State-of-the-art Production of fuel ethanol using Granular Starch Hydrolyzing Enzymes (GSHE)

Bioenergy-1
From Concept to Commercial Process
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Presentation Outline

- Introduction
- Benefits of No-cook Process For Glucose Using GSHE in Alcohol Fermentation
- What Is GSHE?
- How Does GSHE Work?
- Process Conditions for GSHE
- Summary
Applications Of Glucose From Starch

BioFuel,

17 Billion Liters

- MSG
- Lysine
- Citric Acid
- Ascorbic Acid
- Gluconic Acid
- Lactic Acid
- High Fructose
- Sorbitol
- Future Growth

1.5 Million MT (2 Million MT)
500,000 MT (600,000 MT)
500,000 MT (1.25 Million MT Glucose)
250,000 MT (320,000 MT)
70,000 MT (150,000 MT)
70,000 MT (100,000 MT)
70,000 MT (100,000 MT)

Significant Growth Potential

10 Million MT (10 Million MT Glucose)
Grains Used For Ethanol

Agricultural Raw Materials For Fuel Alcohol Production

- Corn
- Wheat
- Sorghum
- Rye
- Barley
- Triticale
- Rice
Conventional Ethanol Production Process

- **Milo**, Corn, Wheat, Rye, Barley, Tapioca
- **Water**
- **Grinding**
- **Slurry Tank**
- **JET COOKER** >100°C, 5-8 MIN
- **Secondary Liquefaction** 95°C, ~90 MIN (optional)
- **Thermo-Stable Alpha Amylase**
- **Glucoamylase**
- **Yeast**
- **Alcohol Recovery**

**Liquefaction** → **Saccharification** → **Fermentation**

**Distillation & Dehydration** → **DDGS**

**Storage Tank**

* pH adjustment steps are not shown
Liquefaction

Picture of a typical jet used in primary liquefaction

Starch → Combining Tube → Liquefied Starch to Hold Loops → Steam

Drawings copied with permission of Hydrothermal Corp.
Thermal Energy Destroys the Granular Structure of Granular Starch resulting in solubilization.

Liquefaction Introduction

Starch Degrading Enzymes

- alpha-amylase
- glucoamylase
- fungal amylase or beta-amylase
- pullulanase
Energy Costs ($/MM BTUs)
Forecast Assumes 5% Increase Per Year

Source: Historical: DOE
Forecast: GCOR Estimate
Liquefaction Energy Cost ($/Gallon of Ethanol)

GCOR Estimate: Assumes 10% of Gas Energy Per Gallon
STARGEN™ Enzymes: No Cook Process

Granular Starch Hydrolyzing Enzymes & Application For Hydrolyzing Granular Starch in Ethanol Production
Granular Starch Hydrolyzing Enzymes: Glucoamylases and Alpha Amylases

A. niger

Glyco-hydro-15

Catalytic domain

Granular Corn Starch

Linker region

Starch Binding Domain

A. niger Glyco-hydro-15

SBD

Glucose
Potential Benefits of STARGEN™ Enzymes

- **Energy Saving** — Elimination of Jet Cooking
- **Reduction in Osmotic Stress/Reduction in By-products Formation** — Glycerol, Organic Acids, etc.
- **Capacity Increase** — High Density Fermentation - Higher Alcohol Yield
- **Carbon Conversion Efficiency** — Higher Yield
- **Reduction of Yeast Growth Inhibitors** — High Glucose, Maillard Products, etc.
- **Saving on Operational Cost** — Labor, Time, Chemicals
- **Elimination of Calcium Addition** — Reduction of Calcium Salt Formation
- **Value Added By-product (DDGS)** — Higher Protein Content
- **Process Simplification** — Reductions in Unit Operations
- **Saving on Capital Cost** — Capacity Increase/New Plant
Comparison of Soluble Starch and Granular Starch Under Yeast Fermentation For Ethanol

