ADVANCES IN CO-PRODUCT FIBER UTILIZATION FOR NEW PRODUCTS & INCREASED VALUE

Jagannadh Satyavolu
Theme Leader
Biomass Conversion and Biofuels
Corn pericarp fibers are rich in hemicellulose

<table>
<thead>
<tr>
<th>Composition</th>
<th>Corn Fiber from Kernels</th>
</tr>
</thead>
<tbody>
<tr>
<td>hemicellulose</td>
<td>39-40</td>
</tr>
<tr>
<td>% cellulose</td>
<td>11-13</td>
</tr>
<tr>
<td>% lignin</td>
<td>3-6</td>
</tr>
<tr>
<td>% ash</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

A commercial source for corn fiber is *Dried Distillers Grains* (DDG)
## DDG Composition

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Original DDG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Protein (wt %)</td>
<td>25.72</td>
</tr>
<tr>
<td>Crude Fat (wt %)</td>
<td>10.48</td>
</tr>
<tr>
<td>Ash (wt %)</td>
<td>1.76</td>
</tr>
<tr>
<td><strong>Neutral Detergent Fiber (wt %)(^a)</strong></td>
<td><strong>53.51</strong></td>
</tr>
<tr>
<td>Acid Detergent Fiber (wt %)(^b)</td>
<td>27.76</td>
</tr>
<tr>
<td>Total Carbohydrates (wt %)</td>
<td>62.04</td>
</tr>
<tr>
<td>Hemicellulose (wt %)</td>
<td>25.75</td>
</tr>
</tbody>
</table>
Value Enhancement Strategies

- Cellulosic Ethanol
- Fiber
- Source of C5
  - Further value for C6
- DDG
- Oil Recovery
- Starch Recovery
- Protein Enrichment
DDG Processing for fiber

Dried Distillers Grain (DDG) → Screening → Protein-rich Fraction → Feed Applications

Selective Hydrolysis → Residual Fiber

Hydrolyzate → Feed and/or other High Value Applications
Residual Fiber after Hydrolysis

Compared to DDG (control),

- the fines fraction has
  - 11% more protein
  - 36% more total lysine

- the fiber after acid hydrolysis has
  - 113% higher crude fat
  - 15% higher total digestible nutrients, and
  - 15% higher digestible energy
  - 69% less total lysine
Residual Fiber after Hydrolysis

- **DDG Control (1)**
- **DDG Fine Fraction (2)**
- **Fiber After Acid Hydrolysis (3)**

**Graph Analysis**

- Protein (Crude)
- Fat (Crude)
- Fiber
- Ash
- Total Digestible Nutrients
- Fiber (Crude)
- Fiber (Neutral Detergent)
- ADF Indigestible
DDG Processing for fiber

Three value added products from DDG:

- Protein rich feed 1
- Energy rich feed 2
- C-5 hydrolyzate 3 Source of Xylose
Residual Fiber after Selective Hydrolysis
SEM images showing differences in surface structure between pre and post-hydrolysis DDG fibers (a), (b)
### Activated Carbons from Corn Fiber

<table>
<thead>
<tr>
<th>Sample</th>
<th>BET Surface Area (m²/g)</th>
<th>Langmuir SA (m²/g)</th>
<th>External Surface Area (m²/g)</th>
<th>Average Pore Width (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDG: Pre-Hydrolysis</td>
<td>10.44</td>
<td>15.47</td>
<td>7.35</td>
<td>9.533</td>
</tr>
<tr>
<td>DDG: Post-Hydrolysis</td>
<td>1705.58</td>
<td>2440.36</td>
<td>1245.13</td>
<td>2.922</td>
</tr>
<tr>
<td>Control: MWV</td>
<td>1226.71</td>
<td>1751.39</td>
<td>797.18</td>
<td>3.620</td>
</tr>
</tbody>
</table>
measured in a 2032 coin-cell configuration system using 1.5 M TEAPF6-PC (Tetraethylammonium hexafluorophosphate in propylene carbonate) solution as the electrolyte
Residual Fiber after Hydrolysis: Co-Product: ACF

Carbonization and activation process:
- BET Surface Area: 1300-1600 m²/g
- Pore Volume: 0.94 cm³/g

Energy Storage applications:
- Li-Ion batteries
- Supercapacitors
- PV cells
- Hydrogen storage
DDG Processing for fiber

Three value added products from DDG:

- Protein rich feed
- Energy rich feed
- C-5 hydrolyzate

1. Protein-rich Fraction
2. Residual Fiber
3. Hydrolyzate

Feed and/or other High Value Applications

High surface area carbons

Source of Xylose
About Xylose

- a natural and zero calorie sugar.
- rapidly absorbed from the small intestine and not metabolized in the liver.
- a safe sugar - is used routinely in medical tests in the proximal small intestine.
- may help prevent progression of obesity-related metabolic disorders by improving lipid oxidation.
- also a sucrose inhibitor suggested to suppress development of obesity-related diseases
- Commercially available at xylitol – a modified sugar alcohol
C5 Platform of Products

**BIOMASS**

- **DDG**
- **Kenaf Bagasse**
- **Soy Hulls**

**Applications**
- sweeteners (xylitol)
- food coloring

**Applications**
- biodegradable polymers

**Applications**
- norbornene / cyclic olefin copolymers (COC)

**Applications**
- aviation fuel

- **Lactam**
- **3-THP**
- **Lactone**

- **4-THP**
- **Cyclopentadiene**

- **Bicyclopentane**
Xylose Isolation Technology

Technology Highlights

• Xylose isolated as a solid sugar
• Conducted under ambient conditions
• Uses cost effective green solvents and reagents
• Regenerate reagent and solvents
• Smaller foot print plant, low capital

Xylose Isolation Cycle

PGBE = propylene glycol ester; (4-methyl-2-phenyl-1,3,2-dioxaborolane)
Quality of Isolated Xylose

NMR analysis of isolated Xylose

HPLC of the Isolated xylose
Proposed Process Flow Sheet for an ethanol plant

- Corn
- Hydrolysis
- Grinding
- Fermentation, etc.
- Pressing / Washing
- Carbonization and Activation
- Ethanol
- High Surface Area Activated Carbon
- XYLOSE
- Xylose Isolation
- Liquor

- Corn Fiber
Value Creation

**Basis:**
- **100,000** bushels per day corn grind
- Fiber Yield: 4.5 lb per bushel
- Available fiber: 450,000 lb per day
- Assigned value for fiber: $0.08 per lb

**Xylose Content:** 20% on fiber

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>as feed</td>
<td>$36,000.00</td>
<td>$(36,000.00)</td>
</tr>
<tr>
<td>as xylose</td>
<td>$122,727.00</td>
<td>$36,000.00</td>
</tr>
<tr>
<td>as high surface area carbons</td>
<td>$36,000.00</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL**
- $36,000.00
- $122,727.00
Thank you