Lignocellulosic Ethanol Process Development and Scale-Up

UF UNIVERSITY of FLORIDA
IFAS

Florida Center for Renewable Chemicals and Fuels

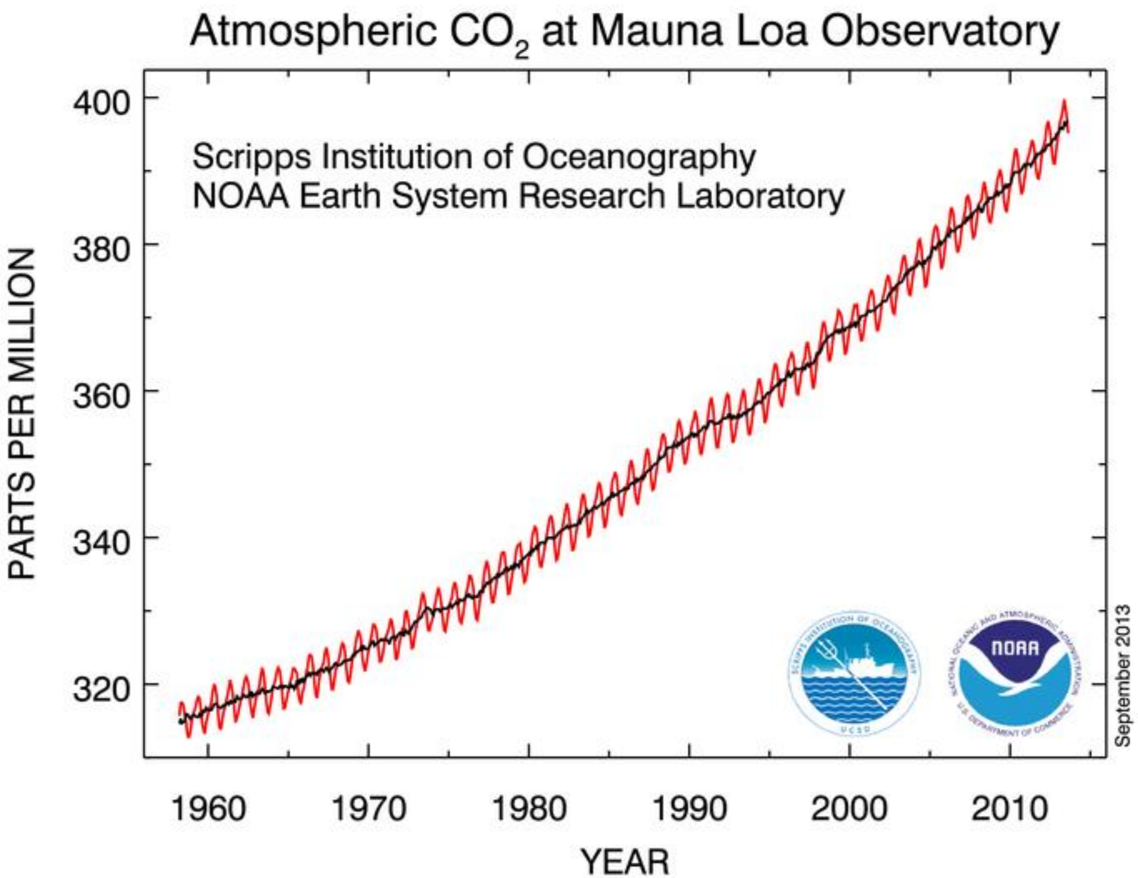
BUCKEYE
TECHNOLOGIES INC.

Introduction

One barrel of oil (42 gal) makes 19.4 gal of gas. The rest is used to make things like:

Solvents	Diesel fuel	Motor Oil	Bearing Grease	Tool Racks	Car Battery Cases	Epoxy	Paint
Ink	Floor Wax	Ballpoint Pens	Football Cleats	Mops	Slacks	Insect Repellent	Oil Filters
Upholstery	Sweaters	Boats	Insecticides	Umbrellas	Yarn	Fertilizers	Hair Coloring
Bicycle Tires	Sports Car Bodies	Nail Polish	Fishing lures	Roofing	Toilet Seats	Fishing Rods	Lipstick
Dresses	Tires	Golf Bags	Perfumes	Denture Adhesive	Linoleum	Ice Cube Trays	Synthetic Rubber
Cassettes	Dishwasher parts	Tool Boxes	Shoe Polish	Speakers	Plastic Wood	Electric Blankets	Glycerin
Motorcycle Helmet	Caulking	Petroleum Jelly	Transparent Tape	Tennis Rackets	Rubber Cement	Fishing Boots	Dice
CD Player	Faucet Washers	Antiseptics	Clothesline	Nylon Rope	Candles	Trash Bags	House Paint
Curtains	Food Preservatives	Basketballs	Soap	Water Pipes	Hand Lotion	Roller Skates	Surf Boards
Vitamin Capsules	Antihistamines	Purses	Shoes	Shampoo	Wheels	Paint Rollers	Shower Curtains
Dashboards	Cortisone	Deodorant	Footballs	Guitar Strings	Luggage	Aspirin	Safety Glasses
Putty	Dyes	Panty Hose	Refrigerant	Antifreeze	Football Helmets	Awnings	Eyeglasses
Percolators	Life Jackets	Rubbing Alcohol	Linings	Clothes	Toothbrushes	Ice Chests	Footballs
Skis	TV Cabinets	Shag Rugs	Electrician's Tape	Combs	CD's & DVD's	Paint Brushes	Detergents
Dentures	Model Cars	Folding Doors	Hair Curlers	Vaporizers	Balloons	Sun Glasses	Tents
Cold cream	Movie film	Soft Contact lenses	Drinking Cups	Heart Valves	Crayons	Parachutes	Telephones
Fan Belts	Car Enamel	Shaving Cream	Ammonia	Enamel	Pillows	Dishes	Cameras
Refrigerators	Golf Balls	Toothpaste	Gasoline	Anesthetics	Artificial Turf	Artificial limbs	Bandages

