**Influence of artificial biological aging on physicochemical, biological and ecotoxicological properties of five biochars - a laboratory incubation study**

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**Highlights**

* Each biochar possessed increased microbial activity after aging
* Increased biological activity was associated with decreased available nutrients
* Initial specific surface area highly affected the aging-mediated changes

**1. Introduction**

Biochar (BC) is a solid by-product of biomass combustion under oxygen limited conditions, known as pyrolysis [1]. Biochar proved to be useful as soil amendment [2], and considered effective in carbon sequestration and reduction of agricultural greenhouse gas emissions [1,2], contaminant and heavy metal removal, and other applications [1,2]. Biochar effects as soil amendment do not only depend on soil properties, biochar production conditions, but also on a variety of temporal processes in the environment, called “aging”, including abiotic and biotic redox reactions, interactions with microbes, organic matter, minerals and solutes in the soil environment [3]. Progressive aging alters biochar quantity and quality [4]. This paper evaluates the effects of simulated conditions of artificial biological aging on the physicochemical, biological, ecotoxicological properties of five biochar types compared to their properties before aging. The aim is to support efficient long-term utilization of biochar in soil focusing also on the potential environmental risks posed to soil biota.

**2. Methods**

Triplicate samples of five biochar (BC) types were “aged” by placing samples in 750 mL glass containers so that three calcareous sandy soil layers alternated with the biochar layers. The biochar types were the following: grain husk and paper fibre sludge BC (A1), wood screenings BC (B1), woodchips BC (F1), herbal pomace BC (H1), miscanthus BC (M2). The containers were covered with perforated aluminium foil, so that drying could not occur over 11 weeks; microcosms were watered every 3 week with 20 mL microbial inoculant optimized for calcareous soil. Aerobic conditions were provided by glass capillary tubes inserted into the layers. After 11 weeks the biochar and soil layers were carefully separated and removed. The biochars before and after aging were examined by an integrated methodology, including physicochemical (pH, electric conductivity (EC), specific surface area (BET), loss on ignition (LOI), water holding capacity (WHC), permanganate oxidizable carbon (POXC), cation exchange capacity (CEC), organic matter (OM), plant available nutrients (NPK), heavy metals, metalloids, other elements), biological (aerobic heterotrophic cell counts) and ecotoxicological methods (*Sinapis alba* shoot- and root inhibition test, *Folsomia candida* mortality tests*).*

**3. Results and discussion**

Significant differences between biochars before and after aging were determined by one-way Analysis of Variance (ANOVA) using StatSoft® Statistica 13.1. Table 1 shows the summary of the main effects of biochar aging compared to before aging.

**Table 1** Summary of the main effects of biochar aging.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Biochar type** | ***pH*** | ***EC*** | ***LOI*** | ***WHC*** | ***BET*** | ***Pore vol.*** | ***POXC*** | ***OM*** | ***NO3-N*** | ***P2O5 / K2O*** | ***CEC*** | ***CFU***  ***Bacteria*** | ***Plant growth*** |
| **A1** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **+** | **-** |
| **B1** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **+** | **-** | **0** | **+** | **+** |
| **F1** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **+** | **-** | **-** | **+** | **+** |
| **H1** | **-** | **-** | **-** | **0** | **0** | **0** | **-** | **-** | **+** | **-** | **-** | **+** | **0!** |
| **M2** | **0** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **+** | **-** | **-** | **+** | **-** |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **–** | significant decrease | **–** | decrease | **+** | significant increase | **+** | increase | **!** | ecotoxicity | **0** | no effect |

Each biochar underwent changes through the aging process, especially regarding nutrients and biological activity. The accelerated biological aging resulted in higher microbial activity in case of all biochars depending on their surface areas (BET). The highest increase (more than two-fold) was found for M2 and F1 biochars with the largest (BET). BET values of biochars correlated with the aerobic heterotrophic cell counts (CFU) of weathered biochars. The total N content of each biochar decreased - except A1 with the highest initial NO3-N content – while there was an increase in the available nitrate due to the increased bacterial activity. Most of biochars exhibited significant decrease (~40–60%) in the pH, OM and permanganate oxidizable (labile) carbon content (POXC) as well as in available K and P upon aging. These changes were accompanied by decreases in biochar CEC however previous studies reported higher CEC of biochar after aging. We assume that enhanced bacterial activity triggers microbial OM production and sorption of OM, resulting in a range of new organic functional groups affecting CEC.

**4. Conclusions**

Based on our results the specific surface area of non-aged biochars highly affected the aging-mediated changes. Percentage decrease in available nutrients and labile carbon was the lowest while the decrease in CEC was the highest in the case of M2 biochar with the highest specific surface area suggesting that M2 would be the most efficient and stable charcoal on the long term. Artificial biological aging of biochar represents a promising model for studying weathering effects. Further comparative evaluation of the outcomes of biochar aging in the soil matrix under real field conditions is planned.

**References**

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