



**Genencor International**<sup>®</sup>  
Innovative by Nature<sup>®</sup>

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

**Bioenergy-1**  
**From Concept to Commercial Process**  
**March 5-110,2006**  
**Tomar, Portugal**

Jay K. Shetty, Oreste Lantero and Nigel Dunn-Coleman

[www.genencor.com](http://www.genencor.com)

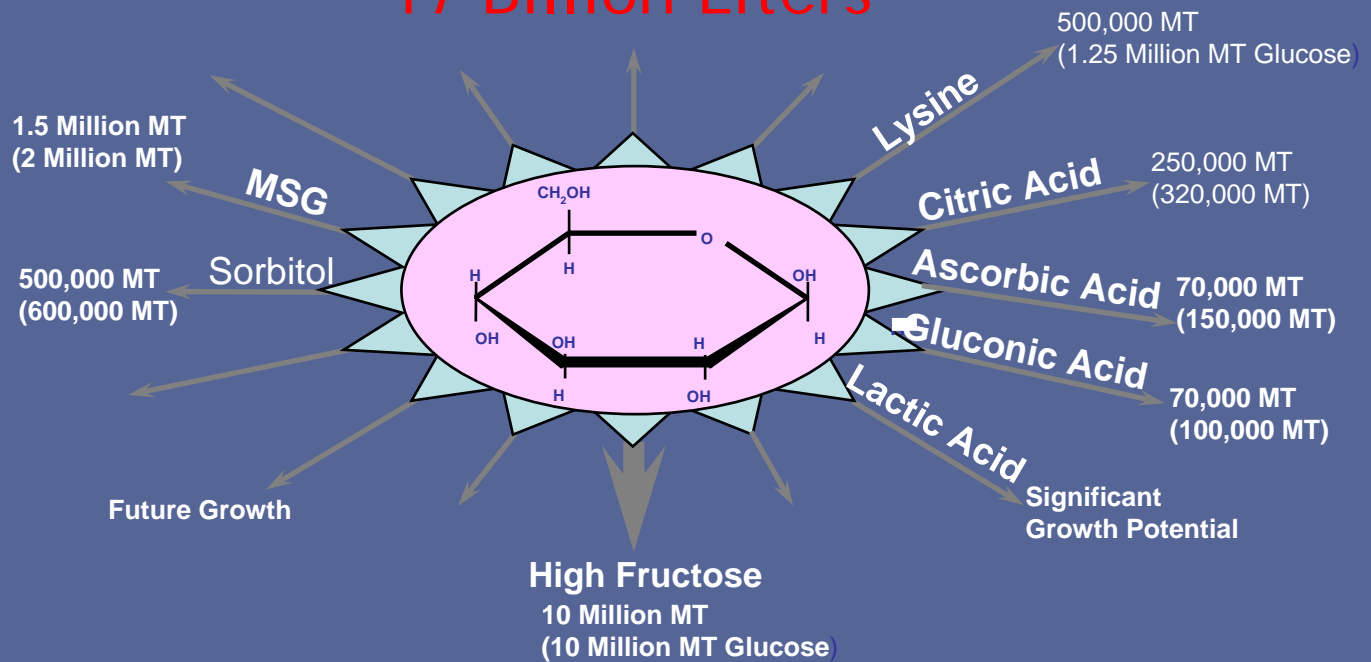
A Danisco Company

- 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



# Grains Used For Ethanol

## Agricultural Raw Materials For Fuel Alcohol Production



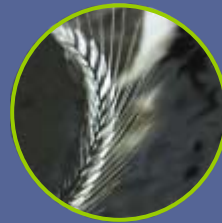
