Characterisitics of elemental compositions of biochars derived from agro-residues

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Thermochemical Technologies

Introduction

Over the last decades the general interest in recycling and upcycling technologies heavily grew and in the agricultural sector, it is not different. Lal estimated already in 2005 that 3,8 billion tons of crop residues alone are produced annually worldwide [1]. This shows the great potential, if use could be made of these residues. One technology to upcycle organic waste fractions, residues and biomass in general would be pyrolysis. While pyrolysis usually gives three different products, gas, oil and char, the focus of this work is the produced biochar. To investigate the potential of agricultural residues, 4 materials were selected, characterized, pyrolyzed at different temperatures and the resulting chars were analyzed.

Materials & Methods

Residues from hemp, rapeseed, milk thistle and breadseed poppy processing were taken from a local provider. The residues were pyrolyzed as received in a muffle furnace. The used temperatures were 300, 500 and 700 °C. The employed heating rate was 10 °C/min. Each sample was heated for 60 min at maximum temperature and was kept in the muffle furnace over night to cool. Nitrogen gas was used at a flowrate of 1 L/min to ensure the inertial atmosphere needed. Every sample was flushed for several minutes with nitrogen gas at a flowrate of 4L/min to remove the present oxygen before the heating started. For analysis, every sample was ground to a fine powder. For the CHN analysis a *TruSpec® Micro* analyzer from *Leco* was used, with a primary combustion temperature of 950 °C and a secondary combustion temperature of 850 °C. EDTA was used for calibration. The ICP-OES analysis for the determination of K and P was based on ISO 16967 and ISO 16968. The element-recovery-rate was calculated with the following formula:

$$100 * \frac{[\text{Element}]_{\text{sample}}}{[\text{Element}]_{\text{Feedstock}} / \text{Yield}_{\text{dry, sample}}}$$

The molar H/C ratio was calculated from the molar masses and the mass fraction of the respective element.

Results & Discussion

The produced char was of black color and brittle in nature, as expected. However, the chars produced at 300 °C still contained condensed tar and it was observed that after the 60 min at 300°C the pyrolysis process was not finished yet, as gases were still being produced.

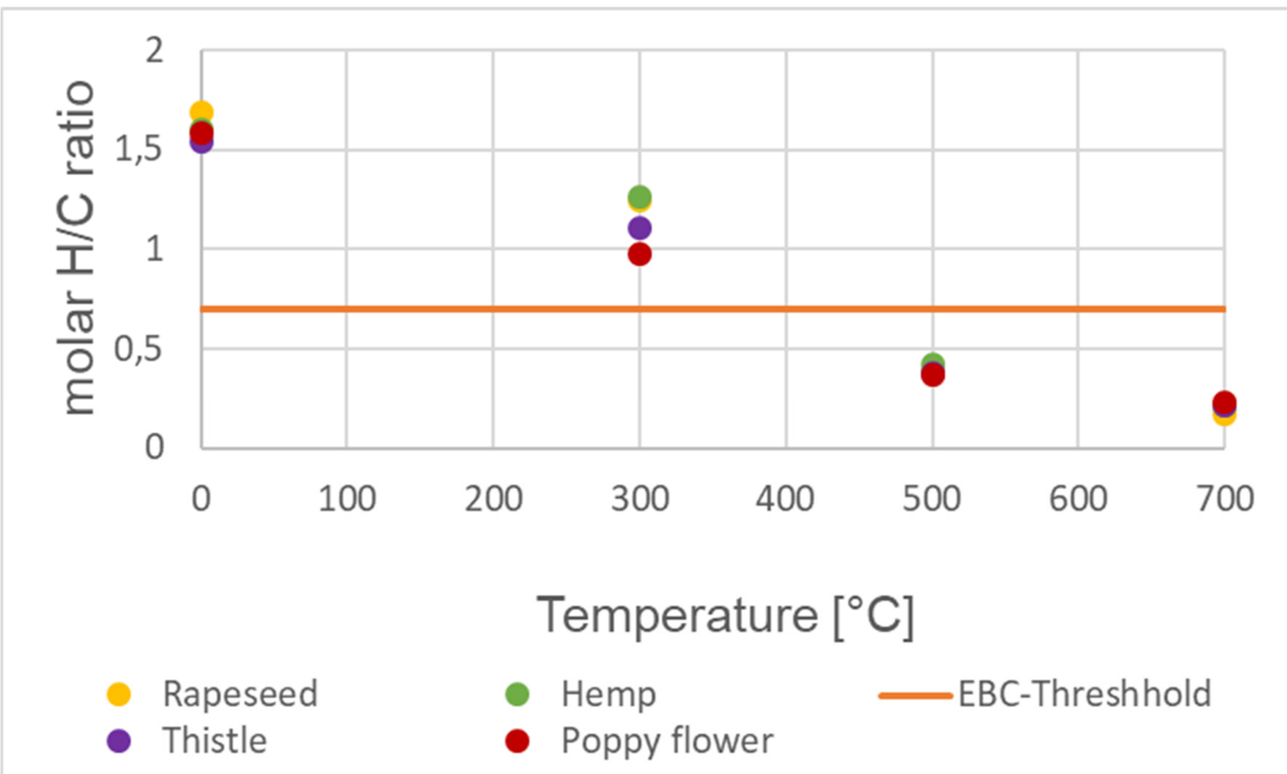

Figure 1: Molar H/C ratio of the different samples and the EBC-threshold. No carbonate content was determined, as originally required by the EBC [2].

