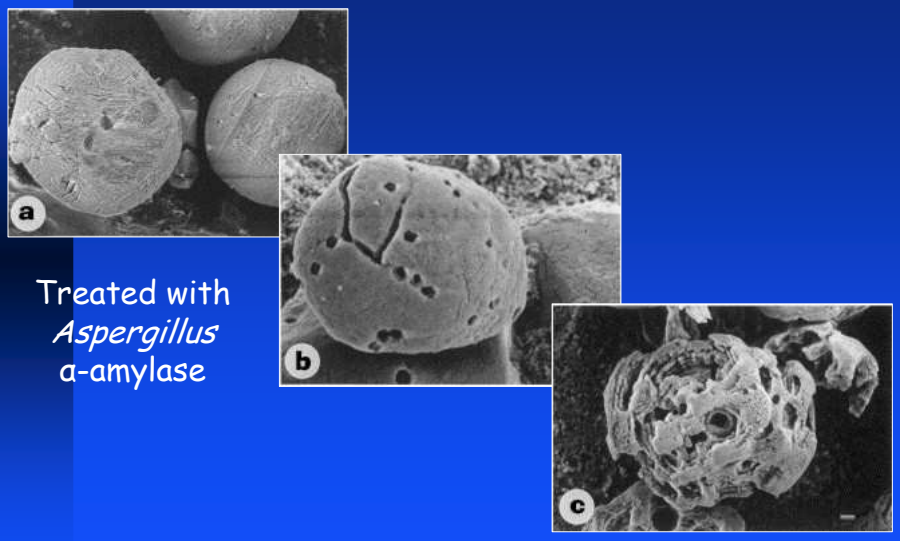


5
Next generation technologies bio-ethanol from starch

Genencor introduce Stargen™

1. Enzyme cocktail that eliminates reduced heating requirements and pH adjustments during the process
2. Enzymatic hydrolysis and fermentation performed in the same process vessel: Integration results in enzyme, time and cost savings

