BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF CIVIL ENGINEERING

BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF CHEMISTRY

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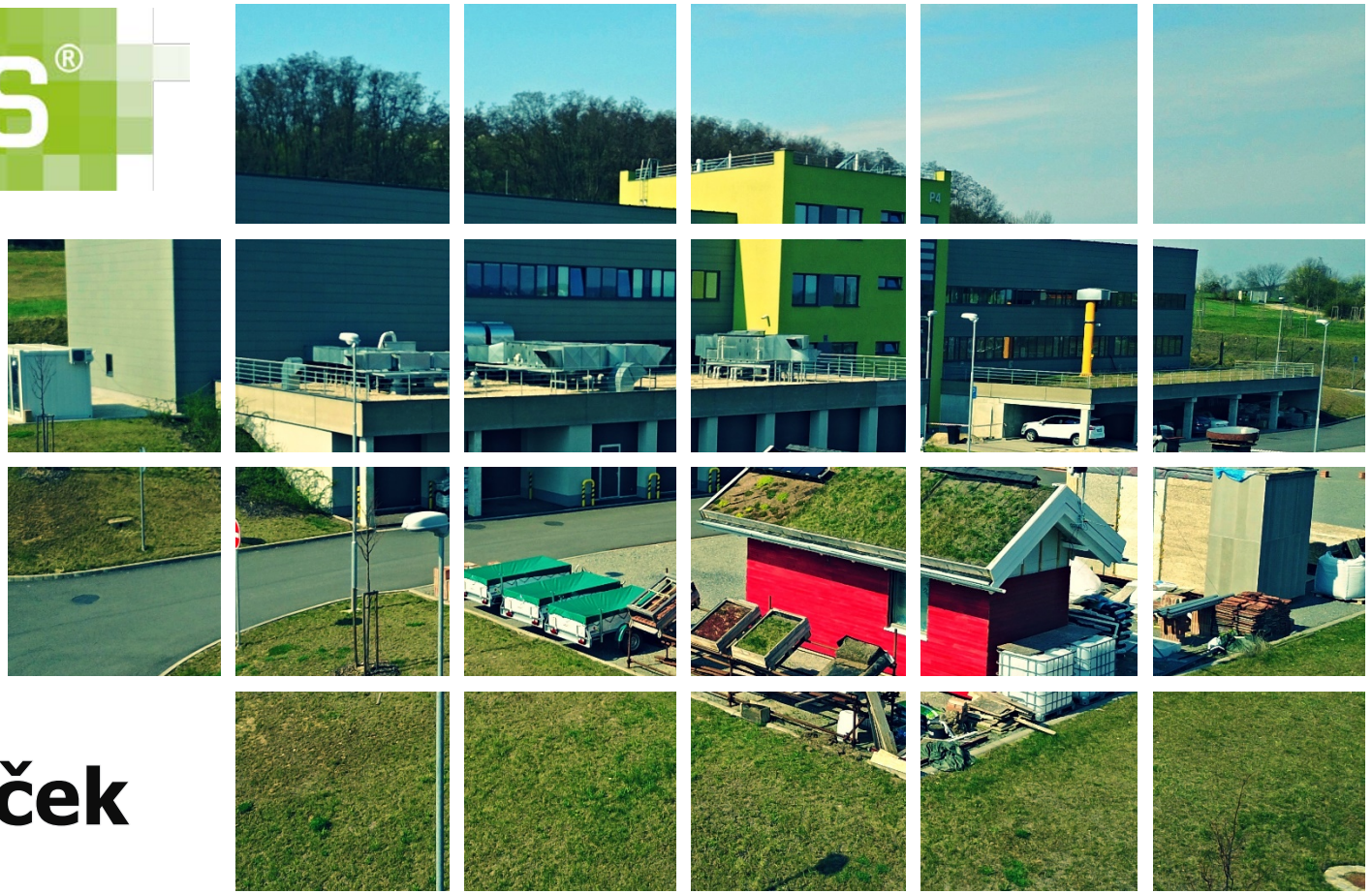
Mendel University in Brno



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Pyrolysis of Food Waste – Solid Carbonaceous Product/Biochar for Material Use

Outline:

1. Introduction
2. Pyrolysis of food waste
3. Characteristics of SCP / biochar
4. Future for food waste

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1. Introduction

- **Food waste** (FW) is a biodegradable waste from kitchens, restaurants, and public canteens;
- (!) FW represent of significant amounts of landfill gases and leachate;
- (!) FW can be a source of pathogenic micro-organisms, toxins and other infectious pathogens.

