Co-combustion of Lignite with Biochar

Jale Yanik, Asli Toptas, Yeliz Yildirim
Department of Chemistry, Faculty of Science, Ege University, 35100 Izmir, Turkey
Outline

- General Aspects
- Aim
- Materials and Methods
- Results
- Conclusion
What is Biochar?

Solid product from thermochemical processing of biomass

- Agro wastes
- Forest wastes
- Industrial wastes
- Animal wastes…
What is Biochar?

- lower amount of volatile organic compounds (VOCs),
- no water,
- they can be stored for many years without decay.
- The higher energy density allows savings on transport and storage compared to ordinary biomass pellets.

Biochar is higher in BTU values than white pellets with nearly identical physical qualities as coal thereby creating a value-added product.
What is Biochar?

Biochar production
Co-combustion of Lignite with Biochar

**Aim**

a solution for environmental problems related to
- wastes from agriculture and poultry farms
- greenhouse gas emissions from coal-based power plants.

Combustion behavior various raw/torrefied biomasses and their blends with a Turkish lignite were investigated by TG analysis.
# Co-combustion of Lignite with Biochar

## MATERIALS

<table>
<thead>
<tr>
<th></th>
<th>Vine stem</th>
<th>Olive stem</th>
<th>Corn stalk</th>
<th>Broiler litter</th>
<th>Laying hens litter</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proximate analysis (wt%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>8.3</td>
<td>15.6</td>
<td>10.1</td>
<td>18.4</td>
<td>18.6</td>
</tr>
<tr>
<td>Ash</td>
<td>3.9</td>
<td>2.8</td>
<td>5.7</td>
<td>6.8</td>
<td>18.3</td>
</tr>
<tr>
<td><strong>Ultimate analysis (dry wt%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>40.9</td>
<td>43.5</td>
<td>29.6</td>
<td>35.7</td>
<td>32.6</td>
</tr>
<tr>
<td>H</td>
<td>5.3</td>
<td>5.8</td>
<td>3.9</td>
<td>5.3</td>
<td>4.3</td>
</tr>
<tr>
<td>N</td>
<td>1.0</td>
<td>1.3</td>
<td>1.3</td>
<td>9.6</td>
<td>5.9</td>
</tr>
<tr>
<td>S</td>
<td>0.5</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>O</td>
<td>48.4</td>
<td>46.5</td>
<td>59.3</td>
<td>42.4</td>
<td>38.7</td>
</tr>
</tbody>
</table>

- broiler litter: poultry excreta, spilled feed, feathers, and bedding materials (straw, sawdust, etc.)
- laying hens litter: poultry excreta
### Co-combustion of Lignite with Biochar

#### Ash Composition, wt %

<table>
<thead>
<tr>
<th></th>
<th>Fe$_2$O$_3$</th>
<th>Na$_2$O</th>
<th>K$_2$O</th>
<th>MnO</th>
<th>MgO</th>
<th>CaO</th>
<th>Al$_2$O$_3$</th>
<th>SiO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHL</td>
<td>0.36</td>
<td>2.55</td>
<td>6.69</td>
<td>0.10</td>
<td>4.55</td>
<td>81.86</td>
<td>0.16</td>
<td>2.92</td>
</tr>
<tr>
<td>BL</td>
<td>0.78</td>
<td>5.11</td>
<td>26.53</td>
<td>0.11</td>
<td>6.22</td>
<td>39.52</td>
<td>1.09</td>
<td>18.73</td>
</tr>
<tr>
<td>OS</td>
<td>0.59</td>
<td>2.09</td>
<td>22.48</td>
<td>0.10</td>
<td>6.94</td>
<td>59.78</td>
<td>0.86</td>
<td>5.59</td>
</tr>
<tr>
<td>VS</td>
<td>0.67</td>
<td>4.41</td>
<td>25.69</td>
<td>0.12</td>
<td>6.46</td>
<td>53.25</td>
<td>1.48</td>
<td>6.32</td>
</tr>
<tr>
<td>CS</td>
<td>1.33</td>
<td>5.53</td>
<td>30.33</td>
<td>0.10</td>
<td>11.14</td>
<td>16.44</td>
<td>2.56</td>
<td>31.16</td>
</tr>
<tr>
<td>Lignite</td>
<td>4.17</td>
<td>0.76</td>
<td>1.41</td>
<td>0.01</td>
<td>1.73</td>
<td>2.48</td>
<td>24.08</td>
<td>53.71</td>
</tr>
</tbody>
</table>