Introduction

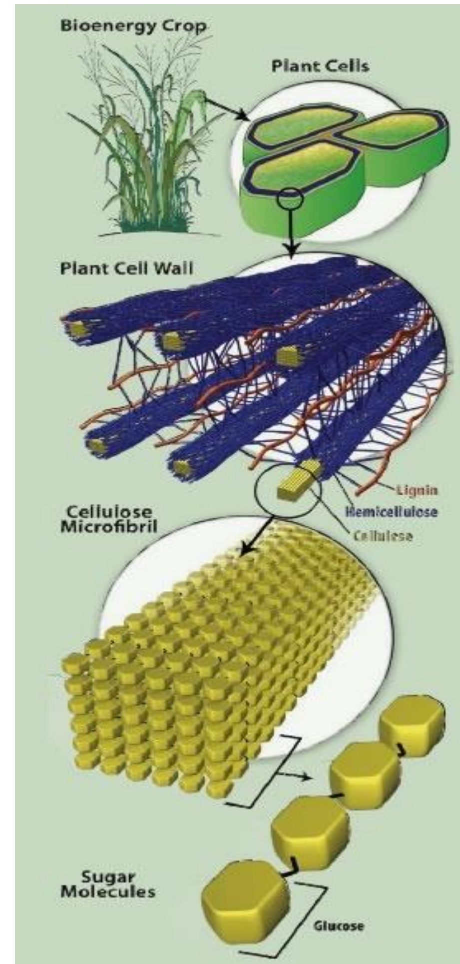


The use of fossil fuels has contributed to environmental changes

The instability of oil prices greatly affects our everyday lives

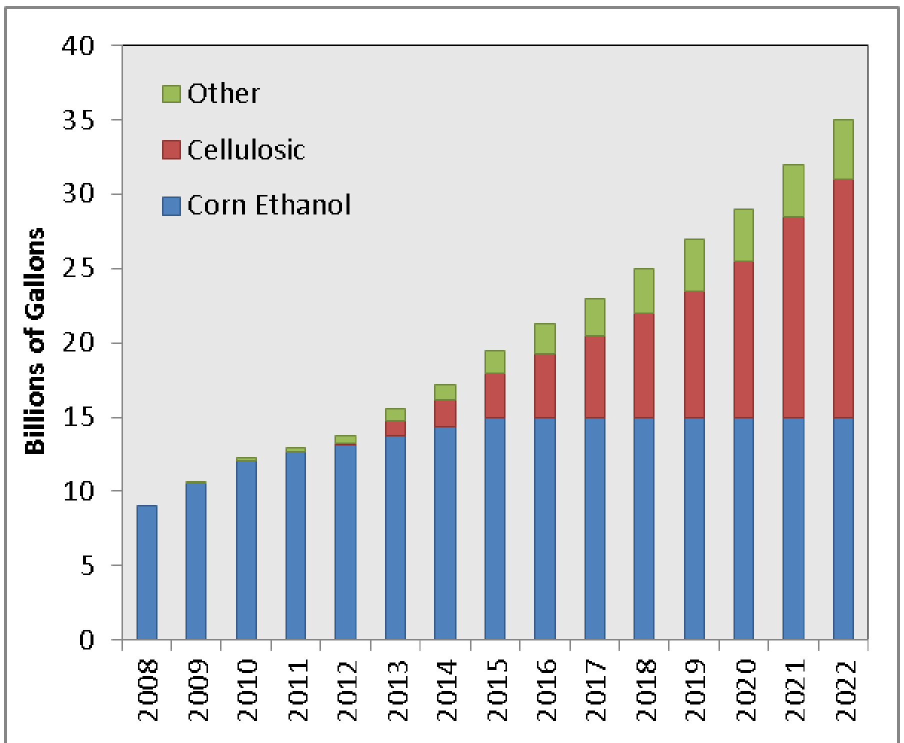
Introduction

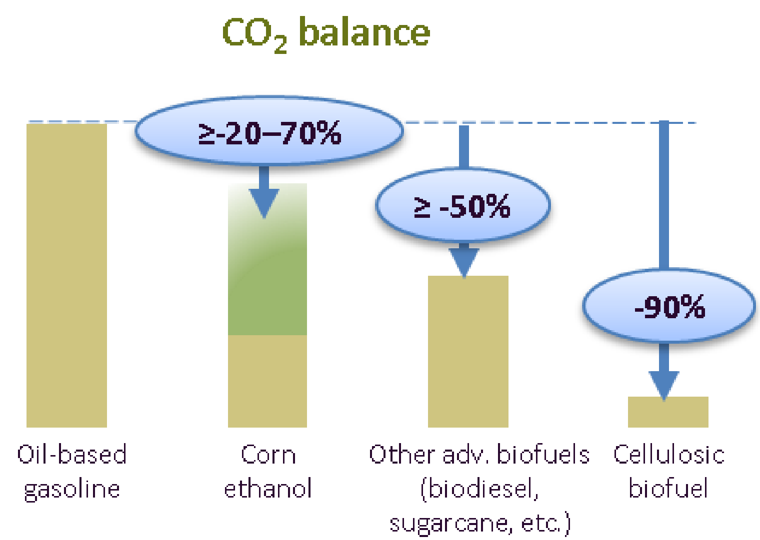
- Lignocellulosic biomass as energy source
  - Abundant resource
  - High sugar content
- Resistant to degradation
- Pretreatment is essential for downstream processes



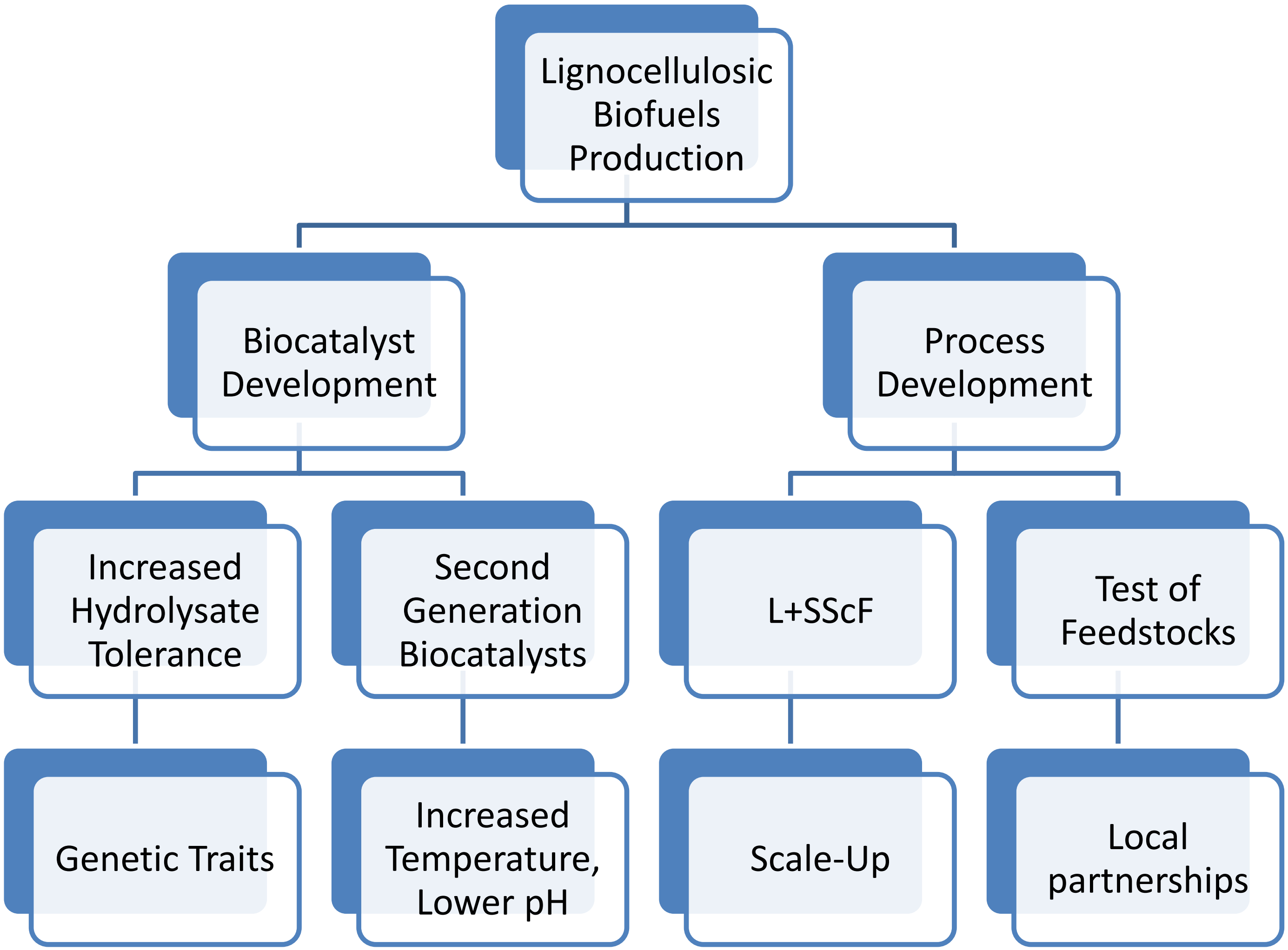
Introduction

Energy Policy Act (2005) and the Energy Independence and Security Act (2007) established mandated minimum usage requirements referred to as the Renewable Fuel Standard



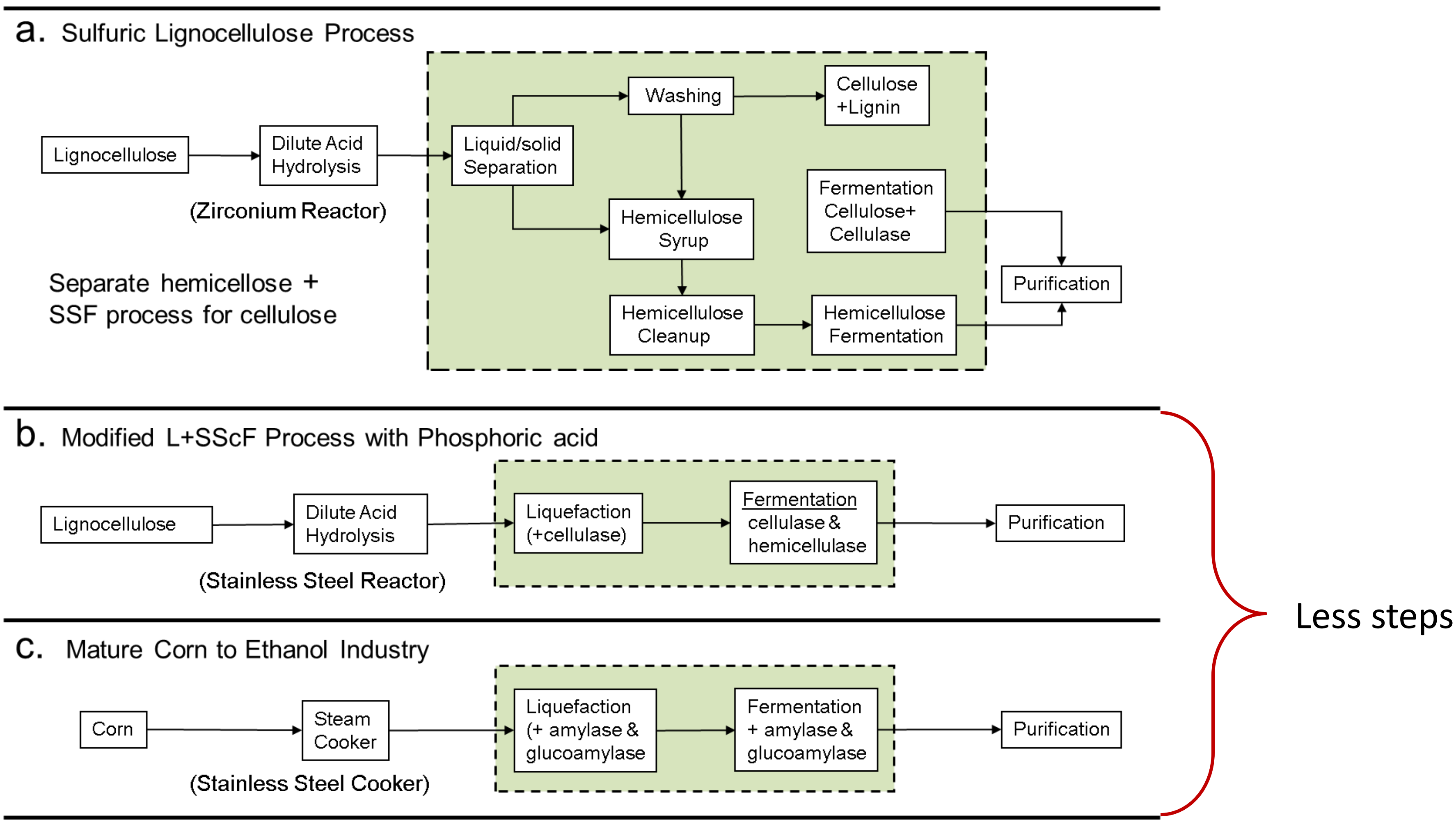


Introduction



COMMERCIALIZATION!!

