Cellulosic Ethanol from Corn Fiber: Technology, Challenges and Future Improvements

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Agenda

- Introduction to D3MAX
- D3MAX technology
- Ace Ethanol project update
- Lessons learned
- Areas for improvement

Introduction

- D3MAX owns and licenses technology to convert corn fiber and residual starch in a corn dry mill ethanol plant to cellulosic ethanol
- BBI International developed the technology while working with the Coors Brewery in Golden, Colorado from 2007-2008.
- Our first license was sold to Ace Ethanol in Stanley, WI in 2018
- Construction of the Ace D3MAX plant started October 1, 2018; startup is scheduled to begin October 2019
- Our business model is to license our technology to ethanol plants; we charge a one-time license fee; no on-going royalties to use the D3MAX technology

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D3MAX Timeline

2015

Create D3MAX

July 2015 D3MAX, LLC formation

Develop PPM and start equity raise

2016

Equity Raise

Complete equity raise

Design and fabricate pilot plant

2017

Pilot Testing

Development Agreement with Ace Ethanol

Pilot testing March-Nov 2017

Start FEL 3 design for D3MAX at Ace

2018

Engineering

Complete FEL 3

Capital cost estimate by Fagen

Project approval April 24, 2018

Oct 1 start construction at Ace Ethanol

2019

Construction

Engineering, procurement and construction by Fagen

Startup Oct 2019

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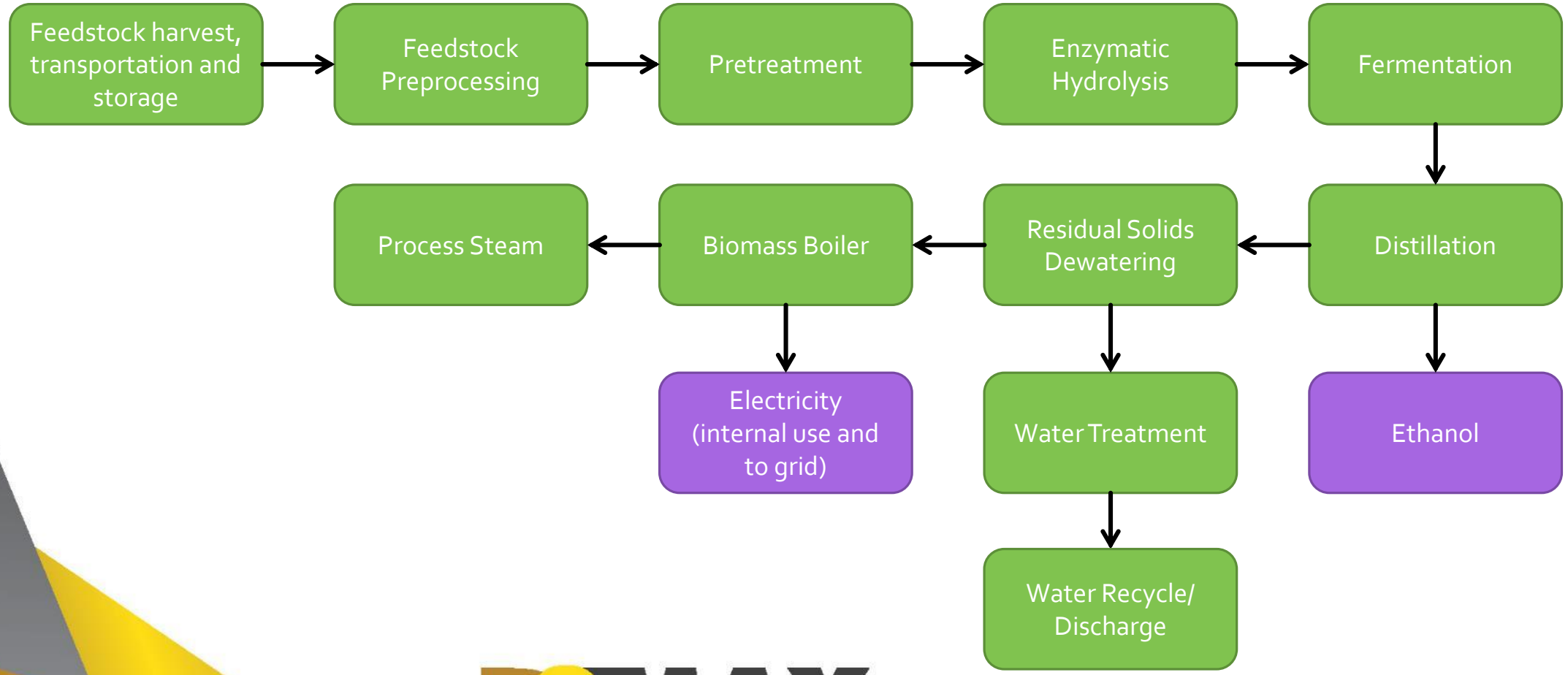
Typical Cellulosic Ethanol Process using Dilute Acid Pretreatment, Enzymatic Hydrolysis & Fermentation



