Characterization of pyrolysis products for production of biochar from Giant Miscanthus by slow pyrolysis

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Outline

- Giant Miscanthus (Geodeae-Uksae 1)
- Research Objectives
- Experimental- Slow Pyrolysis
- Results- Product Yields
- Results- Biochar Characterization
- Conclusions
Giant Miscanthus (Geodae-Uksae 1)

- **Miscanthus**
  - Perennial grass with C₄ carbon fixation
  - 17 species native mainly to Asia and Africa
  - Energy crops: M. sinensis, M. sacchariflorus, M. x giganteus

- **Geodae-Uksae 1**: Variety of *Miscanthus sacchariflorus* found in Korea
  - 4 m tall, average diameter of stalk: ~1cm
    (about twice taller and thicker than *M. sacchariflorus*)
  - Estimated yield: 30 ton/ha (air-dried basis)
  - Mass-cultivation started in 2011

Utilization of *Geodae-Uksae 1*

- **Primary routes being considered**
  - Dedicated combustion for combined heat and power
  - Biofuel production

- **Biochar production – Alternative route**
  - No major study has been carried out for biochar in Korea
    - ✓ Soil quality enhancement and increase in crop productivity yet to be proven
  - Great potential for biochar production from *Geodae-Uksae 1* as well as other agricultural biomass resources
  - Target set for reduction of greenhouse gas emission: 35% reduction on a BAU basis by 2020 in the agriculture

- **Objectives of this study**
  - To investigate the pyrolysis characteristics and biochar yield of *Geodae-Uksae 1*
  - To characterize its biochar properties
  - To produce biochar for further investigations on its behavior in water and soil
**Experimental - Slow Pyrolysis**

- Slow pyrolysis – ideal for biochar production
  - Lab-scale reactor: sample weight 250g max
  - Test conditions:
    - Temperature: 300 – 700 °C
    - Heating rate: 10 °C/min
    - Purge gas: N₂
    - Sample length: 4cm long

![Pyrolysis Reactor](image)

**Properties of Geodae-Uksae 1**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximate Analysis (wt.%) (air-dried)</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>8.27</td>
</tr>
<tr>
<td>Volatile matter</td>
<td>75.75</td>
</tr>
<tr>
<td>Fixed carbon</td>
<td>15.15</td>
</tr>
<tr>
<td>Ash</td>
<td>0.83</td>
</tr>
<tr>
<td>Ultimate Analysis (wt.%daf)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>49.05</td>
</tr>
<tr>
<td>H</td>
<td>6.21</td>
</tr>
<tr>
<td>O</td>
<td>44.57</td>
</tr>
<tr>
<td>N</td>
<td>0.17</td>
</tr>
<tr>
<td>S</td>
<td>N.D.</td>
</tr>
<tr>
<td>Lower Heating Value (MJ/kg)</td>
<td>16.78</td>
</tr>
</tbody>
</table>

**Thermo-gravimetric analysis (TGA)**

(Sample weight: 7mg, Heating rate: 10°C/min)
Product yields from slow pyrolysis of Geodae-Uksae 1

Yield at 500°C
• Char: 27.15 wt.%
• Tar: 50.03 wt.%
• Gas: 22.82 wt.%

Properties of Biochar: Proximate analysis

Proximate analysis of biochar
Properties of Biochar: C,H,O composition

Van Krevelen diagram of biochar elemental composition

Properties of Biochar - Pore volume distribution

- Macropores mainly in the range of 5-40μm
- Cell walls get thinner at higher temperatures

### Table: C content and C yield of biochar

<table>
<thead>
<tr>
<th>Temp. (°C)</th>
<th>C content (wt.%dry)</th>
<th>C yield (wt.%dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>66.19</td>
<td>73.55</td>
</tr>
<tr>
<td>400</td>
<td>74.69</td>
<td>51.86</td>
</tr>
<tr>
<td>450</td>
<td>78.29</td>
<td>51.67</td>
</tr>
<tr>
<td>500</td>
<td>79.42</td>
<td>48.36</td>
</tr>
<tr>
<td>550</td>
<td>79.43</td>
<td>46.7</td>
</tr>
<tr>
<td>600</td>
<td>83.67</td>
<td>48.65</td>
</tr>
<tr>
<td>700</td>
<td>85.93</td>
<td>48.38</td>
</tr>
</tbody>
</table>

### Pore volume distribution of biochar

Analyzer: Automated Mercury Porosimeters 9520
Sample weight: 0.0574 - 0.0663 (g)
Pressure: 0.53-60000 (psia), Pore range: 10nm – 100μm
Properties of Biochar: Surface area

\[ \text{N}_2\text{-BET Surface area for pore size range of 2-50 nm (mesopores)} \]

2. E. Gray at al, journal of Materials Science, vol 20, 597-611

Properties of Bio-oil

- Key properties of bio-oil
  - Mixture of 100+ heavy compounds
    - Light aqueous fraction and heavy oil fraction
    - Increase in the proportion of aromatic hydrocarbons above 500°C.
  - High water content: low heating value, ignition delay during combustion
  - Corrosive
  - Reploymerization
  - Formation of carbon deposit during combustion

- Practical route for utilization of bio-oil
  - Co-combustion with heavy oil
Pyrolytic Gas (Non-condensables)

- CO and CO\textsubscript{2} dominant in the early stage of pyrolysis
- H\textsubscript{2}, CH\textsubscript{4} and heavier hydrocarbons released at higher temperatures
- Potential for use as heat source for pyrolysis

![Graph showing gas composition history for pyrolysis at 700°C](Image)

Gas composition history for pyrolysis at 700°C
(purge gas: N\textsubscript{2}, 1.2 liter/min)

Conclusions

- Pyrolysis characteristics of \textit{Geodae-Uksae 1}
  - Typical pyrolysis behavior of land biomass
  - Product yield at 500°C: 27% biochar, 50% bio-oil, 23% non-condensable gases
    - Bio-oil: usable as low quality fuel for co-combustion
    - Non-condensable gases: usable as heat source for pyrolysis

- Biochar properties
  - Carbon content \textasciitilde 80wt.% (48 wt.% of carbon from raw material present in biochar)
  - Huge increase in mesopore surface area at 550°C to over 230 m\textsuperscript{2}/g
  - Macropores ranges from 5 – 40 μm

- Further investigations
  - Inhomogeneity in properties for fractions from different heights of \textit{Geodae-Uksae 1}
  - Design of efficient pyrolysis process/device
  - Biochar properties in water – including pH and adsorption
  - Biochar properties in soil
Thank you!

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