Enzyme use for corn fuel ethanol production

Foro Global de BioEnergía Rosario 2007

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novozymes

Unlocking the magic of nature

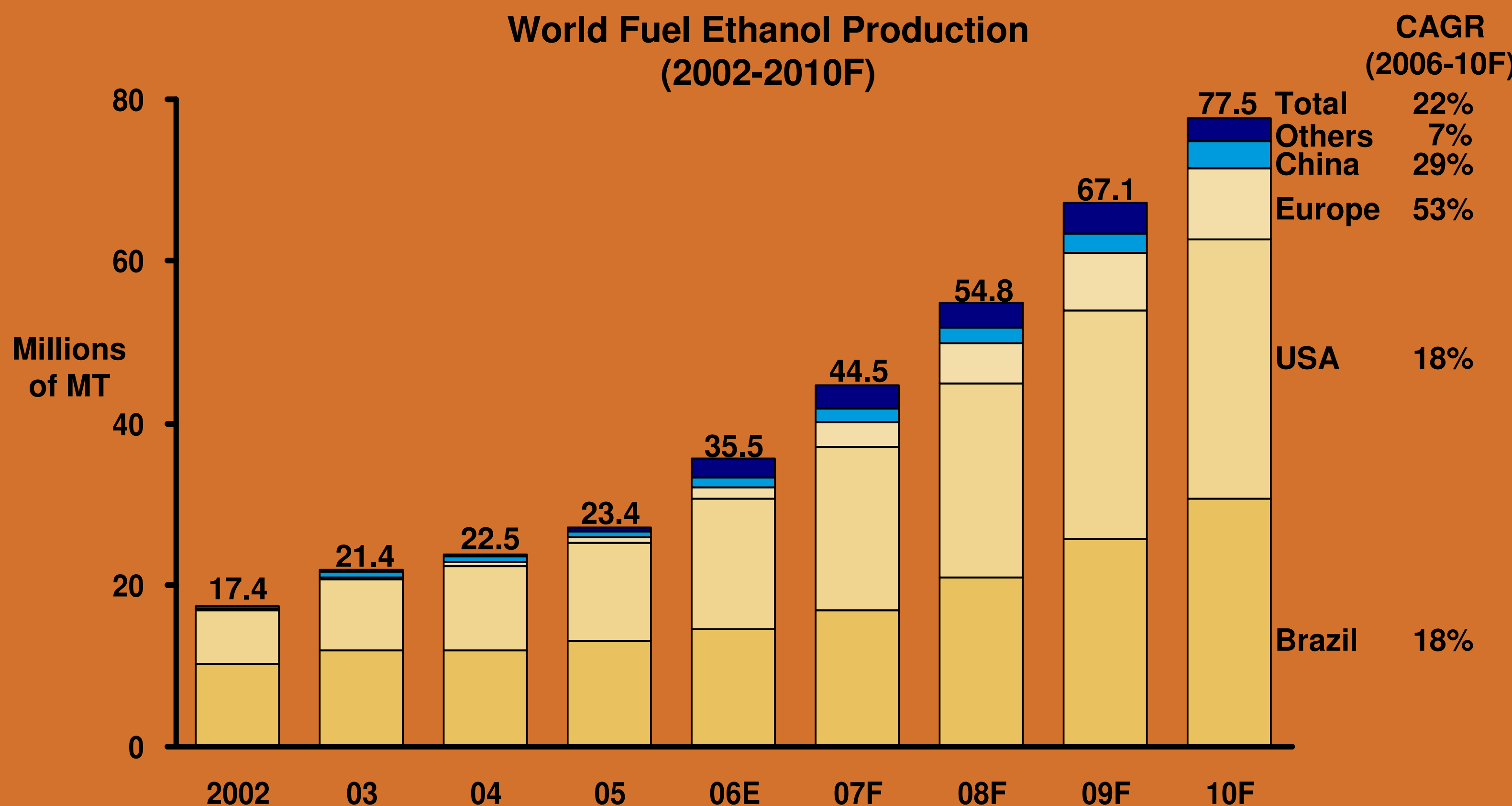
July 12th, 2007

Agenda

- Global Biofuel Outlook
- Novozymes at a glance
- What are enzymes
- Using Enzymes to produce Fuel Ethanol from Grains