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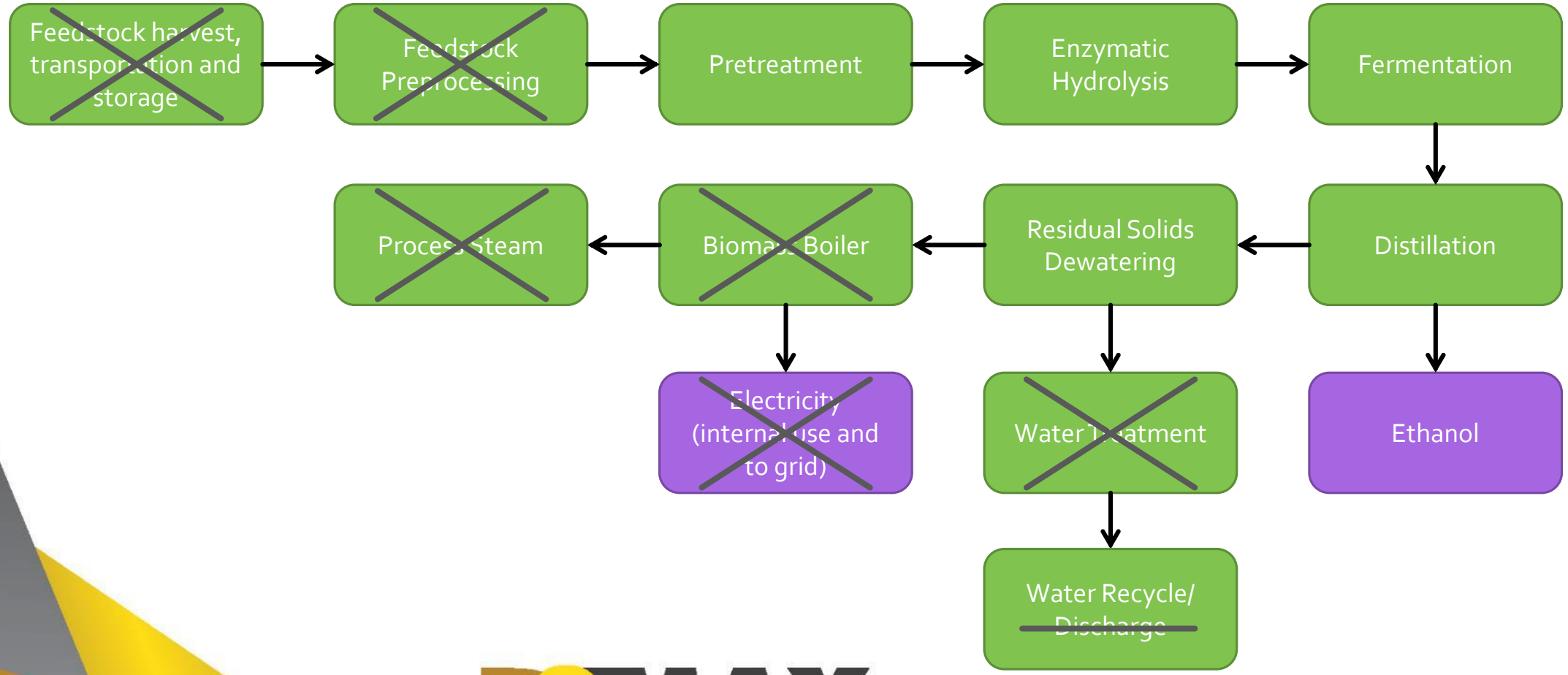
D3MAX Cellulosic Ethanol Process using Dilute Acid Pretreatment, Enzymatic Hydrolysis & Fermentation



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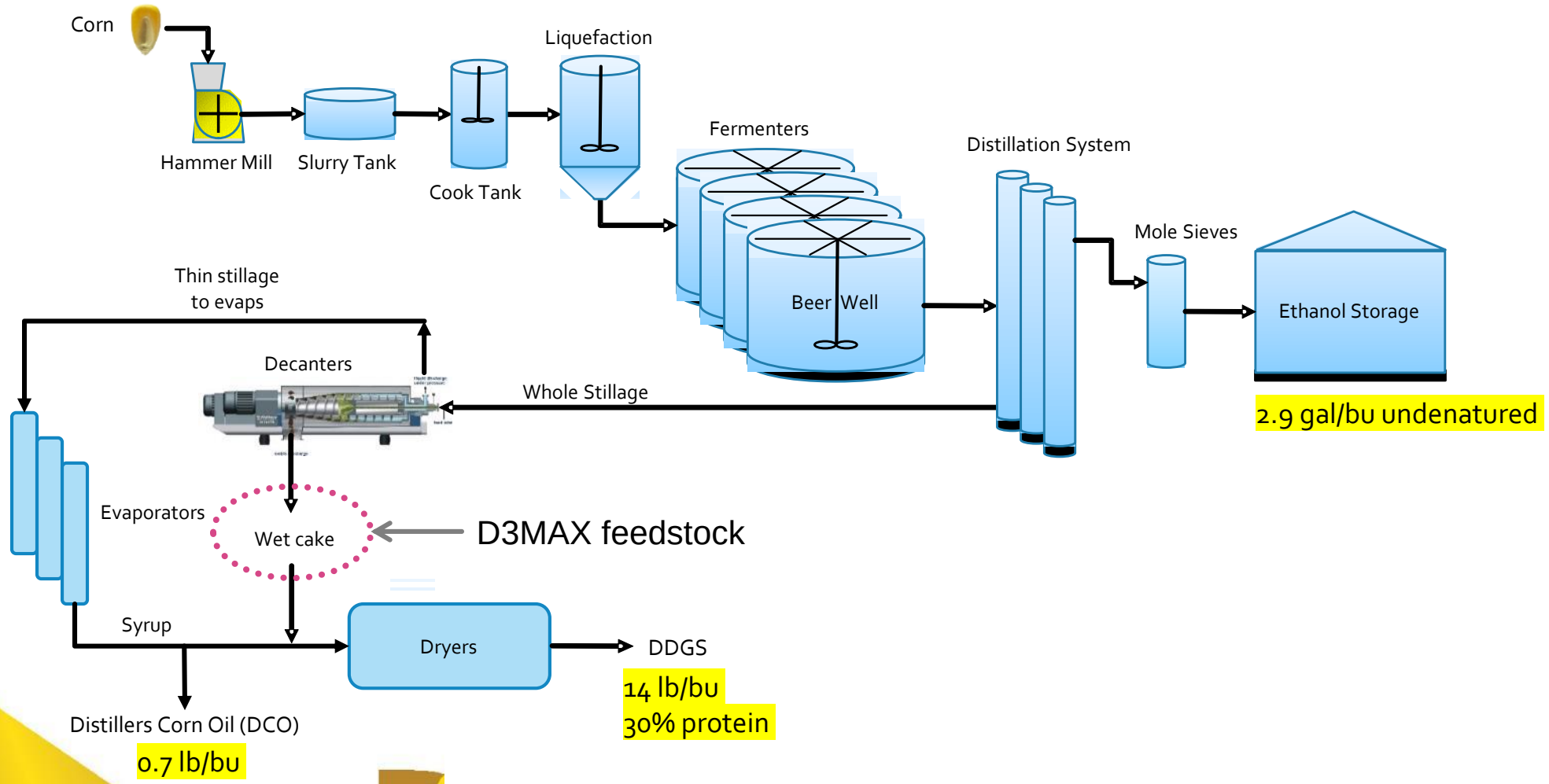
Dry Mill Ethanol Plant without D3MAX



