Short-term study on the decomposability of hydrochars in a Cambisol

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Introduction

The process of hydrothermal carbonization (HTC) converts biomass into a carbonaceous product named hydrochar. It is hypothesized that hydrochar may contribute to carbon (C) sequestration, thereby sustaining its function as a soil conditioner. The objectives of our study were: i) to quantify the stability of hydrochar against microbial decomposition compared to other organic materials used as soil conditioners, and ii) to elucidate the effect of hydrochar production conditions (feedstock, processing temperature and time) on its decomposability in an arable soil.

Material and Methods

- A variety of hydrochars (*N* = 8) differing in production conditions (sugarbeet pulp (S) & draff (D); temperature 180-250 °C, time 4-12 h), as well as reference materials (wheat straw (WS), mature compost (MC), white peat (WP), sugarbeet pulp biochar (SB)) were applied to a cambisol (50% sand, 42% silt, and 8% clay; 1% C_{org}) in a rate equivalent to 30 t ha^{-1}.
- The 248 d incubation trial was conducted in closed Erlenmeyer flasks (22 °C, 60% of max. soil water holding capacity).
- The stability of organic materials was quantified by measuring CO_2 emission using NaOH traps.
- The amount of C mineralized (C_{min}, %) from organic materials was calculated.
- A double-exponential decay model was used in order to quantify the mean residence times (MRT) of C_1 which was considered as a labile C fraction, and C_2, which corresponded to a stable C fraction. MRTs were summarized for graphical presentation.
- Correlation coefficients were calculated for the variables: C_{min}, C_1, C_2, processing temperature and time, H/C and O/C mol ratio.

Results

- Enhanced CO_2 emission in WS and hydrochar treatments (not shown).
- Increasing processing temperature enhanced stability of hydrochar in soil (Fig. 1).
- Feedstock and processing time had only little effect on hydrochar decomposability (Fig. 1; Tab. 1).
- The O/C ratio is a function of processing temperature: lower O/C ratio of hydrochar indicates decreased decomposability (Tab. 1).
- The MRT of tested organic materials followed the order: WS << hydrochars < WP <<< SB, MC (Fig. 2).