Growing Demand

Global fuel ethanol production has doubled in the past 5 years, and will continue to grow at 20% plus annually through 2010



Source: F.O. Licht, Novozymes Analysis

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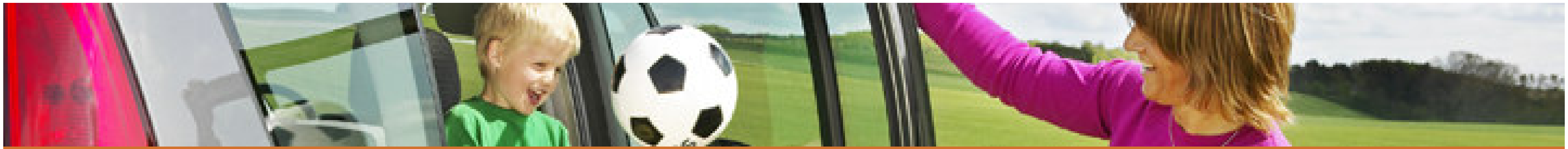


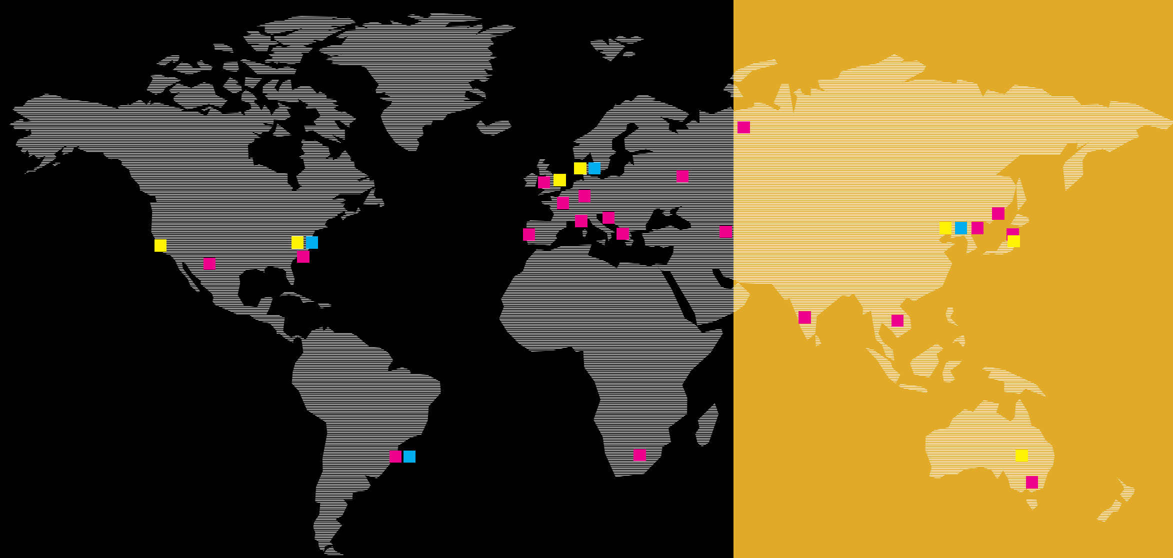
World leader in industrial enzymes

- Leading-edge biotechnology expertise
  - 600+ products in 40 different industries
  - More than 5,000 patents granted and pending

- Commitment to innovation
  - 13% of sales reinvested in R&D
  - Products launched within the last 5 years account for 30% of turnover

We find the magic of nature in a handful of soil or a compost heap. Then we turn it into solutions for fuel ethanol and other applications.

