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Short communication

Ecotoxicity tests on solid residues from microwave induced pyrolysis of different organic residues: An *addendum*

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ABSTRACT

Microwave-induced pyrolysis of organic wastes has been demonstrated to be a suitable technology for the production of syngas ($H_2 + CO$). However, there is a need for developing alternatives to manage the residual streams from this process. In this short communication, the use of the solid fraction from microwave-induced pyrolysis as a soil conditioner and its ecotoxic effect on the growth of barley and cress plants have been studied. The porous structure of these chars has been found out to be one of the possible factors related to the germination rates. This alternative has resulted to be highly promising since the toxic effect on plants germination was very limited or non-existing regardless of the municipal waste char composition.

1. Introduction

Pyrolysis of complex residues, such as municipal solid wastes, involves the production of a solid fraction (char) which usually has a low value owing to its high ash content [1–3]. Among the different recycling alternatives, char is typically used as a raw material for fueling [4,5] and the production of adsorbents [6,7]. However, ashes lead to a decrease in the calorific value of the chars and carbon concentration, probably being more feasible their use as a soil amendment since they are known to increase soil fertility and cycle nutrients back into agricultural fields [8]. The influence of different pyrolysis parameters on the stability, nutrient availability, salinity, hydrophobicity or pH of the chars has been studied [1,9]. In general, chars from high temperature pyrolysis use to be alkaline, with a more developed porosity and higher amounts of ashes. These characteristics make chars to be useful on excessive acid soils to improve the availability of nutrients or in soils with low water retention. Furthermore, high temperature-derived chars have been pointed out to be especially attractive for sequestering carbon, since they contain highly recalcitrant carbon that can stay for years in the soil [1].

During the last years, a series of investigations on the microwave-induced pyrolysis (MIP) of different organic substrates were carried out. Results regarding the influence of operational conditions on the gas and oil fractions were published in *Journal of Analytical and Applied Pyrolysis* [10,11]. This short communication is an *addendum* to those works. Herein, the possibility of using the solid residue from the pyrolysis of municipal solid wastes, both dried and wet, and agricultural waste (straw) as an additive to soils is evaluated from a biological standpoint by means of plant toxicity tests.

2. Experimental procedure

2.1. Char preparation

The biochars were obtained by means of MIP of three different feedstocks:

1. An organic fraction from a municipal solid waste (MSW), obtained from a landfill in Seville (Spain). This fraction was subjected to a size reduction of 1–3 mm. The MSW-derived char is labelled as MSW-Char.
2. An organic fraction from a municipal solid waste, dried and partially cleaned from inerts (MSWd). This fraction was taken from the previous fraction (MSW) and subjected to removal of moisture and inert solids, such as glass or metals. After this pre-

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treatment, the fraction size was reduced to 1–3 mm. The char produced from this fraction is labelled as MSWd-Char.

3. An agricultural residue. This sample was obtained from a biodiesel production plant located in Salamanca (Spain) and is composed of straw. The sample was also milled to a size range of 1–3 mm. The straw derived char is labelled as STR-Char.

MIP was performed using an unimode microwave oven provided by MES (*Microondes Énergie Systèmes*) consisting of a microwave magnetron with a maximum output power of 2 kW operating at 2450 MHz and a single mode cavity where the sample-containing quartz reactor was placed. To ensure an oxygen-free atmosphere, the reactor was purged with N_2 for 30 min at a flow rate of 50 mL_{STP} min^{-1}. Then, the flow rate was reduced to 10 mL_{STP} min^{-1} and the microwave irradiation was switched on during 1 h, being regulated to reach 800 °C. More details on the experimental work can be found in a previous publication [10].

Biochars from MIP were characterized as follows. The moisture, ash and volatile matter content were obtained by means of a LECO TGA-601. To perform the ultimate analysis, a LECO-CHNS-932 micro-analyzer and a LECO-TF-900 furnace were used. The micro-analyzer provides carbon, hydrogen, nitrogen, and sulfur percentage composition. The oxygen content was determined by difference (Table 1).

The content of metals from the char was determined by means of atomic absorption spectroscopy using an Agilent 7700x device. The results from this characterization are presented in Table 2 along with the limit levels on heavy metals as defined by the European Ecolabel on soil improvers [12].