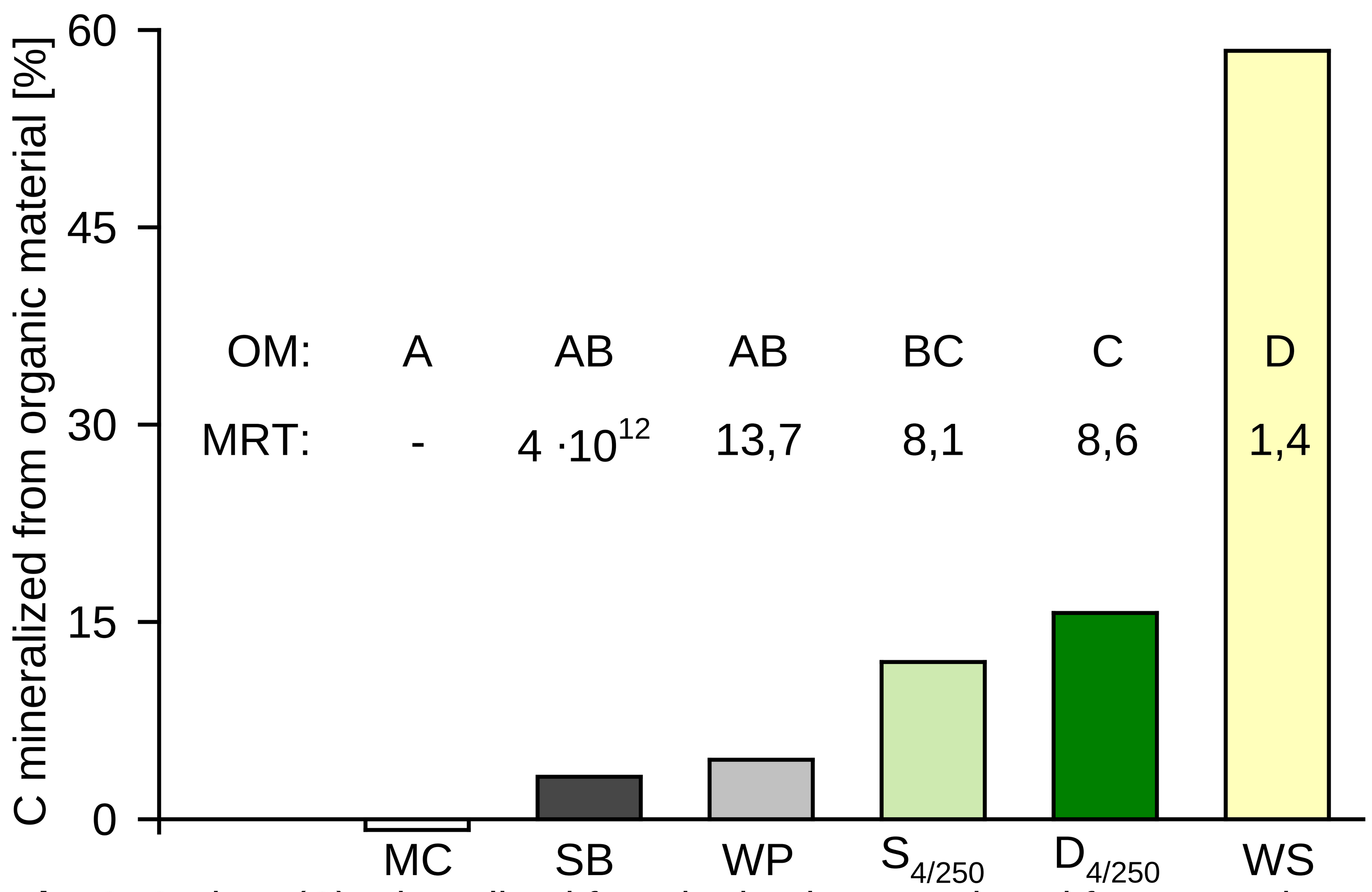

Fig. 2. Carbon (C) mineralized from hydrochars produced from sugarbeet pulp (S) and draff (D) at a temperature of 250 °C and time of 4 h and reference materials (WS = wheat straw, MC = mature compost, WP = white peat, SB = sugarbeet pulp biochar) after 248 days of incubation. ANOVA: Organic materials (OM) labeled with the same letter are not significantly different (p ≤ 0.05). MRT = mean residence time in years (MC not included).