Introduction

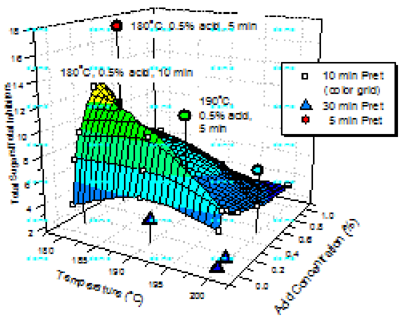


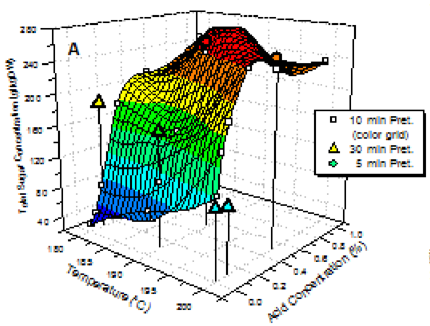
Bioresour. Technol. 102, 2702-2711.

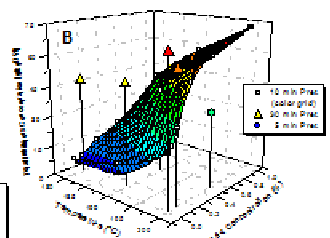
Sugarcane Bagasse

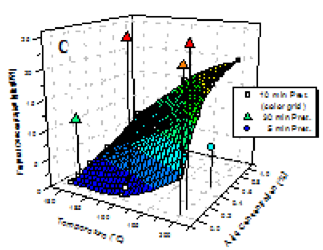
Optimization of Sugarcane Bagasse Pretreatment

Temperature (°C)	Acid Concentration (%)	Residence Time (min)	Total Sugars (g/kg)	Ratio Sugars to Inhibitors
180	0.5	5	157	17.3
190	0.5	5	261	10.5
180	0.5	10	211	10.8

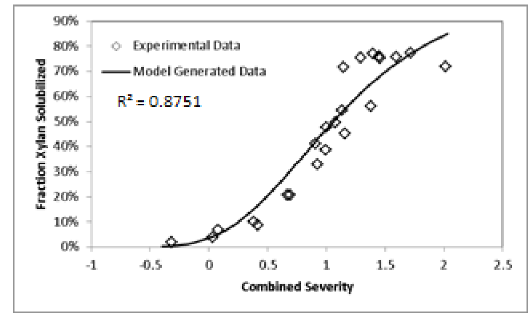








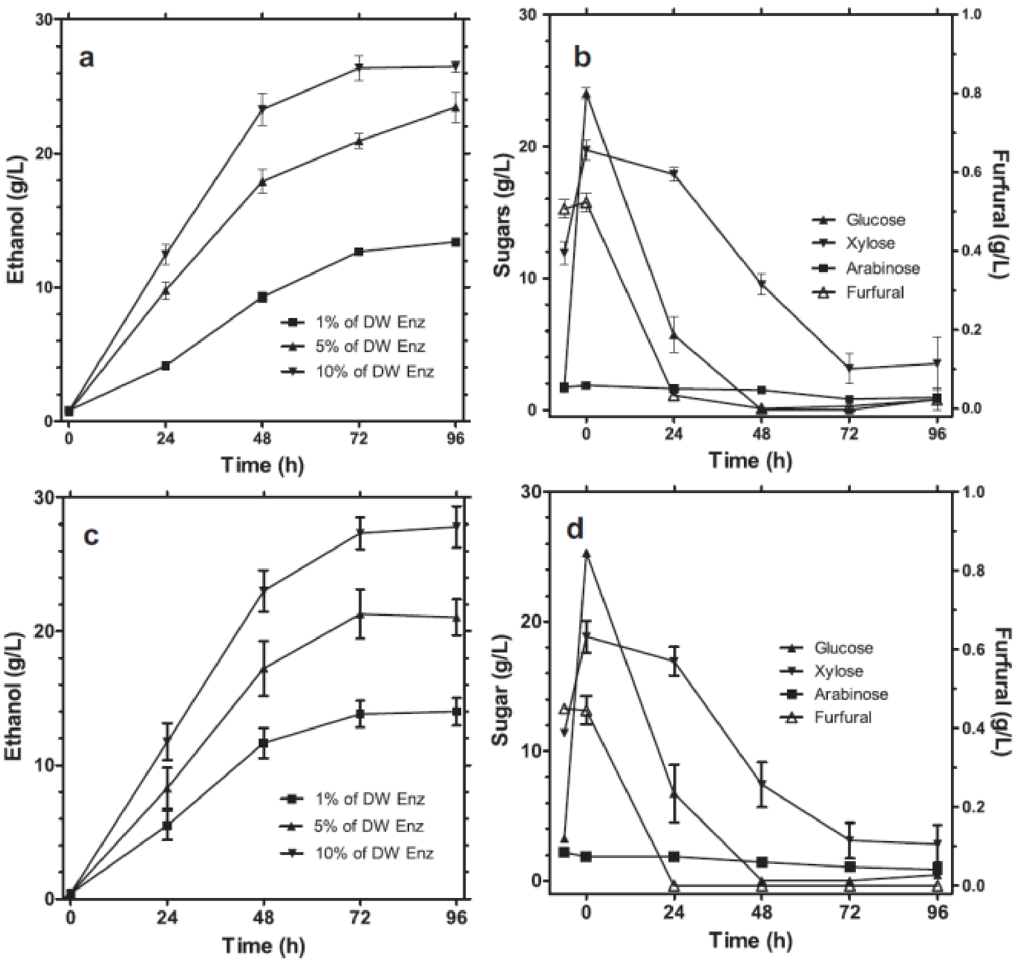
A) Total Sugars, B) Total Inhibitors, and C) Furfural



$$R_o = t * e^{\frac{T_r - 100}{14.75}} \qquad \ln[-\ln(1-\alpha)] = \log R_o - pH$$

R_o = Severity coefficient; t = Time (min); T_r = Pretreatment temperature; α = Fraction of hemicellulose remaining

Sugarcane Bagasse



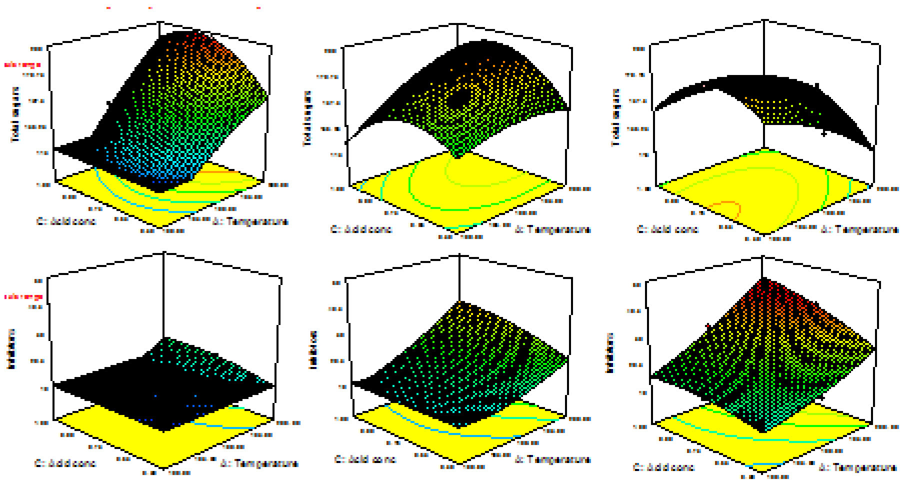
- ✓ The optimized pretreatment conditions were used to process sugarcane bagasse and sorghum bagasse
- ✓ The use of 50% hydrolysate eliminated the need for adding commercial sugars during seed propagation
- ✓ L+SScF using the developed seed resulted in overall yields between 0.27 to 0.28 g/g
- ✓ Fermentation time reduced to 72 h.