Corn



Wheat



Sorghum



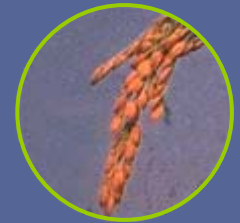
Rye



Barley

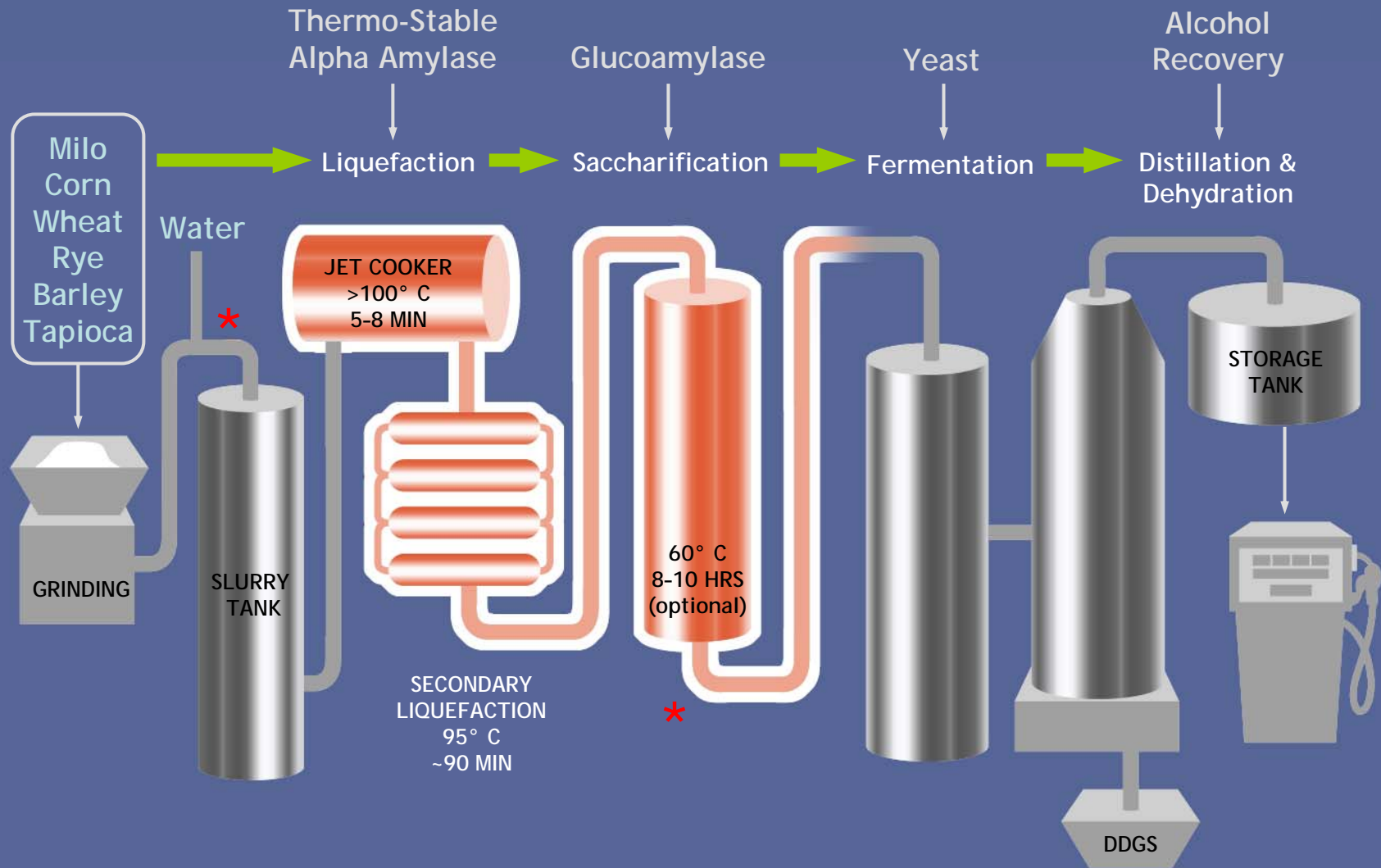


Triticale



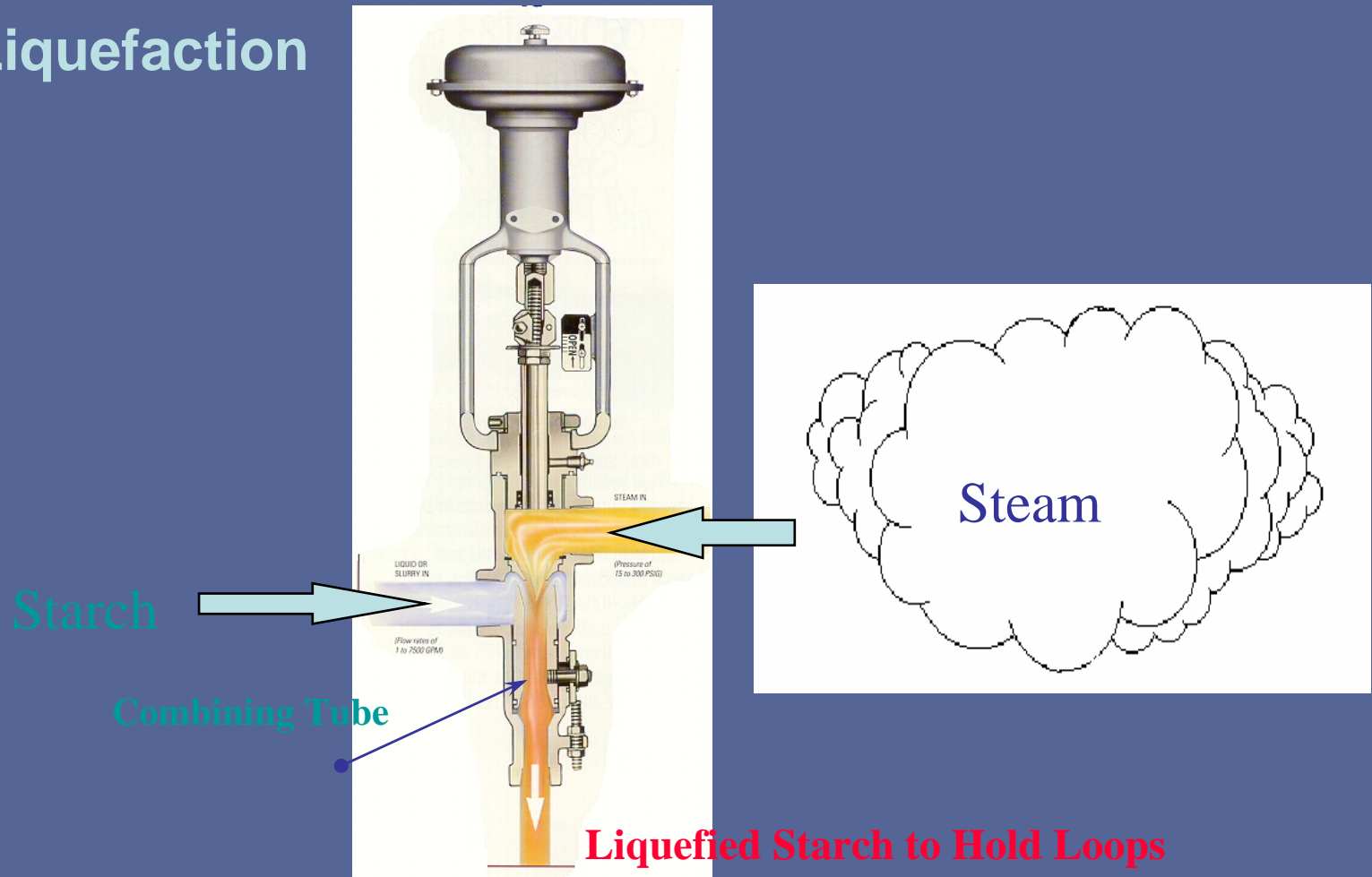
Rice

# Conventional Ethanol Production Process



\* pH adjustment steps are not shown

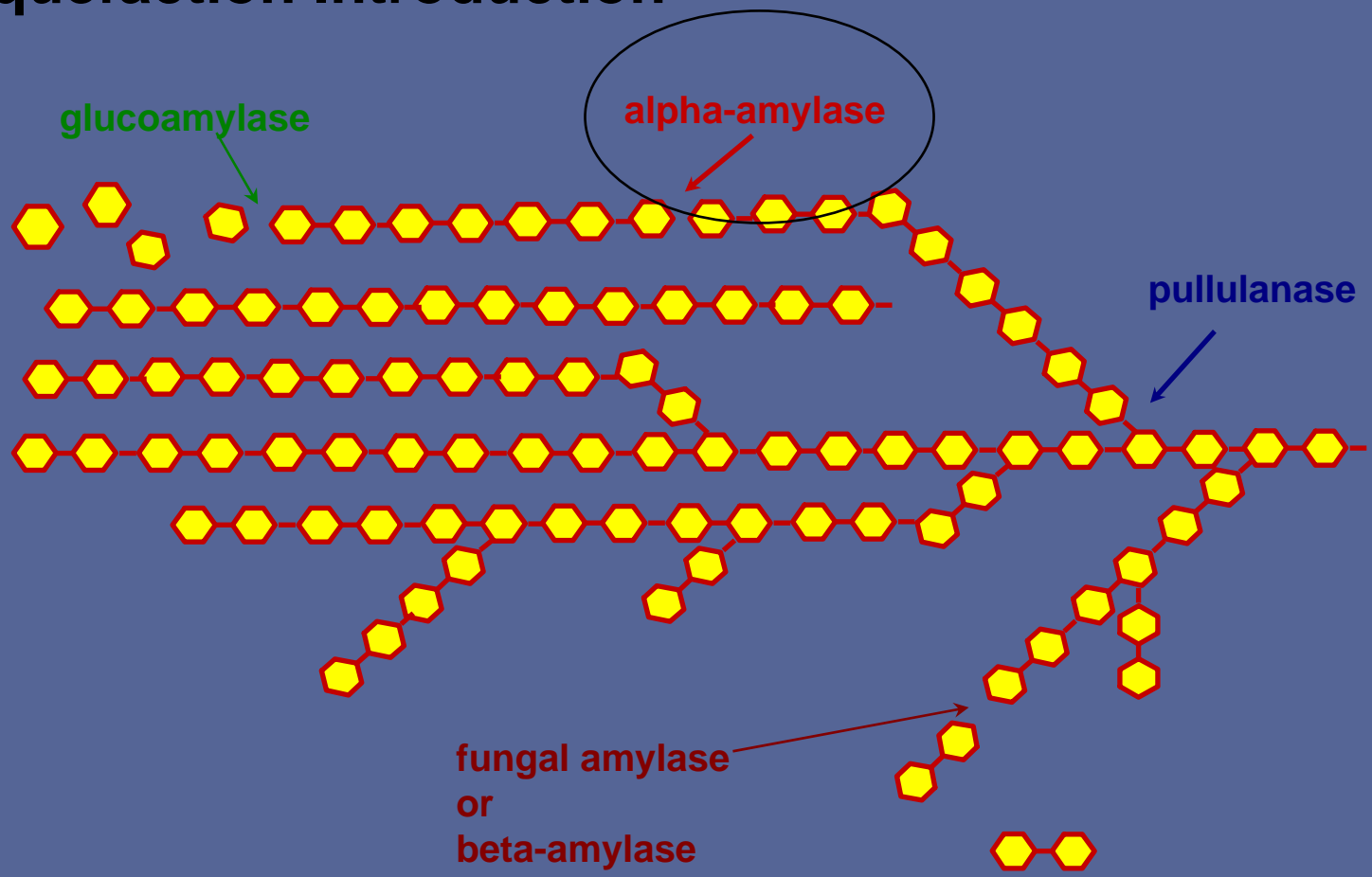
## Liquefaction



Picture of a typical jet used in primary liquefaction

# Thermal Energy Destroys the Granular Structure of Granular Starch resulting in solubilization

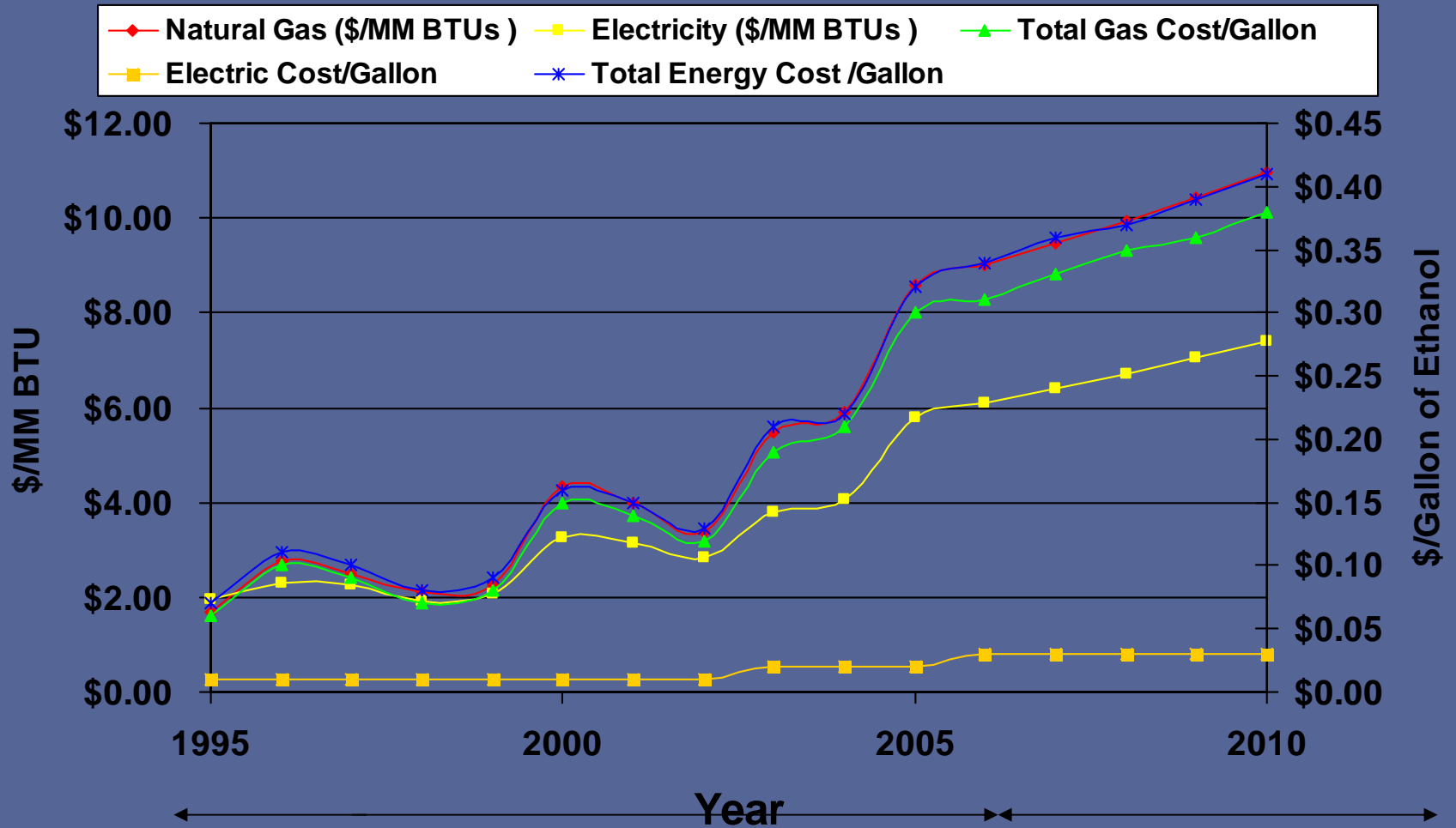