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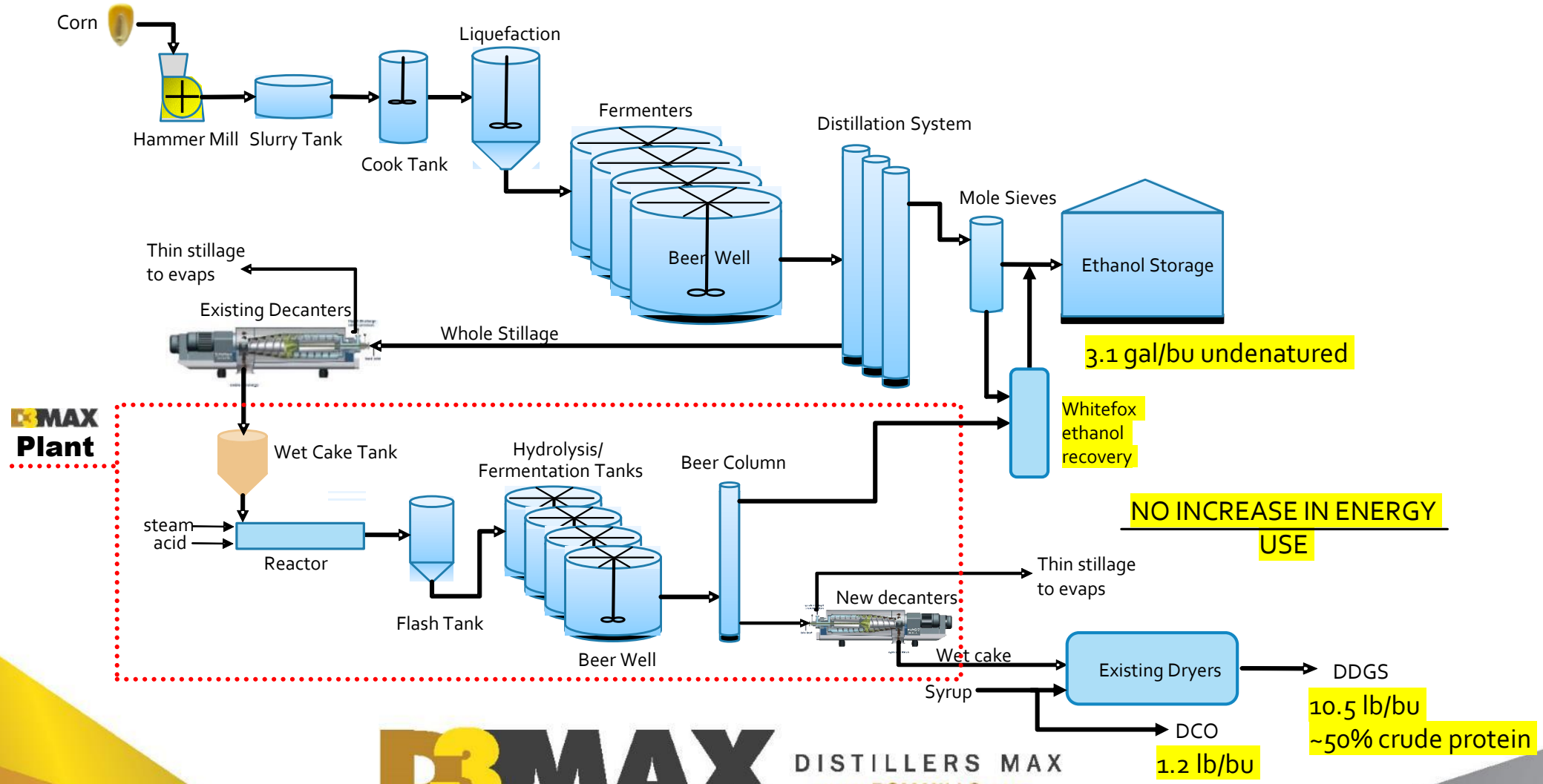
D3MAX Process - Dry Mill with D3MAX



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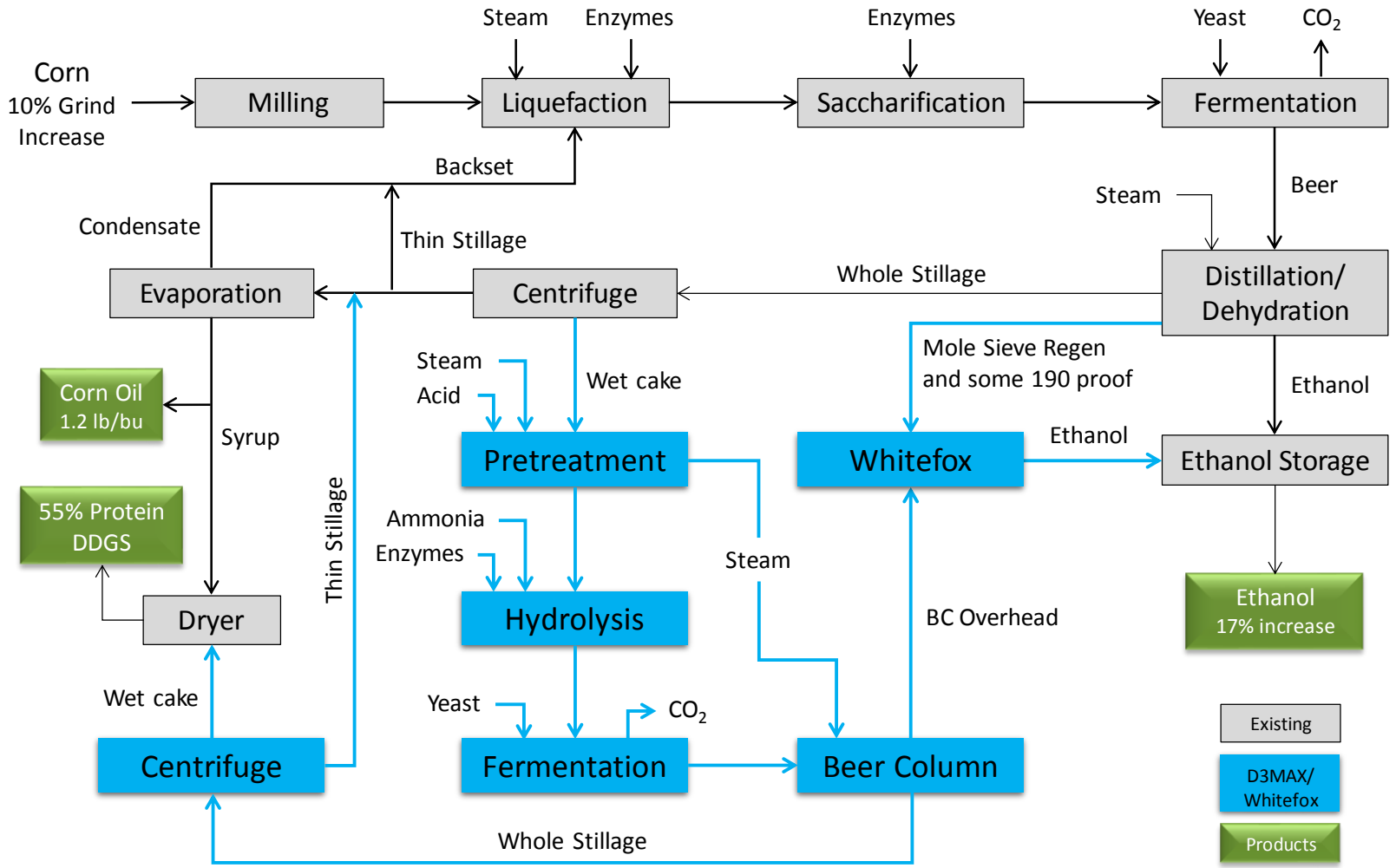
D3MAX Block Flow Diagram



