PRODUCTION AND ANALYSIS OF CRUDE BIOCHAR PRODUCED FROM WHEAT BRAN

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Introduction

Biochar is solid material mainly produced by the pyrolysis of biomass. It is generally a carbonated material with high porosity and a high level of aromatization. Thanks to its properties, biochar is used in various industries, such as power production, agriculture, wastewater treatment, construction, pharmacy and many others. A significant advantage of biochar production is that it is often produced from agricultural and food waste, which corresponds to circular economics's philosophy. The physicochemical properties of biochar strongly depend on the feedstock type. An interesting raw material with potential to produce biochar is wheat bran, a by-product of milling, which falls into the group of lignocellulosic biomass and is produced in large quantities.

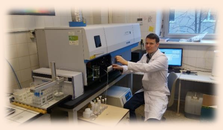
AIM of the study

The main aspect of this work was developing a pyrolysis procedure for biochar production and determination of the products' physicochemical properties.

Pyrolysis

Experimental

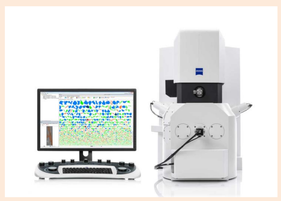
- Crude **wheat bran** from Voženílek milling company was used for pyrolysis.
- **Pyrolysis** of wheat bran was performed in a furnace under an anaerobic nitrogen environment. Three pyrolysis temperatures were tested – 300, 400 and 500°C. Heating rate was 5°C/min. The pyrolysis lasted 1 hour after reaching the set temperature.
- **Particle distribution** of produced biochar was evaluated by sieve analysis
- **pH** and **conductivity** was measured in aqueous extract prepared by the 1hr shaking in ration 1:5 biochar:water
- **Elemental analysis** was performed by ICP-OES Horiba Jobin Yvonne Ultima 2 and C,H,N,S Elemental analyser Euro-Vector EA 3000.



Al, Ca, Cd, Co, Cu, Cr, Fe, K, Mg, Mn, Na, Ni, P, Pb, Zn

Samples for ICP-OES analysis were digested by microwave digestion system Milestone MLS 1200 Mega – 100 mg of biochar + 5ml HNO3 + 1ml H2O2

- **BET surface area analysis** was performer on Quantachrome NOVA 2200e. Samples of biochar were deggased under vacuum and 150°C. After deggassing, N2 was adsorbed for 70 hrs.



- **Scanning electron microscopy** (Carl Zeiss EVO 18 SEM) of samples was used for the visual assessment of the surface of biochar.
- **Determination of PAHs** in biochar was carried out by GC-MS Thermo TSQ 9000. PAHs were extracted into toluene by Gerhardt Soxtherm in (2,5 g of biochar to 150 ml of toluene). Samples were evaporated to final volume 25 ml.

Results

Yield of pyrolysis

Pyrolysis temperature proved to be strongly influential on yield of biochar.

Temperature (°C)	Yield (%)
300 °C	64,9 ± 2,5
400 °C	49,7 ± 3,5
500 °C	29,2 ± 2,1

Sieve analysis of biochar

	Particle distribution (%)			
	> 4 mm	2-4 mm	0,5-2 mm	< 0,5 mm
	0	0,11	40,9	59,0
300 °C	0,261	3,09	30,8	65,9
400 °C	2,29	2,62	41,2	53,9
500 °C	0,121	1,91	67,2	30,7

Elemental composition of bichar

Vzorek		N (%)	C (%)	H (%)	H/C
300 °C	A	5,53	61,2	9,67	0,155
	B	5,38	61,5	9,52	
	C	5,22	60,6	9,30	
	Mean	5,38	61,1	9,50	
	SD	0,13	0,4	0,15	
400 °C	A	5,56	66,1	4,95	0,082
	B	5,39	65,8	5,70	
	C	4,95	64,6	5,48	
	Mean	5,30	65,5	5,38	
	SD	0,26	0,7	0,31	
500 °C	A	5,21	66,4	4,19	0,062
	B	5,32	65,9	4,07	
	C	5,72	67,5	4,17	
	Mean	5,42	66,6	4,15	
	SD	0,22	0,7	0,05	

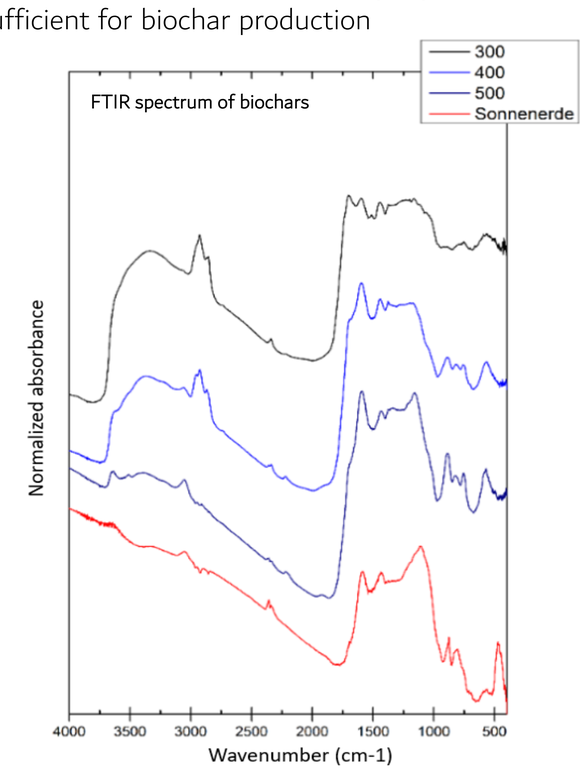
Major elements in biochar are N, C, H. Furthermore, the prepared biochar contained a significant amount of potassium and phosphorus. The content of toxic elements was below the limit defined by the European biochar certificate.