## Liquefaction Introduction



## Starch Degrading Enzymes

# Energy Costs (\$/MM BTUs)

## Forecast Assumes 5% Increase Per Year

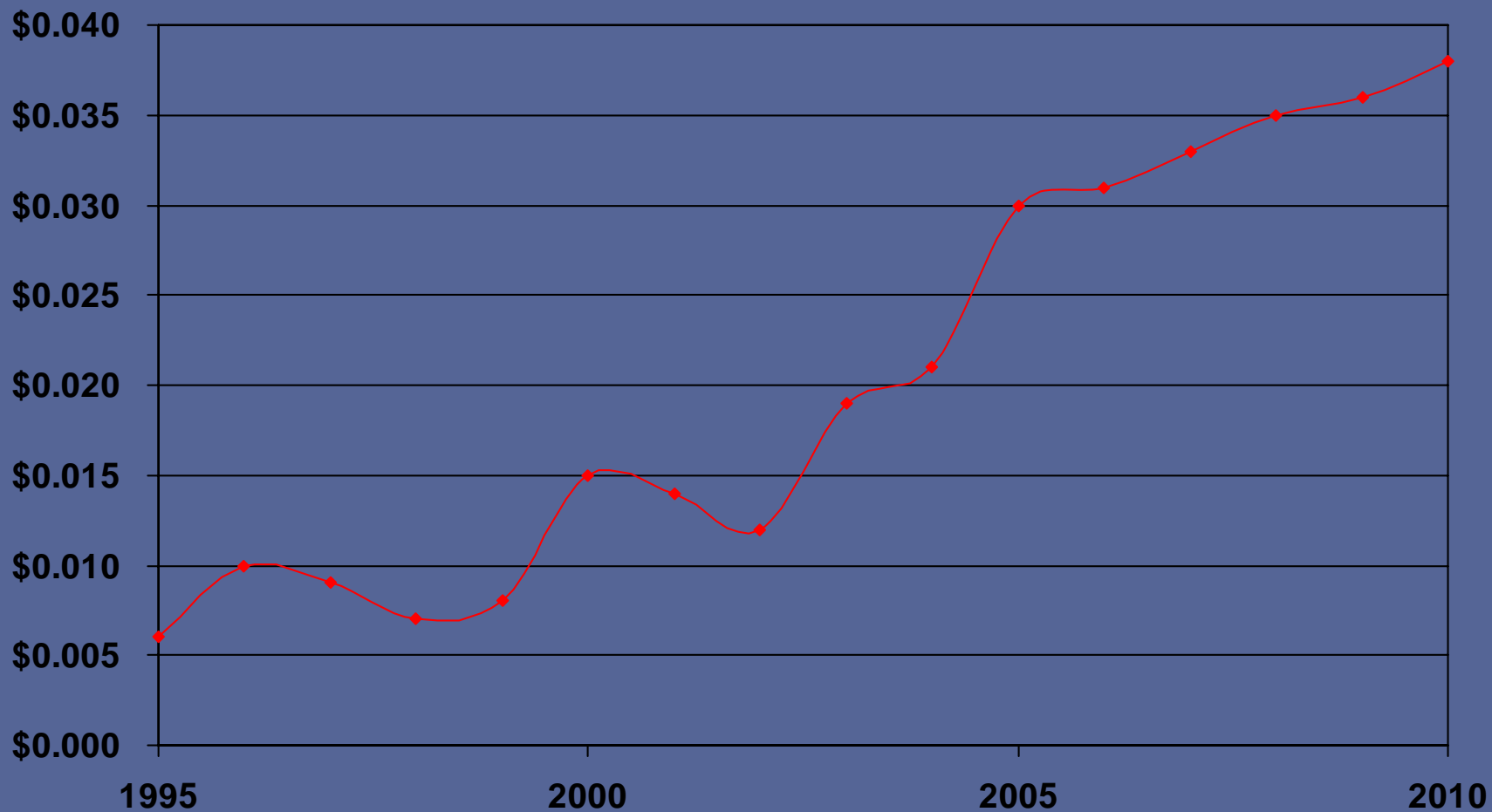


Source: Historical : DOE

Forecast: GCOR Estimate




# Liquefaction Energy Cost (\$/Gallon of Ethanol)



GCOR Estimate: Assumes 10% of Gas Energy Per Gallon

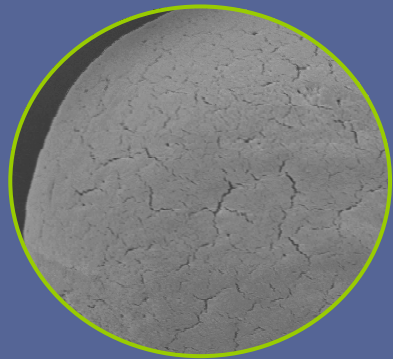
## STARGEN™ Enzymes: No Cook Process



Granular Starch Hydrolyzing  
Enzymes & Application For  
Hydrolyzing Granular Starch  
in Ethanol Production