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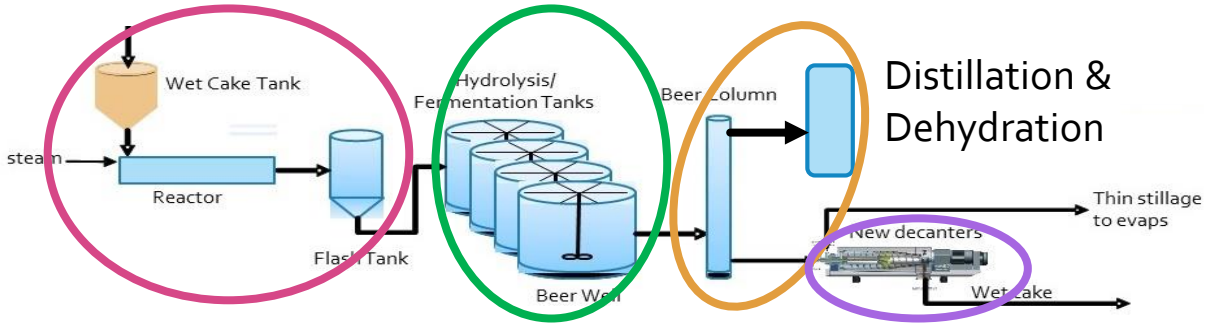
D3MAX Technology

- There are three primary steps for the D3MAX process:
  - Pretreatment – converts hemicellulose to monomeric sugars and oligomers
  - Enzymatic Hydrolysis – converts cellulose to glucose and oligomers to monomers
  - Fermentation – ferments glucose, xylose, arabinose and other sugars to ethanol
- Followed by traditional ethanol distillation, membrane dehydration, and whole stillage processing



Pretreatment

Hydrolysis & Fermentation

Whole Stillage Processing

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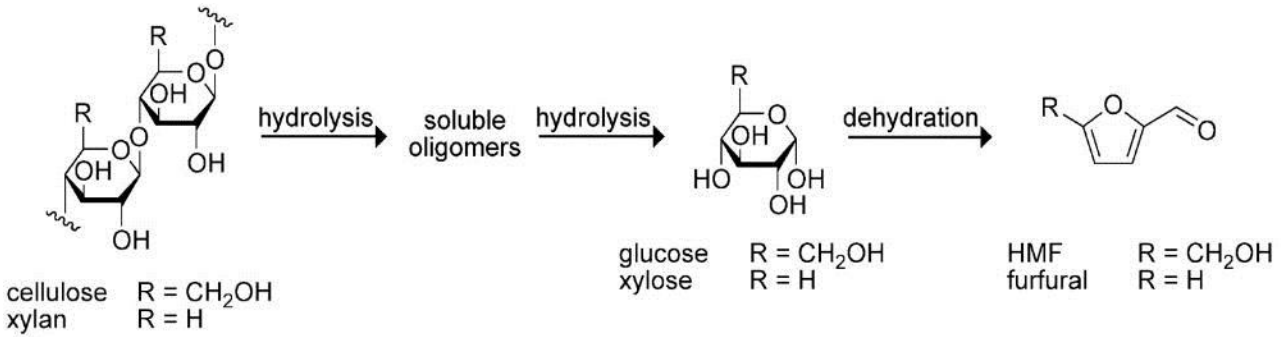
Step 1: Pretreatment

Wet cake (35% solids)

Wet cake + water (25% solids)

Pretreatment Reactor:
Acid + heat + time



Pretreated wet cake

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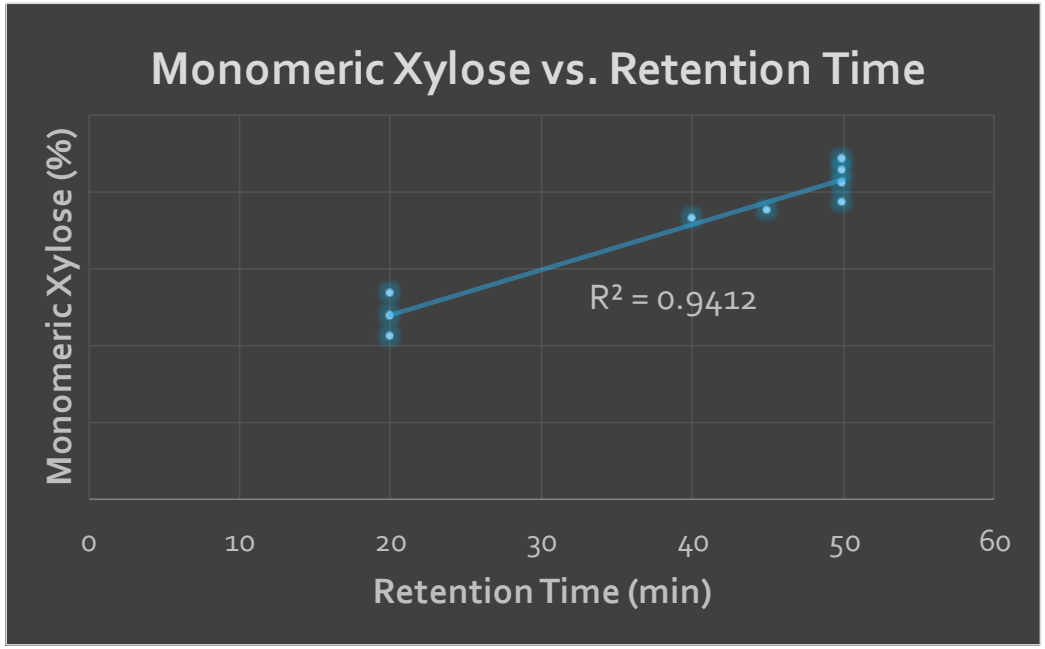
Sugar Yields in Pretreatment