Current Process Using Conventional GA

Granular Starch with Conventional- GA

Granular Starch with Granular Starch Hydrolyzing Enzymes
STARGEN™ Enzymes

- Alpha-amylase helps in granular starch hydrolysis
- AG-I has strong granular starch hydrolytic activity
- AG-II has weak granular starch hydrolytic activity
Synergy: Alpha Amylase + Glucoamylase

Incubation of Granular Starch with Purified GSH- Glucoamylase and Purified GHS- Alpha Amylase at pH 5.0, 32°C, 4 Hours

Graph showing Mg Glucose Released in 4 Hours with AA, GA, and AA+GA compared.
SEM of Granular Corn Starch Treated with Purified Glucoamylase, pH 4.5, 32°C

Granular Corn Starch

2 Hours Incubation

4 Hours Incubation

Electron Micrograph Images courtesy of Dr. David Johnston & Dr. Peter Cooke – United States Department of Agriculture’s Eastern Regional Research Center
SEM of Granular Corn Starch Treated with Purified Alpha Amylase, pH 4.5, 32°C

Granular Corn Starch

2 Hours Incubation

4 Hours Incubation

8 Hours Incubation

Electron Micrograph Images courtesy of Dr. David Johnston & Dr. Peter Cooke – United States Department of Agriculture’s Eastern Regional Research Center
Enzymatic Drilling of Granular Starch

Electron Micrograph Images courtesy of Dr. David Johnston & Dr. Peter Cooke — United States Department of Agriculture’s Eastern Regional Research Center

Granular Starch

Granular Starch + STARGEN™ 2 Hours

Granular Starch + STARGEN™ 4 Hours

Granular Starch + STARGEN™ 8 Hours
STARGEN™ Enzymes

A proprietary blend of granular starch hydrolyzing alpha amylase from A. *kawachi* and glucoamyrase from A. *niger*
Effect of Particle Size: Laboratory Scale (32% DS, STARGEN™ 001)

% thru 30 mesh

- #6: 54.0%
- #4: 65.7%
- 2.0 mm: 85.9%
- 1.5 mm: 89.8%
- 1.0 mm: 93.3%

% residual starch

- #6: 22%
- #4: 16%
- 2.0 mm: 9%
- 1.5 mm: 13%
- 1.0 mm: 10%

Effect of pH on Ethanol Yield and Residual Starch Content in Distiller’s Grains

![Graph showing the effect of pH on Ethanol Yield and Residual Starch Content in Distiller’s Grains. The graph plots mash pH on the x-axis and % Ethanol and % Residual Starch on the y-axis. The pH values range from 3.0 to 6.5, and the Ethanol yield reaches a peak around pH 4.5, while the residual starch content increases with increasing pH.]
Conventional Ethanol Production Process

**Grinding Slurry Tank**

- Water
- Liquefaction
  - Thermo-Stable Alpha Amylase
  - Glucoamylase
- Saccharification
- Fermentation
- Distillation & Dehydration
- Alcohol Recovery

**Milo Corn Wheat Rye Barley Tapioca**

- JET COOKER
  - >100°C
  - 5-8 MIN
- Secondary Liquefaction
  - 95°C
  - ~90 MIN
- pH adjustment steps are not shown

**Storage Tank**

- DDGS
**Low Energy Ethanol Production Process**

- **Grinding Slurry Tank**
- **Water**
- **Alcohol Recovery**
  - **Distillation & Dehydration**
  - **Storage Tank**

- **Saccharification & Fermentation**
  - **STARGEN™ & Yeast**
  - **Milo Corn Wheat Rye Barley Tapioca**

- **pH adjustment steps are not shown**

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* A Danisco Company
STARGEN™ Has Potential to Transform the Ethanol Industry!

- No Cook = Less Energy Input
- Fewer Side Products = Higher Ethanol Yield
- Fewer Process Steps = Less Equipment
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