Our commitment to the Ethanol Industry begins with our global efforts and focus

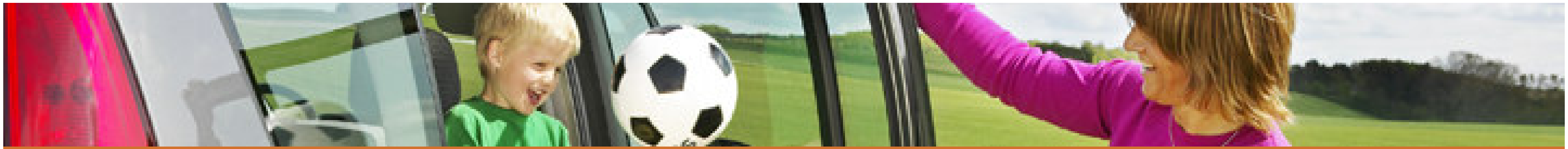


Sales Offices

Production

Research

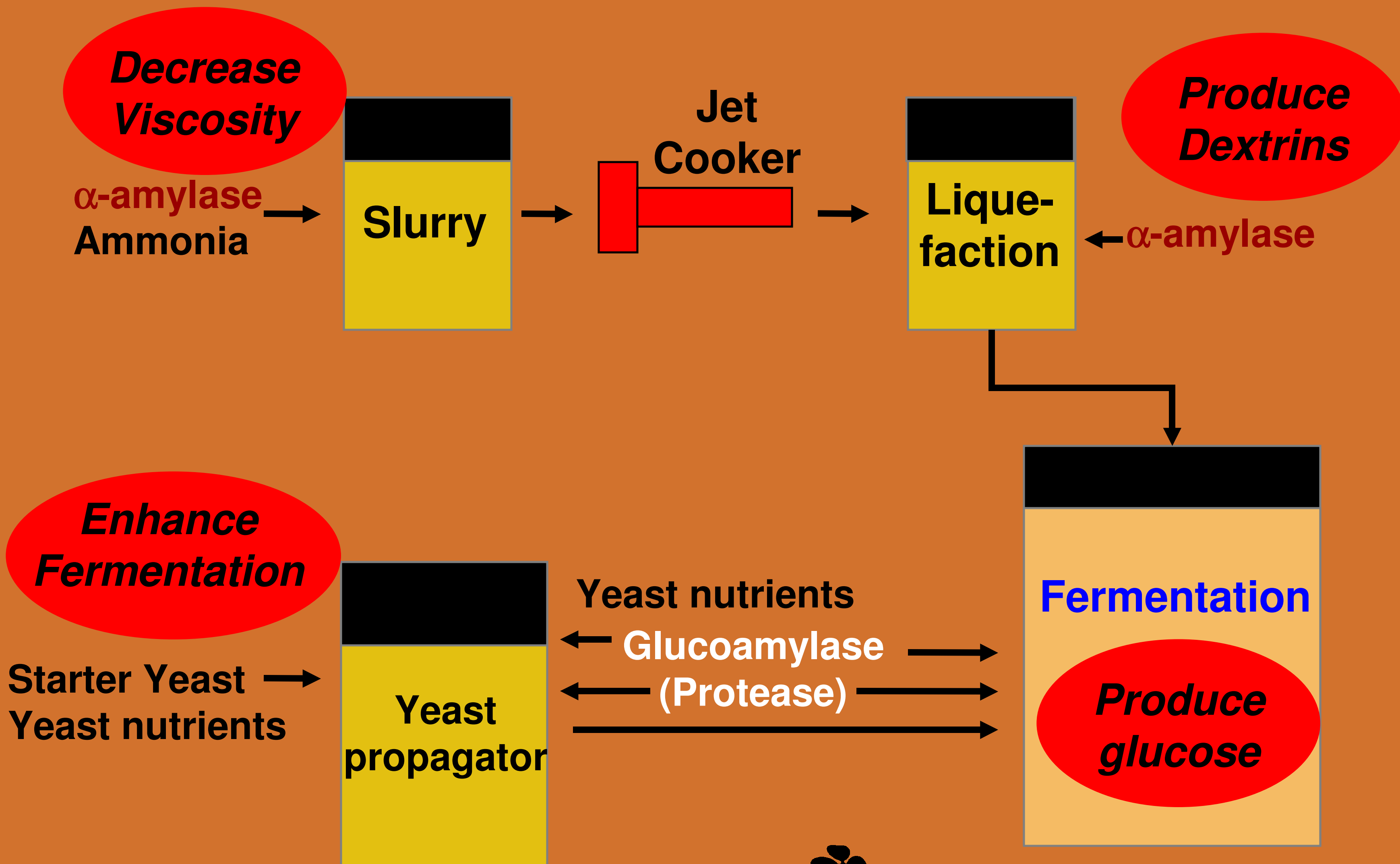
More than 4,500 employees globally



Enzymes Are:

- Functional proteins (as opposed to structural); catalysts
- Primarily made up of chains of amino acids linked together by peptide bonds.
- Found in all living organisms
- Safe, however, good chemical hygiene is always recommended.
  - ✓ Work under mild conditions
  - ✓ Replace harsh chemicals such as strong acids
  - ✓ Biologically degradable
  - ✓ A “clean technology”

Why & Where Enzymes are Added



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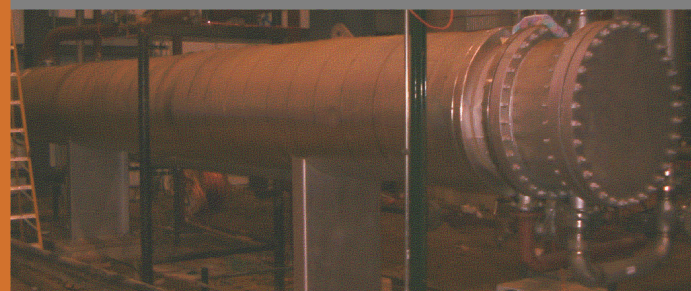
Liquefaction

“The cook process”

Liquefaction

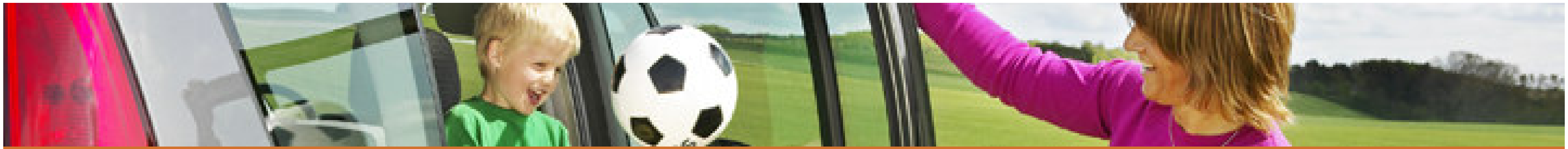
- Converts large chain amylose and amylopectin to a mixture of smaller chain length dextrins
- DE generation
  (Final DE Target 10-12)

Tube & Shell Heat Exchanger



- Decreases viscosity
- Lower viscosity increases heat exchanger efficiency and makes the mash easier to pump

Cook Tubes

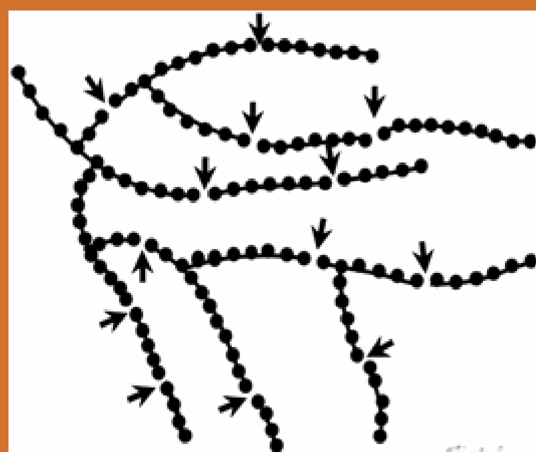


Smoother Operations using Liquozyme® SC DS

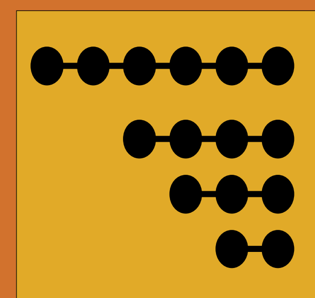
- State of the art enzyme for liquefaction (protein-engineered B. stearothermophilis)
- Smooth your production with the highest tolerance for process variations
  - Superior thermostability and pH tolerance maintains performance in fluxuating conditions
  - Viscosity reducing properties excellent over a wide pH range (up to pH 6.2)
  - The choice of over more than ¾'s of all operating ethanol plants
- No impact on production from calcium deficiencies or mash variances
  - Conventional alpha-amylases suffer reduced performance due to weak thermostability and calcium dependency
  - No "band-aids" required to compensate for stability issues

