Lodz University of Technology
Faculty of Process and Environmental Engineering

Biomass torrefaction – a new direction of using torrefied materials and it's properties

Ostravice, 08.09.2026

DSc eng. Szymon Szufa, MBA, Associate Professor
mobile. +48606134239

Faculty of Process and Environmental Protection
Lodz University of Technology
ul. Wólczańska 213,
93-005 Łódź


labFactor

AGENDA

- BIOTRAINVALUE PROJECT
- LABORATORY PILOT SCALE REACTOR APPARATUS
- TYPES OF APPLICATIONS OF TORREFACTION APPLICATIONS AND IT’S PRODUCTS
- MAIN PROJECT RESULTS
- 2st INTERNATIONAL CONFERENCE OF THERMOCHEMICAL AND CONVERSION AND BIOENERGY - 24-26 SEPTEMBER 2026, ŁÓDZ

BioTrainValue

*„**BIO**mass Valorisation via Superheated Steam Torrefaction, Pyrolisis, Gasification Amplified by Multidisciplinary Researchers **TRAIN**ining for Multiple Energy and Products' Added **VALUE**s"*

Grant Nr. 101086411

MAIN OBJECTIVES BioTrainValue
https://biotrainvalue.eu/ :

- ❑ **RESEACH**
- ❑ **TRAINING**

MARIE CURIE ACTIONS

RESEARCH: *Development and experimental* ***testing of new technologies and equipment for biomass torrefaction*** *with application of superheated steam for production of high-value innovative bio-based products at the* ***European scale****.*

TRAINING: *Formation of an international and inter-sectoral network of organisations working with a* ***joint research programme in the fields of biomass torrefaction*** *and creation of respective bioproducts*

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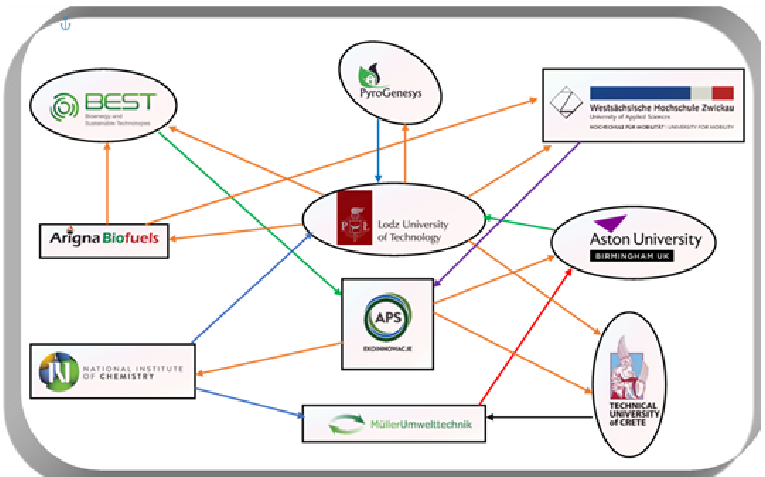
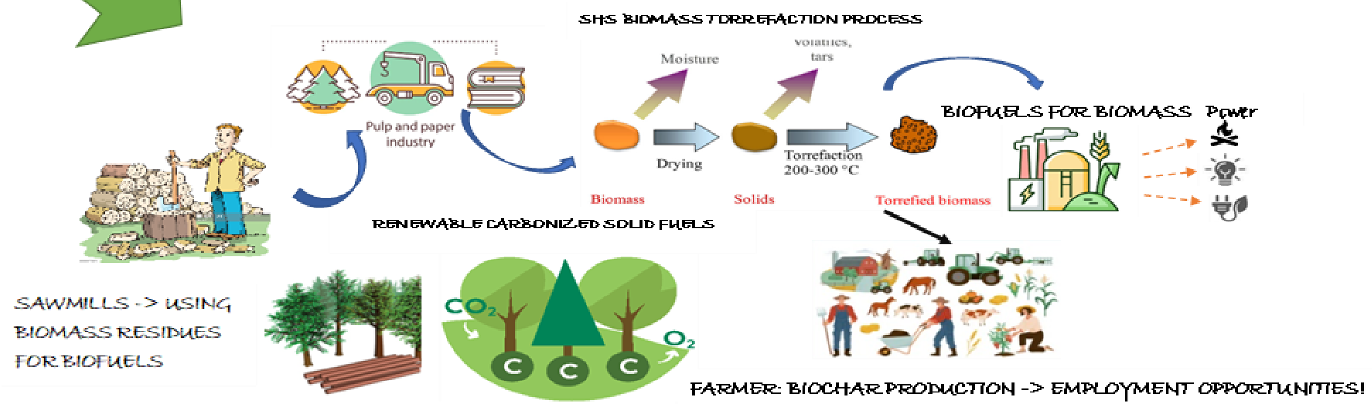


