**Effect of biochar amendment on soil carbon balance and soil microbial activity**

S. Steinbeiss¹, G. Gleixner¹, M. Antonietti²

¹Max Planck Institute for Biogeochemistry Jena, ²Max Planck Institute of Colloids and Interfaces Golm

---

**Introduction**

The increased burning of fossil fuels for energy supply within the last 100 years released huge amounts of carbon dioxide into the atmosphere. In contrast, the naturally build-up of fossil fuel deposits takes millions of years. To counteract the problems following increasing atmospheric CO2 concentrations, methods have to be developed to retain organic carbon in a stable form that can be stored for longer time periods.

We investigated the behavior of hydrothermally synthesized biochar in two soil types, arable soil and forest soil, that differ in the composition of their microbial community. Parent material for biochar production was glucose and yeast, respectively, at which the yeast-derived biochar contained 5 % nitrogen. Labeling of the biochar with 13C enabled the quantification of carbon losses via respiration and the calculation of turnover times for both biochars in the different soils.

The extraction of phospholipid fatty acids from soils incubated with biochar was used as tool to quantify microbial biomass in the soil and to identify groups of microorganisms that are able to utilize biochar as carbon source.

**Results**

Respiration rates strongly decreased during incubation in all treatments (Fig. 1).

Biochar addition always increased soil organic carbon loss. Yeast-derived biochar seemed to be better degradable than glucose-derived biochar in arable and forest soil (Fig. 2).

Calculated turnover times varied between 4 and 29 years depending on biochar and soil type (Fig. 3).

Soil microbes utilized both biochars. Glucose-derived biochar was primarily decomposed by gram-negative bacteria, while yeast-derived biochar was taken up by fungi (Fig. 4).

Consequently, yeast-derived biochar strongly increased the proportion of fungi in the soil microbial community (Tab. 1).

**Conclusions**

Mean residence times of the biochars demonstrate that biochars produced by hydrothermal pyrolysis would add to the decadal soil carbon pool.

Inherited soil microorganisms were able to adapt to the new carbon source and utilized both types of biochar.

Condensation grade and chemical structure of the biochars were the main drivers for all differences observed between our treatments.

Our results suggest that residence times of biochar in soils can be manipulated with the aim to "design" the best possible biochar for a given soil type.

**Fig. 1:** Respiration rates for all treatments including controls during incubation.

**Fig. 2:** Losses of biochar carbon and soil organic carbon after four months of incubation given relative to the respective initial amounts in the treatments.

**Fig. 3:** Calculated mean residence times for the biochars in the different treatments. Error bars reflect the uncertainty caused by the variability of the proportion of biochar carbon in the respiration gas.

**Fig. 4:** Isotopic shift of PLFA biomarkers (treatment after incubation – initial values) for certain microbial groups, i.e. fungi, gram-negative bacteria, gram-positive bacteria and bacteria in general. Error bars reflect variability in isotopic shift within a group of microorganisms.

**Table 1: Proportion of the amount of PLFAs assigned to different microbial groups, i.e. fungi, gram-negative bacteria, gram-positive bacteria and bacteria in general, before and after incubation; sd refers to standard deviation between three replicates.**

<table>
<thead>
<tr>
<th>treatment</th>
<th>fungi</th>
<th>sd</th>
<th>gram(-) bacteria</th>
<th>sd</th>
<th>gram(+) bacteria</th>
<th>sd</th>
<th>bacteria</th>
<th>sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arable/Initial</td>
<td></td>
<td>0.1</td>
<td>41.9</td>
<td>0.9</td>
<td>25.9</td>
<td>0.1</td>
<td>11.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Arable/Glucose</td>
<td>10.8</td>
<td>0.3</td>
<td>41.8</td>
<td>2.1</td>
<td>25.0</td>
<td>2.4</td>
<td>13.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Arable/Yeast</td>
<td>28.0</td>
<td>0.9</td>
<td>30.7</td>
<td>0.7</td>
<td>18.8</td>
<td>0.5</td>
<td>15.7</td>
<td>0.2</td>
</tr>
<tr>
<td>Forest/Initial</td>
<td>11.0</td>
<td>0.2</td>
<td>43.6</td>
<td>0.5</td>
<td>26.8</td>
<td>0.4</td>
<td>10.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Forest/Glucose</td>
<td>10.7</td>
<td>0.2</td>
<td>37.7</td>
<td>0.3</td>
<td>29.9</td>
<td>0.4</td>
<td>13.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Forest/Yeast</td>
<td>27.6</td>
<td>0.8</td>
<td>28.9</td>
<td>0.3</td>
<td>20.3</td>
<td>0.7</td>
<td>16.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Arable</td>
<td>12.0</td>
<td></td>
<td>41.9</td>
<td></td>
<td>26.9</td>
<td></td>
<td>11.6</td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>10.9</td>
<td></td>
<td>39.0</td>
<td></td>
<td>27.3</td>
<td></td>
<td>14.5</td>
<td></td>
</tr>
</tbody>
</table>

**Experimental design**

- Arable soil from Jena Experiment field site
  - Initial Carbon content: 2.5 %
  - Signature: A
  - Δ13CCO2 = -27.7 ‰

- Forest soil from Hainich National Park
  - Initial Carbon content: 5.5 %
  - Signature: F
  - Δ13CCO2 = -27.1 ‰

**Arable soil**

- Control (A)
- + biochar from Glucose (AG)
- + biochar from Yeast (AY)

**Forest soil**

- Control (F)
- + biochar from Glucose (FG)
- + biochar from Yeast (FY)

- Biochar addition corresponding to 30 % of initial soil carbon content
- Labelling of biochar with 13C
- Biochar derived from glucose
  - Δ13CCO2 = 3.6 ‰
- Biochar derived from yeast
  - Δ13CCO2 = -2.8 ‰