Evaluation of slow pyrolysis of kitchen and garden biowaste to produce biochar

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Introduction

Biowaste is one of several important waste streams that are progressively addressed by European circular economy and waste legislation. In the EU between 118 and 138 million tons of biowaste are generated annually [1].

Objectives:

- Characterization of the studied biowaste (kitchen, spring garden and autumn garden biowaste) and the biochar obtained it.
- The effect of slow pyrolysis temperature on the yield and physicochemical properties of the obtained biochar.

Materials and methods

Three different types of biowaste that had been collected from households in the Silesia region of Poland were used in this work.

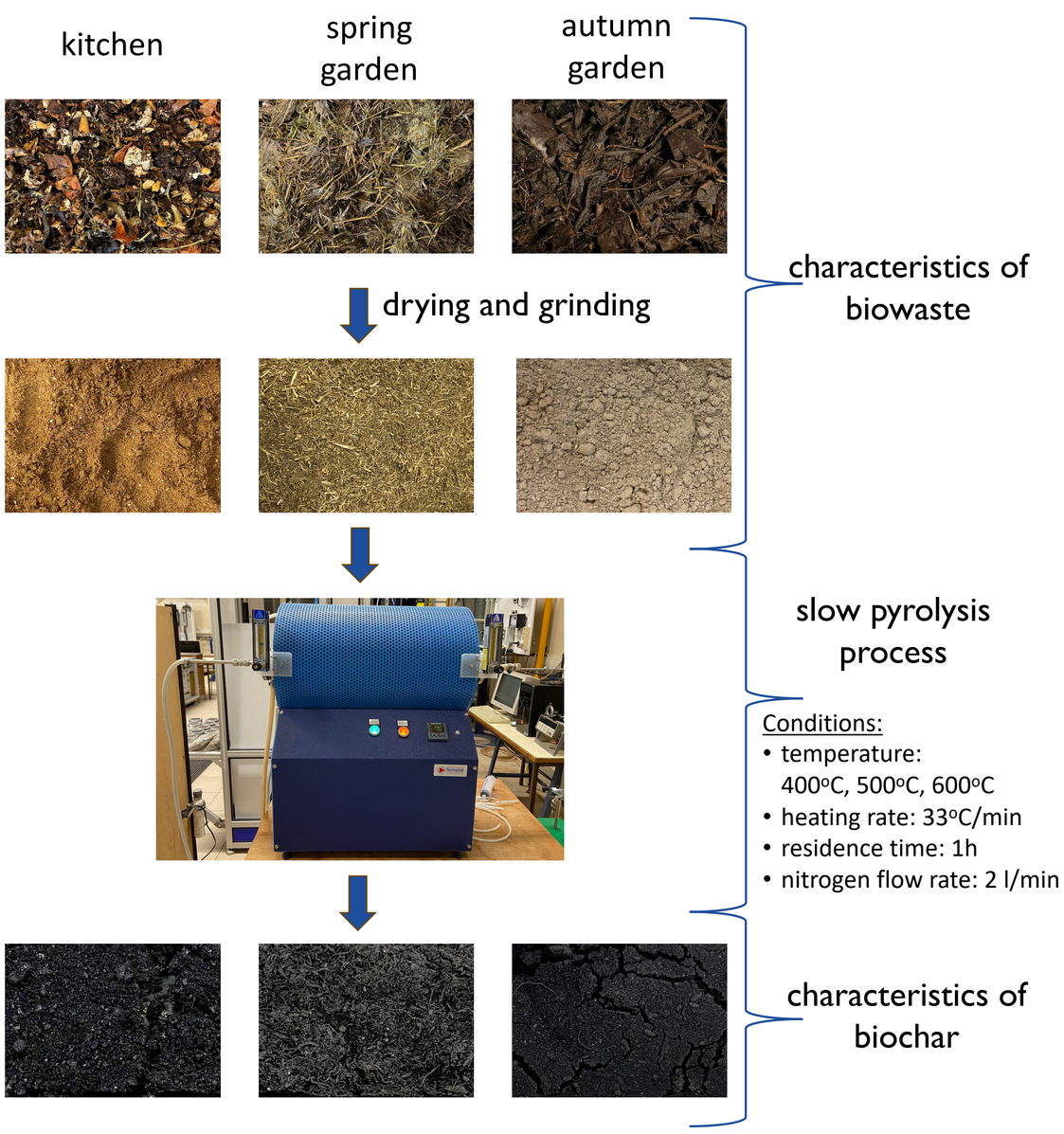

Figure 1. Schematic presentation of the methodology.