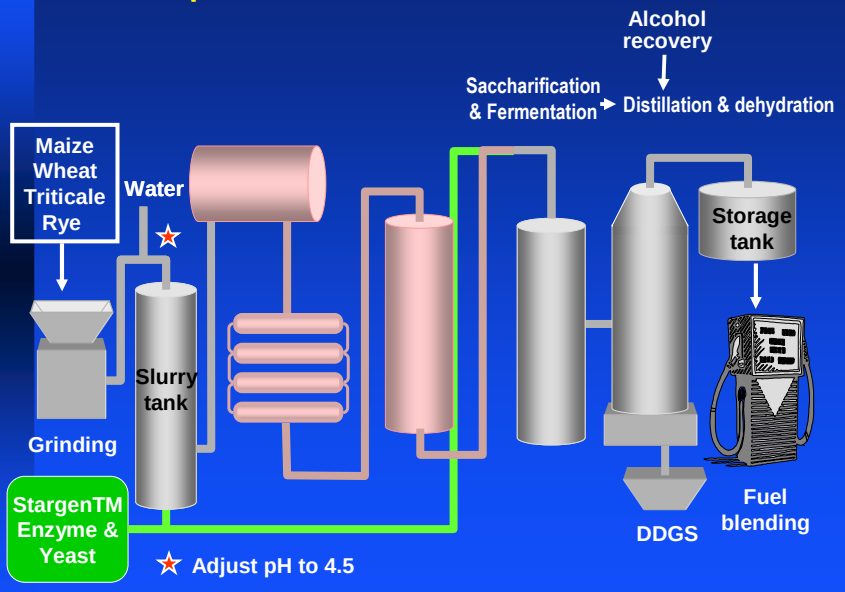
Enzymatic hydrolysis of raw starch



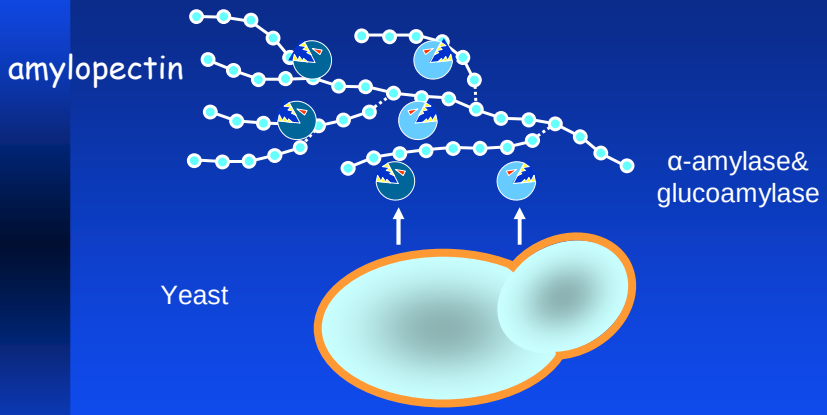
Treated with *Aspergillus* α-amylase

[Buleon, A., P. Colonna, V. Planchot, and S. Ball. 1998. Starch granules: structure and biosynthesis. *Int. J. Biol. Macromol.* 23:85-112.]

Ethanol production from starch



Raw-starch degrading yeast?



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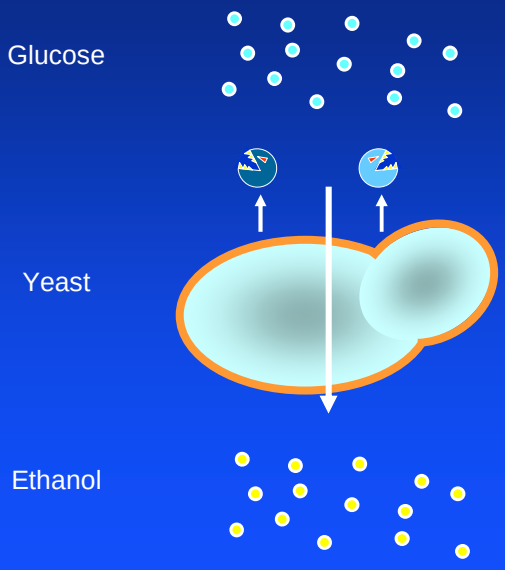
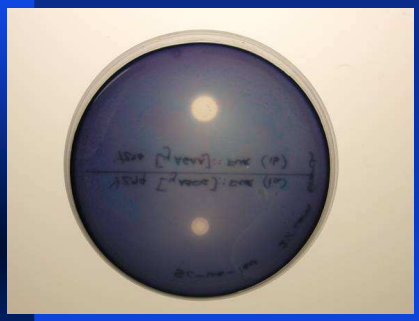
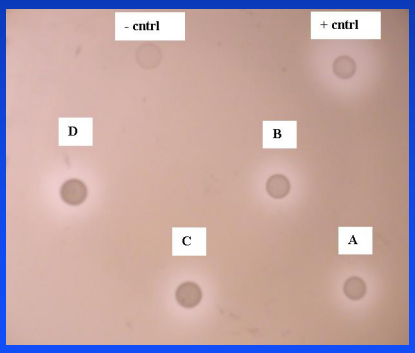


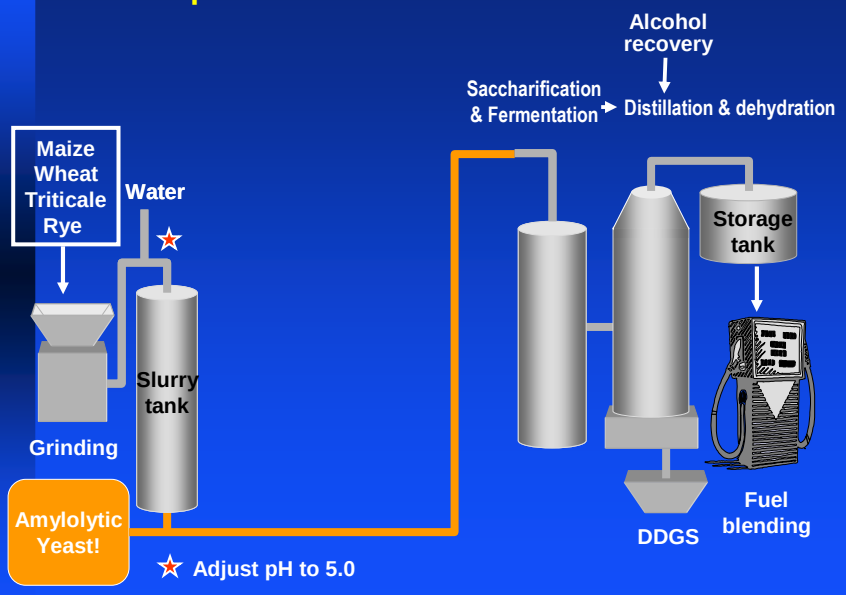
Is this possible?





