Production of biochar and development of predictive methods for determining performance in value-added composite materials

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OUTLINE

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- Biochar Production
  - Feedstocks, Reactor, and Characteristics
- Biochar Distribution
  - Polyester Resin and Digital Image Analysis
- Concrete
  - Production and Results
- Conclusions
- Future Work
Composites are a mixture of polymers and solid filler materials.

Synthetic polymers are used everywhere in everyday life.
- Thermoplastics are commonly made from petroleum.

Solid fillers added for a variety of reasons (reinforcement, thermal resistance).

Carbon black is the oldest and most commonly used filler.
- Non-renewable
- Expensive

Other common fillers include sand, silica, clay, and wood.
INTRODUCTION: BIOCHAR AS A FILLER

Biochar has several characteristics that make it an ideal filler:

- Low Density- Lightweight materials!
- Black colour
- Improved Mechanical Characteristics
- Increased Thermal Stability
- Wide Range of Surface Functionalities
- Atmospheric Carbon Sequestration
- Production of Green Composites!

Filler dispersion in the composites is extremely important!

A brick made with biochar floating on water. Source: Hans-Peter Schmidt, Ithaka Institute
OBJECTIVES

- Produce large volumes of consistent biochar for realistic testing.
- Develop a predictive method for biochar distribution in resins.
- Analyze biochar performance in composite materials:
  - Thermoplastics and Concrete
  - Mechanical Strength, Thermal Stability, Acoustics
- Connect biochar properties to composite performance.
## BIOCHAR PRODUCTION: FEEDSTOCKS

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Source</th>
<th>Volatiles (%)</th>
<th>Fixed Carbon (%)</th>
<th>Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscanthus</td>
<td>Agriculture</td>
<td>86.6</td>
<td>11.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Wood Chips</td>
<td>Forestry</td>
<td>73.8</td>
<td>13.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Dry Distiller’s Grains (DDG)</td>
<td>Bio-Ethanol Production</td>
<td>82.0</td>
<td>12.6</td>
<td>5.2</td>
</tr>
</tbody>
</table>
Pyrolysis Pilot Plant:

- 3.3 L reactor
- Mechanically Fluidized
- Two Heating Sources
  - Ceramic Band Heaters
  - Induction Heating
- Two Feeding Methods
  - Side Mounted Screw Feeder
  - ICFAR “Slug Injection” Feeder (DDG)
BIOCHAR PRODUCTION: REACTOR

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Pyrolysis experiments between 350°C and 550°C.

Vapour residence time of approximately 10 seconds.

Feed rate of 1 kg per hour.

Continuous screw extractor removes biochar in a semi-batch operation:
- Feed biomass for 40 minutes.
- Extract biochar using screw for 5 minutes.
- Refill feed hopper.
Volatile matter as a function of temperature for pilot plant biochar
Ash content as a function of temperature for FCR biochar
Using ICP analysis to determine metals content.

Most prevalent metals in each biochar (in decreasing order):

- **Miscanthus:**
  - Calcium, Potassium, Magnesium, Iron, Phosphorus
- **Wood Chips:**
  - Calcium, Iron, Aluminum, Potassium, Magnesium
- **Dried Distiller’s Grain:**
  - Potassium, Phosphorus, Sulphur, Magnesium, Sodium
**OBJECTIVE:** Find a method of predicting and analyzing how biochar will distribute in materials

- Resins were created using a clear, fast curing, polyester resin.
- Solid white pigment and 6 wt% biochar added for contrasting colours.
- Digital image analysis was used to analyze the resin pixel by pixel.
- Analysis gives an average RGB intensity, and the variance of intensity among pixels (scale from 0 to 256).
- Perfect distribution would have uniform intensity, no variance.
Four replicates of different biochar/resin composites were created.

Testing for reproducibility.

