Conversion of Woody Biomass to Chemicals, Energy and Materials

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Imagine a renewable world
Outline

- Introduction
- Hot-Water Extraction
- Wood Extract Hydrolysis
- Membrane Separation
- Fermentation
- Solid products
- Conclusion
Woody Biomass

Chemical components of wood

21% hardwoods

Lignin

25% softwoods

2-8% extractives

35% hardwoods

hemicellulose

25% softwoods

45% cellulose

carbohydrates

4% hardwoods

25% softwoods
Wood Components:

- Inorganic Components
  K & Ca (400 ~ 1000 ppm);
  Mg & P (100 ~ 400 ppm); and 70 others

- Extractives
  Aliphatic and alicyclic: Terpenes; terpenoids; esters; fatty acids; alcohols; ...
  Phenolic: phenols; stilbenes; lignans; isoflavones; ...
  Others: sugars; cyclitols; tropolones; amino acids, ...

- Hemicellulose

- Lignin

- Cellulose
Incremental Deconstruction

- Maximize value achievable
- Minimize energy loss
- Minimize waste byproducts generation
- Multiple product mix
Integrated Biorefinery:

Woody Biomass → Hot-Water Extraction → Residual Woody biomass → Alkaline Pulping → Unbleached Pulp → Bleached Pulp → Paper products or Cellulose products → Carbohydrates → Aromatics → Plastics Adhesives, Solvent Surface agents...

Methanol → Hydrolysis / Separation → Acetic Acid → Food additives: sugar oligomers → Sugars → Xylitol, Ethanol, Butanol, Acetone, Hydrogen, Lactic Acid, PHA

Gasification Feedstock → Fuel Pellets → Reconstituted Wood Products → Electricity and Steam

Extraction Liquor → Black Liquor → Separation or Co-Gen

Co-Gen or CHP
ESF Biorefinery:
- Hot-Water Extraction
- Hydrolysis
- Fractionation
  - Acetic Acid
  - Methanol
  - Sugars or monosaccharides
  - Aromatics, Furfurals
  - Polysaccharides
- Fermentation to Ethanol, Plastics, ...
Hot-Water Extraction
Maple Wood Extract

- Acetic Acid, Methanol
- Acetyl, Polysaccharides
- Aromatics, Furfurals
- Monomeric Sugars

Starting conditions:
369.20 g OD Maple Woodchips
3024.04 g water, 28°C
Hydrolysis

- Depolymerize macromolecules (of carbohydrates) by inserting water molecules between the monomeric units
- Enzymatic hydrolysis
  - Using a hydrolytic enzyme as catalyst
  - Substrate specific – only working with certain polymer and depolymerize at certain location
- Acid Hydrolysis
  - Using acid (proton) as catalyst
  - Glycosidic bond breakage, no specificity
  - By-product – dehydration reactions
Fractionation

- Solid-liquid separations
  - Aromatics and/or degraded lignin recovery
  - Xylan or xylo-oligomer recovery
  - Catalyst recovery

- Liquid-liquid separations
  - Membrane separations for
  - Sugar stream purification
  - Recovery of chemicals
Nano-Filtration Membrane System
Membrane Separation

- Resistances:
  - Osmotic Pressure
  - Friction – Porous Solids
- Model:

\[
\Delta p = \pi + \frac{\mu}{k} U \left( 1 + \frac{U^2}{a + U^2} bU \right)
\]
Flux versus Pressure

![Graph showing the relationship between permeate rate and pressure.](image)
Osmotic Pressure Change

![Osmotic Pressure Change Graph](image)

- **π, psi**
- **V₀/V**

The graph shows the change in osmotic pressure (π, psi) as a function of **V₀/V**. The data points indicate a steady increase in pressure with increasing **V₀/V**.
Fractionation of wood extracts

![Graph showing fractionation of wood extracts over time.](image_url)
Acetic acid concentrations

Concentrate Stream

Permeate Stream

Time, minutes

C, mol/L
Separation Efficiency

![Graph showing separation efficiency over time for Xylose and Aromatic Compounds.](#)
Separation Efficiency

![Graph showing separation efficiency over time for different compounds: Acetate, Methanol, Furfural, and HMF. The x-axis represents time in minutes, ranging from 0 to 360, and the y-axis represents Rs, a measure of separation efficiency. Different symbols are used to represent each compound, with lines showing the trend over time.]

Fermentation

- Ethanol
  - *E. Coli*
  - *Pichia Stipitis*

- Butanol
  - *Clostridium acetobutylicum*

- PHA
“Residual” woody biomass use

- Pulping – paper and fiber products
- Fiber board – reconstituted wood products
- Wood fuel – wood pellets
- Biomass energy – CHP
- Hydrolysis: cellulose conversion to platform chemicals
- Lignin conversion to chemicals and/or energy
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- Abstracts submitted by Sunday, February 1, 2009
- Acceptances notified Monday, March 2, 2009
- Extended abstract required by Monday, August 31, 2009
- Full manuscripts (for Journal Publications) due by Monday, September 28, 2009
- Full manuscripts - review, November 1, 2009
- Full manuscripts - final version due by Monday, November 15, 2009
- Full manuscripts - notification from Journal, December 1, 2009

Welcome!

The International Biorefinery Conference 2009 (IBC’09) will be held in Syracuse, New York on October 6-9, 2009. The purpose of the conferences is to showcase the latest developments in the field of biorefinery. Please visit our website for more information concerning the Conference: http://www.biorefineryresearchinstitute.com/ibc09

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