Moving towards commercialization of lignocellulosic biomass to fuels to chemicals. How to deal with heterogeneous biomass?

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Heterogeneous biomass

- Hybrid poplar

- Forest residues

How to deal with heterogeneous biomass?

Objectives

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How can we improve the production of fuels and chemicals from biomass?

How do deal with heterogeneous lignocellulosic biomass?

Preconditioning
Online reaction control
Techno-economical analysis
Life Cycle Analysis (LCA)

Chemical composition of hybrid poplar

Biomass	Cellulose (%)	Hemicellulose (%)	Lignin (%)
P. deltoides, Stoneville	42.2	16.6	25.6
NM 6	49.0	21.7	23.3
CAFI high lignin	43.8	20.4	29.1
CAFI low lignin	45.1	21.5	21.4
Caudina DN 34	43.7	19.6	27.2
DN 182	45.5	20.8	23.6
DN 17	43.7	23.2	23.1
NC 5260	45.1	20.3	21.5

(Sannigrahi et al., 2009)

Chemical composition-challenges

- Agronomy practices for stand establishment
- Water and nutrients management
- Weed control
- Harvest and storage
- Growing seasonal precipitation requirements
- Seasonal changes
- Age

Physical characteristics

- Moisture content
- Particle size
- Bark content
- Leaf/needle content

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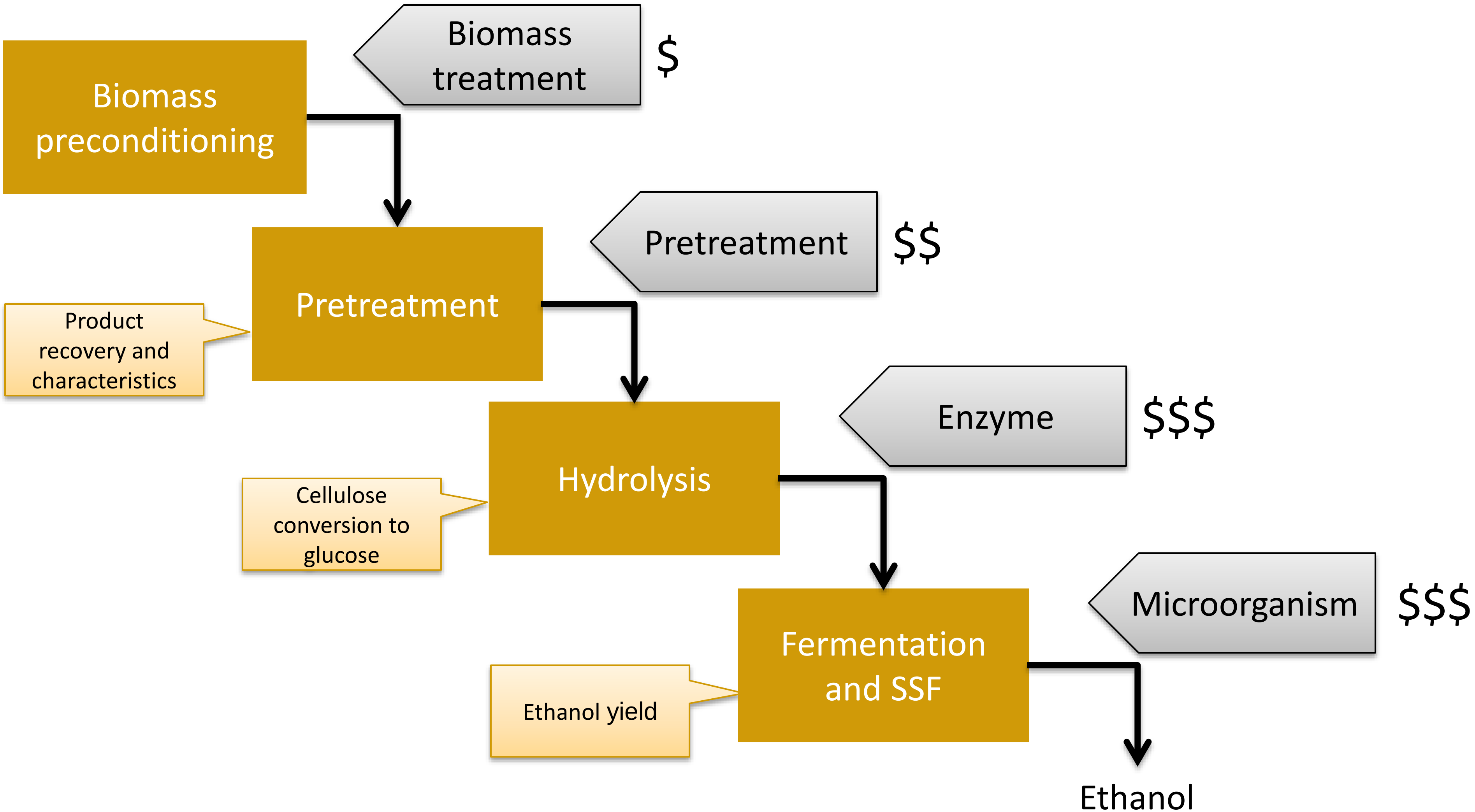
- Harvest and collection
- Storage
- Transportation
- Handling