# Granular Starch Hydrolyzing Enzymes: Glucoamylases and Alpha Amylases

Catalytic domain

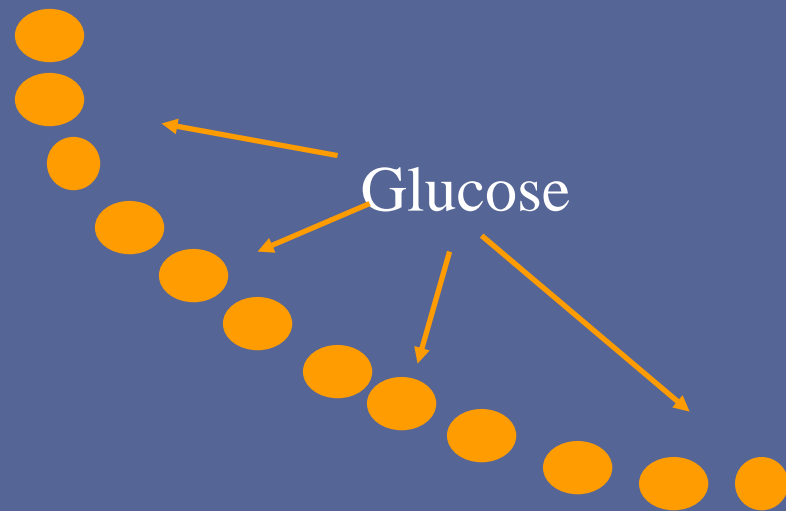
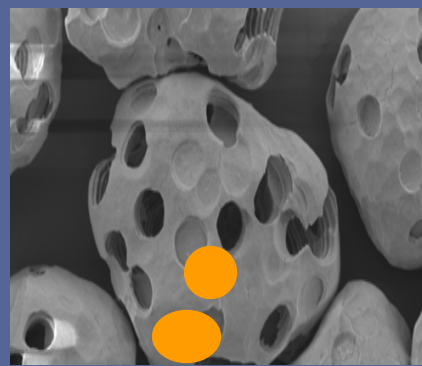


Granular Corn Starch

Linker region



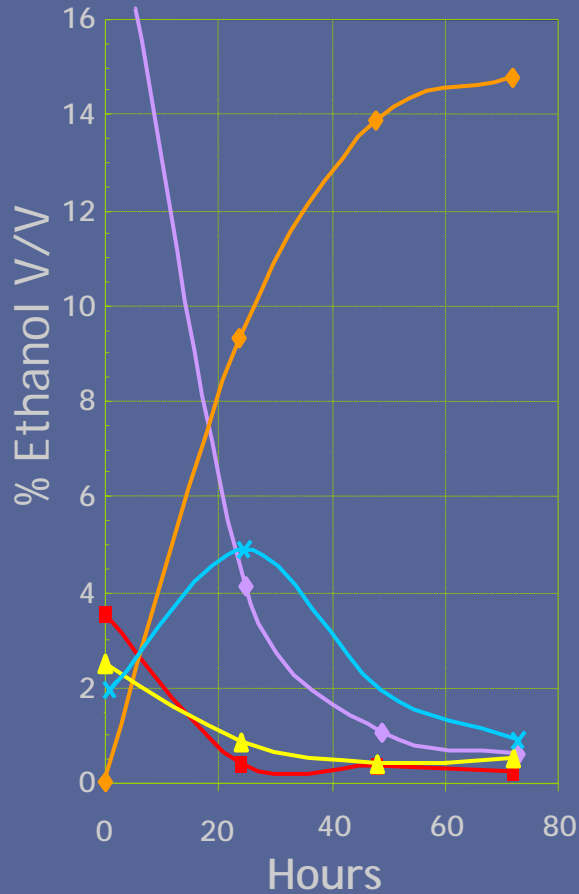
Starch Binding Domain



- **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

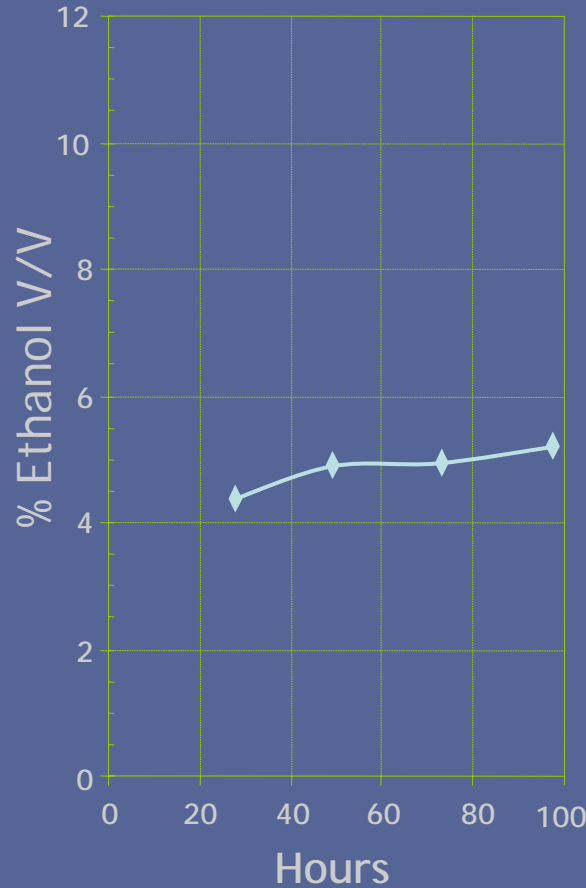
# Comparison of Soluble Starch and Granular Starch Under Yeast Fermentation For Ethanol

## Current Process Using Conventional GA



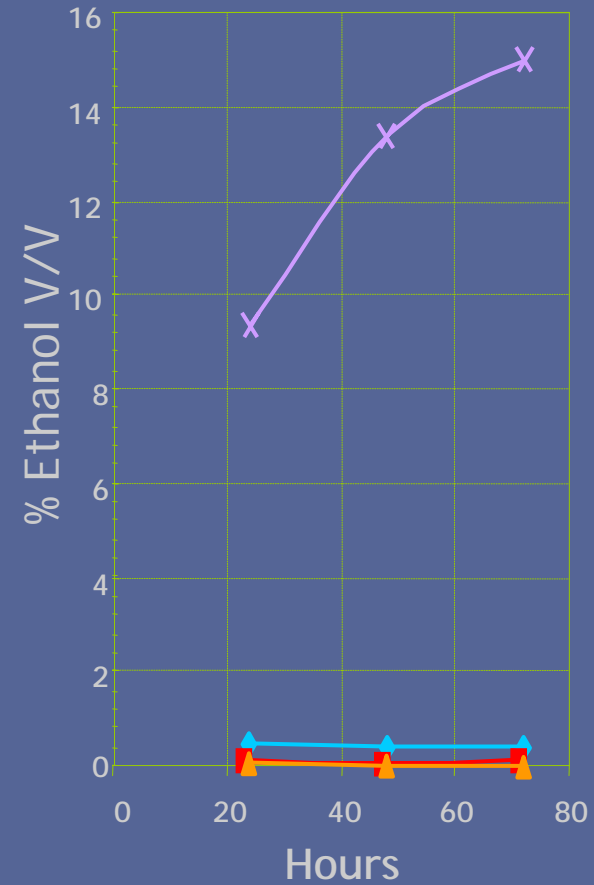
- DP>3 w/v      Glucose w/v
- DP3 w/v      DP2 w/v      Etoh v/v

