Effects of Biomass Feedstock on the Yield and Reactivity of Soot from Fast Pyrolysis at High Temperatures

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Effects of Biomass Feedstock on the Yield and Reactivity of Soot from Fast Pyrolysis at High Temperatures

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ABSTRACT - This study investigated the effect of feedstock on the yield, nanostructure and reactivity of soot. Woody and herbaceous biomass were pyrolyzed at high heating rates and temperatures of 1250 and 1400°C in a drop tube furnace. The collected solid residues were structurally characterized by electron microscopy techniques. X-ray diffraction and N2 adsorption. The reactivity of soot was investigated by thermogravimetric analysis. The results showed that the reactivity of soot, generated at 1400°C was higher than that at 1250°C for all biomass types. Wood and wheat straw soot demonstrated differences with respect to the ash content, particle size and nanostructure. Potassium was incorporated in the soot matrix and to a significant extent influenced the soot reactivity. The particle size distribution of pinewood soot produced at 1250°C was in the range from 27.2 to 283 nm which was broader compared to that of beechwood soot (from 33.2 to 102 nm) and wheat straw soot (from 11.5 to 165.3 nm). In addition, pinewood soot particles contained mainly multi-core structures at 1250°C. The potassium content played a more important role on the soot reactivity than the particle size and nanostructure.

Biomass Feedstock Composition

<table>
<thead>
<tr>
<th></th>
<th>Pinewood</th>
<th>Beechwood</th>
<th>Wheat straw</th>
<th>Alfalfa straw</th>
<th>Leached wheat straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (wt.%, ar)</td>
<td>5.1</td>
<td>4.5</td>
<td>5.5</td>
<td>5.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Ash (at 550°C (wt.%, db))</td>
<td>0.2</td>
<td>1.4</td>
<td>4.1</td>
<td>7.4</td>
<td>2</td>
</tr>
<tr>
<td>Cellulose (wt.%, db)</td>
<td>38.3</td>
<td>35</td>
<td>35.9</td>
<td>18.8</td>
<td>32.1</td>
</tr>
<tr>
<td>Hemihellose (wt.%, db)</td>
<td>17.8</td>
<td>19.2</td>
<td>18</td>
<td>12</td>
<td>23.5</td>
</tr>
<tr>
<td>Lignin insoluble (wt.%, db)</td>
<td>29.6</td>
<td>32</td>
<td>19.2</td>
<td>14.7</td>
<td>13.8</td>
</tr>
<tr>
<td>Lignin soluble (wt.%, db)</td>
<td>1.8</td>
<td>1.5</td>
<td>6.5</td>
<td>6.8</td>
<td>2</td>
</tr>
<tr>
<td>Extractives (wt.%, db)</td>
<td>8.8</td>
<td>7.5</td>
<td>10.1</td>
<td>39.6</td>
<td>13.3</td>
</tr>
<tr>
<td>Protein (wt.%, db)</td>
<td>0.6</td>
<td>1.9</td>
<td>6.3</td>
<td>5.1</td>
<td>1.3</td>
</tr>
<tr>
<td>K (mg kg⁻¹, db)</td>
<td>200</td>
<td>3600</td>
<td>11000</td>
<td>20000</td>
<td>13000</td>
</tr>
<tr>
<td>Ca (mg kg⁻¹, db)</td>
<td>600</td>
<td>2000</td>
<td>2500</td>
<td>12900</td>
<td>1300</td>
</tr>
<tr>
<td>Si (mg kg⁻¹, db)</td>
<td>50</td>
<td>200</td>
<td>8500</td>
<td>2000</td>
<td>6200</td>
</tr>
</tbody>
</table>

Methodology

1. Soot Collected at 1250-1400 °C
2. Soot characterization
   - TEM microscopy (particle size, and shape, nanostructure)
   - TEM EELS analysis
   - Ash composition analysis
   - FTIR analysis
   - X-ray diffraction
3. Yields & Composition
   - Organic
   - Ash

Reactivity (10°C min⁻¹)
5 vol.% O₂ = 95 vol.% N₂
5 vol.% CO₂ = 95 vol.% N₂
(TGA measurements were conducted dynamically)

Conclusion

- The thermogravimetric analysis results showed that the reactivity towards O₂ and CO₂ of soot depends mainly on the potassium content in the original fuel and on the heat treatment temperature and less on the soot nanostructure.
- Soot yields from pyrolysis of pinewood and beechwood were higher than from wheat straw and alfalfa straw.
- Lower lignin content leads to the lower soot yields and has stronger influence on soot yields than potassium.