Enzyme use for corn fuel ethanol production

Luis Alessandro Volpato Mereles

Foro Global de BioEnergía
Rosario 2007

July 12th, 2007
Agenda

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

- **Decrease Viscosity**
  - α-amylase
  - Ammonia

- **Enhance Fermentation**
  - Starter Yeast
  - Yeast nutrients

- **Fermentation**
  - Yeast nutrients
  - Glucoamylase (Protease)

- **Produce Dextrins**
  - α-amylase

- **Jet Cooker Liquefaction**

- **Slurry**

- **Produced glucose**

Flowchart:

1. Slurry → Jet Cooker → Liquefaction → Fermentation
2. Yeast propagator → Yeast nutrients → Glucoamylase (Protease) → Fermentation
3. Ammonia → α-amylase → Decrease Viscosity
4. α-amylase → Produce Dextrins
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)
- Decreases viscosity
- Lower viscosity increases heat exchanger efficiency and makes the mash easier to pump
Smooother 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

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Calcium</td>
<td>&gt;5ppm*</td>
</tr>
<tr>
<td>Typical pH Range</td>
<td>5.6 – 6.0</td>
</tr>
<tr>
<td>Slurry Hold Temperature</td>
<td>83 - 85°C</td>
</tr>
<tr>
<td>Slurry Hold Time</td>
<td>30 - 60 min</td>
</tr>
<tr>
<td>Liq Hold Temperature</td>
<td>83 - 85°C</td>
</tr>
<tr>
<td>Liq Hold Time</td>
<td>90 - 150 min</td>
</tr>
<tr>
<td>Total Enzyme Dose</td>
<td>0.0155- 0.031%w/w</td>
</tr>
</tbody>
</table>

*Generally present in water and grain*
SSF
Simultaneous Saccharification & Fermentation

“Yeast Nutrition and Production of Alcohol”
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.
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!
SSF Process Flow

Mash from Cook

Mash Coolers

Yeast Propagator

Spirizyme Fuel Yeast

31-32°C
pH 3.6-4.0

Ferm. #1

Ferm. #2

Ferm. #3

Ferm. #4

32-35°C
pH 3.8–4.5

Batch Fermentation
Spirizyme Fuel is added to the fermenter.

CO2 to Scrubber

Water

To Beerwell and Distillation
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)

Approx. a 1:1:1 ratio
EtOH:CO₂:DDGS

CO₂ = 17.1 lbs (7.8 kg)
DDGS = 16.2 lbs (7.3 kg)

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

Heat 6.5 MJ

Max: ~93%
Simplified bio-ethanol production processes

1st generation corn-based ethanol production

Waste biomass → Pre-treatment process → Cellulose → Enzyme process → Fermentable sugars → Fermentation process → Fuel ethanol

Future 2nd generation biomass-based ethanol production
For more information please access

www.novozymes.com

www.biomass.novozymes.com

Thanks for your attention!