Eucalyptus

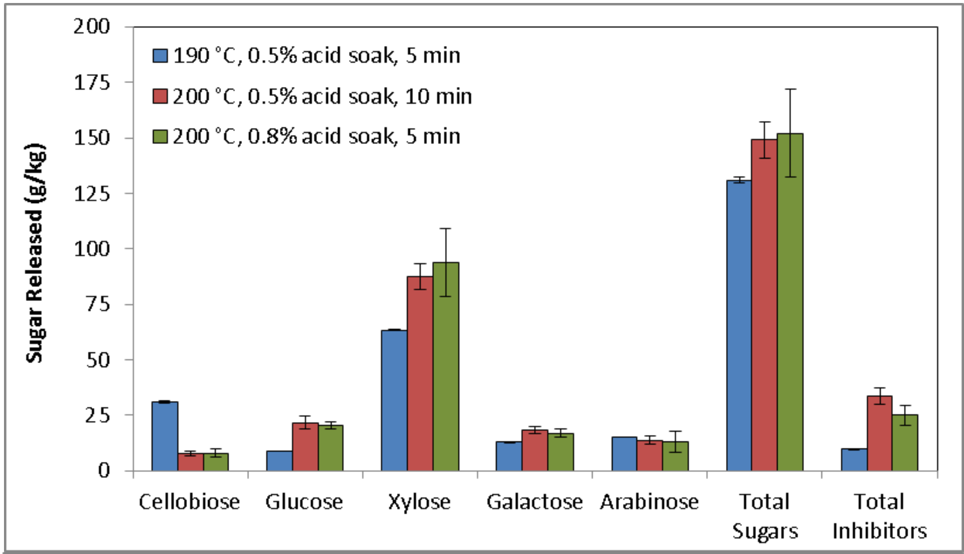
Why study *Eucalyptus*?

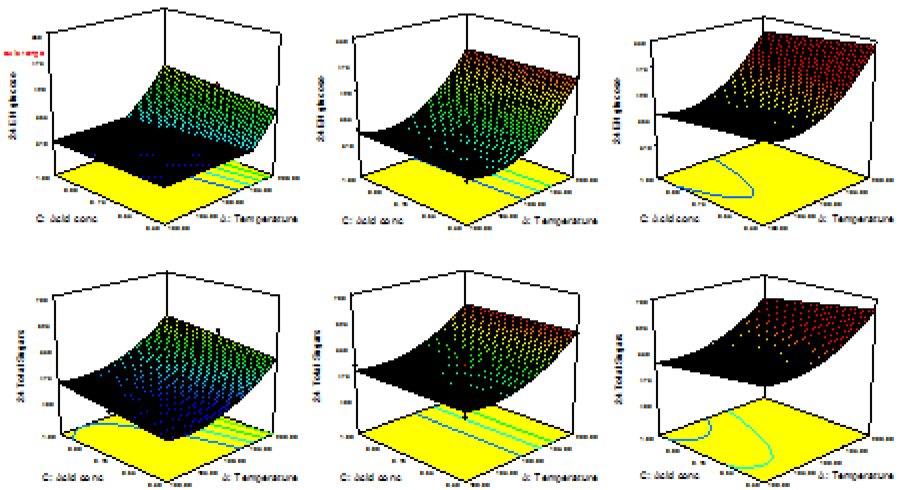
- Short rotation, fast growing hardwood
- Increased density
  - Lower storage cost
- Freeze tolerant strains have been developed
- Reduce logistics costs by growing locally
- *Eucalyptus benthamii* used for optimization
- *Eucalyptus grandis* also tested

Eucalyptus



5 min 10 min 15 min





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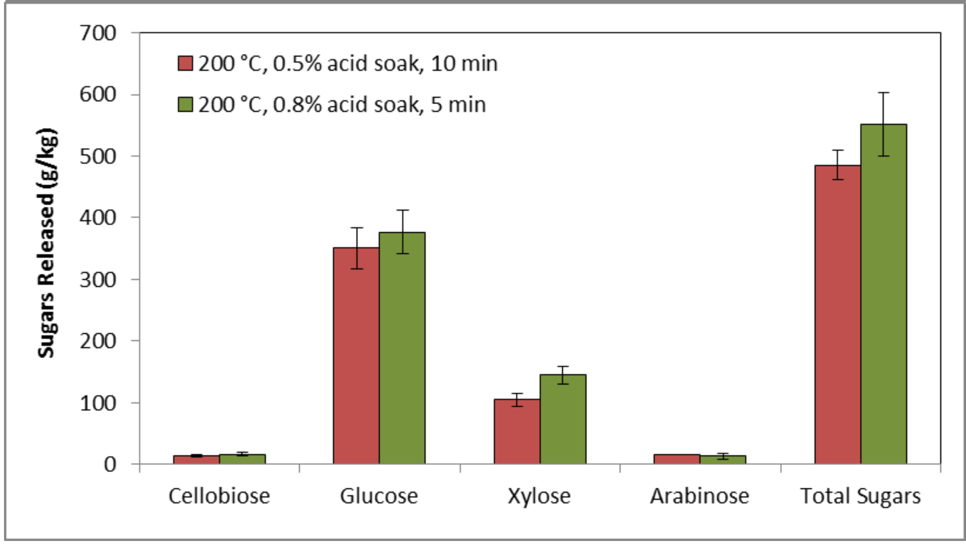
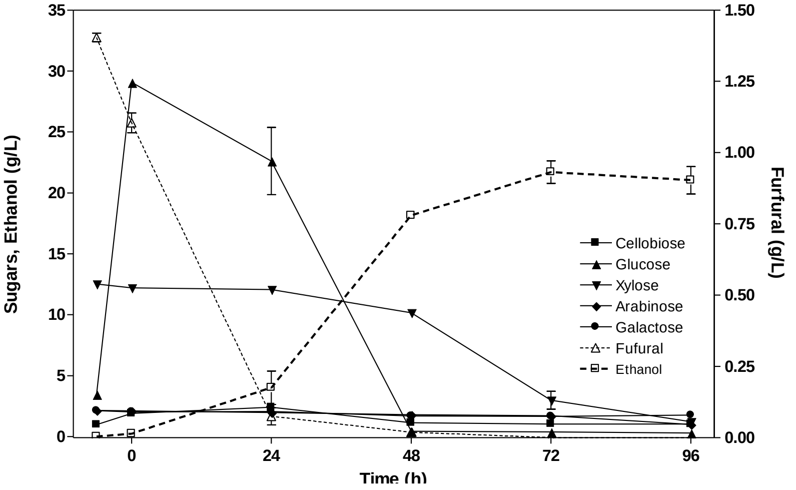


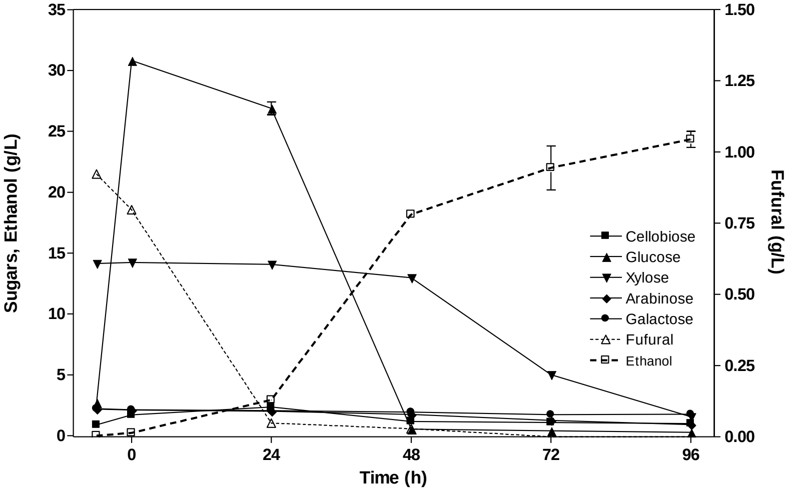
Eucalyptus

- L+SScF *E. benthamii*
  - Test both optimum conditions
  - Monitor sugars, inhibitors
- 200 °C, 0.5% acid soak, 10 min – 64 gal EtOH/ton
- 200 °C, 0.8% acid soak, 5 min – 74 gal EtOH/ton