## Granular Starch with Conventional- GA



Hours

## Granular Starch with Granular Starch Hydrolyzing Enzymes



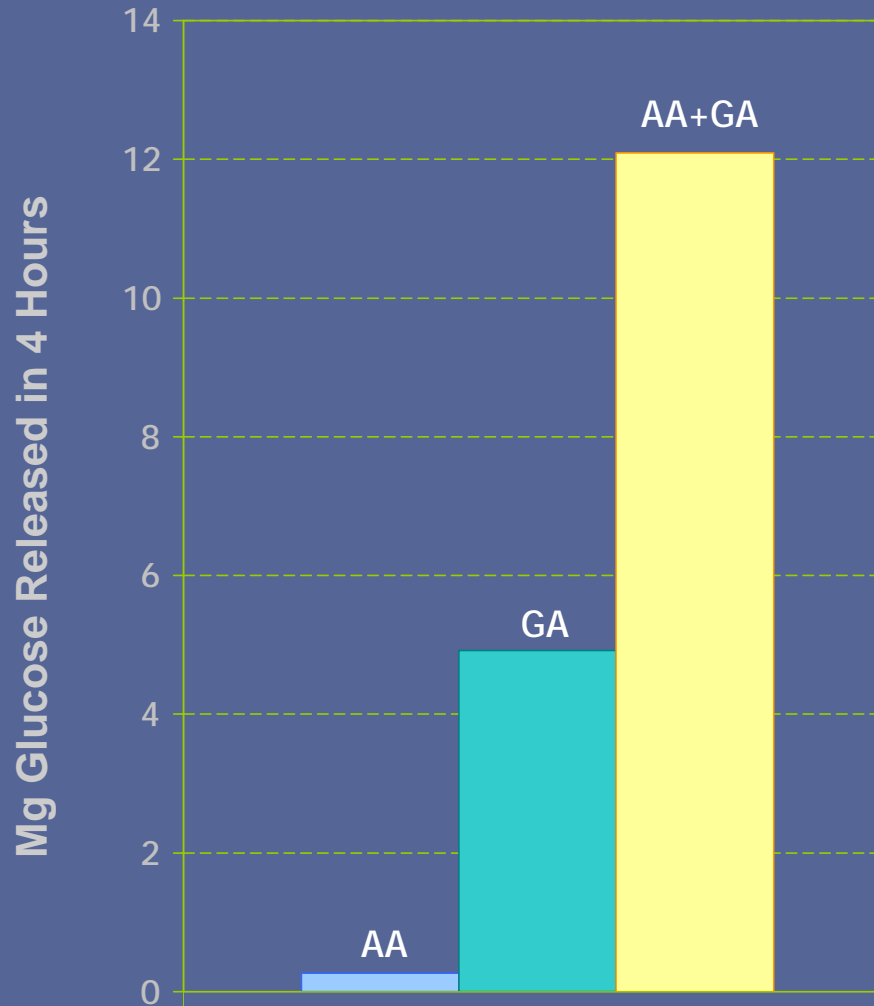
- DP>2 w/v      Glucose w/v
- DP2 w/v      Etoh v/v

## STARGEN™ Enzymes

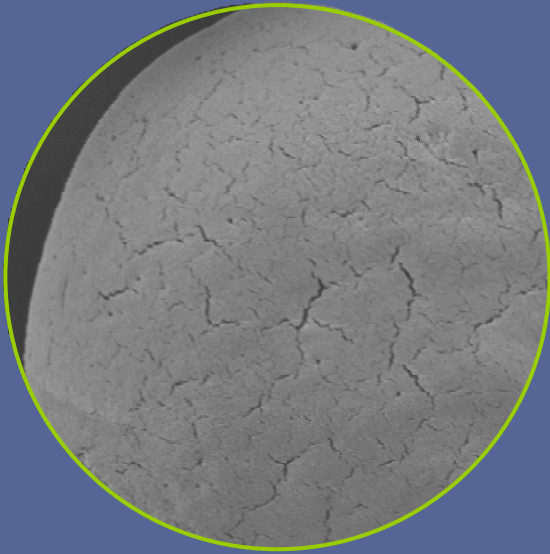
- Alpha-amylase helps in granular starch hydrolysis
- AG-I has strong granular starch hydrolytic activity
- AG-II has weak granular starch hydrolytic activity

# Synergy: Alpha Amylase + Glucoamylase

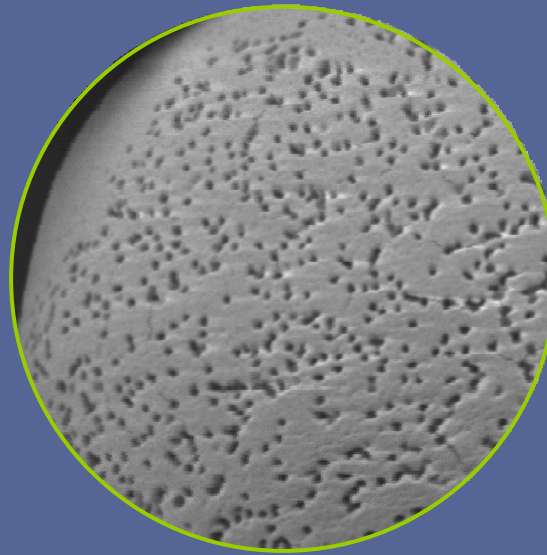
Incubation of Granular Starch with Purified GSH- Glucoamylase and Purified GHS- Alpha Amylase at pH 5.0, 32°C, 4 Hours



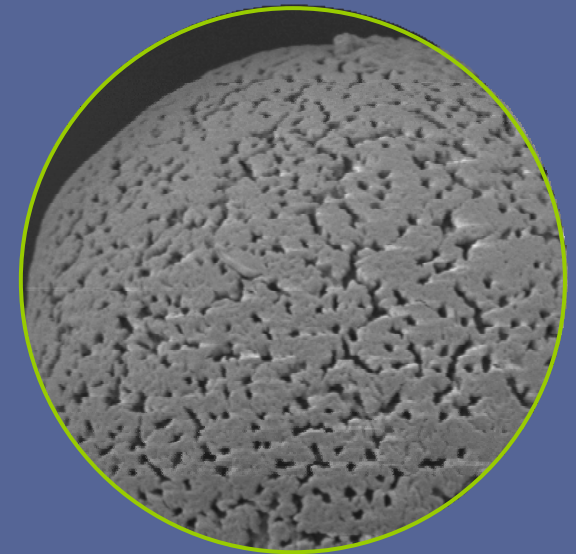
# SEM of Granular Corn Starch Treated with Purified Glucoamylase, pH 4.5, 32° C



Granular Corn Starch



2 Hours Incubation

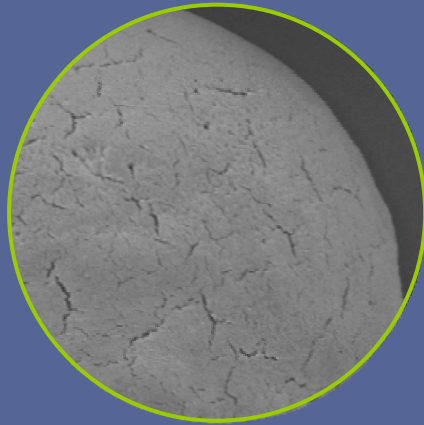


4 Hours Incubation

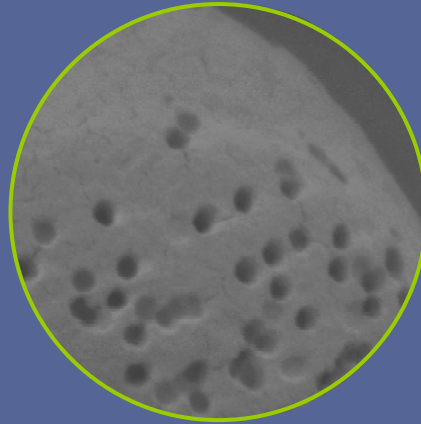
*Electron Micrograph Images courtesy of  
Dr. David Johnston & Dr. Peter Cooke —  
United States Department of Agriculture's  
Eastern Regional Research Center*



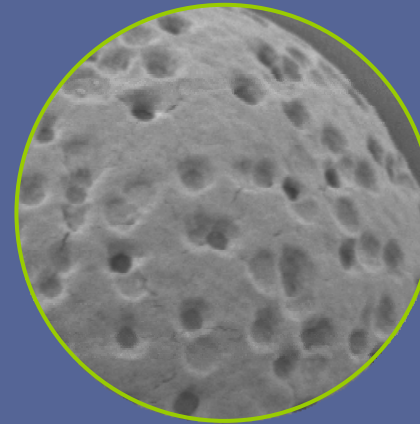
# SEM of Granular Corn Starch Treated with Purified Alpha Amylase, pH 4.5, 32° C



