Agro-energy feedstock: Miscanthus

- Miscanthus x giganteus
- Sterile hybrid propagated though rhizomes
- Bulk sample harvested in Germany Air dried and stored in freezer
- Composite sample being used for all analyses
Agro-energy feedstock: Miscanthus

- Perennial crop
  - Grows to 11-14 ft in height/year

- High biomass yields
  - C4 grass with high rate of carbon fixation
  - 14 – 17 tons/acre (up to 27 tons/acre in trials)
  - Crop stands survive 25-30 years without significant loss in biomass yields

- Presently used in Europe for power and heat generation
Moisture and Ash content

- Moisture content of air dried Miscanthus sawdust (6 mm)
  - 4.6%

- Ash content
  - Measured by ramped heating to 525 °C in a muffle furnace
  - 2.2%
  - Higher than Loblolly pine (0.2 %) & sweetgum (0.8 %)
Elemental analysis

Measured on 0.05 mm ground samples using elemental micro analyzer

Biomass to Bioethanol
Inorganic elements

- Analyzed in 6 mm ground samples
- Acid digestion followed by ICP-emission spectroscopy
- Coulometric method for total halogen (Cl+Br+I)
Inorganic elements

Biomass to Bioethanol
Inorganic elements

- **Ca**: 750.0 mg/Kg
- **K**: 2000.0 mg/Kg
- **Mg**: 1250.0 mg/Kg
- **S**: 1500.0 mg/Kg
- **Mn**: 750.0 mg/Kg
- **Cl+Br+I**: 1000.0 mg/Kg

*Species comparison:
- **Miscanthus**
- **Sweetgum**
- **L.Pine**
Extractives

- Solvent-soluble, non-volatile material
- Extracted with dichloromethane
- Characterized using GC-MS
- Extractives content:
  - 1.0 %
    - 2.9 % for Loblolly pine
    - 0.4 % for Sweetgum
  - Water soluble extractives (important for grassy biomass)
    - 3.6 %
Dichloromethane extractives composition

- Carboxylic acids
- Resin acids
- Alkanols
- Sterols
- Lignin/Aromatic

Biomass to Bioethanol
Dichloromethane Extractives: Miscanthus

- Tetradecanoic acid
- Pentadecanoic acid
- Hexadecanoic acid
- 9,12-Octadecadienoic acid
- Octadecanoic acid
- Octacosanol
- Dehydroabietic acid
- Ergosterol
- Stigmasterol
- Sitosterol

Biomass to Bioethanol
### Water soluble extractives: Miscanthus

<table>
<thead>
<tr>
<th>Compound</th>
<th>Amount (µg/g Miscanthus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha-L-Galactopyranose</td>
<td>40.24</td>
</tr>
<tr>
<td>Alpha-D-Arabinopyranose</td>
<td>52.81</td>
</tr>
<tr>
<td>Xylitol</td>
<td>512.22</td>
</tr>
<tr>
<td>D-Glucose</td>
<td>30.12</td>
</tr>
<tr>
<td>p-hydroxyl cinnamic acid</td>
<td>1145.21</td>
</tr>
<tr>
<td>D-Mannitol</td>
<td>1358.42</td>
</tr>
<tr>
<td>Mannose</td>
<td>105.84</td>
</tr>
</tbody>
</table>

- **Mannose**
- **Glucose**
- **Arabinopyranose**
- **Xylitol**
- **Mannitol**
- **P-hydroxyl cinnamic acid**
Acid soluble and insoluble lignin

- **Klason lignin**
  - Acid insoluble lignin isolated using NREL methods
  - Extractive free (40 mesh) sample hydrolyzed using 72 % H₂SO₄

- **Acid soluble lignin**
  - Measured using UV-vis spectrophotometer
  - Calculated from absorption at 205 nm

- **Pretreatment effluents**
  - pH adjusted by the addition of 72 % H₂SO₄ and autoclaved at 121 °C for 1 hour
  - Solution filtered and lignin content measured as the sum of solid residue (Klason lignin) and soluble lignin measured with UV.
Lignin content and composition

Klason lignin
Miscanthus: 25 %
Loblolly pine: 29 %
Sweetgum: 26 %

Acid soluble lignin
Miscanthus: 1.1 %
Loblolly pine: 0.5 %
Sweetgum: 2.6 %

<table>
<thead>
<tr>
<th></th>
<th>Guaiacyl</th>
<th>Syringyl</th>
<th>p-Coumaryl</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>HW</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Grass</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Biomass to Bioethanol
Carbohydrate analysis

- 40 mesh extractive free wood
- Hydrolyzed with 72% H₂SO₄
- Diluted to 3% H₂SO₄ and autoclaved at 121°C for 1 hour
- For pretreatment effluents
  - pH adjusted by the addition of 72% H₂SO₄
  - Autoclaved at 121°C for 1 hour
  - Filtered and filtrate used for sugar analysis
- Sugars measured using HPLC with pulsed amperometric detector
Carbohydrate profile

% dry weight of carbohydrates

Biomass to Bioethanol
Summary: Miscanthus composition

- Higher ash content than sweetgum or pine
  - Higher contents of P, K, Si and halides
- Dichloromethane extractives mostly carboxylic acids, alkanols and sterols
- Water extractives mostly derived from carbohydrates
- 26% total lignin content
  - Lower than woody biomass feedstocks
- Carbohydrates are mostly glucose and xylose
  - Xylose content highest among the three feedstocks