Densification of Biomass Feedstocks

Alan Doering, Agricultural Utilization Research Institute

Fueling the Future:
The Role of Woody and Agriculture Biomass for Energy Workshop

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Morris

Sponsored by:
University of Minnesota Extension, WesMin RC&D; Minnesota Department of Natural Resources

www.extension.umn.edu/agroforestry
Goal
Solid Fuel Focus Areas

- Benefits
- Market Potential
- Densification
- Equipment Requirements
- Fuel Characteristics
- Pellet Quality
- Economics of Pellet Production
Market Potential

- Biomass → Combined Heat & Power
- Biomass → Methanol
- Biomass → Ethanol (Cellulosic)
- Biomass → Methane
- Biomass → Pellet Fuels
- Biomass → Co-Firing
Market Potentials

• Pellet Fuel
  – Wood pellet stove/boiler
  – Corn stove/boiler
  – Multi-fuel stove/boiler
  – Outdoor furnace boiler
Market Potential

»CONCERNS:

• Liability
  – Proper fuel for stove/furnace
• Ignition
• Ash handling/storage
• Emissions
Why Biomass Densification?

• Improved transportation
• More efficient storage
  – Bales vs. loaves
• Reduced biomass losses
• Moisture reduction
• Improvements in processing equipment
Forms of Densification

Goal: To increase mass per unit of volume

- Grinding/particle reduction
- Compression
- Densification
Equipment Requirements

• Focus on particle size
• Grinding capabilities
  – Industrial grinders
  – Hammer mills

Photos: Warren & Baerg Mfg.
Processing Effect on Density

Effect of Grinding on Density

- **Corn Stover:**
  - Pre-grind on tub grinder (maximum 6 inch fiber lengths) – 2.25 pounds/cubic foot
  - 3/8” hole screen hammer mill grind – 6.25 pounds/cubic foot

- **Ryeegrass:**
  - 38”X18”X16” bale – 10.5 pounds/cubic foot
  - tub grinder (maximum 6 inch fiber lengths) – 2.0 pounds/cubic foot
  - 3/8” hole screen hammer mill grind – 6.0 pounds/cubic foot
  - 5/32” hole screen hammer mill grind – 7.5 pounds/cubic foot
  - ¼” pellet using a 9:1 L/D pellet die – 36.6 pounds/cubic foot
Equipment Requirements

- Pellet Mills
  - Ring die
  - Flat die
Equipment Requirements

- Pellet Dies
  - Ring die
  - Flat die
Equipment Requirements

- Pellet Dies
  - Compression Ratios (L/D ratio)
  - Diameter
  - Metals
    - Steel
    - Chrome
    - Alloy
    - Abrasion resistant
Equipment Requirements

• Conditioning Capabilities
  – Most valuable resource
  – Steam vs. Water
Sample Pellets & Characteristics

- Mixed Grass steam only
  - ⅛" x 9:1 cm

- Biomass Fuel Pellet
  - Wood Pellet
  - Wheat Straw steam only
  - ¼" x 7.5:1 oz
  - ¼" x 9:1 oz
Briquetting

AURI / University of Minnesota
Pellet / Briquetting Characteristics

AURI / University of Minnesota
# Pellet / Briquetting Characteristics

<table>
<thead>
<tr>
<th>Form</th>
<th>Product</th>
<th>Bulk Density lbs/ft³</th>
<th>Durability %</th>
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</thead>
<tbody>
<tr>
<td>Pellets</td>
<td>Corn Stover</td>
<td>34 - 38</td>
<td>94 - 96</td>
</tr>
<tr>
<td></td>
<td>Switchgrass</td>
<td>33 - 36</td>
<td>73 - 87</td>
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<tr>
<td>Briquettes</td>
<td>Corn Stover</td>
<td>26 - 30</td>
<td>67 - 90</td>
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<td>Switchgrass</td>
<td>22 - 33</td>
<td>40 - 70</td>
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</table>

AURI / University of Minnesota
Fuel Characteristics

• Energy Content
  – Residual oil issues
• Ash
• Sulfur
• Chlorides
• Particulate
• Combustion Characteristics
# Fuel Characteristics

