Cereal Straw Biorefinery

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Conceptual Process For Integrated Power, Fuel, Chemical, and Pulp Fiber Production

Whole straw 4.64 Mt → Straw Preprocessing → Internode 2.61 Mt → Pulping of Straw → Extracted Internode 2.0 Mt → Pulp Production → Pulp 1.5 Mt

- Field Deposit Nodes, Leaves/Sheath
- Power Production
- Ion – Exchange Removal of Non-Carbohydrate Impurities
  - Sugars by Xylanase Treatment
  - Catalytic Hydrogenation
  - Mixture of alcohol/glycol products ≈ 0.5 Mt
- Dissolved plant material To agricultural soil application
- Bioactive Products

Internode 2.0 Mt → Sugar production 2.0 Mt

Straw Preprocessing 2.0 Mt → Power Production

OD 1 Mt → Pulp Production

OD 0.61 Mt → Bioactive Products

OD 0.5 Mt → Mixture of alcohol/glycol products

OD 0.05 Mt → Agricultural soil application
Technical Issues

- What’s Known
- Transportation
- Quest for Brightness
- Liquor treatment
- Trial Run Opportunities
- Mill start up
What’s Known

- Straw Pulping is not new
- Major fiber source in China
- Fiber length similar to hardwood
- Easily pulped
- Hard to convey
- Enough wheat and alfalfa straw in Washington for all paper produced, not just copy paper
Will this work on Commercial Machines?

- Commercial trials on Linerboard Papermachine, Molded Pulp machines, Paperboard Cylinder Machine
- Pilot Papermachine trials on various grades of bleached, semi-bleached and unbleached grades
- Commercialization on molded pulp machine
- Upcoming trials in new molded pulp mill
Proposed Work 2009-11

- Phase 1 Hydroseeding
- Phase 2 Liquor Utilization
- Phase 3 Bleaching of Market Pulp
- Phase 4 Feasibility Study for Eastern WA Facility
22 Oct. 2008  Hydromulch Seedling Counts; Pullman, WA
Phase 1 Hydroseeding

- Experimental design around selected pulping methods and application rates
- Impact of black liquor on soil
- Impact of black liquor as a fertilizer
Phase 2 Liquor Utilization

- Optimized Pulping and Spent Liquor Recovery
- Optimized Liquor Concentration
- Hydrogenation of Hemicellulose Sugars to produce glycols
- Optimized Membrane Purification of Liquor
- Utilization of Liquor for Dust Abatement
Liquor/Chemical Applications

- Soil amendment and dust suppression
- Recovery of sugar structures
- Hydrolysis/fermentation to glycols
- Hydrogenation to produce commercially valuable glycols
- Purification of Sugar solution
- Concentration of hemicellulose solution
Potential Washington Agro-Industry Manufacturing Configuration

1. Much research done. In development stages
2, 3 – Nearly commercial (2006), needs some optimization
4 – Requires Research/Development
5 – Process presently commercial/needs R/D for bio-sugar and glycerin feeds
6 – Requires Research/Development – Current Agenda 2020 USDOE Projects
Potential Operations

**Potential Hemicellulose Extraction**
- Extract
- Purify
- Concentrate
- Hydrolyze
  - $\approx 1.6$ ton

- C5/C6 Sugar Mixture

**Pulping**
- straw
  - Dissolved Organics in Black Liquor $\approx 9$ tons
  - Pulp $\approx 9$ tons

**Wheat 20 tons**

- To Fermentation
  - EtOH

- To Hydrogenation
  - Mixed Glycols
Five and Six Carbon Sugar to Glycol Block Flow Diagram

1. **Monomer Sugars**
   - Glucose, Xylose
   - Lactose

2. **Hydrogenation**
   - Hydrogen
   - H₂, CO₂, CH₄

3. **Hydrocracking**
   - Hydrogen
   - H₂, CO₂, CH₄

4. **Mixed Glycols**

5. **Separations Distillation**
   - Propylene Glycol
   - Ethylene Glycol
   - Glycerin
   - Butanediols
   - Alcohols

**Steam High Pressure**
- Steam
- Low Pressure
- Hot Waste Water
- Cooling Water
10,000 Mt Glycol Production Facility
Changchun, China
Phase 3 Bleaching of Market Pulp

- Alternative Pulping Chemistry for High Brightness Grades
- Evaluate Elementally Chlorine Free (ECF) Bleaching
Quest for Brightness

- Major Hurdle
- 73 brightness TCF wheat straw is currently achievable for use in newsprint or book grade
- 80 brightness is a minimum for commercial copy paper
- 80+ brightness achieved with seed alfalfa straw
- Research is ongoing
- Higher brightness grade a plus for biorefinery/market pulp mill
Production of Bleached Market Pulp

- Customers are asking for pulp samples for evaluation
- Inland Empire in Spokane and Blue Heron in Portland are interested in possible straw trials, but need pulp for internal evaluations
Yakima Straw Pulp Mill

- Start Up First Quarter 2009
- Starting up on alfalfa straw
- Will expand to wheat straw
- Mill has committed to production expansion
- Approximately 25 new jobs will be created
Feasibility of an Eastern Washington Biorefinery, Pulpmill, Biomass Power Generation Facility

- Products and Markets
- Process Configuration
Budget

- Phase 1 Hydroseeding
  - $15,000
- Phase 2 Liquor Utilization
  - $35,000
- Phase 3 Bleaching of Straw Market Pulp
  - $35,000
- Phase 4 Feasibility Study
  - $10,000
- Phase 5 Final Report
  - $5,000