Liquefaction & Cook

- Liquozyme® SC DS randomly cleaves large chain amylose and amylopectin to a mixture of smaller chain-length dextrins

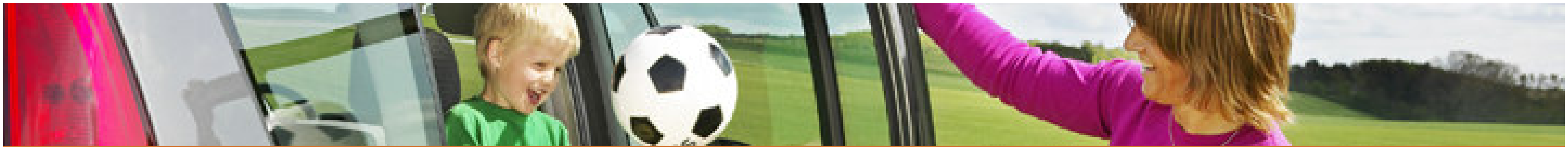


Dextrins

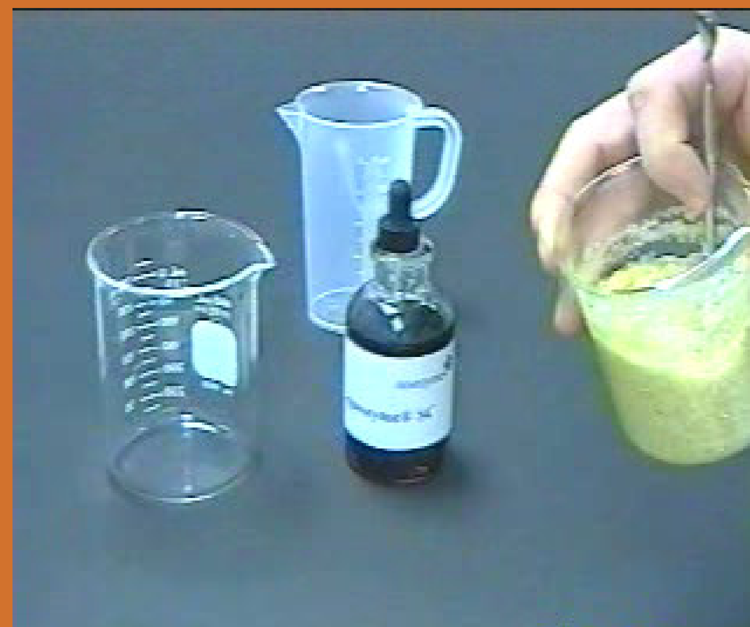


GOALS:

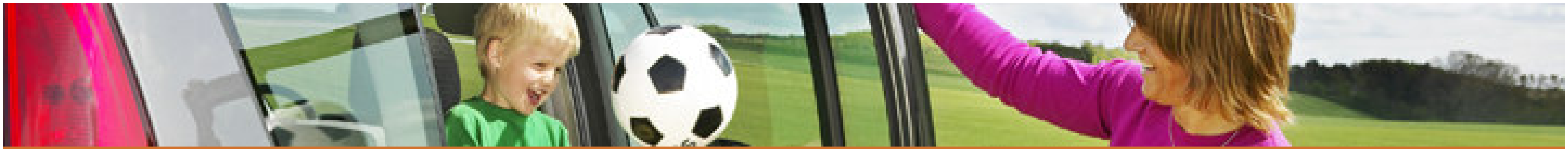
- DE Generation with final target of **10-12**
- Further viscosity reduction



