Hydrothermal Carbonisation of Spent Coffee Grounds and Subsequent Anaerobic Digestion of Process Water

Bethany Campbell

Dr Judy Lee
Prof. Rex Thorpe
Dominik Peus
Waste Biomass

- Abundant
- High water content
- Low energy content

Sewage sludge
80 % moisture

Food waste
70 % moisture

Green waste
29 - 46 % moisture
Hydrothermal carbonisation (HTC)

• Complete immersion in liquid water
• 180 – 300 °C
• Autogenous or applied pressure (10 – 50 bar)

Kumar, S. (2010) pp. 1
HTC Products

- Hydrochar solid product
  - Reduced O/C and H/C ratios
  - Improved fuel and combustion properties
  - Easier to dewater

- Polluted process water
  - High COD and BOD
  - Low pH
  - Colouring
  - Solubilised inorganic Content

- Gas

Spent coffee grounds (SCG)

- Consistent model system for scientific purposes
- 10 million tons of coffee produced in 2018 globally [1]
- ~ 6 million tons of SCG as waste each year [2]
- Currently incinerated
- Moisture content of 55 – 80 % [3]

Spent Coffee Grounds

UltraPure Water

10 wt% DS input

COD = 33,700 mgO₂/L
pH = 3.92

Dischargeable effluent [1]
COD < 125 mgO₂/L
Or > 75% COD reduction

HTC of SCG

### Input

<table>
<thead>
<tr>
<th>Spent Coffee Grounds</th>
<th>Value</th>
<th>Error (+/-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (g)</td>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>TC (%)</td>
<td>53.6</td>
<td>0.9</td>
</tr>
<tr>
<td>C (g)</td>
<td>32.2</td>
<td>0.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Carbon (g)</strong></td>
<td><strong>32.2</strong></td>
</tr>
</tbody>
</table>

### Output

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Error (+/-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Char</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (g)</td>
<td>33.4</td>
<td>1.1</td>
</tr>
<tr>
<td>TC (%)</td>
<td>79.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Solid C (g)</td>
<td>26.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Liquid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>0.55</td>
<td>0.00</td>
</tr>
<tr>
<td>TC (g/L)</td>
<td>9.83</td>
<td>0.44</td>
</tr>
<tr>
<td>C (g)</td>
<td>5.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RHP (bar)</td>
<td>2.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Head vol (ml)</td>
<td>200</td>
<td>20</td>
</tr>
<tr>
<td>CO2 (mol)</td>
<td>0.023</td>
<td>0.006</td>
</tr>
<tr>
<td>C (g)</td>
<td>0.276</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Carbon (g)</strong></td>
<td><strong>32.1</strong></td>
</tr>
</tbody>
</table>

- Solid Yield 56 ± 2 %
- Carbon Yield to Solid 82 ± 4 %
- Carbon Yield to Liquid 17 ± 1 %
Anaerobic Digestion of Treated and Untreated PW

Experiment AD I

Feed
- Day -14 - 0: glucose
- Day 1 – 146: untreated process water

Experiment AD II

Feed
- Day -14 - 0: glucose
- Day 1 – 34: untreated process water
- Day 35 – 77: treated process water

33,700 mgO₂/L

27,900 mgO₂/L

Discussed in the paper to be published associated with this conference!
Anaerobic Digestion of Untreated PW

Variable initial CH₄ production

Stable CH₄ production

Increased OLR

Decreased OLR

82 – 87 % CH₄ biogas throughout

Day 0 – 90: 0.4 gₐCOD L⁻¹ d⁻¹
Day 90 - 125: 0.77 gₐCOD L⁻¹ d⁻¹
Day 125 – 148: 0.31 gₐCOD L⁻¹ d⁻¹
Anaerobic Digestion of Untreated PW

Graph showing the changes in pH and VFA/TA over time. Key points:
- Initial drop in pH and increased VFA/TA
- Increased alkalinity
- Improved stability
- Increased OLR
Anaerobic Digestion of Untreated PW

Effluent COD (mgCOD L⁻¹)

Day

COD Degradation Efficiency (%)
Conclusion

• HTC recovers 82 % of the C from SCG
• Subsequent AD recovers up to 49% of the aqueous COD as CH₄
• Total C recovery as useable fuel = 90%
• No obvious inhibitory compounds
• Issues with stability potentially due to overloading at start of experiment
Thank you – any questions?

Acknowledgements:
Antaco – Funding and Project direction
Dan Driscoll and Ben Gibbons (University of Surrey) – Aid in Use of Analytical Instruments
Anaerobic Digestion of Treated and Untreated PW

\[
\text{COD degradation efficiency, } t \ (\%) = \frac{\text{COD}_{\text{AD},t-1} \cdot V_{\text{AD}} - \text{COD}_{\text{AD},t} \cdot V_{\text{AD}}}{\text{COD}_{\text{Inf},t-1} \cdot V_{\text{Inf}}}
\]

\(\text{(yesterday absolute COD (g) after addition) – (today absolute COD (g) before removal)}\)

\(\text{absolute COD (g) added}\)