Maize starch with recombinant amylolytic yeast growing. Stained afterwards with iodine to show starch degradation.

Ethanol production from starch



6
Future technologies for bio-ethanol from lignocellulose

Lignocellulose sources

maize stover

bagasse

woodchips

Miscanthus as energy crop

Renewable biomass available

1. **Residues**		
Agriculture		
Maize residues	6.7 Mt/a	(118 PJ/a)
Sugarcane bagasse	3.3 Mt/a	(58 PJ/a)
Wheat straw	1.6 Mt/a	(28 PJ/a)
Sunflower residues	0.6 Mt/a	(11 PJ/a)
Agricultural subtotal	**12.3 Mt/a**	**(214 PJ/a)**
Forrestry industry		
Plantatation residues	4.0 Mt/a	(69 PJ/a)
Sawmill residues	0.9 Mt/a	(16 PJ/a)
Paper & board mill slurry	0.1 Mt/a	(2 PJ/a)
Forrestry industrie subtotal	**5.0 Mt/a**	**(87 PJ/a)**
2. **Energy crops**		
From 10% of available land	**67 Mt/a**	**(1 170 PJ/a)**
Total, annual basis	**84 Mt/a**	**(1 470 PJ/a)**
3. Intruder plants	**8.7 Mt**	**(151 PJ)**

Lignocellulose composition

Sugarcane bagasse

Non-fermentable
sugars
high energy
aromatics

Lignin
28%

Arabinan
2%

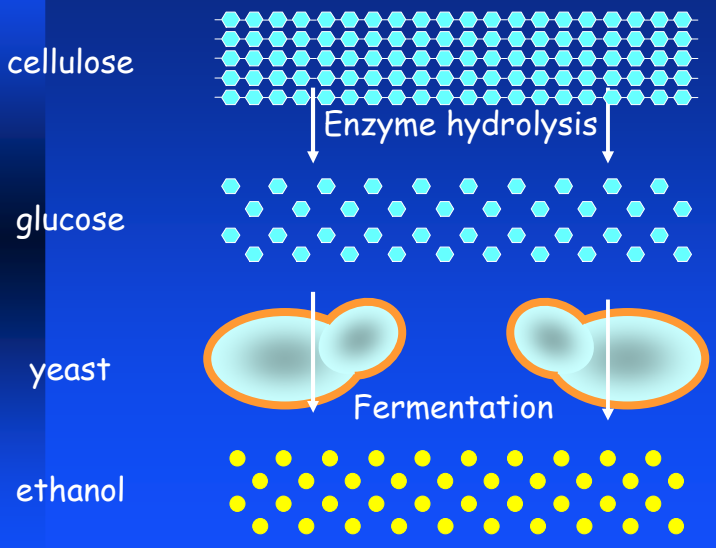
Pentoses
(fermentable)