The molar H/C ratio was in the range of 1,54-1,69 for the feedstocks and dropped to 0,98-1,26 at 300 °C, 0,36-0,42 at 500°C and 0,17-0,23 at 700 °C. This makes the chars produced at 500 and 700 °C viable candidates for the European biochar certificate (EBC) that requires molar H/C ratios < 0,7 [2]. Except the hemp sample at 500 °C, all chars at 500 and 700 °C could even be candidates for the EBC Feed categories as their molar H/C ratio was below the required 0,4 [2]. However, this is just an indicator as the EBC refers to the organic C-content, thus requiring the quantification and subtraction of carbonate from the total C-content [2]. Temperature has a strong impact on the molar H/C ratio as can be seen in Figure 1. The nitrogen retention was highly temperature dependent as seen in Figure 2 and it drops from 71-93 % at 300 °C to 39-48 % at 500 °C and 29-42 % at 700 °C. No specific trend was observed for both K- and P-retention. It was above 80 % for all samples. Further research would be required in order to identify where the missing portions of the elements remain. This should include condensing and analyzing the liquid fractions as well as collecting and analyzing the gaseous fraction and emitted dusts.

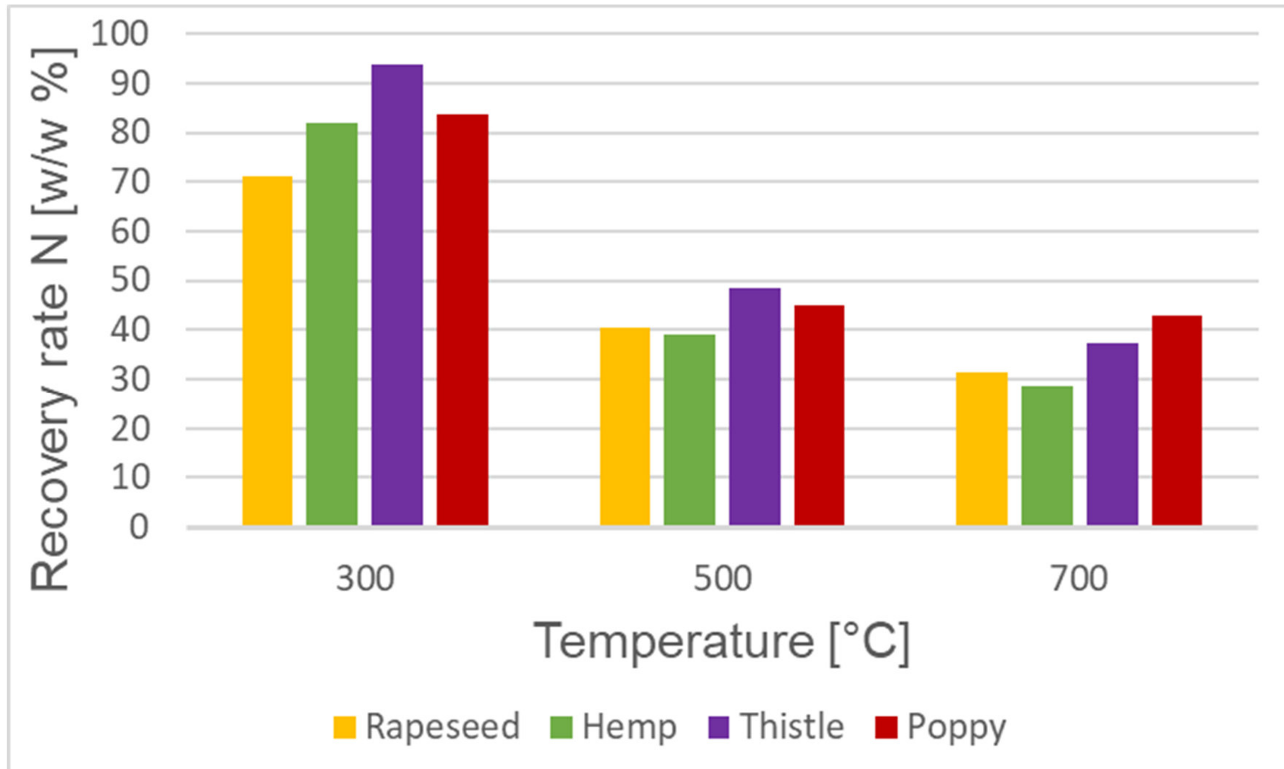

Figure 2: Recovery rate of nitrogen in the produced chars

Conclusion

The high nutrient retention and the low molar H/C ratio indicate that all investigated feedstocks are viable for the production of agriculturally used biochar. Depending on whether a low molar H/C ratio or high N-retention is desired, the temperature during the process should be either ≥ 500 or < 500 °C respectively. Further research is required to identify the ideal process conditions that give the optimal results for a given feedstock.

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[2] EBC (2012-2022) 'European Biochar Certificate - Guidelines for a Sustainable Production of Biochar.' Carbon Standards International (CSI), Frick, Switzerland. (http://european-biochar.org). Version 10.2 from 8th Dec 2022

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