Affect of preconditioning



Switchgrass and sugarcane bagasse preparation

Starting material

Air-dry (10 % moisture)

Soak to 80% moisture

Moisture adjustment

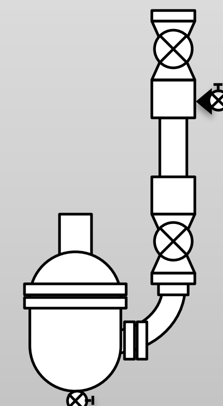
No SO_2 added

Add 3% SO_2

SO_2 addition

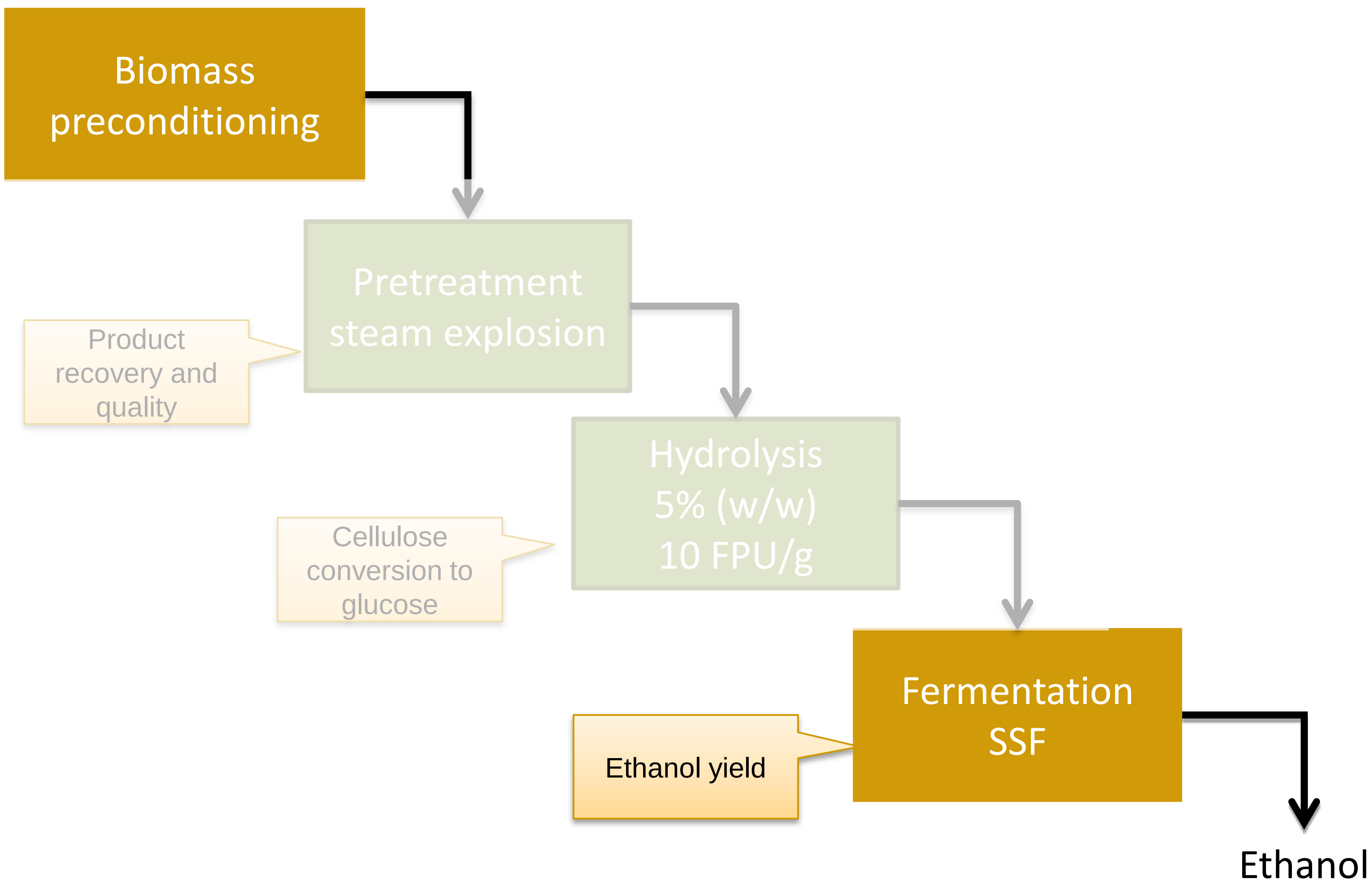
Steam explosion

195-205 ° C
7.5-10 min

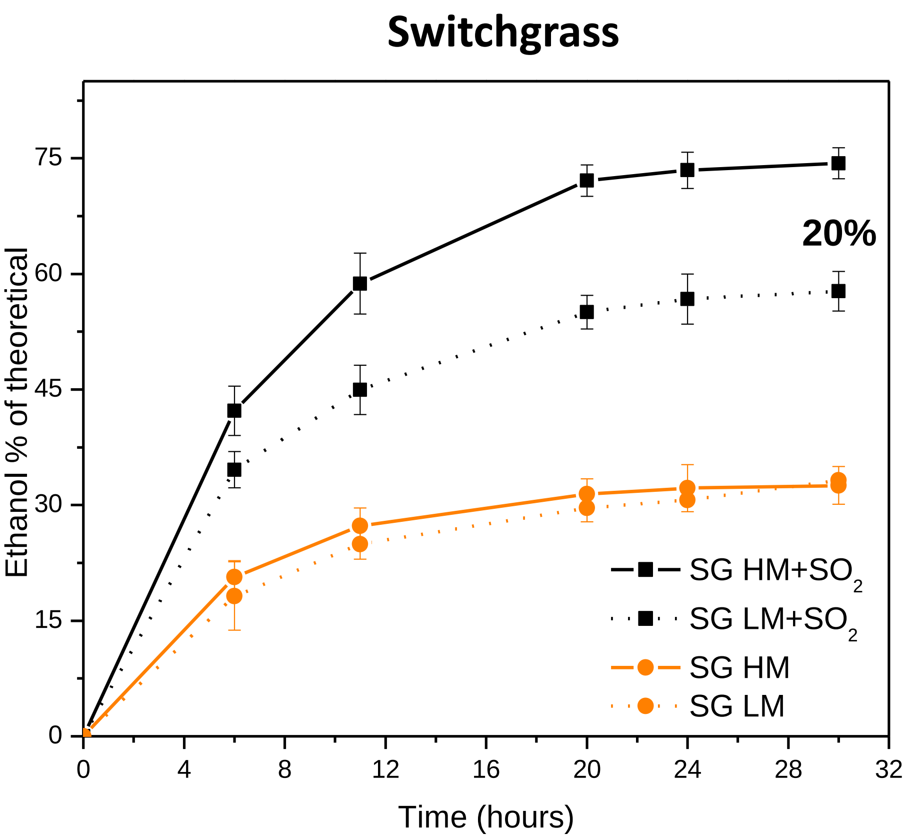