1. Introduction

- **The main chemical components of FW:** carbon, oxygen, nitrogen, lipids, proteins, carbohydrates, hemicellulose, cellulose, lignin, unstructured carbohydrates, starch, sugar, sucrose and glucose;
- in EU countries, FW is most often processed by composting, anaerobic digestion or a combination (fertilizer for agriculture).

1. Introduction

- The European Parliament has called to **reduce FW**;
- it is no more acceptable to use the FW for animal livestock;
- In the EU, **88 million** tonnes of food were discarded in 2014 and should be reduced by 30% by 2025 and halved by 2030;

What is the future for the use of food waste?

1. Introduction

Our aim is to maximize the use of the FW as a (secondary) raw material in accordance with the principles of the "**Circular Economy Strategy**“ by thermal treatment.

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2. Pyrolysis of food waste

- The thermal treatment of FW can be performed by **pyrolysis** technology with following outputs: **solid carbonaceous product (SCP) / biochar**, pyrolysis oil and pyrolysis gas;
- our work **summarizes the results of FW mixing with additives, pelletizing process, and thermal pyrolysis process**;
- SCP / biochar **parameters**: calorific value, organic carbon, surface area (S_{BET}), P, Mg, K, Ca, heavy metals, pH, and electrical conductivity.

2. Pyrolysis of food waste

Dried FW

+additives

Pelletized dried FW

Pyrolysis

Solid carbonaceous product / biochar

Pyrolysis oil and pyrolysis gas

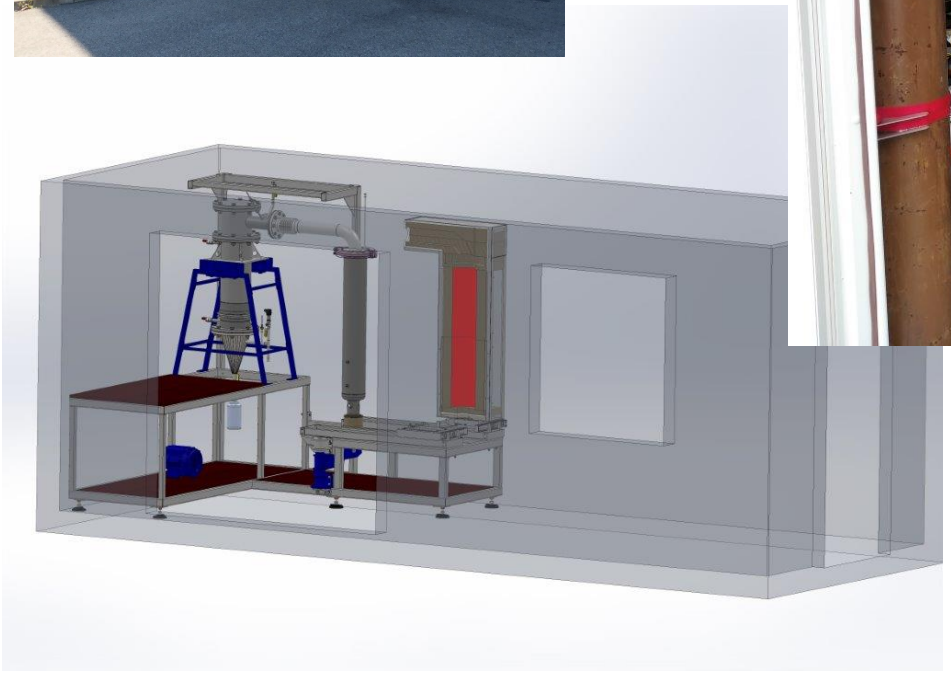
3. Characteristics of SCP/biochar

SCP/biochar composition after TP: moisture, temperature, and yields

Additive type	Ratio FW:ADD1:ADD2 (%)	Moisture (%)	Maximum temperature (°C)	Yields (%)		
				SCP / biochar	Pyrolysis oil	Pyrolysis gas
Mix0 (control): Dried and pelletized FW	100 : 0 : 0	3.94	600	30.9	41.7	27.4
Mix1: Wooden sawdust	75 : 25 : 0	3.97	600	35.3	43.3	21.3
Mix2: Wooden sawdust + Zeolite	75 : 20 : 5	6.05	600	32.5	43.3	24.2

2. Pyrolysis of food waste

Thermal pyrolysis unit



3. Characteristics of SCP/biochar

The aims of our FW research:

- energy production;
- the transformation of FW into **new product** for agricultural use / blue-green infrastructure (BGI).