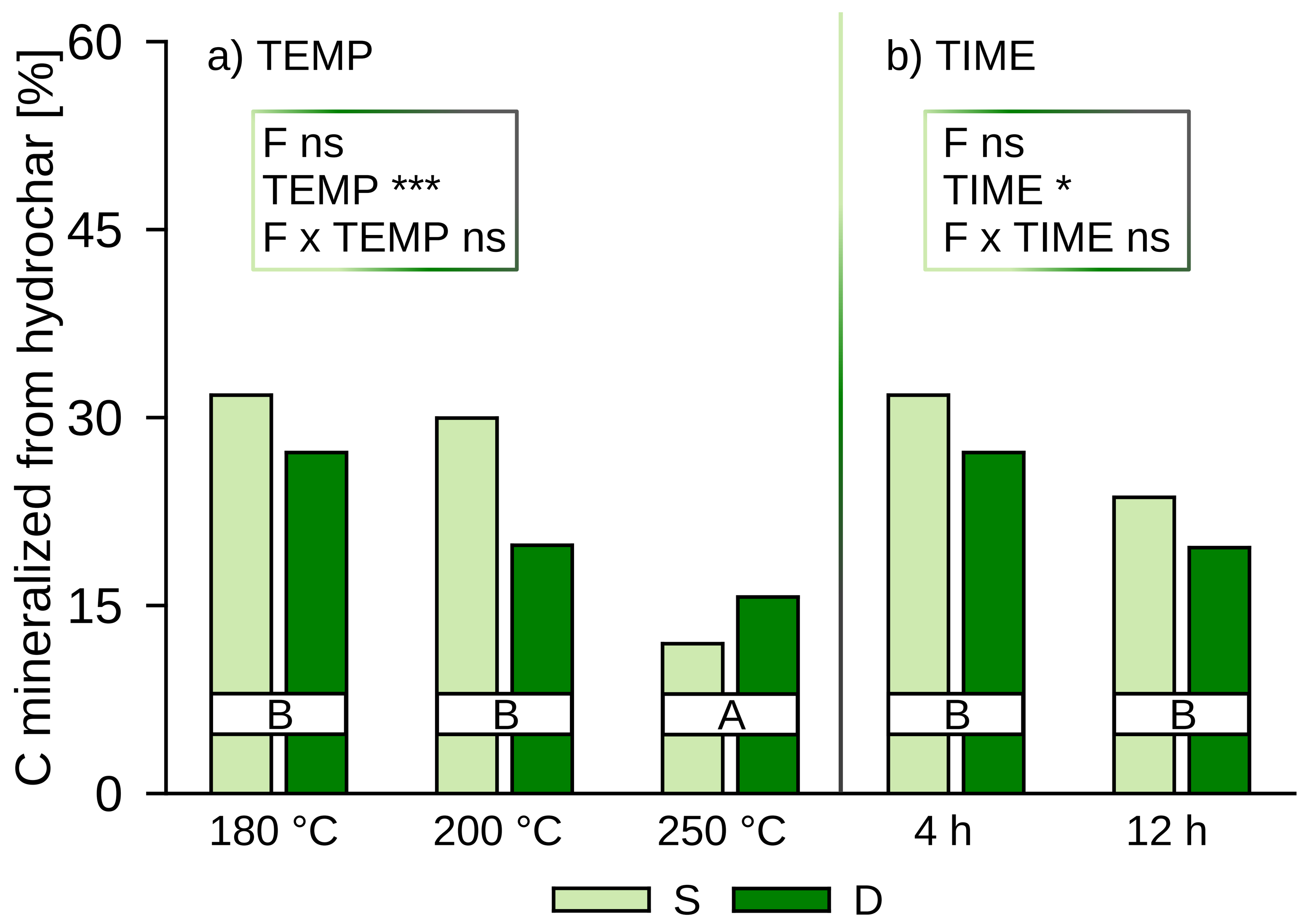

Fig. 1. Carbon (C) mineralized from hydrochars produced from sugarbeet pulp (S) and draff (D) as feedstock (F) a) at a temperature (TEMP) of 180, 200 and 250 °C (time 4 h) and b) for a time of 4 and 12 h (TEMP 180 °C) after 248 days of incubation. ANOVA (in boxes): means across F with the same letter (boxes over bars) are not significantly different (p ≤ 0.05).

Tab. 1. Pearson's correlation coefficients for carbon mineralized from hydrochar (C_{min}) and selected hydrochar properties and production conditions. Labile hydrochar-C fraction (C_1), stable hydrochar-carbon (C_2), mean residence time of C_1 fraction (MRT_1), mean residence time of C_2 fraction (MRT_2), processing temperature (TEMP) and time (TIME), hydrogen/carbon (H/C) and oxygen/carbon mol ratio (O/C).

	C_{min}	C_1 [g kg soil^{-1}]	C_2	MRT_1 [day]	MRT_2 [year]	TEMP [°C]	TIME [hour]	H/C [ ]
C_1	0.81*							
C_2	-0.80	-0.61						
MRT_1	-0.36	-0.44	0.69					
MRT_2	-0.83	-0.66	0.93	0.56				
TEMP	-0.77	-0.52	0.79	0.66	0.80			
TIME	-0.06	-0.41	-0.31	-0.36	-0.32	-0.45		
H/C	0.40	0.28	-0.18	-0.13	-0.28	-0.64	0.03	
O/C	0.89	0.69	-0.91	-0.65	-0.84	-0.80	0.11	0.20

* Underlined correlation coefficients are significant (p ≤ 0.05).

Conclusions

Mean residence time of hydrochar was at least 5 times higher compared to wheat straw, but numerous orders of magnitude lower compared to biochar. Our study showed that hydrochar application to soil may compensate for the growing humus-C deficit on agricultural land, which is caused by the increasing removal of cereals straw and other crop residues for bioenergy purposes, but its potential for long-term C sequestration seems to be limited.