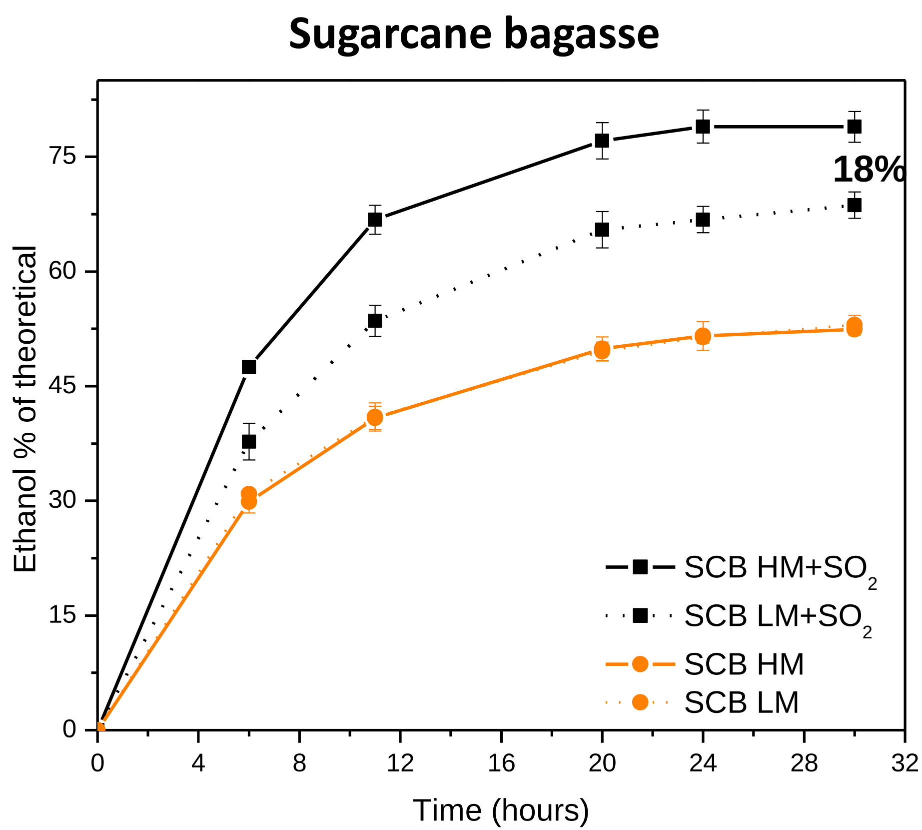
Pretreatment

Fermentation



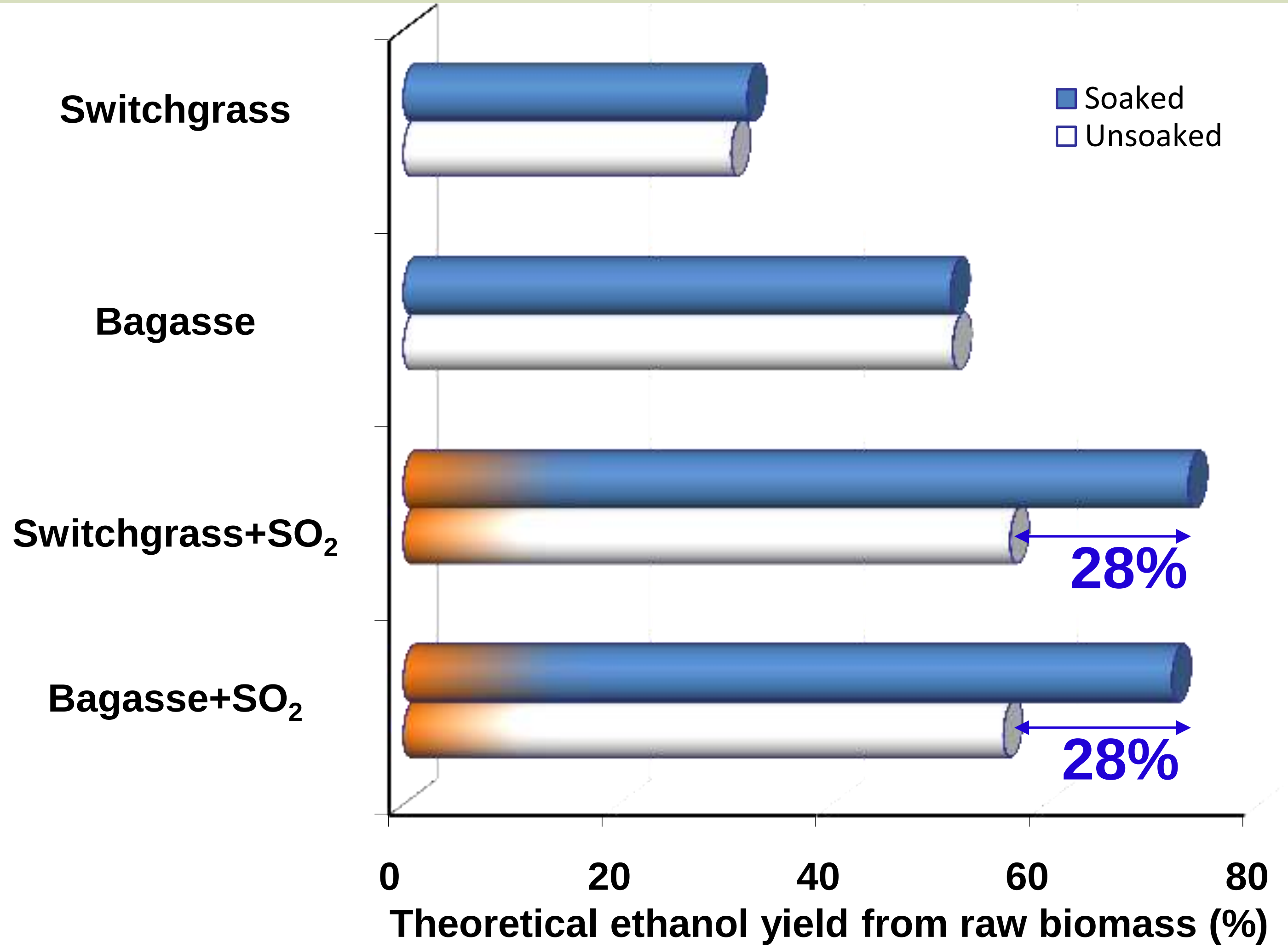
SSF — 5% (w/w), 10 FPU/g cellulose, 5 g/L of *S. cerevisiae*