Viscosity Reduction - Demo



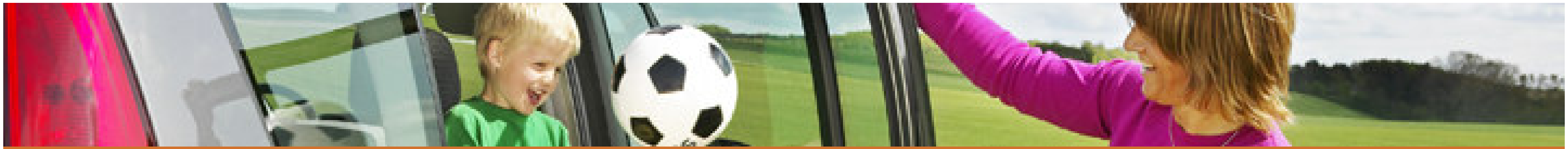
- Mixed Corn Mash + Boiling Water
- Note Viscosity from starch gelatinization
- Add 1 drop Liquozyme®SC DS
- Ensure good agitation
- Note rapid viscosity break



Operating Conditions For Single Dose Dry Mill Liquefaction Using Liquozyme SC DS

	Typical
Free Calcium	>5ppm*
Typical pH Range	5.6 – 6.0
Slurry Hold Temperature	83 - 85°C
Slurry Hold Time	30 - 60 min
Liq Hold Temperature	83 - 85°C
Liq Hold Time	90 - 150 min
Total Enzyme Dose	0.0155- 0.031%w/w

*Generally present in water and grain



SSF

Simultaneous Saccharifaction & Fermentation

"Yeast Nutrition and Production of Alcohol"

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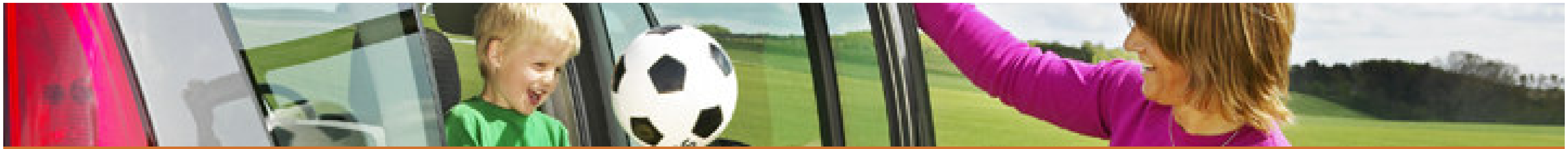

SSF – Simultaneous Saccharification and Fermentation

Spirizyme® Fuel gluco-amylase generates fermentable sugars in the fermentor at the same time as the yeast is converting the sugar to ethanol.

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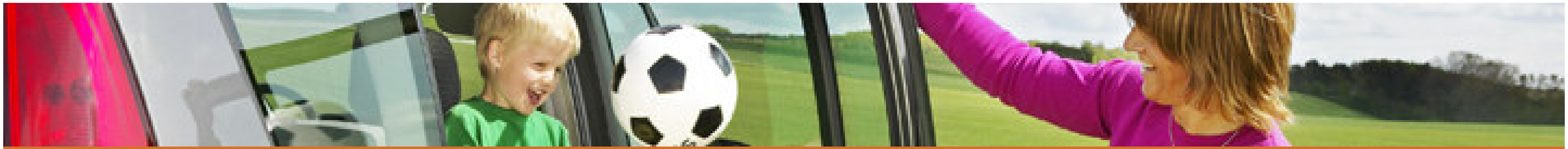
Spirizyme® Fuel ensures maximum ethanol production

- Higher performance than traditional glucoamylases
  - Quicker glucose production
  - Lower maltose levels
  - Lower DP3 levels
- Concentrated formulation
  - Reduced volume of enzyme dosage by 20 – 30%
  - Less ordering and handling
- Greater thermostability
  - Robust performance in temperature ranging from 32°C to 70°C
  - Reduced rate of infection in saccharification step
- Proven performance
  - The most widely used glucoamylase in the world for fuel ethanol production
  - The leading choice for new plants since its introduction