Xylan
25%

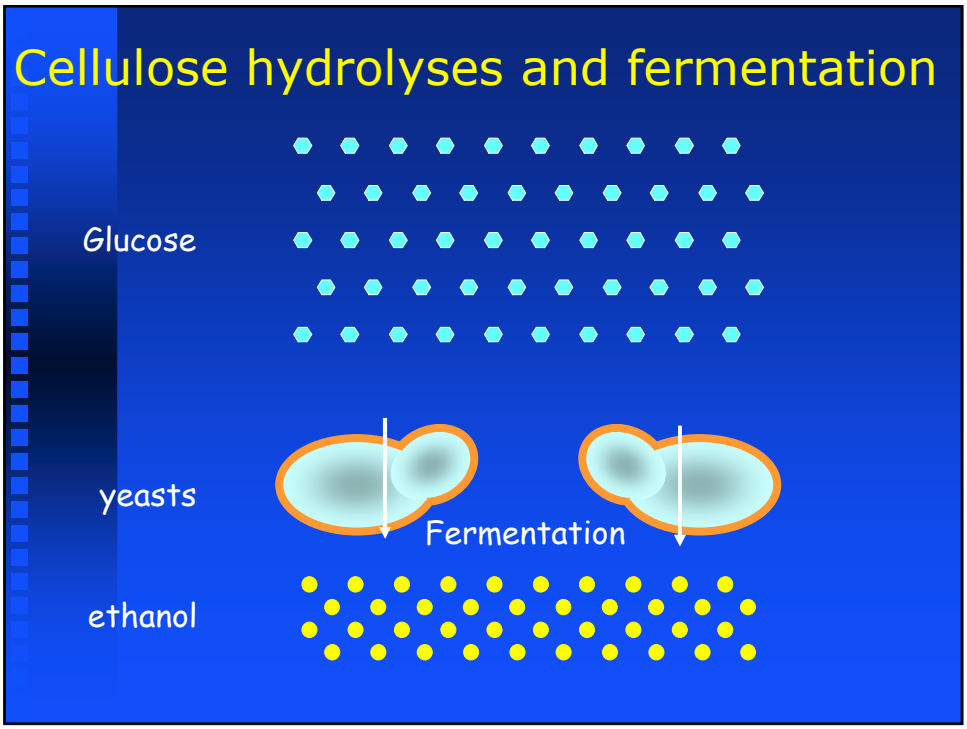
Cellulose
46%

Hexoses
(fermentable)