The 3rd FOREBIOM Workshop 05 & 06 June, 2014 Anadolu University, Eskişehir, Turkey
Co-combustion of Lignite with Biochar

Composition of lignocellulosic material (wt\%)  

<table>
<thead>
<tr>
<th></th>
<th>Vine stem</th>
<th>Olive stem</th>
<th>Corn stalk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>59.1</td>
<td>49.6</td>
<td>52.1</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>5.1</td>
<td>7.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Lignin</td>
<td>25.4</td>
<td>26.7</td>
<td>34.4</td>
</tr>
<tr>
<td>Extractives</td>
<td>2.4</td>
<td>11.0</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Co-combustion of Lignite with Biochar

**EXPERIMENTAL**

Fixed bed reactor (V: 1 L)

- **Biochar yield, %** = \( \frac{\text{mass of char}}{\text{mass of biomass (db)}} \times 100 \)

- **Energy densification** = HHV of biochar / HHV of biomass

- **Energy yield, %** = biochar yield * energy densification

Heating rate: 5 °C/min
Pyrolysis temp: 250-350 °C/min
Holding time: 1 h
N2 flow: 25 ml/min.
Feed: 100 g
Co-combustion of Lignite with Biochar

Combustion Experiments

Thermogravimetric Analysis (TGA)

Experimental conditions;
- Heating rate: 20 °C /min
- Combustion atmosphere: Air
- Air flow: 100 mL / min
- Sample amount: ~ 30 mg
Co-combustion of Lignite with Biochar

Combustion Experiments

- dewatering
- volatilization and burning
- char burning
- burnout
Co-combustion of Lignite with Biochar

Data Analysis

I, ignition temperature
B, burnout temperature, the rate of weight loss become <1 wt.%/ min
M, highest dm/dT value
Reactivity = 100 x maximum combustion rate / peak temperature

Co-combustion of Lignite with Biochar

Biochar Yield

![Biochar Yield Graph]

Biochar yield, %

- CS
- OS
- VS
- LHL
- BL

- 250
- 300
- 350
Co-combustion of Lignite with Biochar

Elemental Analysis of Biochar

The 3rd FOREBIOM Workshop 05 & 06 June, 2014 Anadolu University, Eskişehir, Turkey
## Fuel properties of biochars and lignite

<table>
<thead>
<tr>
<th></th>
<th>CS</th>
<th>OS</th>
<th>VS</th>
<th>LHL</th>
<th>BL</th>
<th>Lignite</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ultimate Analysis, wt % (db)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.55</td>
<td>0.39</td>
<td>0.38</td>
<td>0.42</td>
<td>0.49</td>
<td>1.11</td>
</tr>
<tr>
<td><strong>Proximate Analysis, wt % (db)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VM</td>
<td>41.6</td>
<td>50.9</td>
<td>40.5</td>
<td>46.1</td>
<td>40.3</td>
<td>49.9</td>
</tr>
<tr>
<td>FC</td>
<td>46.1</td>
<td>40.8</td>
<td>48.7</td>
<td>15.3</td>
<td>39.5</td>
<td>38.6</td>
</tr>
<tr>
<td>Ash</td>
<td>9.3</td>
<td>4.9</td>
<td>5.5</td>
<td>35.6</td>
<td>16.4</td>
<td>11.5</td>
</tr>
<tr>
<td>HHV\textsuperscript{b}, MJ kg\textsuperscript{-1}</td>
<td>25.6</td>
<td>22.3</td>
<td>26.2</td>
<td>14.7</td>
<td>23.4</td>
<td>25.1</td>
</tr>
</tbody>
</table>
Co-combustion of Lignite with Biochar