- Hemicellulose in the wet cake is hydrolyzed by dilute acid to monomeric and oligomeric sugars
- Xylan is the most difficult carbohydrate to convert to monomeric xylose

Average Soluble Sugar Yields	
Xylose	92%
Arabinose	90%
Galactose	89%
Mannose	77%
Fermentation Inhibitors	
HMF	0.3 g/l
Furfural	0.9 g/l
Acetic Acid	2.5 g/l



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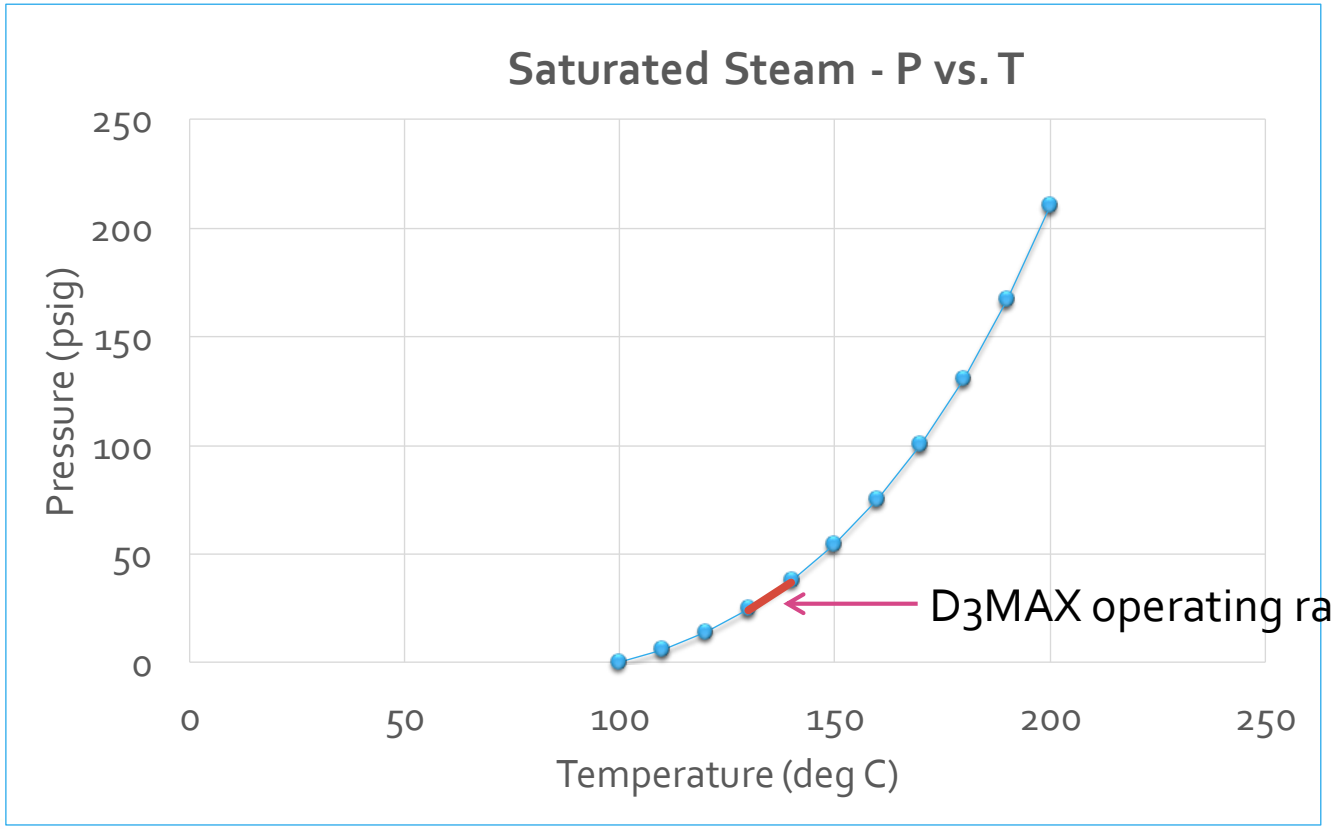
Pretreatment Reactor Temp vs Pressure



Low pretreatment temperature results in lower capex and opex, and lower corrosion rates when using an acid catalyst

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Pretreatment Reactor installed at Ace Ethanol

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Step 2: Enzymatic Hydrolysis

a) Lower temperature b) Raise pH c) Add enzymes

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Start of Enzymatic Hydrolysis

(video)

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Enzymatic Hydrolysis + 6 hours

(video)