(Ewanick and Bura, 2011; *Bioresource Technology* 102)

Final results — theoretical ethanol yield from raw biomass



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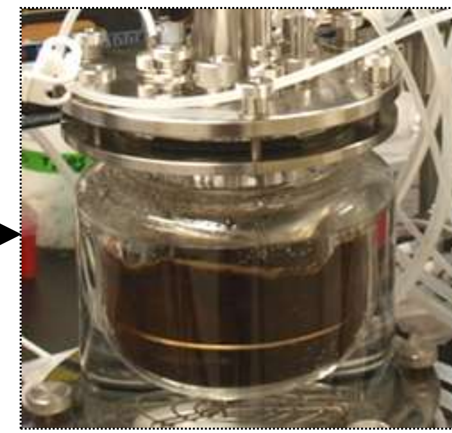
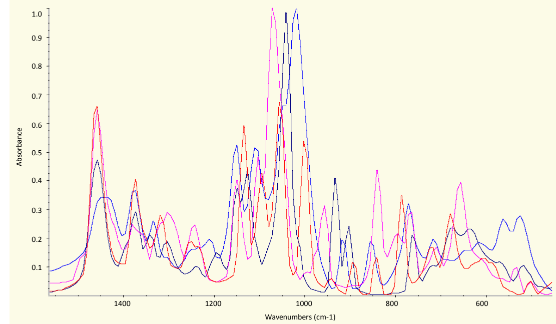
Pretreatment

Hydrolysis

Fermentation

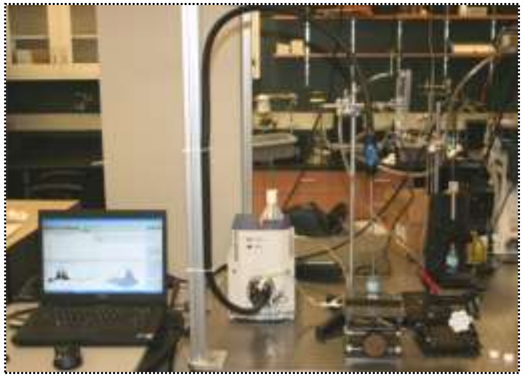


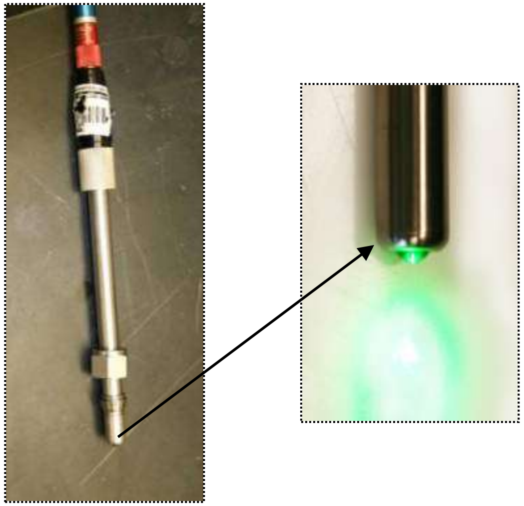
Improving analytical methods

	Current	Spectroscopic
Methods	  HPLC, GC, wet chemistry, enzymatic	 **Raman** *High resolution chemical modification from molecular vibration*
Issues	-time and cost -not online -less robust -requires trained personnel -destructive and invasive	-background fluorescence -resolution of multiple compounds -detection limits

What is so special about UW Raman?

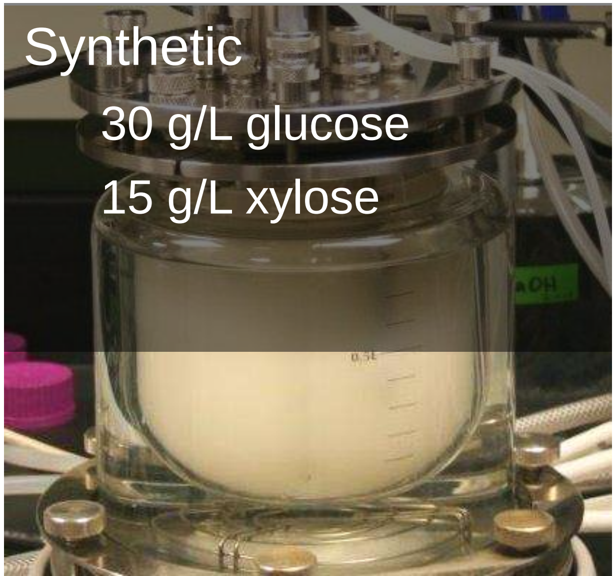
- Raman Instrument
  - Kaiser Rxn2 System
  - 785 nm excitation
  - **6 mm ball probe (UW patent)**
    - Sapphire spherical lens
    - Interfacial measurements
    - No moving parts
    - Sampling error **<<1%**
    - Temperature range: -40° C – 350° C
    - Pressure range: 0-350 Barr
    - Effective sampling of liquids, slurries, powders, pastes and solids
- **Chemometric techniques (UW)**
- **Algorithms to remove fluorescence (UW)**