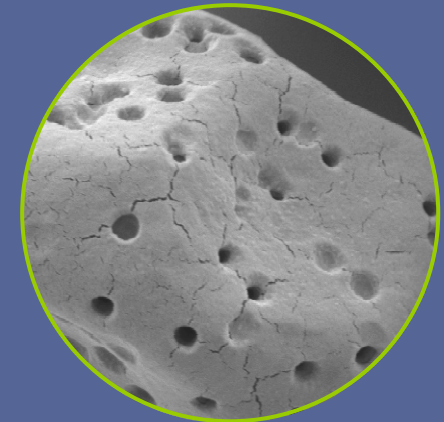
Granular Corn  
Starch



2 Hours Incubation



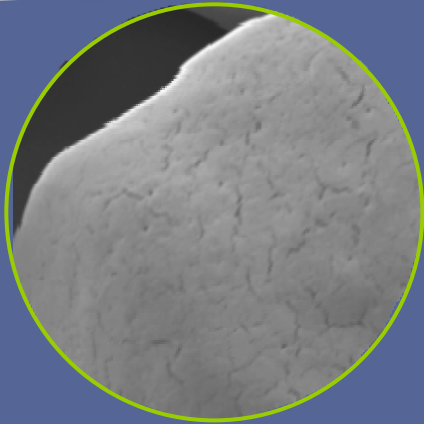
4 Hours Incubation



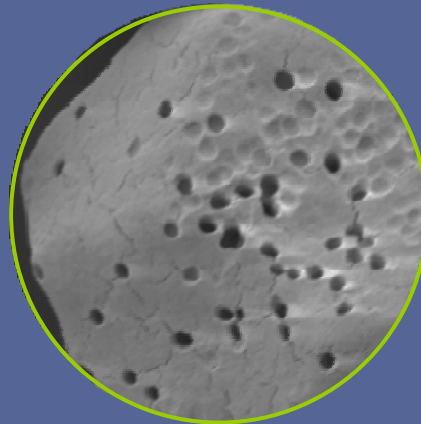
8 Hours Incubation

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

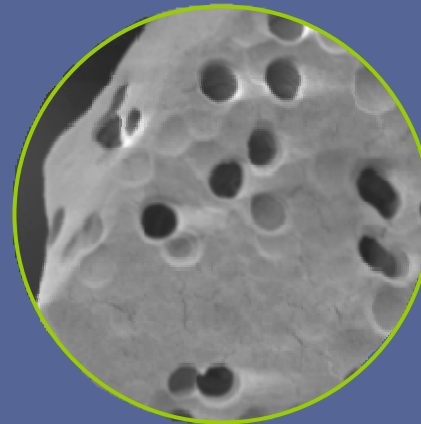
# Enzymatic Drilling of Granular Starch



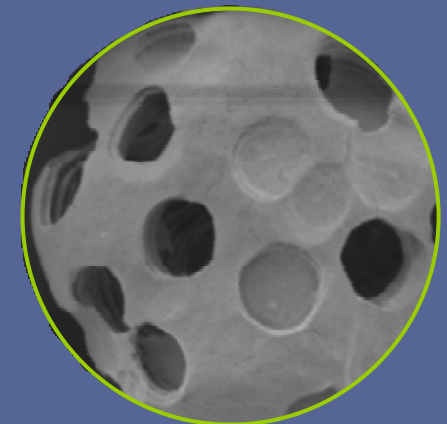
Granular Starch



Granular Starch  
+  
STARGEN™  
2 Hours

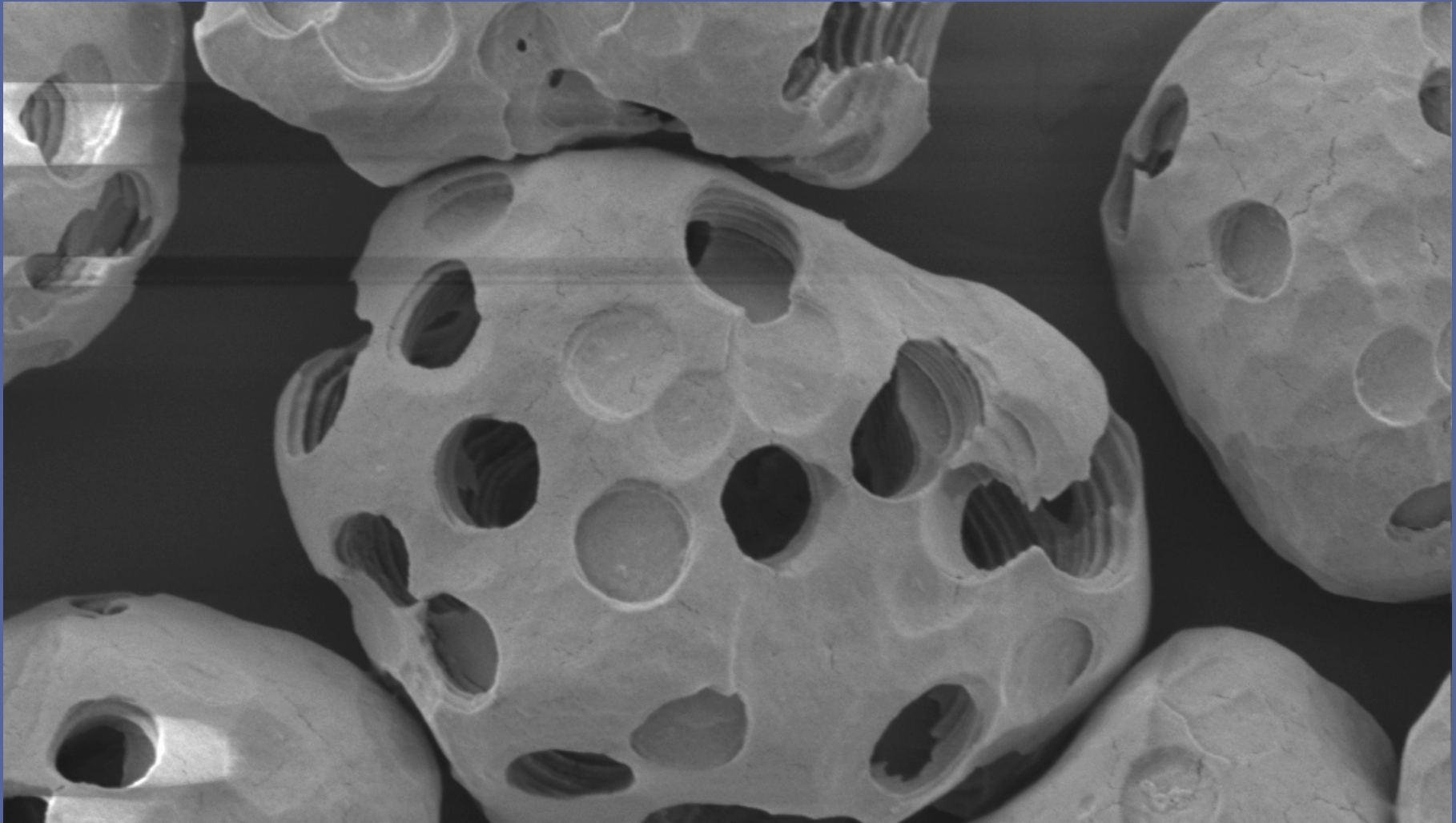


Granular Starch  
+  
STARGEN™  
4 Hours