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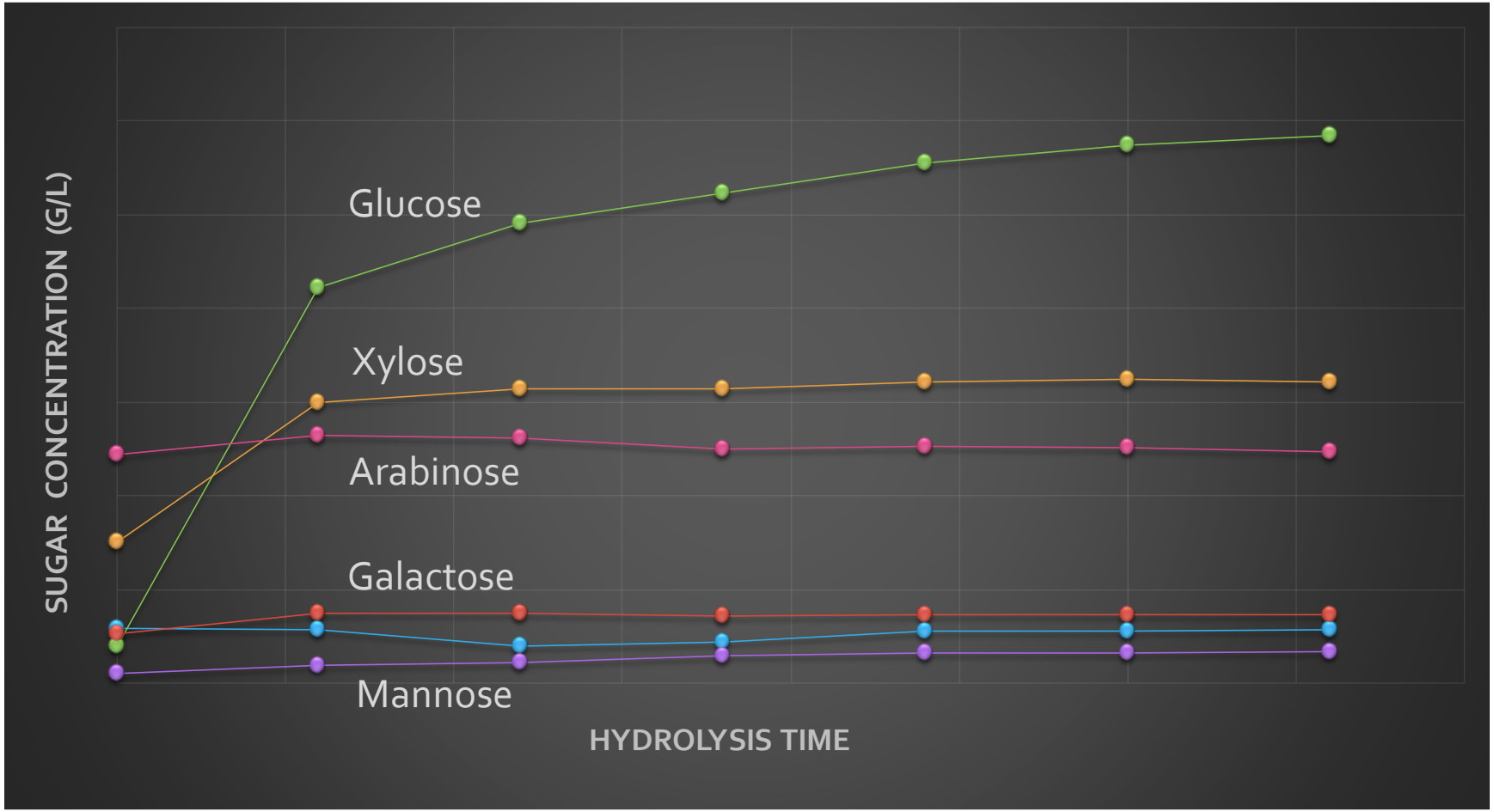
Sugar Yields in Enzymatic Hydrolysis



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Step 3: Fermentation

a) Lower temperature b) Adjust pH c) Pitch yeast

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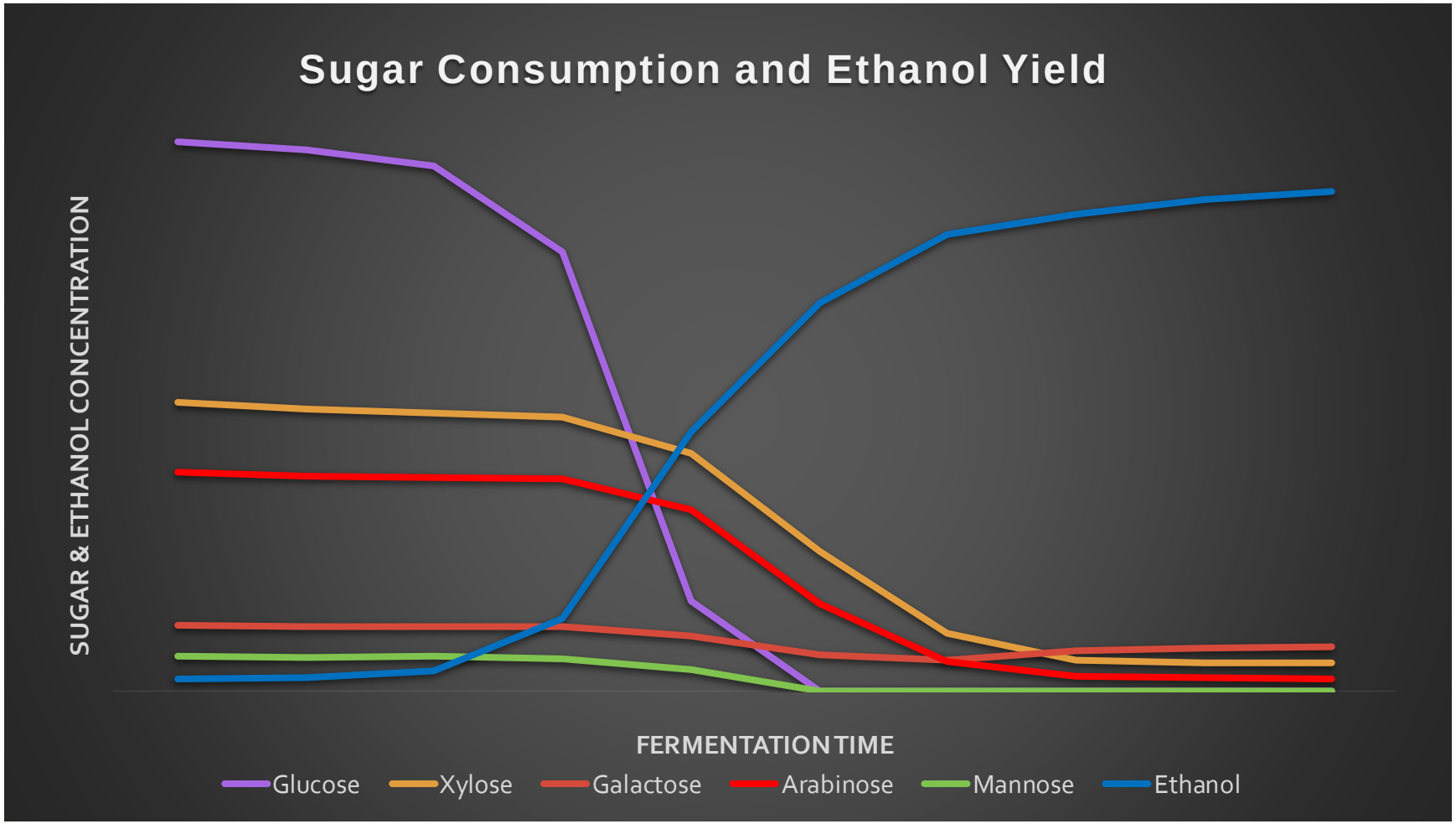
Sugar Consumption in Fermentation