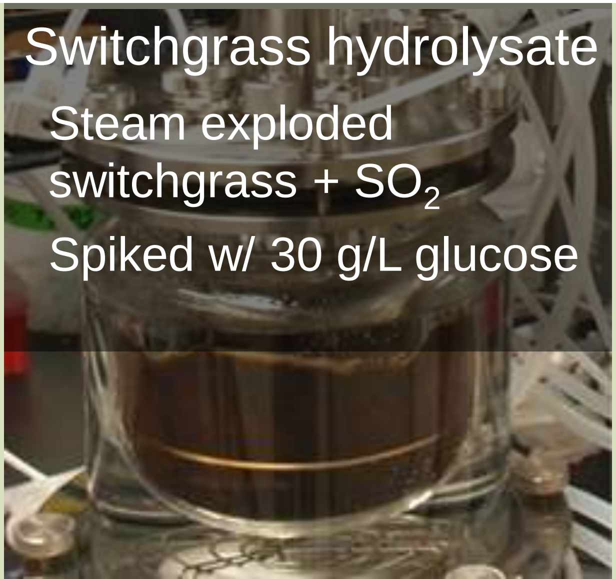




Experimental methods

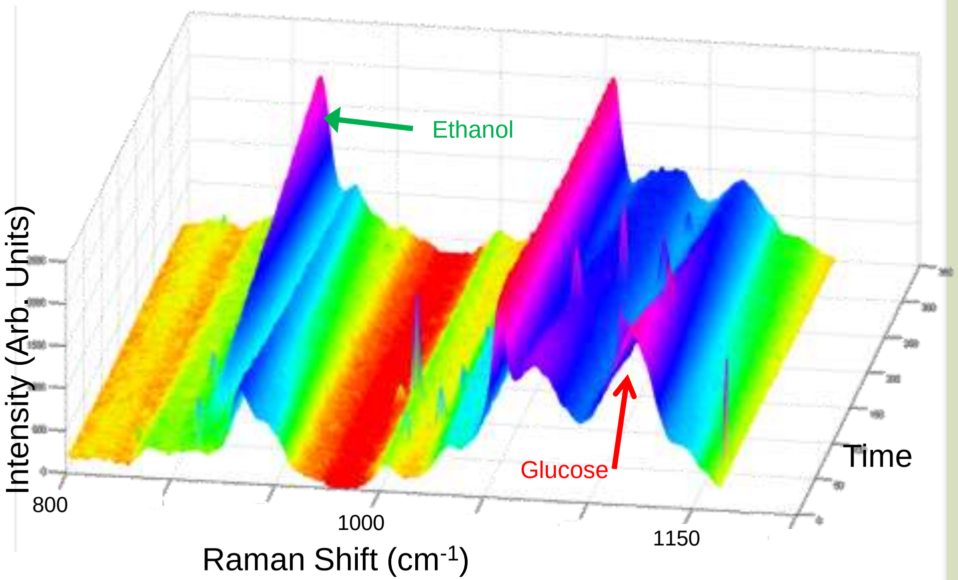
- Fermentation in 1.3 L NBS Bioflo 115 bioreactor
- *S. cerevisiae* ATCC 96581 (6-C only)
- 785 nm Raman ball probe in vessel
- Manual sampling for HPLC analysis