![Graph showing H/C and O/C atomic ratios for different types of fuel, including bituminous coal, antracite, lignite, and biomass.](image)
Co-combustion of Lignite with Biochar

Energy Densifications

Energy Yields

The 3rd FOREBIOM Workshop 05 & 06 June, 2014 Anadolu University, Eskişehir, Turkey
Co-combustion of Lignite with Biochar

- Vine Stem
  - Biomass
  - Biochar

- Olive Stem
  - Biomass
  - Biochar

- Corn Stalk

- Laying hens litter

- Broiler litter
Co-combustion of Lignite with Biochar

Blend: 50 % lignite + 50 % chicken litter
Co-combustion of Lignite with Biochar

Blend: 50 % lignite + 50 % lignocellulosic biomass (OS+VS+CS)
Co-combustion of Lignite with Biochar

Blend: 50 % lignite + 50 % wastes (lignocellulosic + litter)
## Co-combustion of Lignite with Biochar

Combustion Characteristics of Wastes and Biochars

<table>
<thead>
<tr>
<th></th>
<th>Olive Stem</th>
<th>Vine Stem</th>
<th>Corn Stalk</th>
<th>Laying Litter</th>
<th>Broiler Litter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>raw</td>
<td>char</td>
<td>raw</td>
<td>char</td>
<td>raw</td>
</tr>
<tr>
<td>Ignition Temp.</td>
<td>228</td>
<td>317</td>
<td>250</td>
<td>302</td>
<td>262</td>
</tr>
<tr>
<td>Burnout Temp.</td>
<td>493</td>
<td>497</td>
<td>476</td>
<td>503</td>
<td>517</td>
</tr>
<tr>
<td>T&lt;sub&gt;max&lt;/sub&gt;, °C</td>
<td>313</td>
<td>417</td>
<td>307</td>
<td>407</td>
<td>302</td>
</tr>
<tr>
<td>Reactivity</td>
<td>3.9</td>
<td>3.2</td>
<td>5.1</td>
<td>3.1</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Co-combustion of Lignite with Biochar

Combustion Characteristics of Blends and Lignite

<table>
<thead>
<tr>
<th></th>
<th>Lignite</th>
<th>Blend 1</th>
<th>Blend 2</th>
<th>Blend 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignition Temp. ºC</td>
<td>359</td>
<td>320</td>
<td>305</td>
<td>307</td>
</tr>
<tr>
<td>Burnout Temp. ºC</td>
<td>644</td>
<td>539</td>
<td>499</td>
<td>517</td>
</tr>
<tr>
<td>$T_{\text{max}}$, ºC</td>
<td>484</td>
<td>439</td>
<td>400</td>
<td>432</td>
</tr>
<tr>
<td>Reactivity</td>
<td>1.3</td>
<td>0.8</td>
<td>1.3</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Blend 1: 50 % lignite + 50 % chicken litter chars

Blend 2: 50 % lignite + 50 % lignocellulosic biomass chars (OS+VS+CS)

Blend 3: 50 % lignite + 50 % chars derived wastes (lignocellulosic + litter)
Co-combustion of Lignite with Biochar

CONCLUSION

- Torrefaction moves the chemical and physical properties of lignocellulosic biomass and poultry litters close to that of lignite.

- Although biochars are more reactive than lignite, reactivity of blends similar to or less than that of lignite.

- Ignition and burnout temperatures of blends are lower than that of lignite.
Co-combustion of Lignite with Biochar

CONCLUSION

➢ The effect of biochar on the combustion characteristics of blend varied with kind of torrefied wastes; biochars from poultry litter led to decrease in reactivity, whereas biochars from lignocellulosic biomass led to more decrease in ignition and burnout temperatures.