3. Characteristics of SCP/biochar

Biochar parameters according to IBI and EBC

General parameter	Selected parameter	Unit	Guidelines to biochar certification			
			International Biochar Initiative (IBI)		European Biochar Certificate (EBC)	
			Category A	Category B	EBC - Urban	EBC - Agro
Toxicant assessment, maximum allowed thresholds - HMs	As	mg·kg^{-1} dry wt-mass	13	100	13	13
	Cd		1.4	20	1.5	1.5
	Cr		93	100	90	90
	Cu		143	6 000	100	100
	Pb		121	300	120	120
	Hg		1	10[a]	1	1
	Ni		47	400	50	50
	Zn		416	7 400	400	400
Other parameters	C_{org}	%	≥60	≥30	≥50	
	pH	pH	Declaration		Declaration	
	Electrical conductivity	dS·m^{-1}	Declaration		Declaration	
	S_{BET}	m^2·g^{-1}	-		≥150	

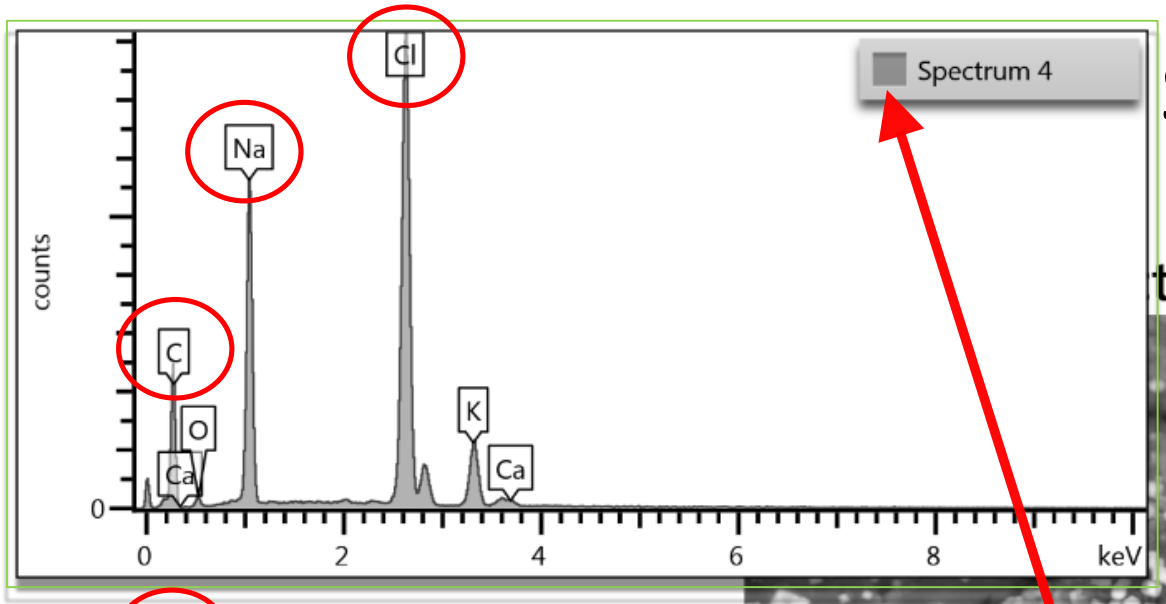
3. Characteristics of SCP/biochar

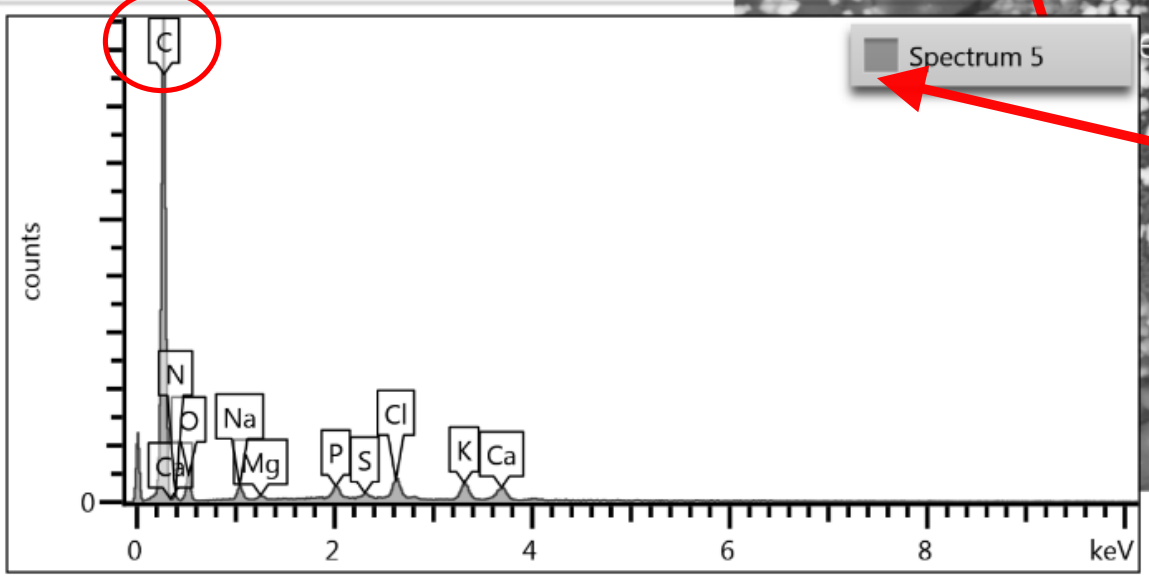
SCP/biochar composition after TP: calorific value, C_{org}, and S_{BET}

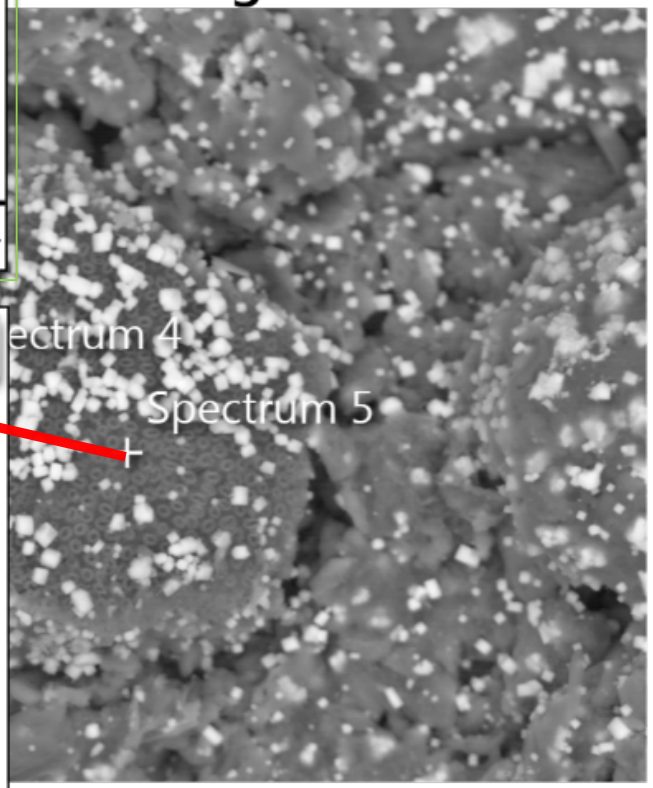
Additive type	Ratio FW:ADD1:ADD2 (%)	Calorific value MJ·kg^{-1})	C_{org} (%)	S_{BET} (m^2·g^{-1})
Mix0 (control): Dried and pelletized FW	100 : 0 : 0	23.82	66.51	1.36
Mix1: Wooden sawdust	75 : 25 : 0	26.13	72.45	1.83
Mix2: Wooden sawdust + Zeolite	75 : 20 : 5	22.36	65.30	2.17
Limits according EBC, EBC Urban / Agro [18]		n/d	50	150