PAHs in Biochar

The content of polyaromatic hydrocarbons increased with increasing pyrolysis temperature. The total concentration of PAHs determined in 500°C samples was 2,28 ± 0,1 mg/kg of biochar. Most abundant PAH in biochar was naphalen

FTIR analysis of biochar

Rate of carbonization can be observed in the field of wavenumbers 3500 – 2500 cm-1 characteristic for OH groups. Pyrolysis at 500°C caused almost complete elimination of OH groups in biochar. A decrease in absorbance at 1720 – 1700 cm-1 and an increase in absorbance in the region of 1600 are also evident. This indicates the decomposition of carbonyl compounds and the formation of polyaromatic structures. 500°C and 1 hour of pyrolysis proved to be sufficient for biochar production



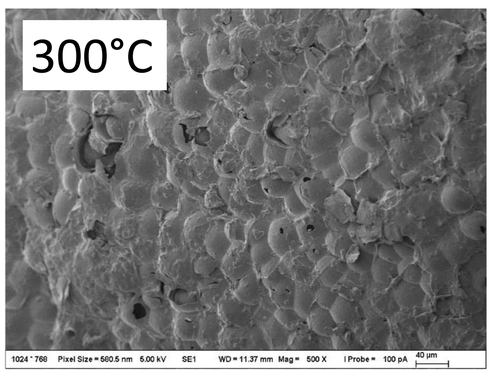
BET surface area analysis

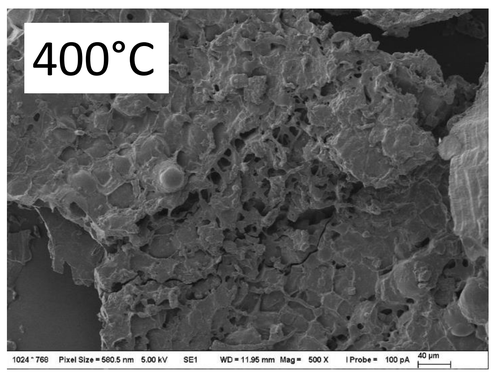
Specific surface of the biochar raises with temperature. However, the crude biochar did not have a sufficient specific surface area as defined in the European biochar cerificate. The raw biochar will need to be further activated chemically or physically.

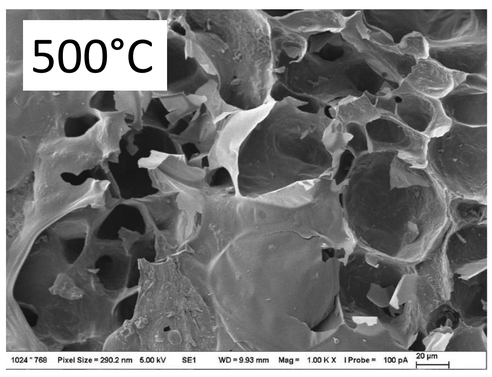
Sample	Specific surface (m^2/g)	Pore volume (cc/g)
300 °C	0,604	$6{,}90 \cdot 10^{-4}$
400 °C	2,61*	$6{,}38 \cdot 10^{-5}$
500 °C	3,40	$3{,}65 \cdot 10^{-3}$

SEM

Thermally initiated developemenent of the biochar porosity can be observed on SEM pictures. Biochar produced at 300 and 400°C contained intact lignocellulosic fibers and low porosity. A positive development of porosity was observed only in samples pyrolyzed at 500°C







Conclusions

Characterization of biochar was proceeded according to the European biochar certificate, which included size distribution analysis, SEM, BET surface area analysis, thermogravimetry (TGA), elemental analysis, FTIR spectral analysis and analysis of PAHs. FTIR, elemental analysis and SEM proved that 500 °C pyrolysis for 3 hours was optimal to produce well-carbonized biochar with the optimal structure. Yield of the process was 290,2 g of biochar from 1 kg of bran. Biochar contained a significant amount of K (45.7 ± 0.7 µg/g), and P (4.,8 ± 0.6 µg/g) and did not exceed the allowed limit of total PAHs (2.28 µg/g) set by European biochar certificate. The surface of the biochar significantly raised with the pyrolysis temperature with 3.4 m2/g for 500°C. This parameter can be substantially improved by subsequent chemical or physical activation. Wheat bran proved to be a material suitable as a feedstock for production of biochar with the potential for agricultural use.