200°C, 0.5% acid soak, 10 min



200°C, 0.8% acid soak, 5 min



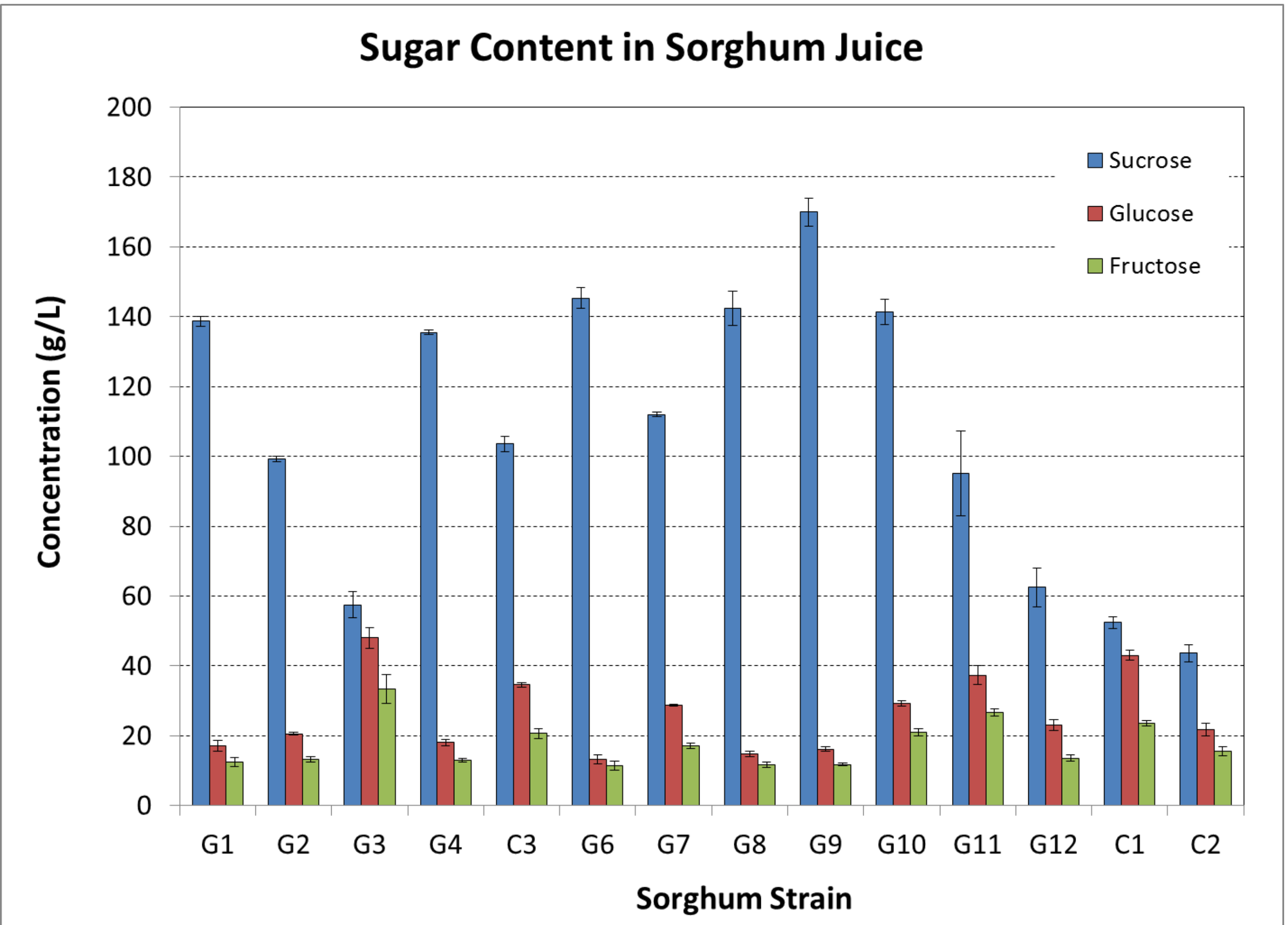
Sweet Sorghum

Used in Florida mainly as silage for livestock

Fast growing, warm weather annuals

Tolerant to droughts

Sweet Sorghum

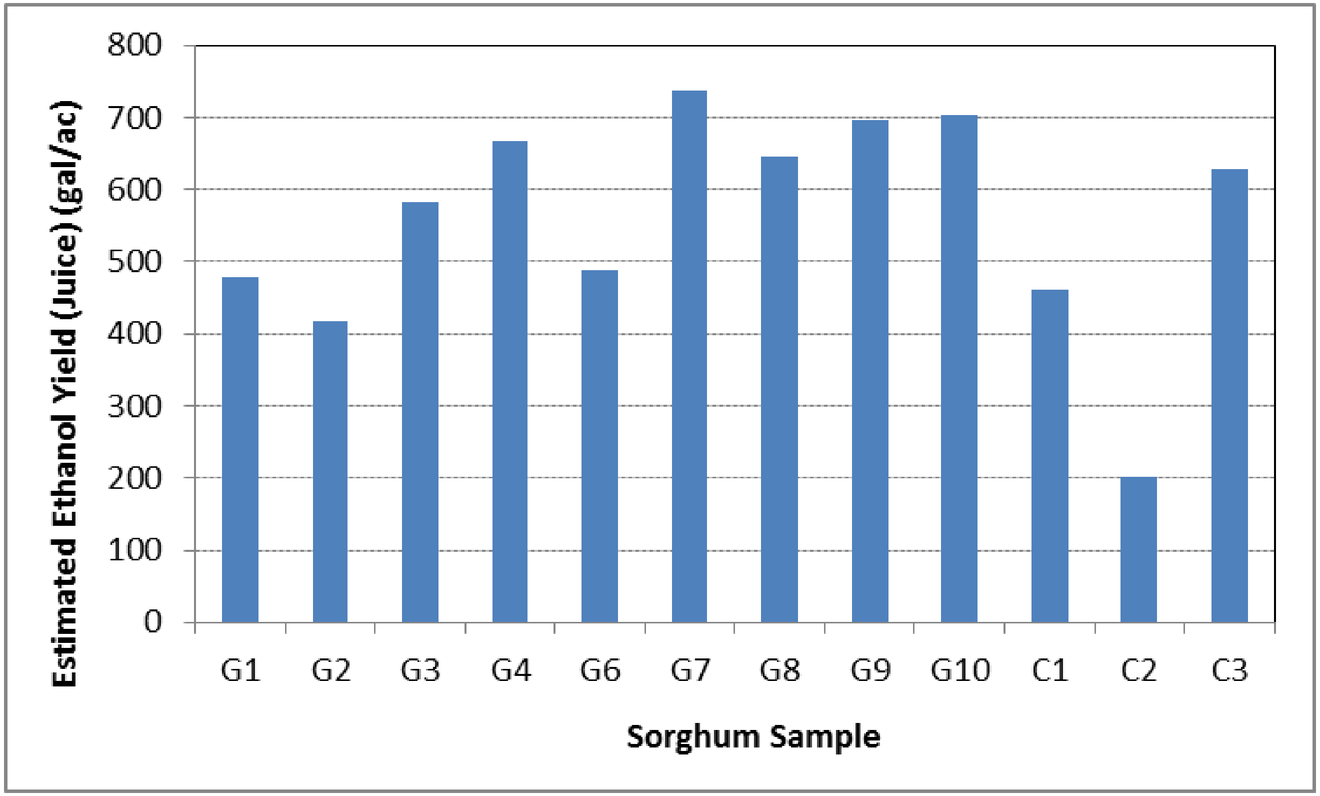


Between 27 – 43 tons/ac for the strains studied

67 – 76% moisture

Potential sugar production from juice = 1.3 – 4.8 tons sugar/ac

Sweet Sorghum

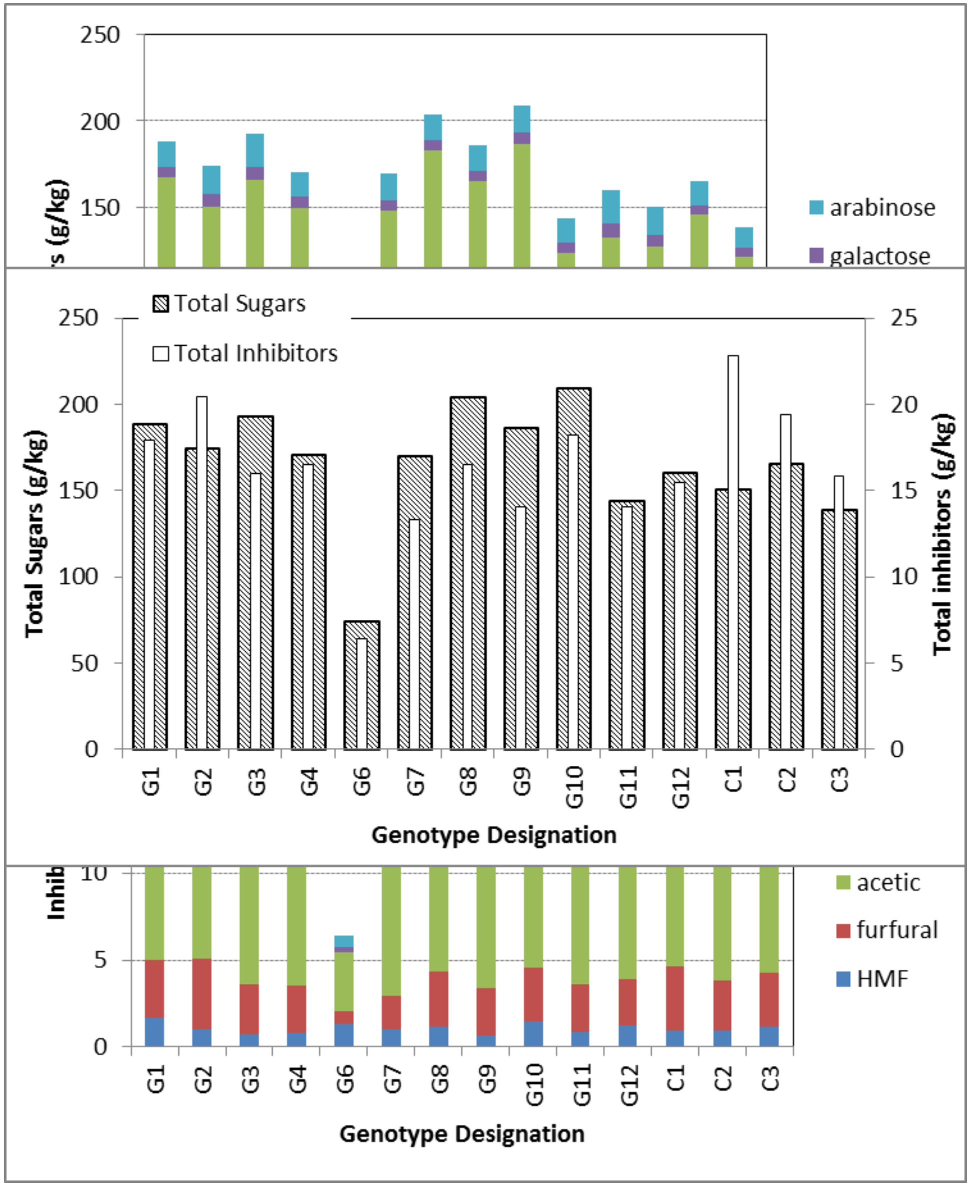


Sweet Sorghum

<u>200 – 730 gallons</u> of ethanol per acre can obtained from the juice

Corn Ethanol - ~3 gal/bu (for 2012, Renewable Fuels Association), 123 bu/ac (for 2012, USDA National Agricultural Statistics Service), resulting in **<u>369 gallons</u>** of ethanol per acre