Results

- All the biowaste tested had a high moisture content. Therefore, the biowaste required pre-drying before the slow pyrolysis process.
- Comparing the results of the ultimate analysis (Table 1), shows that kitchen biowaste has the highest content of all components (except O).
- The yield of both garden biochar, was almost twice as high as that of kitchen biochar (Table 2). However, the garden biochar contained more than three times as much ash as the kitchen biochar.
- As the pyrolysis temperature increases, the VM, C, H, N, O, HHV and LHV of all biochar decreases (Table 2).

Table 1. Properties of the tested biowastes.

biowaste	kitchen	spring garden	autumn garden
proximate analysis (% wt.) (dry basis)			
MC (total moisture content) (% wt.) (wet basis)	68.10	81.53	63.51
VM (volatile matter content)	76.55	42.43	43.75
A (ash content)	6.81	17.75	43.83
FC (fixed carbon)*	16.64	39.82	12.43
ultimate analysis (% wt.) (dry basis)			
C (carbon content)	43.36	31.94	29.99
H (hydrogen content)	7.03	4.53	4.02
N (nitrogen content)	3.12	2.84	1.19
S (sulphur content)	0.10	0.07	0.03
O (oxygen content)*	38.87	42.82	20.92
Cl (chlorine content)	0.71	0.05	0.01
other measurements (dry basis)			
HHV (higher heating value), MJ/kg	17.24	10.60	11.16
LHV (lower heating value), MJ/kg	15.69	9.60	10.27
CC (combustible compounds) (%wt.)	93.19	82.25	56.17
OS (total organic matter content) (%wt.)	90.06	81.77	55.32
MS (total mineral substances content) (%wt.)	9.94	18.23	44.68
C_{org} (total organic carbon content) (%wt.)	37.47	35.29	23.18
pH – (wet basis)	5.18	9.20	8.62

* by difference

Conclusions

- The properties of kitchen biowaste are comparable to literature data and are similar to the properties of typical biomasses used to produce biochar by slow pyrolysis, while the properties of the two garden biowaste differ significantly.
- Both garden biowaste studied may have been contaminated (soil, stones) during collection, which influenced the high ash content.
- For all the biowaste tested, the biochar yield decreased with increasing pyrolysis temperature.
- Compared to biowaste before slow pyrolysis, carbon and fixed carbon content as well as the HHV was higher in the kitchen biochar and lower in both garden biochar.

Table 2. Yield and properties of biochar obtained from slow pyrolysis of biowaste.

biochar	kitchen			spring garden			autumn garden		
	400°C	500°C	600°C	400°C	500°C	600°C	400°C	500°C	600°C
Y_m (mass yield of biochar), % wt. (dry basis)	36.64	32.02	28.71	66.53	58.13	60.07	66.99	63.15	60.68
proximate analysis (% wt.) (dry basis)									
VM (volatile matter content)	20.49	14.88	11.14	12.59	11.65	5.89	15.42	12.10	5.76
A (ash content)	18.57	21.81	21.09	64.69	65.38	72.57	61.71	64.38	71.32
FC (fixed carbon) *	60.94	63.31	67.77	22.73	22.96	21.54	22.87	23.52	22.93
ultimate analysis (% wt.) (dry basis)									
C (carbon content)	58.02	54.81	55.55	25.34	26.60	21.00	27.84	27.45	25.62
H (hydrogen content)	4.00	3.02	2.67	2.41	1.71	1.41	2.80	2.54	1.47
N (nitrogen content)	3.64	3.46	3.01	1.44	1.52	1.05	1.15	1.00	1.02
O (oxygen content) **	15.77	16.90	17.68	6.12	4.79	3.97	6.50	4.63	0.57
other measurements (dry basis)									
HHV (higher heating value), MJ/kg	22.68	20.84	21.90	9.04	8.95	7.51	9.96	9.02	8.40
LHV (lower heating value), MJ/kg	21.80	20.17	21.31	8.51	8.58	7.20	9.35	8.46	8.07
CC (combustible compounds), (% wt.)	81.43	78.19	78.91	35.31	34.62	27.43	38.29	35.62	28.68

* by difference

** by difference (without considering the sulphur and chlorine content)

[1] European Commission (2020), https://data.europa.eu/doi/10.2779/691513