2.2. Plants growth tests

The plant tests were executed in line with the OECD Guideline for Testing of Chemicals 208 *Terrestrial Plant Test: Seedling Emergence and Seedling Growth Test* (2006). The different chars were therefore mixed with natural soil in a 1 wt.% and 3 wt.% concentration (on wet weight basis) and the germination and growth of two different higher plant species (barley (*Hordeum vulgare*) and cress (*Lepidium sativum*)) were evaluated. The compost usage to arable land is in many European countries restricted till 15 ton dry compost ha^{-1} y^{-1}, but in Austria a dosage of 40 ton dry compost ha^{-1} y^{-1} can be applied for non-food regular application [13]. Taking into account a normal depth of soil tillage of 0.2 m and a soil density of 1500 kg m^{-3}, this results in a maximum addition of compost (dry weight) to arable soil of 1.3 wt.%. The 3 wt.% concentration consequently includes a safety factor of 2.3. The tests were performed in triplicate using 180 g of natural soil to which chars from MSW, MSWd and STR were added in two different concentrations; also the natural soil without addition (blank) was tested. The applied soil was sandy-loam type (clay: 12.0%, silt: 21.2% and sand 66.8%). The soil was a mixture of equal amounts of natural soils collected on three different locations in Belgium (Lokeren and Moerbeke). Before use, the soils were sieved over a 2 mm screen to remove stones and other inert materials, recognizable roots and other plant debris, and thoroughly mixed. The duration of the tests was 10 days (in the case of barley) and 14 days (in the case of cress) and the relative germination rate (percentage of germinated plants compared to the total number of seeds initially added to the soil), as well as the fresh and dry biomass weight yields (mass of plants produced, fresh and after a drying step, respectively) were evaluated.

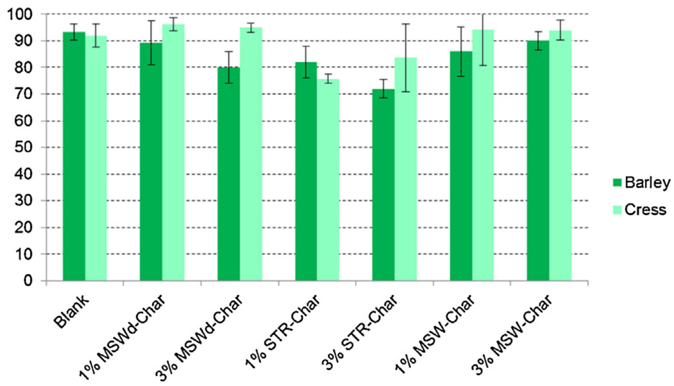

Fig. 1. Relative germination rate (%) of barley and cress using different char types and concentrations.

2.3. Porosity determination

Skeletal and bulk densities were determined by helium (Accupyc II 1340, Micromeritics) and envelope (Geopyc 1360 Envelope Density Analyzer, Micromeritics) pycnometry, respectively. The overall porosity was determined from the bulk and skeletal densities.

3. Results and discussion

The relative germination rate of the two plants in the different amended soils is represented in Fig. 1. In general, this parameter remains at a value of ca. 90% with the exception of STR-Char soils.

The biomass production yields are shown in Fig. 2. Fresh yields are always higher than dry yields due to the amount of accumulated

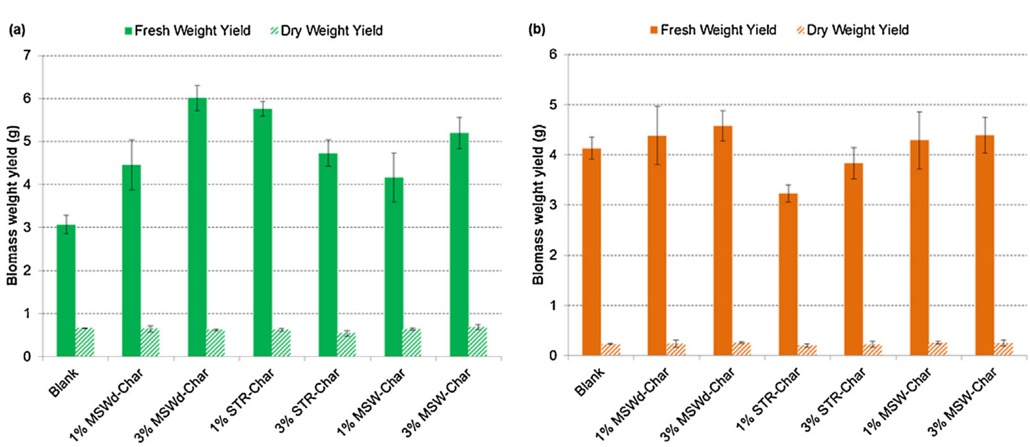

Fig. 2. (a) Barley plants and (b) Cress plants yields using different char types and concentrations.