## Information stated on dry basis

<table>
<thead>
<tr>
<th>Grains</th>
<th>Btu/lb.</th>
<th>Ash %</th>
<th>Carbon %</th>
<th>Hydrogen %</th>
<th>Nitrogen %</th>
<th>Sulfur %</th>
<th>Oxygen % (by difference)</th>
<th>Total Chlorine ug/g</th>
<th>Chloride ug/g</th>
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<tbody>
<tr>
<td>Corn - Shell #2</td>
<td>7,810</td>
<td>1.2</td>
<td>44.6</td>
<td>6.6</td>
<td>1.2</td>
<td>0.1</td>
<td>46.3</td>
<td>701</td>
<td>520</td>
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<tr>
<td>Distillers Dried Grain with Solubles</td>
<td>9,579</td>
<td>4.9</td>
<td>49.9</td>
<td>7.2</td>
<td>4.8</td>
<td>0.4</td>
<td>32.9</td>
<td>3,017</td>
<td>2,558</td>
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<tr>
<td>Distiller’s Dried Grain without Solubles</td>
<td>9,709</td>
<td>2.0</td>
<td>50.4</td>
<td>7.1</td>
<td>5.6</td>
<td>0.7</td>
<td>34.2</td>
<td>774</td>
<td>690</td>
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<tr>
<td>Oats</td>
<td>8,746</td>
<td>3.6</td>
<td>46.7</td>
<td>6.7</td>
<td>1.8</td>
<td>0.2</td>
<td>41.2</td>
<td>738</td>
<td>576</td>
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<table>
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<tr>
<th>Processing Co-Products</th>
<th>Btu/lb.</th>
<th>Ash %</th>
<th>Carbon %</th>
<th>Hydrogen %</th>
<th>Nitrogen %</th>
<th>Sulfur %</th>
<th>Oxygen % (by difference)</th>
<th>Total Chlorine ug/g</th>
<th>Chloride ug/g</th>
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<tbody>
<tr>
<td>Beet Pulp (dried shreds)</td>
<td>6,405</td>
<td>4.3</td>
<td>43.0</td>
<td>6.1</td>
<td>1.2</td>
<td>0.2</td>
<td>45.2</td>
<td>347</td>
<td>297</td>
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<td>Glycerol (crude)</td>
<td>7,181</td>
<td>4.3</td>
<td>37.5</td>
<td>9.8</td>
<td>&lt;0.20</td>
<td>0.1</td>
<td>48.3</td>
<td>20,755</td>
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<tr>
<td>Soybean Hulls</td>
<td>7,720</td>
<td>4.3</td>
<td>43.2</td>
<td>6.2</td>
<td>1.8</td>
<td>0.2</td>
<td>44.3</td>
<td>266</td>
<td>270</td>
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<td>Sunflower Hulls (Confection)</td>
<td>8,530</td>
<td>4.0</td>
<td>47.5</td>
<td>6.2</td>
<td>1.0</td>
<td>0.2</td>
<td>41.2</td>
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<td>2,438</td>
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<td>Wheat Middlings</td>
<td>8,240</td>
<td>5.9</td>
<td>44.9</td>
<td>6.6</td>
<td>3.1</td>
<td>0.3</td>
<td>39.4</td>
<td>1,078</td>
<td>901</td>
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<table>
<thead>
<tr>
<th>Crop Residue</th>
<th>Btu/lb.</th>
<th>Ash %</th>
<th>Carbon %</th>
<th>Hydrogen %</th>
<th>Nitrogen %</th>
<th>Sulfur %</th>
<th>Oxygen % (by difference)</th>
<th>Total Chlorine ug/g</th>
<th>Chloride ug/g</th>
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<tbody>
<tr>
<td>Corn Cobs</td>
<td>7,461</td>
<td>8.3</td>
<td>42.7</td>
<td>5.8</td>
<td>0.4</td>
<td>0.1</td>
<td>42.8</td>
<td>1,844</td>
<td>1,532</td>
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<tr>
<td>Corn Stover</td>
<td>7,961</td>
<td>5.1</td>
<td>43.7</td>
<td>6.1</td>
<td>0.5</td>
<td>0.1</td>
<td>44.6</td>
<td>1,380</td>
<td>997</td>
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<td>Oat Straw</td>
<td>7,586</td>
<td>7.5</td>
<td>42.7</td>
<td>6.0</td>
<td>0.6</td>
<td>0.1</td>
<td>43.2</td>
<td>8,568</td>
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<td>Soybean Straw</td>
<td>7,940</td>
<td>3.7</td>
<td>45.6</td>
<td>6.4</td>
<td>0.6</td>
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<td>1,545</td>
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<td>Wheat Straw</td>
<td>7,713</td>
<td>7.7</td>
<td>43.4</td>
<td>6.0</td>
<td>0.8</td>
<td>0.1</td>
<td>44.5</td>
<td>525</td>
<td>352</td>
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<table>
<thead>
<tr>
<th>Grasses</th>
<th>Btu/lb.</th>
<th>Ash %</th>
<th>Carbon %</th>
<th>Hydrogen %</th>
<th>Nitrogen %</th>
<th>Sulfur %</th>
<th>Oxygen % (by difference)</th>
<th>Total Chlorine ug/g</th>
<th>Chloride ug/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Stem</td>
<td>8,020</td>
<td>6.1</td>
<td>44.4</td>
<td>6.1</td>
<td>0.8</td>
<td>0.1</td>
<td>42.6</td>
<td>1,880</td>
<td>1,132</td>
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<tr>
<td>Switchgrass</td>
<td>7,929</td>
<td>5.7</td>
<td>45.5</td>
<td>6.1</td>
<td>0.9</td>
<td>0.1</td>
<td>41.7</td>
<td>1,980</td>
<td>1,729</td>
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<table>
<thead>
<tr>
<th>Wood</th>
<th>Btu/lb.</th>
<th>Ash %</th>
<th>Carbon %</th>
<th>Hydrogen %</th>
<th>Nitrogen %</th>
<th>Sulfur %</th>
<th>Oxygen % (by difference)</th>
<th>Total Chlorine ug/g</th>
<th>Chloride ug/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardwood Pellet</td>
<td>8,298</td>
<td>0.4</td>
<td>48.3</td>
<td>6.0</td>
<td>&lt;0.20</td>
<td>0.0</td>
<td>45.1</td>
<td>471</td>
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</tr>
</tbody>
</table>

