Food waste hydrochar and biochar as soil amendments: Effect of hydrochar post-treatments

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The depletion of fossil resources and the biowaste accumulation in urban areas have promoted a deep global change in terms of minimizing the latter´s environmental impact and maximizing its lifetime on a circular economy framework [1]. In addition, food safety is also in danger due to the soil degradation promoted by intensive agriculture. Food waste (FW) is the main urban biowaste and can be valorized by diverse thermochemical technologies such as pyrolysis or hydrothermal carbonization (HTC) for biochar and hydrochar production, respectively. Due to their high content of carbon and nutrients, chars are promising products with diverse applications in agriculture such as C sequestrators, bioremediation and soil amendments [2]. The addition of biochar and hydrochar may effectively increase the porosity and decrease the bulk density of soils, raising crop productivity through nutrient availability [3].

The aim of this work is to evaluate the potential application of biochar, fresh hydrochar, and post-treated hydrochar obtained from FW as a soil amending agent. The germination index (GI) of tomato (Marmande RAF) seed was used to analyze the potential phytotoxic effect of adding char (1 – 5%) to a marginal agricultural soil.

FW obtained from a municipal solid waste treatment plant located in Madrid (Spain) was crushed until a smooth paste and stored in airtight buckets at 4 ºC until use. Biochar was produced by pyrolyzing FW in a rotatory reactor tube furnace equipped with a quartz tube at 900 °C for 90 min, using N_2 to ensure an oxygen-free atmosphere. On the other hand, the HTC of FW was carried out at 180 °C for 1 h. The liquid fraction was separated by filtration and the hydrochar was dried at 100 ºC for 24 h. That solid, referred as fresh hydrochar (FHC), was subjected to different post-treatments after washing thrice with deionized water in a 1:10 (w:v) ratio. The resulting suspension was shaken at 120 rpm for 1 h, centrifuged, and filtered to obtain washed hydrochar (WaHC). Then, some samples of WaHC were placed on trays for 4 months at room temperature and turned periodically to allow their maturation through air exchange, obtaining an aged hydrochar (AHC-W). On the other hand, WaHC was thermally treated at 650 °C for 90 min, in the rotatory tube furnace previously described, to produce thermally treated hydrochar (THC-W). The characterization of the feedstock, hydrochar and biochar included the determination of the moisture, ash, volatile matter (VM), and fixed carbon (FC) by thermogravimetric analysis according to ASTM-D7582. The elemental composition (C, H, N, and S) was determined on a CHNS analyzer, and the rest of the elements were quantified by inductively coupled plasma atomic emission spectroscopy (ICP-MS). Individual volatile fatty acids (VFA) (C2 - C7, including iso-forms) in the effluents of the washing process were identified using gas chromatography-mass spectrometry. pH and electrical conductivity (EC) were measured following the standard methods (UNE-EN 13037-13038).

A marginal agricultural sandy loam soil (Burgos, Spain) with 1% of organic matter, low clay concentration (8%), and a pH of 8.4, was mixed with FHC, WaHC, AHC and THC, and biochar. Prior to germination, mixtures were watered at 75% water holding capacity and stabilized for 1 week in darkness at 28 °C. Germination tests of tomato seeds (Marmande, RAF) were performed on Petri dishes using bare soil as control and soil-char mixtures at 1, 3, and 5% (on a dry-weight basis). Six replicates of each trial were prepared and one was used for pH and EC determination after stabilization. In each replicate, ten seeds of tomato were sown per plate and placed in the dark at 28 °C for 2 d, and then transferred to a growth chamber set at 26 °C/20 °C with a 13 h/11 h light/dark photoperiod. The gemination index (GI) was determined 7 days after sowing (DAS).

Table 1 shows chemical characterization of feedstock and chars. Hydrochars presented a lower pH than raw waste except for THC, since higher temperatures promoted a basic pH. Post-treatments increased EC with significant variations among treatments indicating differences on surface functional groups. The higher temperature used for THC and biochar production increased the fixed carbon compared to the other treatments. No changes in VM were observed in post-treatments at room temperature, indicating a low efficiency of the washing procedure. Regarding C/N ratio, it increased with the washing procedure. All post-treated hydrochar, as well as biochar, reached 20-25 ratio, the optimum range for microbial activity. The O/C and H/C ratios lowered with FW processing and resulted similar among treatments and higher compared to THC and biochar, indicating lower aromaticity resulting in poorer stability when added to soils. Heavy metals concentration in all HC (data not shown) complied with the Spanish regulation to their use as a soil amendment [4] being categorized as A class except for biochar (B class), for which its use in crops derived from the food chain would be prohibited.

Table 1. Chemical characterization of feedstock and chars.