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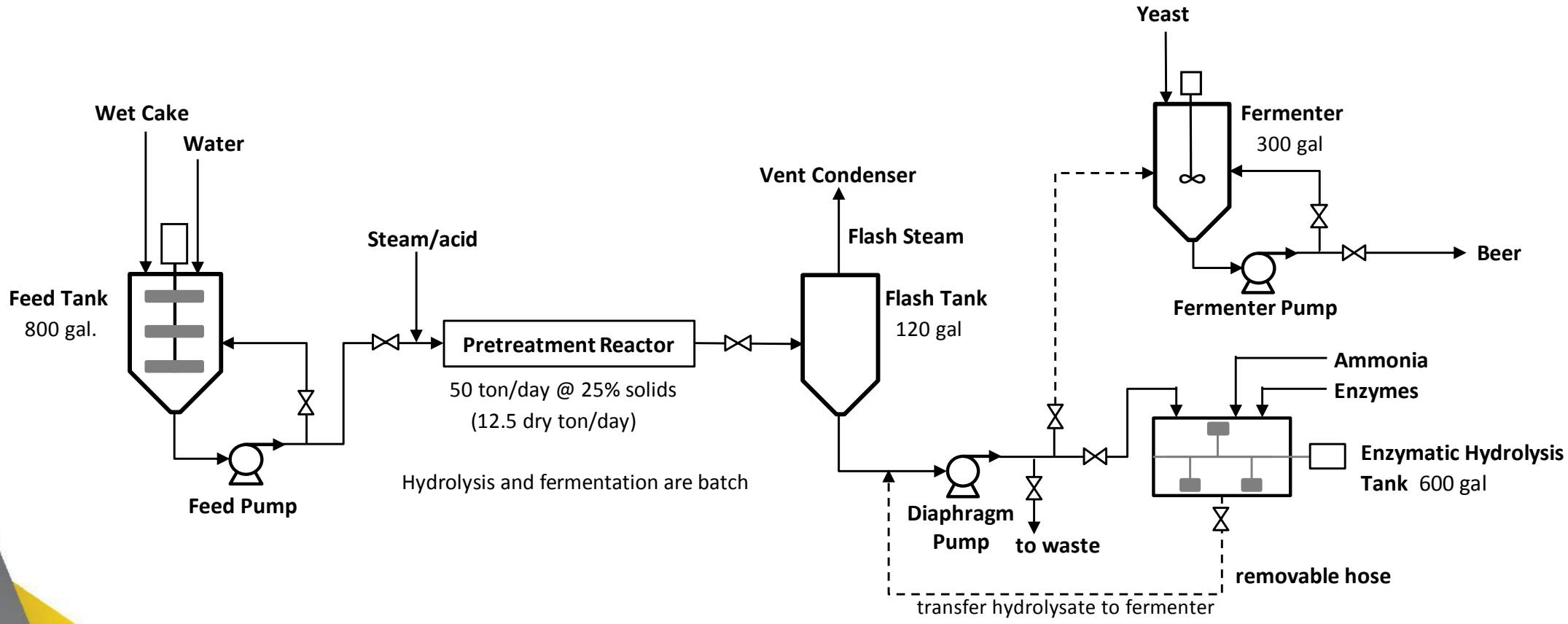
D3MAX Pilot Plant



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Ace Ethanol D3MAX Project Update

- The Ace D3MAX project will be a full-scale, commercial D3MAX plant - all of the Ace wet cake (without syrup) will be processed by the D3MAX plant
- The D3MAX plant will process 225 dry ton/day of wet cake or 750 wet tons at 30% solids and produce approximately 3.5 million gal/year of undenatured cellulosic ethanol
- Ace's overall ethanol yield will increase from 2.9 to 3.1 gal/bu
- DDGS protein will increase from 30% to >50%
- DDGS volume will decrease by ~25%
- Ace's overall energy use will not increase after D3MAX and Whitefox systems are operational