Granular Starch  
+  
STARGEN™  
8 Hours

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



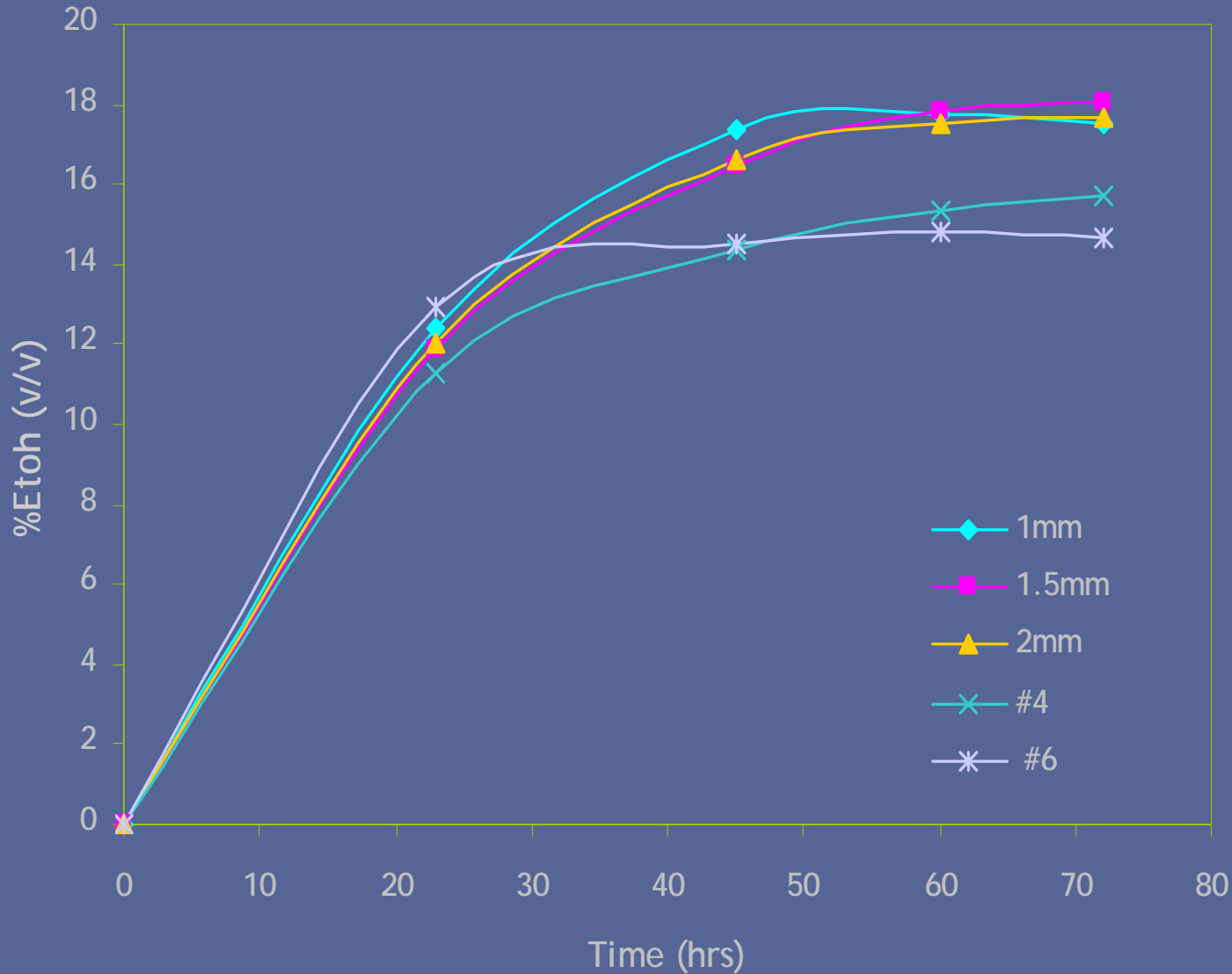
*Electron Micrograph Images courtesy of  
Dr. David Johnston & Dr. Peter Cooke —  
United States Department of Agriculture's  
Eastern Regional Research Center*

## STARGEN™ Enzymes



A proprietary blend of granular starch hydrolyzing alpha amylase from *A. kawachi* and glucoamylase from *A. niger*

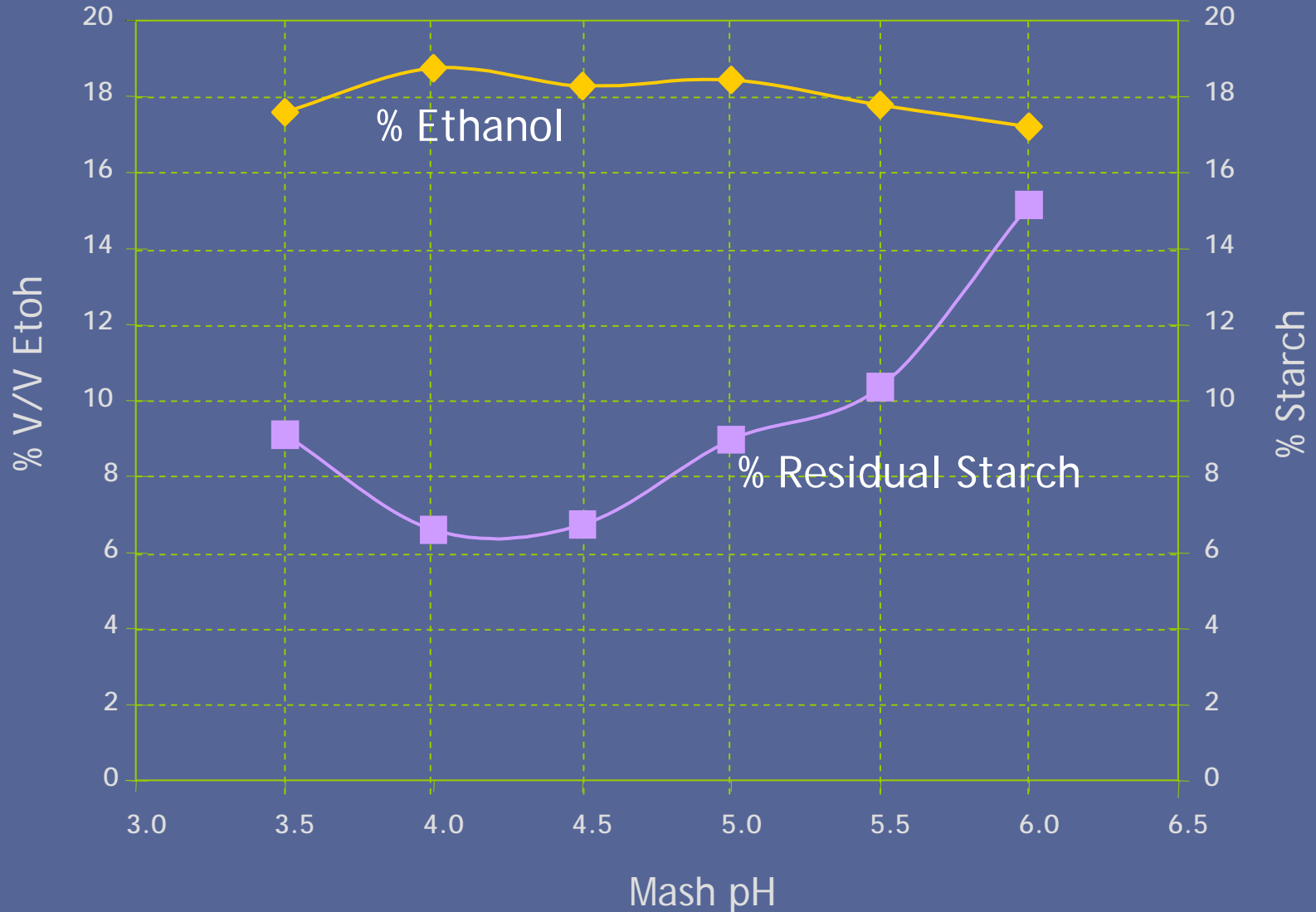
# Effect of Particle Size: Laboratory Scale (32% DS, STARGEN™ 001)