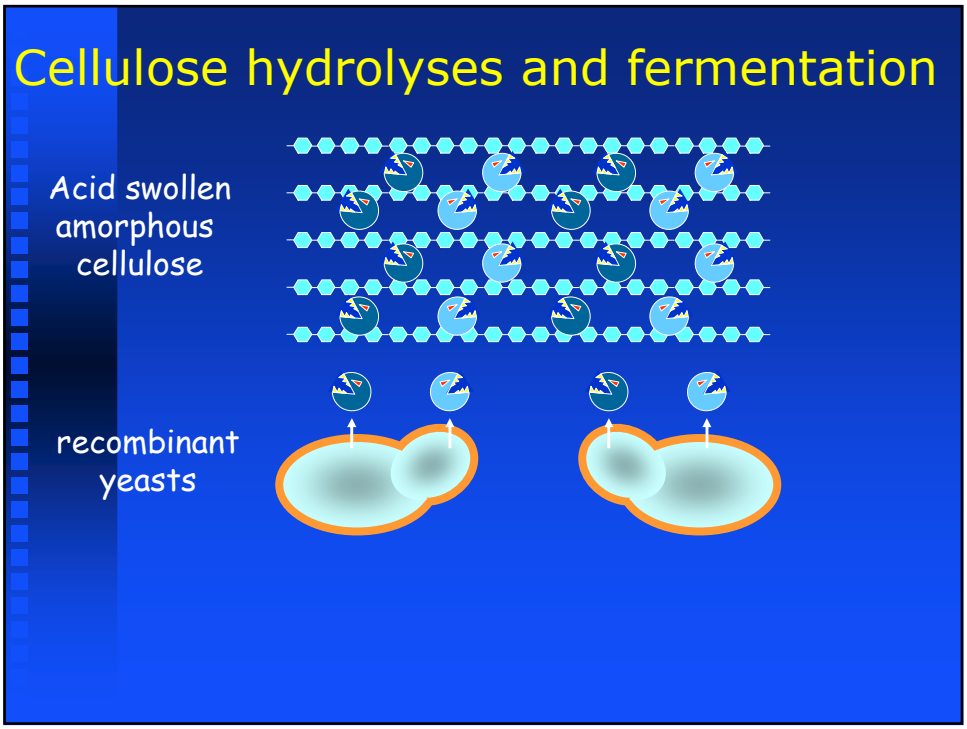
Cellulose hydrolyses and fermentation



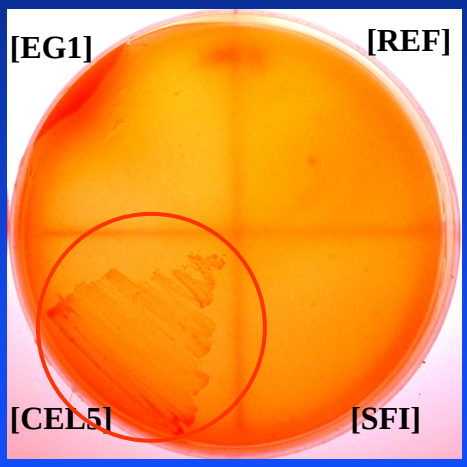
Cellulose hydrolyses and fermentation



Cellulose hydrolyses and fermentation

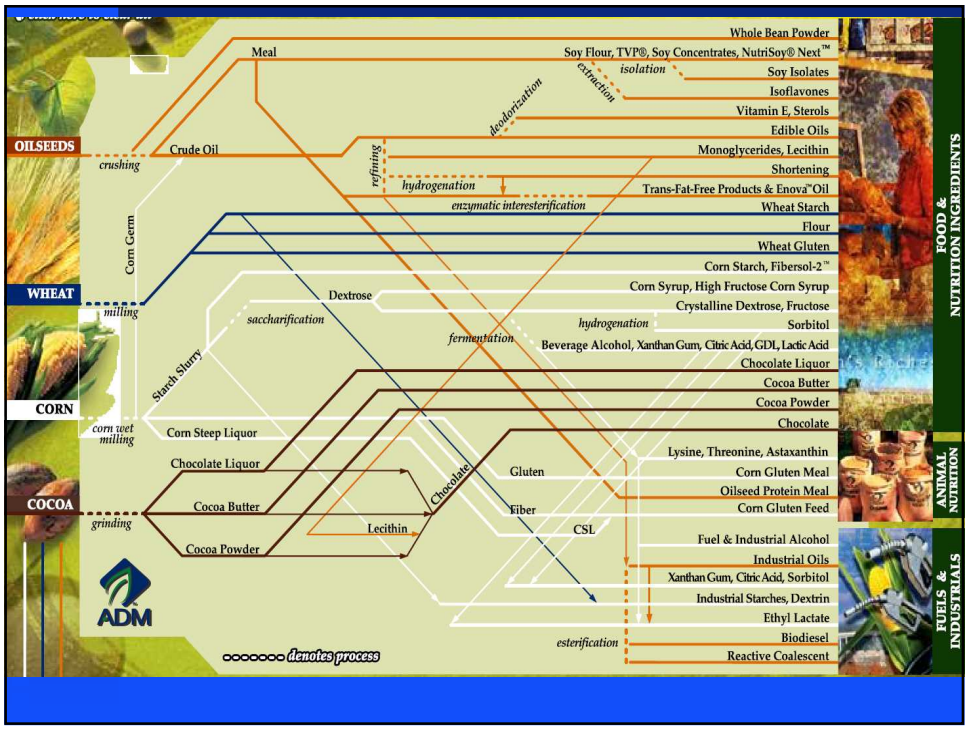


Yeast grow on amorphous cellulose with production of cellulases



Biorefinery Concept

- Process a **range of raw materials** to a **range of value-added products**
- Justification: Volatile Agro and Fuel markets
  - Seasonality of production
  - Changes in market conditions for raw materials/products
  - Starch to ethanol, CO_2 and DDGS plant has limited economic lifespan
- Plan for future profitability, based on co-products
  - Integration of production streams in plant is key
- Develop a biotechnology industry based on renewable resources, not just a bio-fuel plant



Discussion points

1. Fossil fuel won't last! Biofuels are here to stay – get used to it!
2. SA has potential to play in the biofuels arena; should not be too hasty and learn from others' mistakes
3. Which crops will be used for biofuel production in South Africa?
4. Which technologies should be used and developed for biofuel production?
5. How can one ensure that biofuel production in South Africa will remain profitable during economic cycles?
6. Will biofuel production in SA be sustainable?


Thank you!