Charcoal for terra preta

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Modern Biomass Refineries

• Ethanol from corn grain and biocarbons from corn stover (USA)
• Biodiesel from sunflower oil and biocarbons from sunflower shells and stalks (EU)
• Biodiesel from coconut oil and biocarbons from coconut shells, fronds, etc. (Malaysia)
• Biodiesel from marine algae and biocarbons from residual (dry) algal material (Hawaii)
# Fuel Costs

<table>
<thead>
<tr>
<th>FOSSIL</th>
<th>RENEWABLE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>Charcoal</td>
<td>$8/GJ</td>
</tr>
<tr>
<td>Oil</td>
<td>Ethanol</td>
<td>$14/GJ</td>
</tr>
<tr>
<td>Gas</td>
<td>Hydrogen</td>
<td>$18-24/GJ</td>
</tr>
</tbody>
</table>
How can we use charcoal?

- Potting soil (orchids and ornamentals)
- Cooking (barbeque) fuel
- Ultra clean coal (power production)
- Activated carbon (water treatment)
- Metal reductant
- Terra preta (carbon sequestration!)
- Biocarbon fuel cell
Some questions concerning the production of biocarbons:

1. In theory, what limits the yield of bioC (charcoal) from biomass?
2. In theory, what is the energy conversion efficiency of biomass into bioC?
3. In practice, what yield and energy conversion efficiency can be achieved?
4. In practice, how quickly can we convert biomass to bioC?
Useful definitions:

1. \( y_{\text{char}} = \frac{m_{\text{char}}}{m_{\text{bio}}} \)

2. \( 100 = \% \text{ VM} + \% \text{ fC} + \% \text{ ash}; \text{ where} \)
   
   \( \text{VM} = \text{volatile matter}; \text{ fC} = \text{fixed carbon} \)

3. \( y_{\text{fC}} = y_{\text{char}} \times \left\{ \% \text{ fC} / (100 - \% \text{ feed ash}) \right\} \)

4. \( \eta_{\text{char}} = y_{\text{char}} \times \left( \frac{\text{HHV}_{\text{char}}}{\text{HHV}_{\text{bio}}} \right) \)

- C, H₂O, CO₂, and CH₄ are the only significant products.
- The theoretical charcoal (i.e. C) yield is 28 wt%.
- The gas contains significant energy (i.e. CH₄).
Reaction stoichiometry for the products of cellulose pyrolysis at 400 C & 1 MPa (*Ind. Eng. Chem. Res.* 2003, 42, 3690-3699)

\[
C_6H_{10}O_5 \rightarrow 3.74 \text{ C} + 2.65 \text{ H}_2\text{O} + 1.17 \text{ CO}_2 + 1.08 \text{ CH}_4
\]

- Pressure strongly favors formation of charcoal.
- Low gas flow rates also favor the formation of charcoal.
- Elevated pressure and low flow rates together double the yield of charcoal.
Flash Carbonization™ reactor schematic (U.S. patent # 6,790,317; September 14, 2004).

- Fixed-carbon yields from corn cob, oak, and macshell approach the theoretical limit.
- Leucaena offers almost 90% of the theoretical limit.
Flash Carbonization™ demo reactor on the UH campus

![Image of Flash Carbonization demo reactor on the UH campus]
Terra Preta (Amazonian Dark Earths): Highly Fertile Anthropogenic Soils
Terra Preta Soil

Photo source: University of Bayreuth

Typical Upland Amazonian Soil

Photo source: University of Bayreuth

Nov 27, 2007
Effect of Terra Preta on Plant Growth

Photo source: http://tinselwing.wordpress.com/tag/terra-preta/

Terra Preta
Nov 27, 2007

www.hnei.hawaii.edu
www.ctahr.hawaii.edu

Unamended Soil
Volcanic ash soil treated with flash carbonized macadamia nut shell charcoal

0% (w/w)  5% (w/w)  10% (w/w)  20% (w/w)
Control  20% (w/w) charcoal
Charcoal Effect in an Acid, Infertile Soil

0%  5%   NPK + Lime
Preliminary Conclusion:

Charcoal used in the experiment caused a negative effect on plant growth

But why?
• Crop?
• Soil??
• Charcoal???
• **Volatile Matter (VM) content**: a measure of the susceptibility of charcoal to further decompose and form carbon when heated

![Hydrophobic](image1.png) ![Hydrophilic](image2.png)

*22.5% VM Content*  
Nov 27, 2007

*6.3% VM Content*  
www.hnei.hawaii.edu  
www.ctahr.hawaii.edu
Effect of High Volatile Matter (22.5%) Charcoal on Plant Growth
Effect of Low Volatile Matter (6.3%) Charcoal on Plant Growth
Low Volatile Matter Charcoal (6.3%) versus High Volatile Matter Charcoal (22.5%)
Combined Effect of Low Volatile Matter Charcoal Plus Fertilizer

NPK + Lime

NPK + Lime + 10% Low VM
Volatile Matter or Feedstock?

- VM content affected plant growth in macnut shell charcoal
- Does feedstock make a difference?
- Repeat trial with corn cob charcoal
Effect of corn cob charcoal on soybean

Control  High VM  Low VM
Waller-Duncan K Ratio $t$-test

Soybean Fresh Weight (g/pot)

Control  HVM  LVM

- Control
- HVM
- LVM

Legend:
- a
- b

Note: The diagram shows the fresh weight of soybeans for different treatments labeled as Control, HVM, and LVM.
Conclusions

• Volatile matter content influences a charcoal’s effectiveness as a soil amendment
• Low volatile matter charcoals are more effective soil amendments than high volatile matter charcoals
Future Studies

• Will the positive effects observed in greenhouse tests carry over into field trials?
• Will the positive effects persist or diminish with time?
• Will the negative effects of high volatile matter charcoal persist or diminish with time?