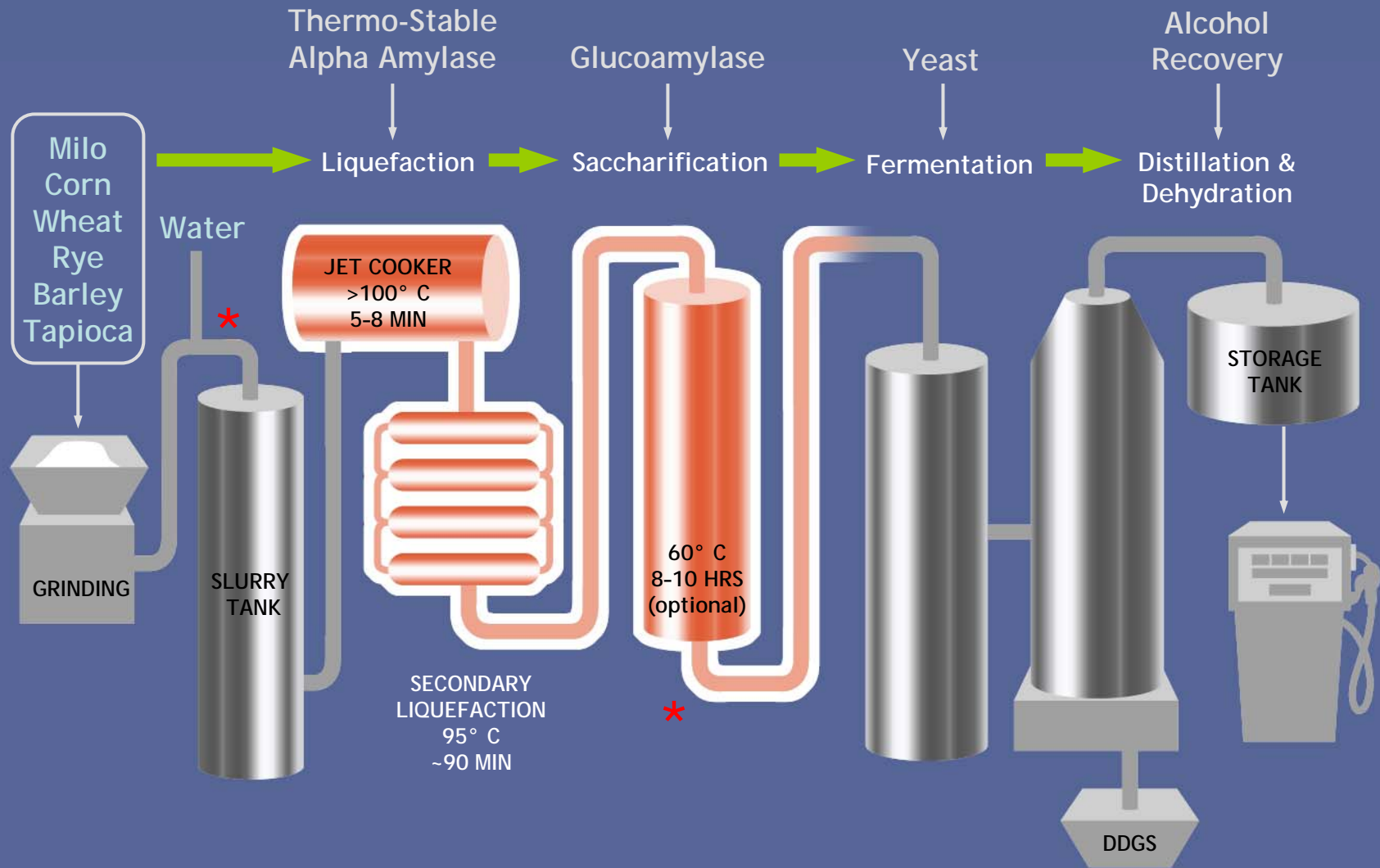
% thru 30 mesh	
#6	54.0%
#4	65.7%
2.0 mm	85.9%
1.5 mm	89.8%
1.0 mm	93.3%

% 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



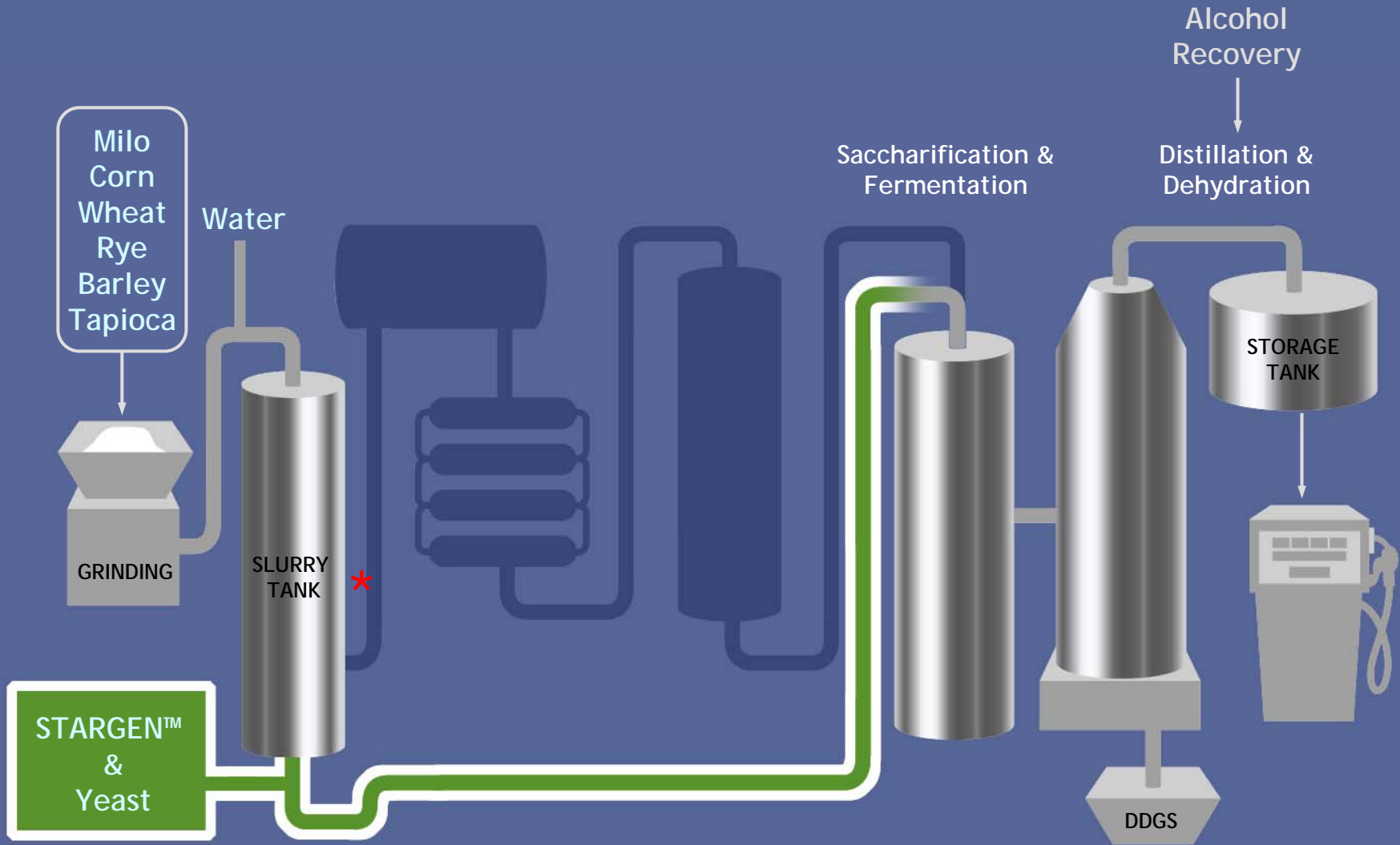
# Conventional Ethanol Production Process



\* pH adjustment steps are not shown



# Low Energy Ethanol Production Process



\* pH adjustment steps are not shown



## TRANSFORMING ETHANOL INDUSTRY USING STARGEN™



SOUND OFF

CREDITS & REFERENCES

# Summary

## A whole new direction in ethanol production.

Introducing STARGEN™, a revolutionary granular starch hydrolyzing enzyme that can transform the fuel ethanol industry.

Genencor's exciting innovation in value-added enzyme technology for low-energy processes can improve operations and put you on the road to higher yields and enhanced plant throughput. Because no cooking is required, less energy is used than in traditional processes. And that results in improved energy balance, one of the hottest new ideas in the fuel ethanol industry.

For more information, contact your Genencor Technical Sales representative or Genencor Customer Relations at 1.800.847.5311. Because when it comes to innovation in ethanol, we can do that.



## Taking ethanol production where it needs to go.

Introducing STARGEN™, a revolutionary granular starch hydrolyzing enzyme that can transform the fuel ethanol industry.

Steer your ethanol production in a new direction with Genencor's exciting innovation in value-added enzyme technology for low-energy processes. STARGEN™ can put you on the road to higher yields with enhanced throughput and reduced overall costs. And because STARGEN™ hydrolyzes ungelatinized starch, less energy is needed than in traditional processes, resulting in improved energy balance.

For more information about how this advancement can yield so much more for the ethanol industry, contact your Genencor Technical Sales representative or Genencor Customer Relations at 1.800.847.5311. Because when it comes to innovation in ethanol, we can do that.



## The sign of what's ahead for ethanol production.

Introducing STARGEN™, a revolutionary granular starch hydrolyzing enzyme that can transform the fuel ethanol industry.

This exciting Genencor innovation can simplify the design and reduce capital requirements for new ethanol plants. Because STARGEN™ hydrolyzes starch without the need for a cook step, it can also create new possibilities for expansion of existing plants. Best of all, no cooking requires less energy than traditional processes, resulting in improved energy balance.

For more information about how less capital can mean so much more for the ethanol industry, contact your Genencor Technical Sales representative or Genencor Customer Relations at 1.800.847.5311. Because when it comes to innovation in ethanol, we can do that.



## STARGEN™ Has Potential to Transform the Ethanol Industry!

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

# Acknowledgements

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Dr. David Johnston and Dr. Peter Cooke