1Methods: Moisture - ASTM D3173; Ash - ASTM D3174; Btu/lb - ASTM D5865; Sulfur - ASTM D4239; Chlorine - ASTM D4208; Carbon, Hydrogen, and Nitrogen - ASTM D5373

2Calculated value using ASTM D3180-89
Pellet Quality

- **Density**
  - 40 pound per cubic foot

- **Dimension**
  - Length 1 ¼” max X ¼” or 5/16”

- **Fines**
  - <0.5% through an 1/8” screen

- **Chlorides**
  - < 300 ppm (0.03%)

- **Ash**
  - 0.5% to 2.0%
  - <6% utility

Pellet Fuels Institute
Pellet Quality

- Pellet Durability
  - PDI tumble tester
  - Force gauge
- Variables
  - Fiber source
  - Particle size
  - Conditioning
  - Feed rate
  - Die speed
  - Die specifications
  - Glass transition of material (50 to 130°C)

(Kaliyan and Morey, 2006a)
Economics of Pellet Production

• Material cost
• Collection/transportation cost
• Grinding/processing
• Pelleting/cooling
• Storage/bagging
• Personnel/equipment
• Fluctuating pellet fuel market
• Debt service
Economics of Pellet Production

- Estimated pellet plant production cost/ton:
  - Assumption: corn stover cost $61/ton
    - 2 ton/hr - $101.45/ton
    - 4 ton/hr - $180.58/ton
    - 8 ton/hr - $147.84/ton

Economics of Pellet Production

- Fixed cost: $3 - $20 per ton based on throughput
- Variable cost: $26.68 per ton
- Raw Material cost: $46 per ton at 12% moisture (including transportation into plant)
- Cost per ton densified: $75.68 - $92.68 per ton

Model based on 3.3-8 ton/hr switchgrass pelleting (King 1999)
*cost do not reflect mgmt., sales, billing, or final delivery
Economics of Pellet Production

• Drying Cost
  – Typically 1,400 – 2,000 Btu required per pound of moisture removed
  – 63% moisture to 13% moisture = 50%
  – 1,000 lbs water X 1,600 Btu = 1,600,000 Btu
  – 1.6 MMBtu X $9.00/MMBtu = $14.40
  • $28.80 / 2,000 pounds @13% moisture
Pelleting Research

- Pellet Mill Efficiencies
- Economics of Pellet Production
- Pellet Fuel Characterization
- Pellet Quality
- Combustion Characteristics
Thank You!

Questions?