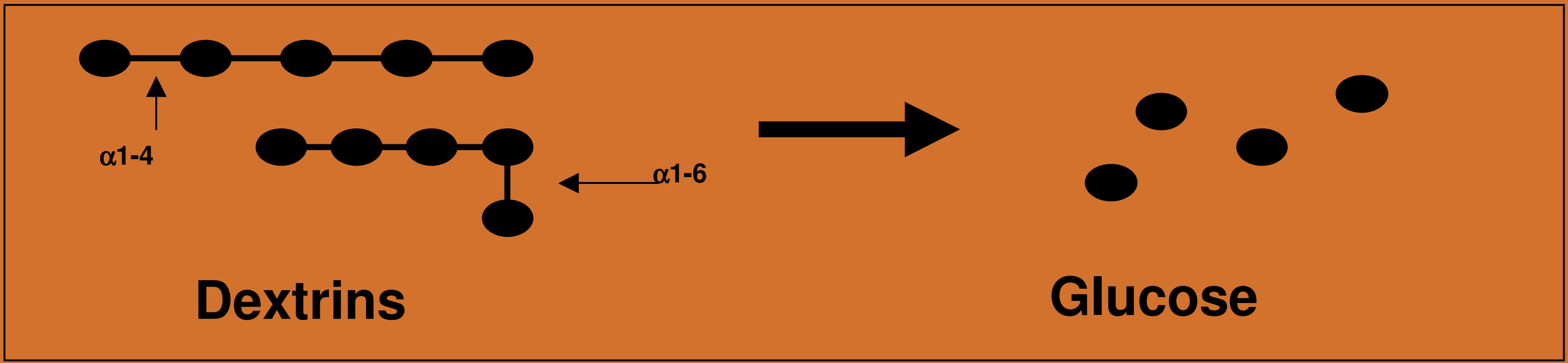


Gluco-amylase: Spirizyme® Fuel

Application

Hydrolyzes 1,4 and 1,6-alpha linkages in liquefied starch. During hydrolysis, the amylo-glucosidase activity removes glucose units in a stepwise manner from the non-reducing end of the substrate molecule.

*Note: 1,4-alpha linkages are more readily hydrolyzed!



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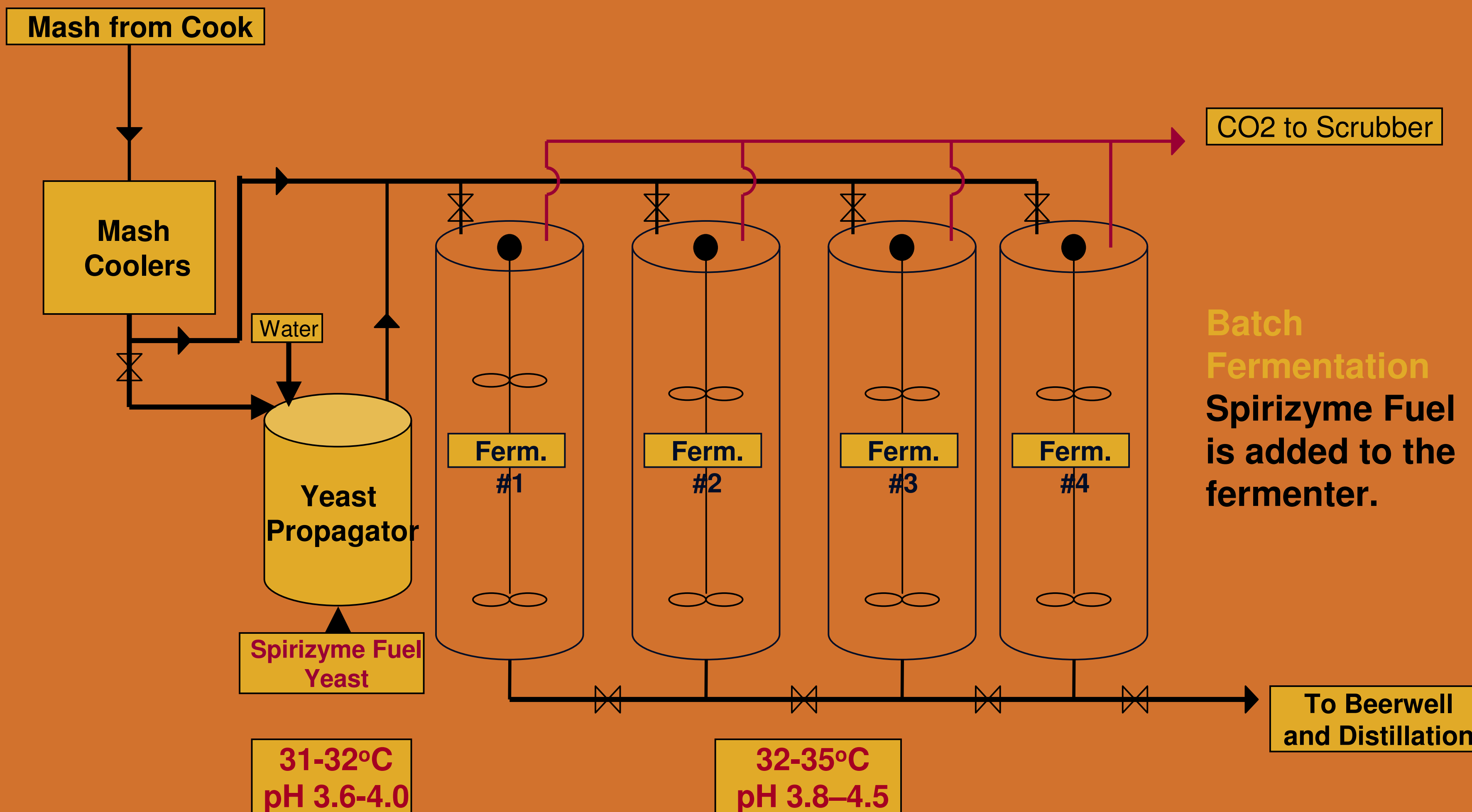
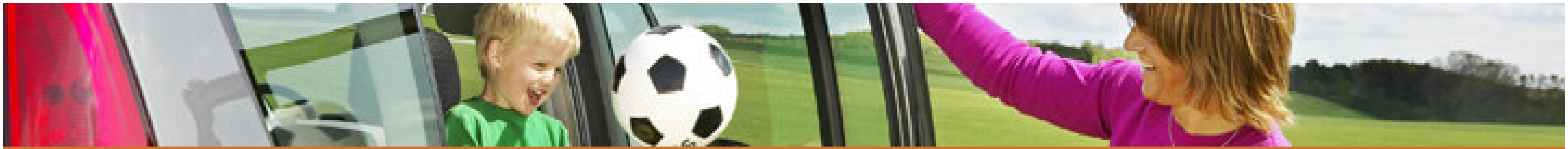
SSF Process Flow