Sweet Sorghum

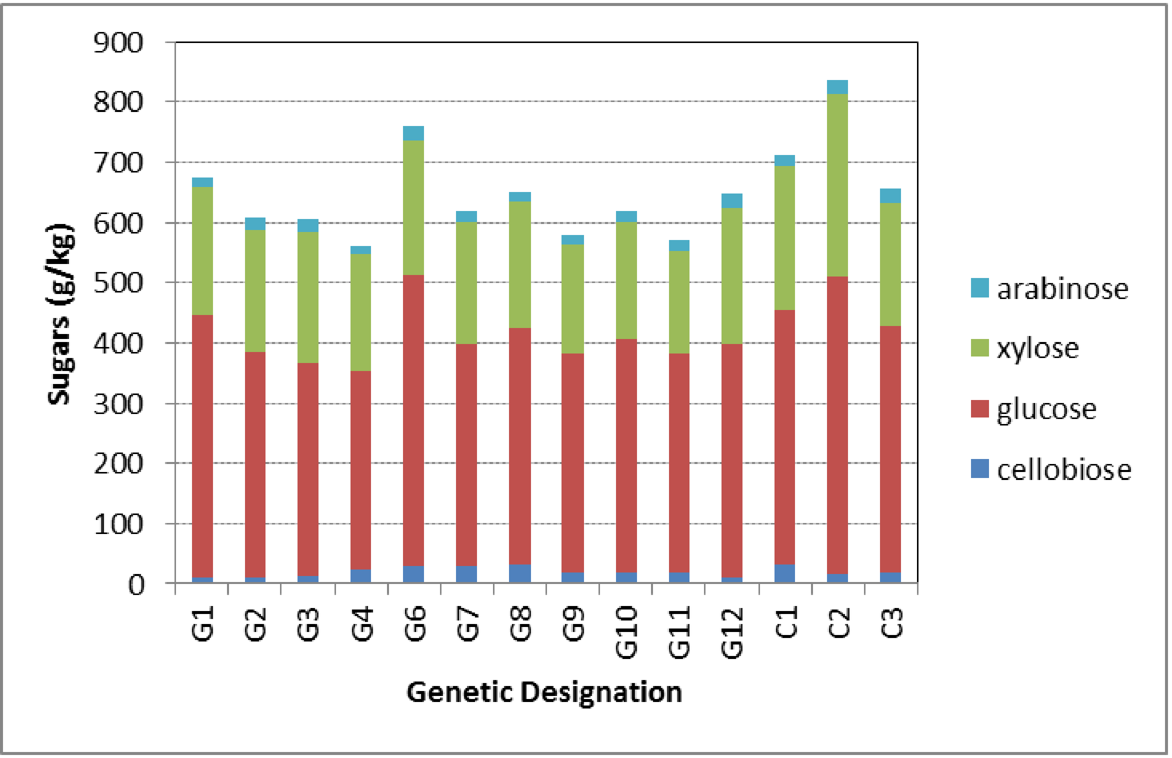


Pretreatment of sorghum – 190 °C, 0.5% acid soak, 5 min

Pretreatment yields generally higher to those obtained from sugarcane bagasse

Inhibitors generated slightly higher than sugarcane bagasse

Sweet Sorghum

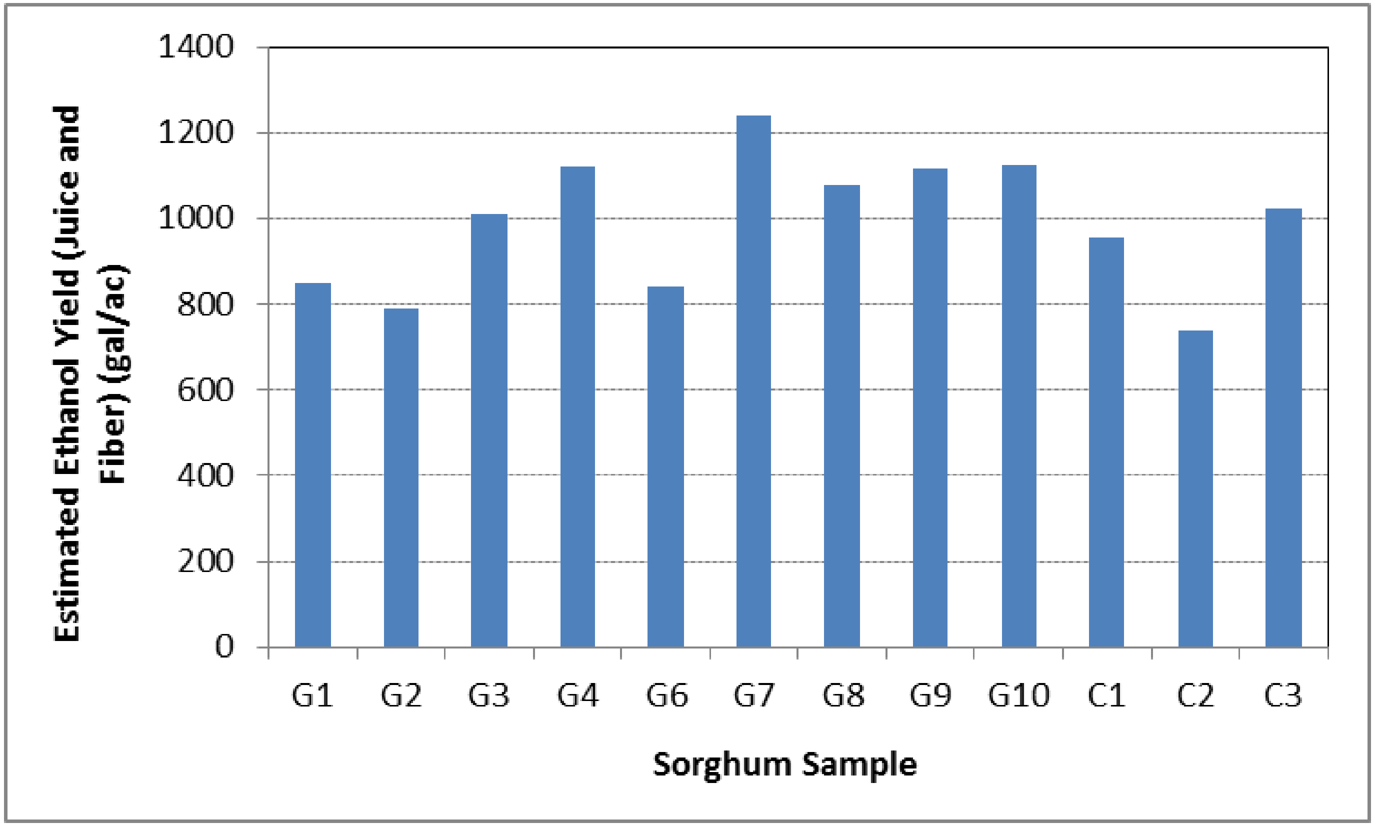


Enzyme hydrolysis:

- 37 °C
- 10% solids loading
- 10% (v/w) of dry weight enzyme loading
- Used Novozymes CTec2

High yields of sugars released

Sweet Sorghum



740 -1240 gallons of ethanol per acre can potentially be produced from sorghum by using the juice and the fiber