3. Characteristics of SCP/biochar

SCP/biochar







3. Characteristics of SCP/biochar

P, Mg, K, and Ca, extraction in water

Additive type	Ratio FW:ADD1:ADD 2 (%)	P ($mg \cdot kg^{-1}$ DS)	Mg ($mg \cdot kg^{-1}$ DS)	K ($mg \cdot kg^{-1}$ DS)	Ca ($mg \cdot kg^{-1}$ DS)	Total ($mg \cdot kg^{-1}$ DS)
Mix0 (control): Dried and pelletized FW	100 : 0 : 0	155	114	24 038	951	25 257
Mix1: Wooden sawdust	75 : 25 : 0	97	100	12 692	734	13 623
Mix2: Wooden sawdust + Zeolite	75 : 20 : 5	540	34	9 463	660	10 698

and extraction in *Aqua Regia*

Additive type	Ratio FW:ADD1:ADD2 (%)	P ($mg \cdot kg^{-1}$ DS)	Mg ($mg \cdot kg^{-1}$ DS)	K ($mg \cdot kg^{-1}$ DS)	Ca ($mg \cdot kg^{-1}$ DS)	Total ($mg \cdot kg^{-1}$ DS)
Mix0 (control): Dried and pelletized FW	100 : 0 : 0	14 426	4 421	40 186	7 716	66 749
Mix1: Wooden sawdust	75 : 25 : 0	10 315	3 650	29 299	6 892	50 156
Mix2: Wooden sawdust + Zeolite	75 : 20 : 5	10 233	2 650	30 031	4 051	46 966

3. Characteristics of SCP/biochar

Heavy metals (HMs), extraction in water

Additive type	Repetition number	HMs, extraction in water (mg·kg^{-1} DS)								
		As	Hg	Cd	Cr	Cu	Ni	Pb	Zn	Total
Mix0 (control): Dried and pelletized FW	No. 1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.01	0.16	0.17
	No. 2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.01	0.01	0.02

and extraction in *Aqua Regia*

Additive type	Repetition number	HMs, extraction in Aqua Regia (mg·kg^{-1} DS)								
		As	Hg	Cd	Cr	Cu	Ni	Pb	Zn	Total
Mix0 (control): Dried and pelletized FW	No. 1	0.81	0.00	0.10	0.00	<LOD	6.88	2.74	4.14	15
Mix0 (control): Dried and pelletized FW	No. 2	<LOD	0.01	<LOD	0.00	<LOD	9.78	2.30	3.48	16
Limits according EBC, EBC Urban/Agro		13	1	1.5	90	100	50	150	400	806
Limits according IBI, category B		100	10	20	100	6 000	400	300	7 400	14 330

3. Characteristics of SCP/biochar

pH, EC, concentration of NH4+, PO4, NO3-, Cl-, SO4, extraction in water

Additive type	Ratio FW:ADD1:ADD2 (%)	pH (-)	EC ($\mu S \cdot cm^{-1}$)	c NH_4+-N ($mg \cdot L^{-1}$)	c NH_4+ ($mg \cdot kg^{-1}$)	c PO_4-P ($mg \cdot L^{-1}$)	c PO_4 ($mg \cdot kg^{-1}$)
Mix0 (control): Dried and pelletized FW	100 : 0 : 0	9.6	13 620	0.5	5.8	10.1	309.7
Mix1: Wooden sawdust	75 : 25 : 0	9.4	898	1.5	19.2	6.0	183.4
Mix2: Wooden sawdust + Zeolite	75 : 20 : 5	10.2	900	1.1	14.4	56.0	1 702.7
Additive type	Ratio FW:ADD1:ADD2 (%)	c NO_3--N ($mg \cdot L^{-1}$)	c NO_{3-} ($mg \cdot kg^{-1}$)	c Cl- ($mg \cdot L^{-1}$)	c Cl- ($mg \cdot kg^{-1}$)	c SO_4^{2-} ($mg \cdot L^{-1}$)	c SO_4^{2-} ($mg \cdot kg^{-1}$)
Mix0 (control): Dried and pelletized FW	100 : 0 : 0	5.2	230.3	7 800	77 989	87	870
Mix1: Wooden sawdust	75 : 25 : 0	5.9	260.4	6 600	65 778	38	379
Mix2: Wooden sawdust + Zeolite	75 : 20 : 5	4.5	197.6	6 100	60 483	79	783

4. Future for food waste

- The aim of this **pilot study** is to present a full-scale reactor for TP of FW;
- we focused on parameters: yields, calorific value, C_{org}, pH, EC…
- SCP / biochar seems to be **attractive solution for energy, agriculture use, and BGI** – for green roofs, walls, and parking lots;
- however, the high **electrical conductivity** detected in the samples due to salt in the FW represents a complication for direct use in agriculture / BGI … adding higher amounts of organic additives to FW.

Pyrolysis of Food Waste – Solid Carbonaceous Product/Biochar for Material Use

Thank you for your attention

Questions???