	FW	FHC	WaHC	AHC-W	THC-W	Biochar
OM %	-	95.0	96.8	96.4	86.2	74.8
pH	5.1	4.6	4.8	4.7	9.0	8.9
EC (mS/m)	9.9	4.9	143.5	231.0	601.0	26.0
VM %	79.5	73.7	74.2	74.5	22.4	25.7
FC %	17.1	23.7	22.4	20.4	63.6	56.2
C/N	18.7	19.5	24.4	21.3	20.4	33.4
O/C	0.8	0.4	0.4	0.4	0.1	0.2
H/C	1.7	1.2	1.3	1.4	0.4	0.2

As observed in Figure 1A, GI decreased for soil amended with BC and FHC in dosages above 3% while aging enhanced germination with increasing the percentage of char applied. Washing (WaHC) slightly increased the GI with respect to the control (100%). Thermal treatment (THC) improved the GI up to 20% of bare soil, regardless of the dosage tested. As shown in Figure 1B, FHC-soil mixtures presented acidic pH that slightly increased with the post treatments while soil amended with biochar (> 1%) showed basic pH and critical EC values (above 240 mS/m) as well as in FHC 5%, resulting in saline stress. No differences were found among the rest of assays. The germination rates were affected by the pH and EC values as can be seen in Figure 1A.

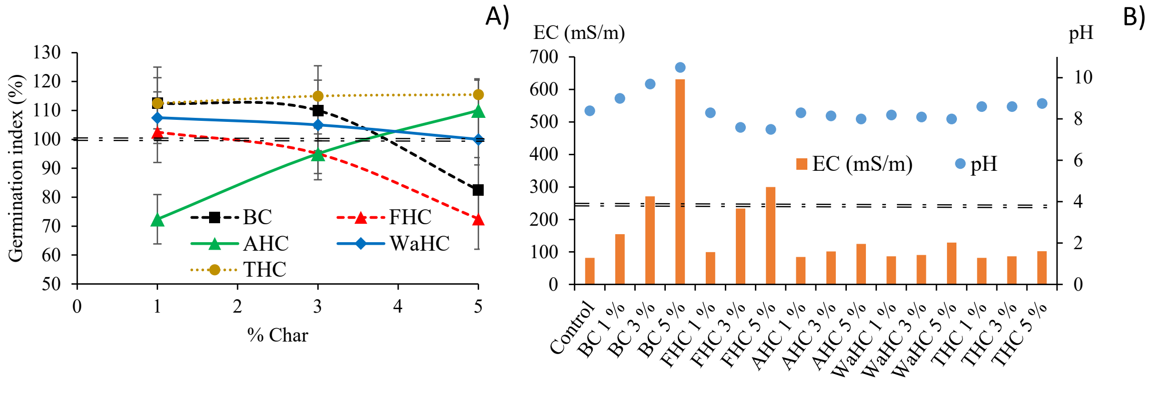

Figure 1. A) Germination rates of tomato seeds compared to control 7DAS. B) pH and EC on stabilized soils.

A decrease of total VFA content (mainly acetic, propionic, and butyric acids) of up to 90% was achieved after 3 washing cycles, as can be seen in Figure 2. These results are consistent with the findings of Bargmann *et al.* (2013) on the effect of HC washing from green biowaste [5].

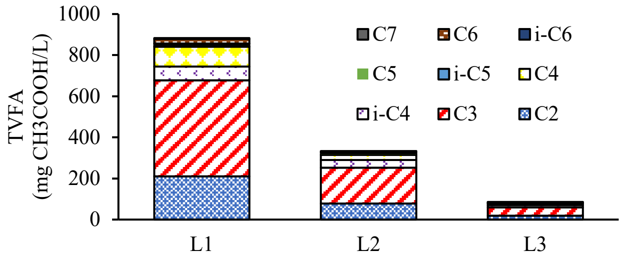

Figure 2. Total volatile fatty acid proportion on leachates of FHC washing.

In conclusion, dosages above 3% of FHC and biochar were harmful for tomato seeds since the EC exceeded saline stress limits affecting GI. All hydrochar post-treatments alleviated this negative effect, maintaining pH and EC at adequate values, being the thermal treatment the best alternative.

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References

1. European Parliament (2018) Directive 2018/850 Amending Directive 1999/31/EC on landfill of waste
2. Suarez E, Tobajas M, Mohedano AF, de la Rubia MA (2022). Chemosphere 297:134223.
3. Khosravi A, Zheng H, Liu Q, et al (2021) Chem Eng J 133142.
4. Real Decreto 506/2013, sobre productos fertilizantes. BOE (2013)
5. Bargmann I, Rillig MC, Buss W, et al (2013) J Agro Crop Sci. 199:360–373.