Stan Mayfield Biorefinery

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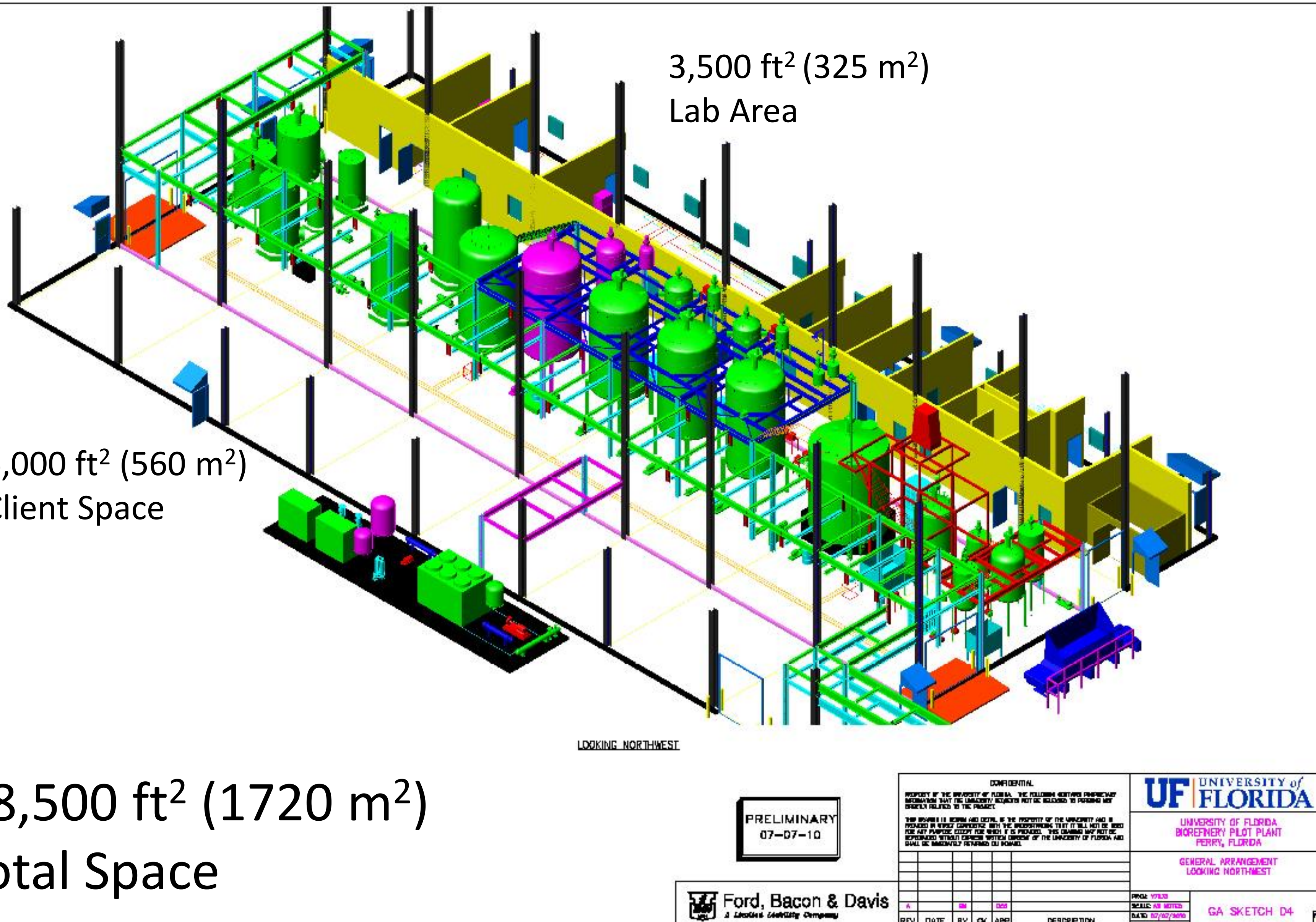

3,500 ft^2 (325 m^2)
Lab Area

6,000 ft^2 (560 m^2)
Client Space

18,500 ft^2 (1720 m^2)
Total Space

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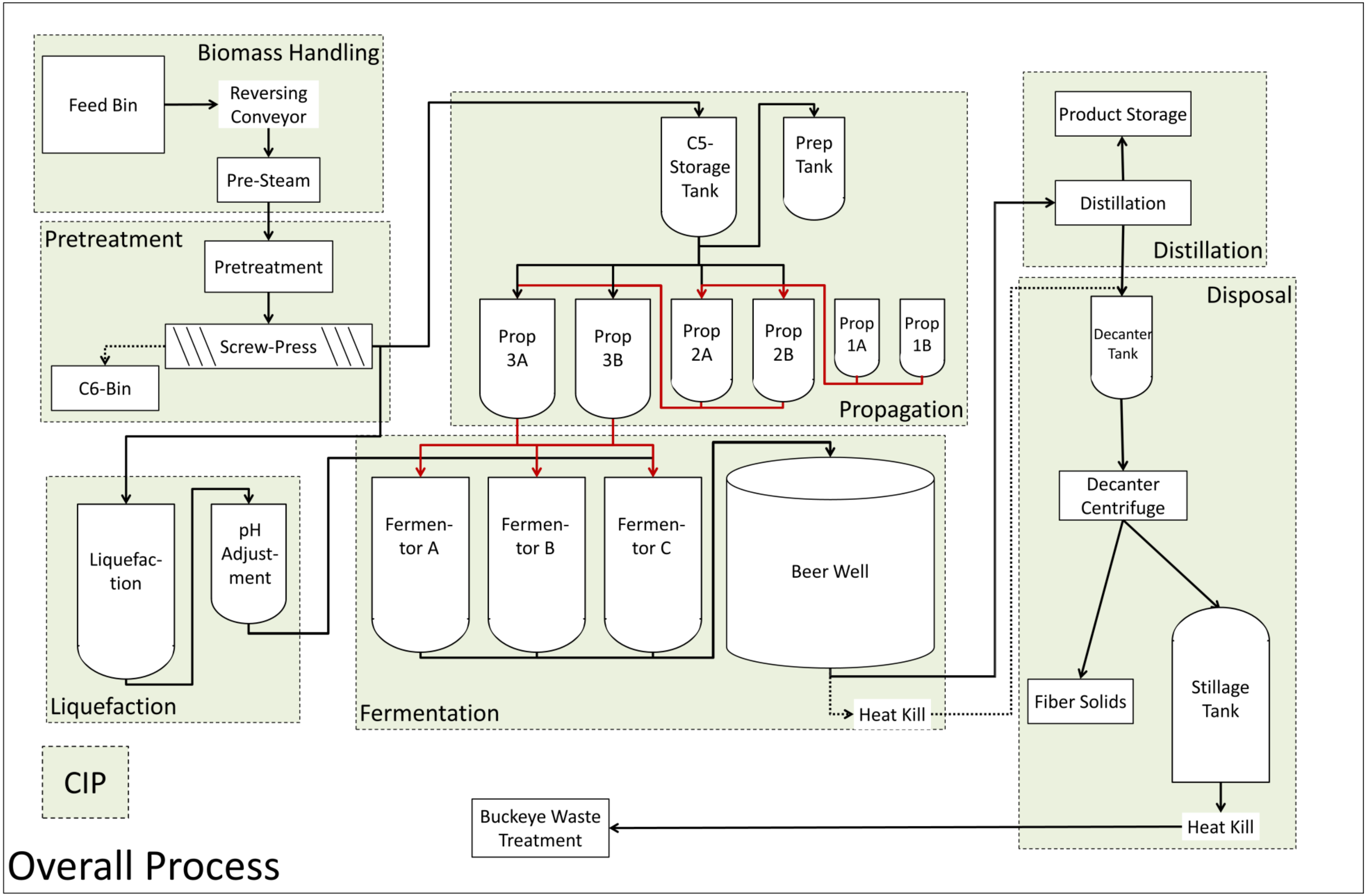

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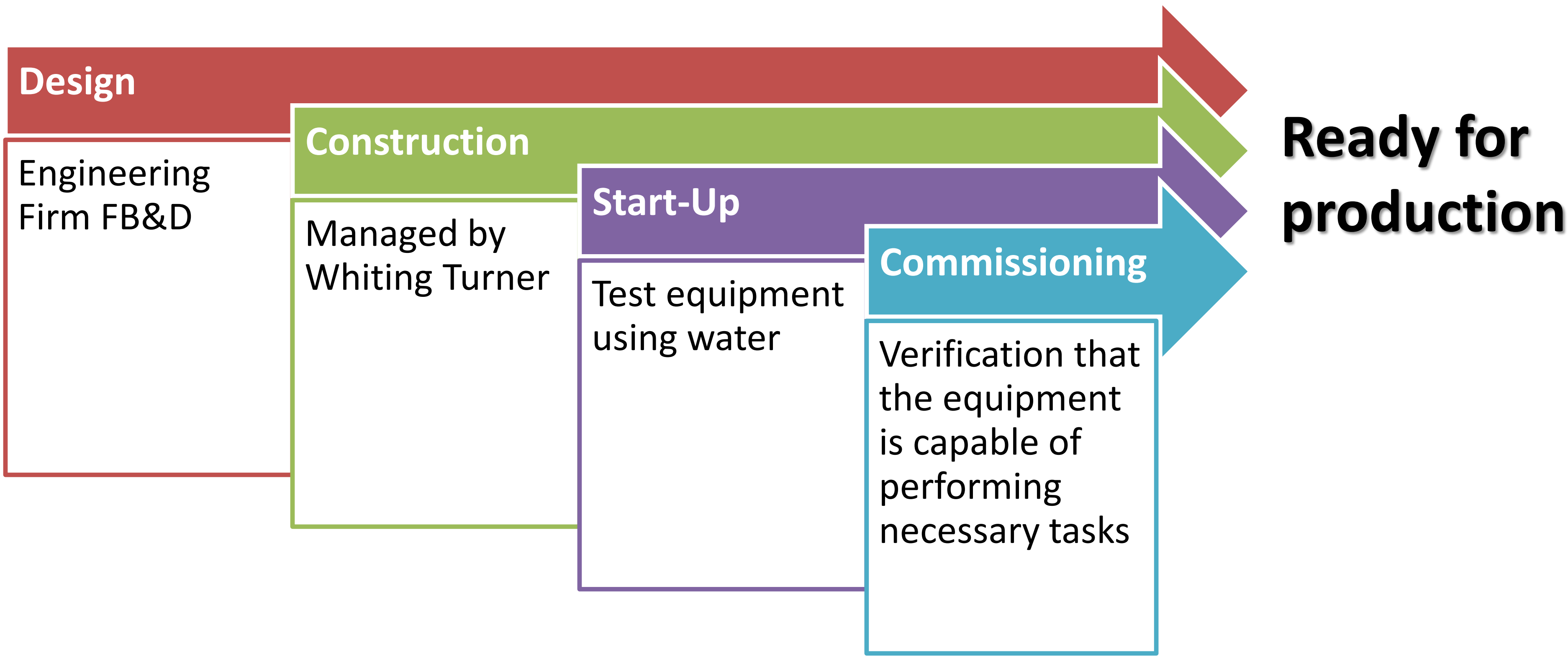