Batch Fermentation

Spirizyme Fuel is added to the fermenter.



1 Bushel of Corn (56 lbs)

Corn = 56 lbs (25.4 kg)

Starch = 33.8 lbs (15.3 kg)

Sugar = 37.5 lbs (17 kg)

Ethanol = 17.9 lbs (2.71 gal ~ 10.27 l)

CO_2 = 17.1 lbs (7.8 kg)

DDGS = 16.2 lbs (7.3 kg)

Approx. a 1:1:1 ratio EtOH:CO_2:DDGS

$$\%\text{Efficiency} = \frac{\text{actual alcohol wt}}{\text{theoretical alcohol wt}} \times 100\%$$

Heat 6.5 MJ

Max: ~93%

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Simplified bio-ethanol production processes

1st generation corn-based ethanol production

Starch e.g. corn

Enzyme process

Ferment-able sugars

Fermen-tation process

Fuel ethanol

Waste biomass

Pre-treatment process

Cellulose

Enzyme process

Future 2nd generation biomass-based ethanol production

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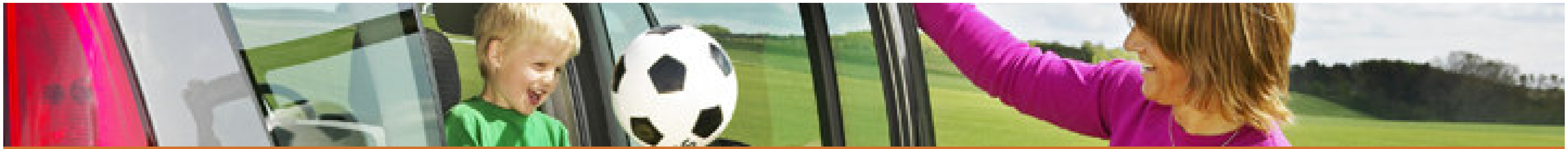

For more information please access

www.novozymes.com

www.biomass.novozymes.com

Thanks for your attention!

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