Checking that different biochar would give different results:

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Pyrolysis Method</th>
<th>Temperature °C</th>
<th>Volatile Matter %</th>
<th>Fixed Carbon %</th>
<th>Ash Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscanthus</td>
<td>Slow</td>
<td>500</td>
<td>7.5</td>
<td>81.4</td>
<td>11.0</td>
</tr>
<tr>
<td>Miscanthus</td>
<td>Fast</td>
<td>500</td>
<td>19.4</td>
<td>70.6</td>
<td>10.0</td>
</tr>
<tr>
<td>DDG</td>
<td>Fast</td>
<td>400</td>
<td>54.7</td>
<td>34.8</td>
<td>10.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Biochar Added</th>
<th>Final Composite Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow Miscanthus</td>
<td>6 wt%</td>
<td>1221 ± 40 g/L</td>
</tr>
<tr>
<td>Fast Miscanthus</td>
<td>6 wt%</td>
<td>1220 ± 84 g/L</td>
</tr>
<tr>
<td>DDG</td>
<td>6 wt%</td>
<td>1293 ± 69 g/L</td>
</tr>
</tbody>
</table>
## BIOCHAR DISTRIBUTION: RESULTS

<table>
<thead>
<tr>
<th>Biochar Used</th>
<th>RGB Intensity</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscanthus- Slow, 500°</td>
<td>125.3 ± 13.8</td>
<td>1.579 ± 0.265</td>
</tr>
<tr>
<td>Miscanthus- Fast, 500°</td>
<td>139.7 ± 11.3</td>
<td>1.132 ± 0.085</td>
</tr>
<tr>
<td>DDG- Fast, 400°</td>
<td>145.2 ± 3.4</td>
<td>1.440 ± 0.196</td>
</tr>
</tbody>
</table>

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**Miscanthus- Slow, 500°**

**Miscanthus- Fast, 500°**

**DDG- Fast, 400°**
More resins were made using miscanthus biochar produced at different temperatures:
Portland Cement
- 3:1 Sand Ratio
- 3:1 Aggregate Ratio

Biochar and carbon were added in place of sand or aggregate.

Three different moulds
- 30 cm x 30 cm x 3 cm
- 10 cm x 10 cm x 2 cm
- 10 cm diameter x 2 cm

Subjected to mechanical, thermal, and acoustic testing.
The addition of biochar and activated carbon greatly reduced the density of the concrete.
Biochar and activated carbon increased the porosity of concrete layers. This results in higher levels of sound absorption. Increasing levels of biochar and activated carbon levels does not further increase absorption.
The Pyrolysis Pilot Plant is capable of producing large quantities of biochar from various feedstocks over several hours of operation.

The polyester resin/biochar composites produce reproducible values of RGB intensity variance representing the distribution of biochar.

The resin/biochar composites showed quantifiable differences in biochar distribution as biochar characteristics changed.

The addition of biochar greatly reduced the final density of the concrete, regardless of whether the sand or aggregate was replaced.

The biochar addition increased the sound absorption properties of the concrete samples.
Collaboration with Professor Alberto Tagliaferro’s group of the Politecnico di Torino.

- Special thanks to Alberto Tagliaferro, Mauro Giorcelli, Pravin Jagdale, and Patrizia Savi.

Incorporating the biochar into thermoplastics:

- Determine mechanical and thermal properties of composites.
- Investigate how results correlate to biochar characteristics.
- See how the results of the polyester resin correspond to the results of the thermoplastics.
- Large volume production of biochar with desirable properties.
Further testing of concrete samples with added biochar:
- Determine the extent and limitations of mechanical reinforcements.
- Determine thermal stability of the concrete samples.
- Find optimal levels of biochar addition for different concrete characteristics.
- Investigate which properties have an impact on concrete characteristics.
ACKNOWLEDGEMENTS

Thank you to:

- Venkateswara Reddy Kandlakuti, ICFAR Laboratory Technician
- Thomas Johnston, ICFAR Technologist
- Natural Sciences and Engineering Research Council of Canada
- Ontario Research Fund
- Verti-Crete of Toronto
THANK YOU!

Questions?