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- Completed start-up
- Continuing with the commissioning
- Fermentations using wild type *E. coli* have been carried out
  - Rich media used
  - Individual 40 gal fermentations (Propagation Tank 2A/B)
  - Several 400 gal fermentations (Propagation Tank 3A/B) using the 40 gal fermentations as inoculum

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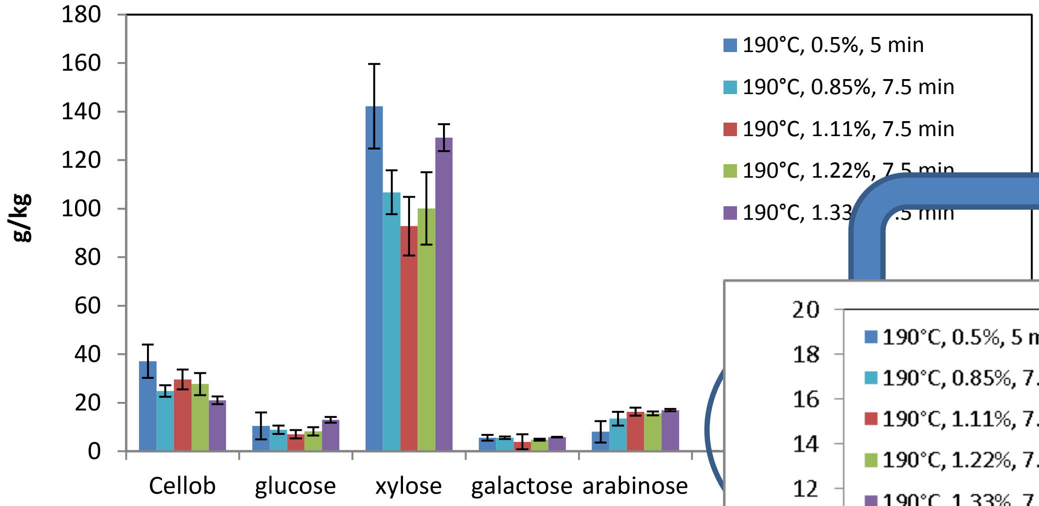
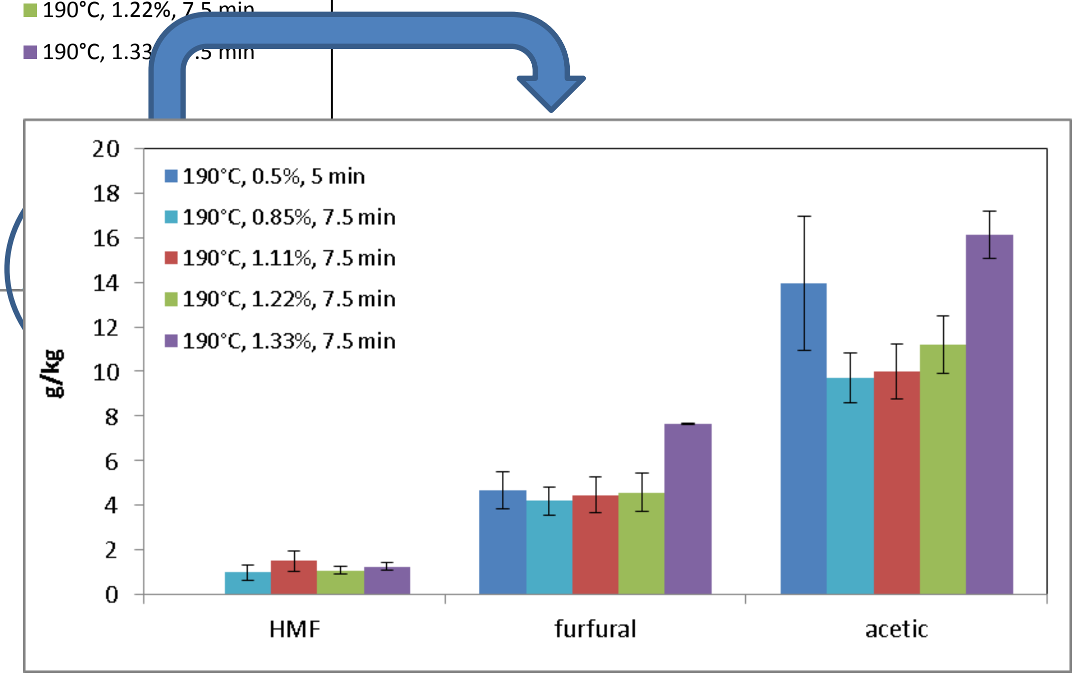
Continuous Pretreatment





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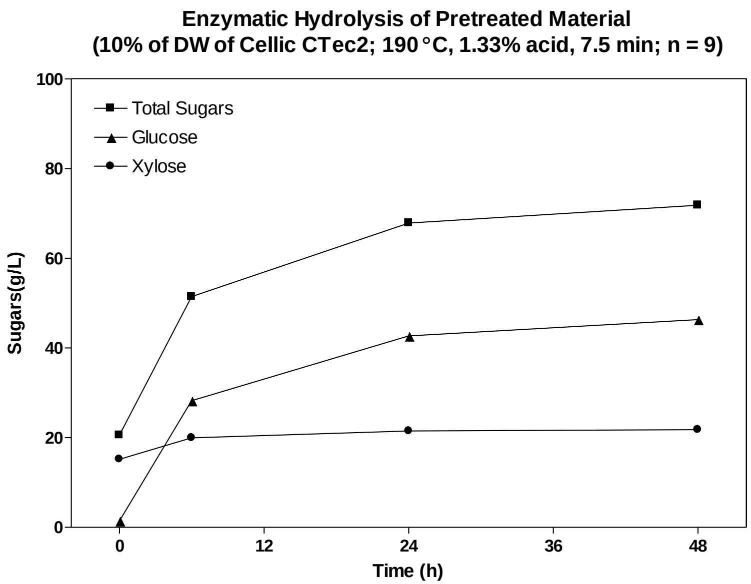

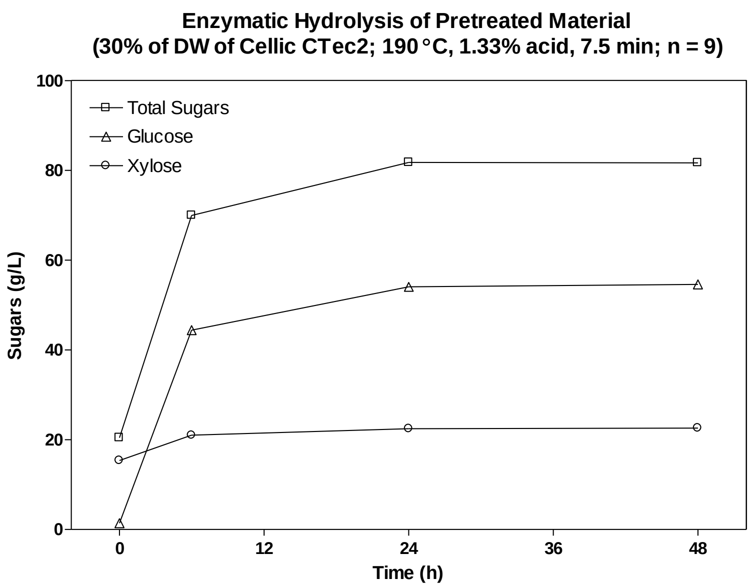

Sugar	Percentage of Dry Weight
Glucan	43.2 ± 0.8
Xylan	22.8 ± 0.8
Galactan	2.2 ± 1.4
Arabinnan	2.1 ± 0.6
Total Sugars	**70.3 ± 1.9**

- ✓ ~87% sugar yield using 10% enzyme after 48 h
- ✓ ~100% sugar yield using 30% enzyme after 48 h

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