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Ace Ethanol – Stanley, WI

D3MAX
Project Site

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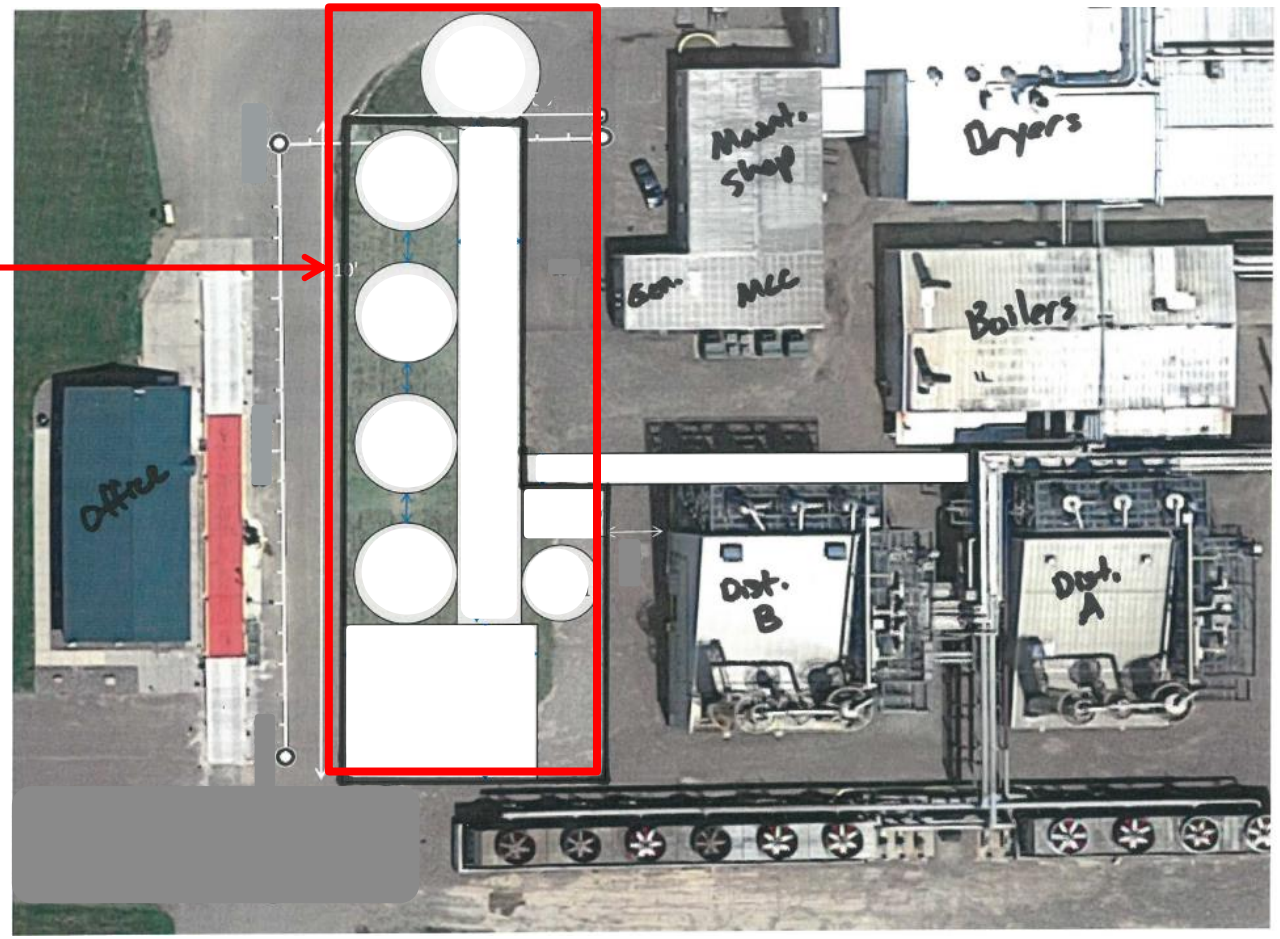
Ace Ethanol - D3MAX Plant Layout

D3MAX corn fiber to ethanol plant



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Start of Construction – Oct 1, 2018

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November 2018

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December 2018

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January 2019

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February 2019

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March 2019

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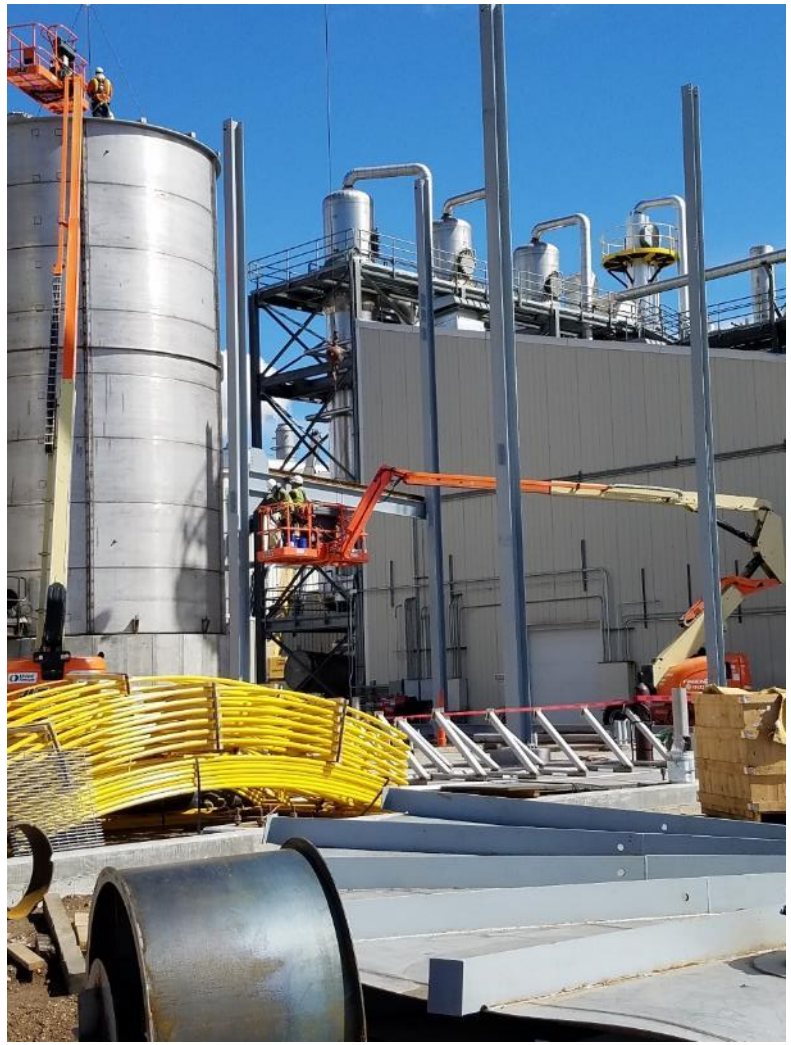
April 2019



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May 2019

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June 2019 - Pretreatment Reactor Shipped

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July 2019

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Lessons Learned

- Wet cake is very abrasive
  - Material selection is important!
- Until the viscosity break in enzymatic hydrolysis, wet cake at 25-30% solids is a very thick slurry (>10,000 cp)
  - Equipment, valves, piping, and instrumentation must all be properly designed for the process conditions
- Removing fiber and creating more syrup creates a difficult material to dry
- pH control is critical to prevent Maillard reactions
  - Maillard reactions reduce ethanol yield, consume amino acids, and darken the high protein DDGS

Areas for Improvement

1. Reduce the cost of monomeric sugar production from corn fiber
   a) Reduce the amount of acid used in pretreatment; this will automatically reduce the amount of base needed to neutralize the acid
   b) Reduce the cost of enzymes and increase their efficiency; customize the enzyme cocktail for corn fiber hydrolysate
   c) Reduce capital costs related to sugar production
2. Improve high protein DDGS drying (if necessary)
   a) Ethanol plants without dryers?
3. Minimize Maillard reactions

Thank you!

For more information please contact
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