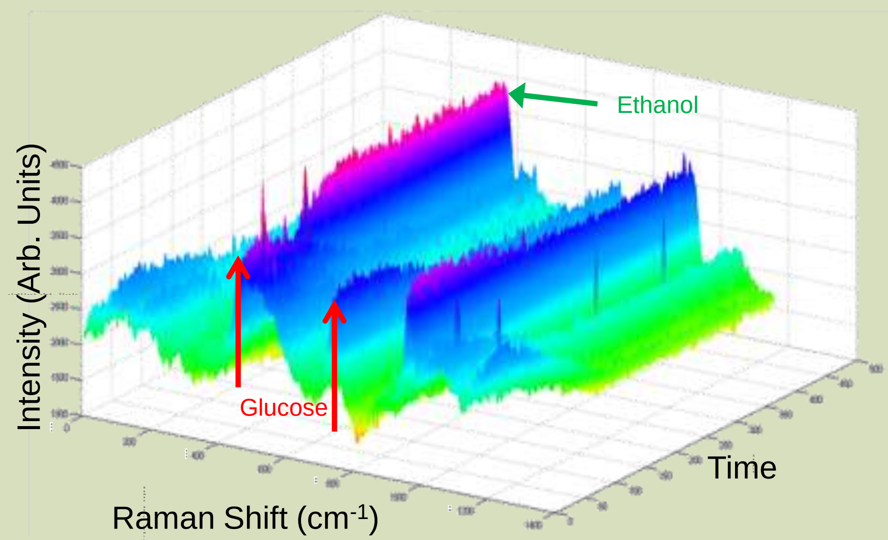


Raman: surface plots

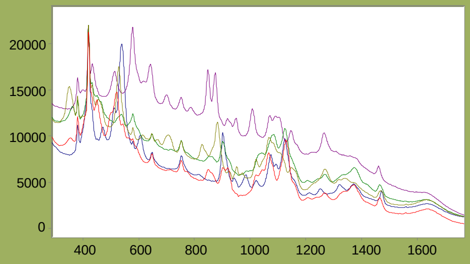
Synthetic sugars



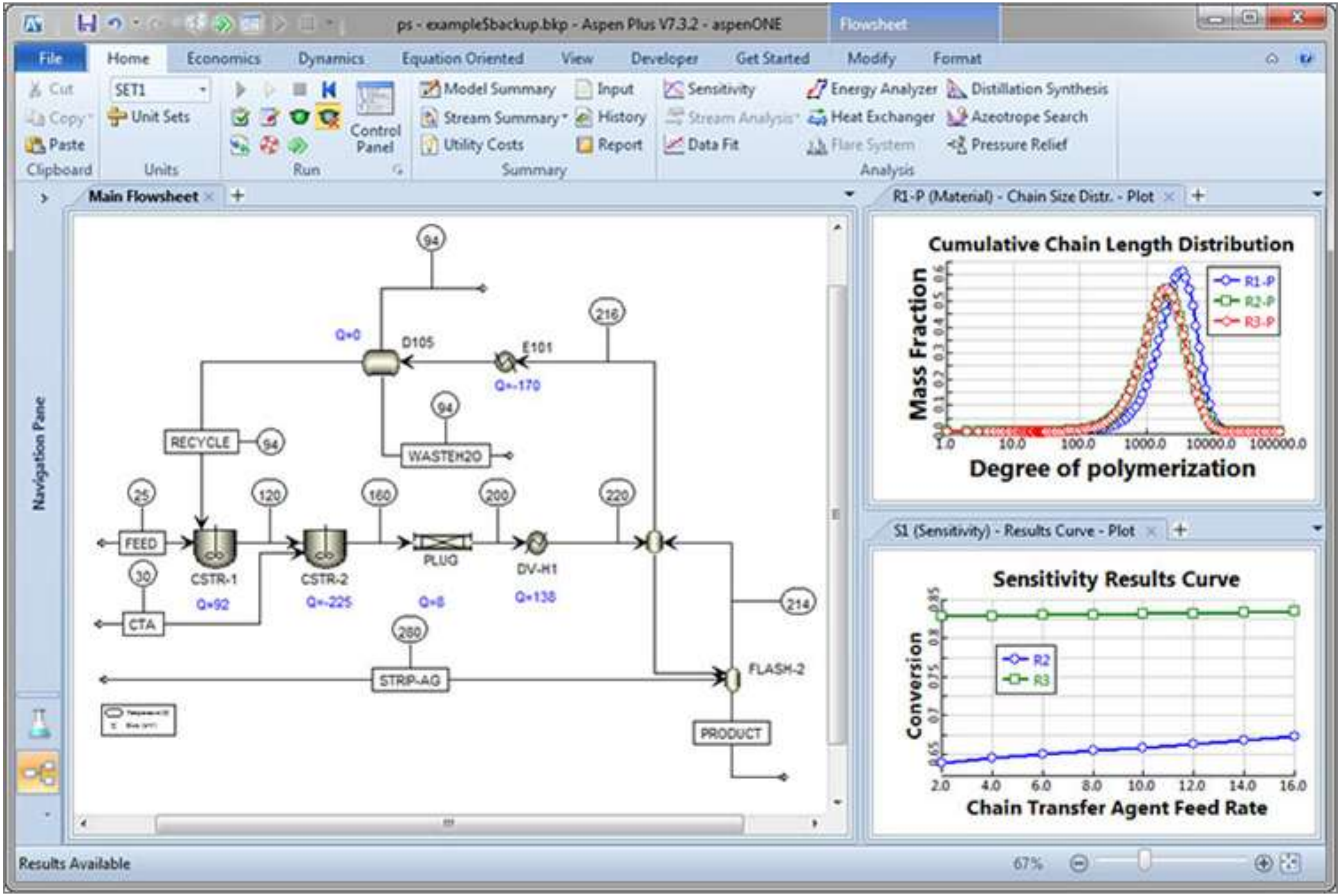
Switchgrass hydrolysate



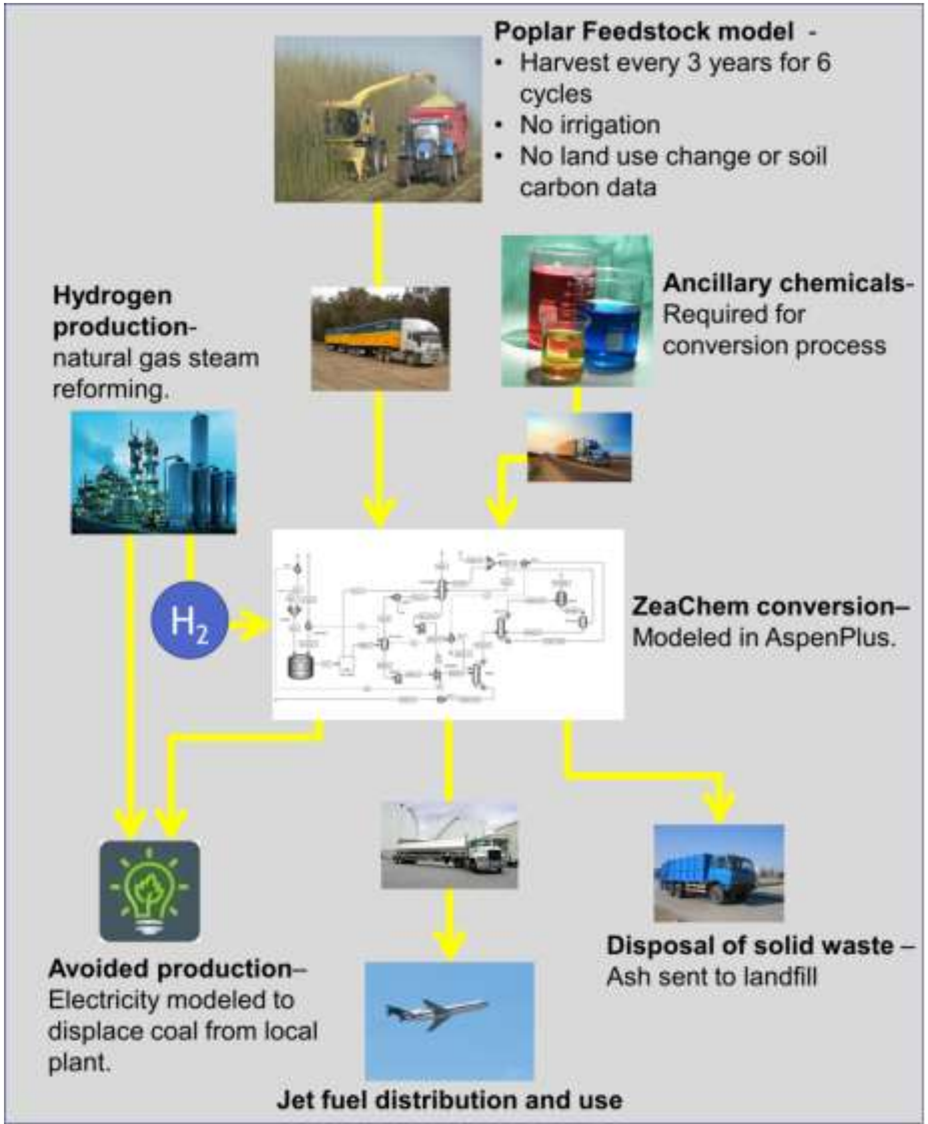
HPLC vs Raman

	HPLC	Raman
		
Sample preparation	$$$	$
Equipment cost	$$$	$$$
Sample run time	30-120 min	1 min
Analysis time for 6 hour fermentation	3 days, 36 data points	Real time, 360 data points
Online probe/sensor?	No	Yes

Techno-economical analysis (ASPEN)



Life Cycle Analysis (LCA)



How to deal with heterogeneous biomass?

1. Preconditioning
2. Online reaction control
3. Techno-economical analysis
4. Life Cycle Analysis (LCA)

Acknowledgements

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