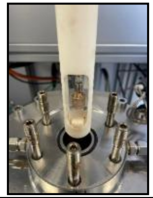
Organization	Characteristic Strengths
TUL	SHS biomass torrefaction, design expert
TUC	Environmental risk assessment SLCA, LCA studies.
WHZ	Economy in engineering Modeling electrical generation
NIC	Reactor-unit operation design Multiscale process modelling
ASTON	Biomass pyrolysis Hydrothermal carbonization
APS	PV-STEAM process design, construction
MUA	Modular biogas process design/construction
BEST	Biomass combustion, boilers certification
PyroGenesys	Pyrochemy- waste to energy technology designing, marketing
Arigna Fuels	Industrial verification of biomass torrefaction process

IMPACT ON SOCIETY AND INDUSTRY BY USING BioTrainValue RESULTS:




Arigna Biofuels
HARVEST
FLAME
SMOKELESS
HARVEST

Reactors



Torrefaction proces products application’s:

- **Biofuels:** Due to its chemical similarity to coal, the produced biochar can be blended with traditional hard coal in power plants without the need for costly modifications to transport infrastructure and mills;

- **Biochars** as plant growth stymulator – for example aquatic plants;

- **Sorbents and catalysts:** Due to its developed porous structure, torrefied material can be used as a low-cost, effective adsorbent for removing contaminants from water and waste gases, as well as a catalyst support;

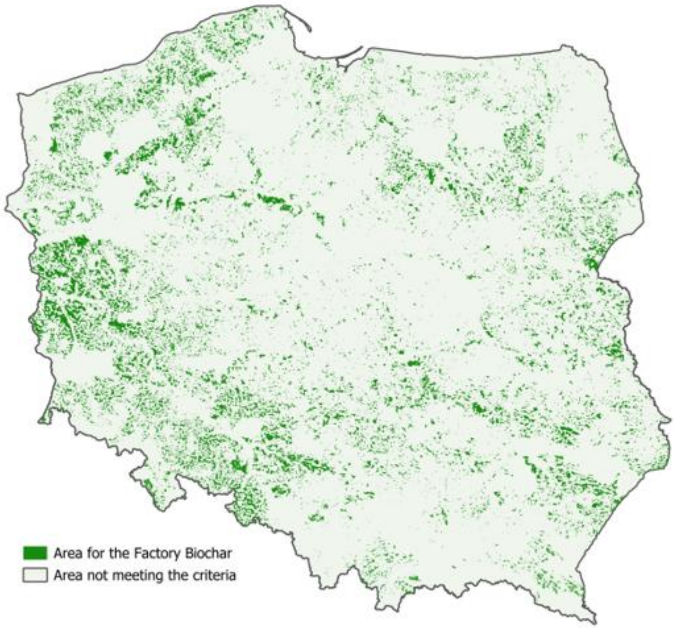
Torrefaction proces products application's:

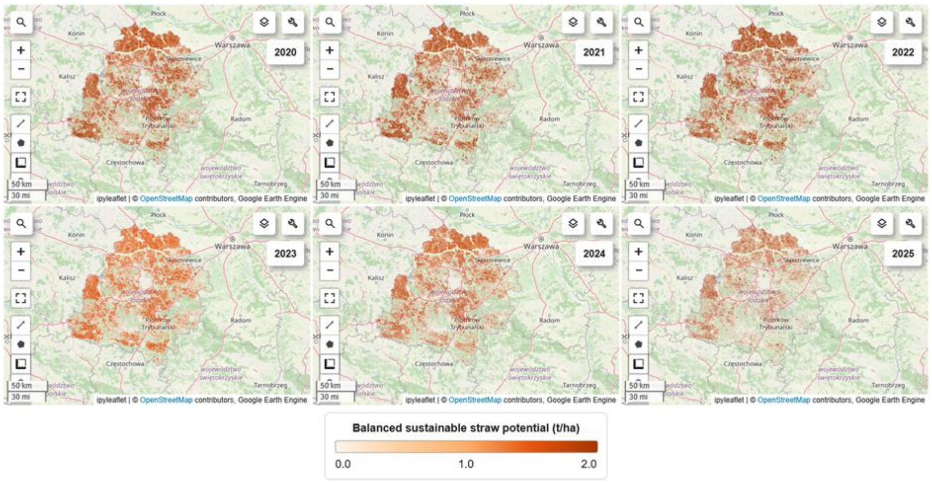
- **Reducing agent in metallurgy:** Biochar successfully replaces petroleum coke or fossil coal as a reducing agent in metal smelting processes (e.g., in steelmaking), thereby reducing the metallurgical sector's carbon footprint;

- **Supercapacitors and fuel cells**: Torrefied biomass serves as a base for producing porous carbon structures with high electrical conductivity, which perform well in **supercapacitors and microbial fuel cells (MFCs);**

- Torrefied woody biomass as a base for producing porus carbon for **anode for sodium-ion batteries;**

Potential of maize straw for applications of torrefaction proces in Poland and in Lodzkie voivoidship



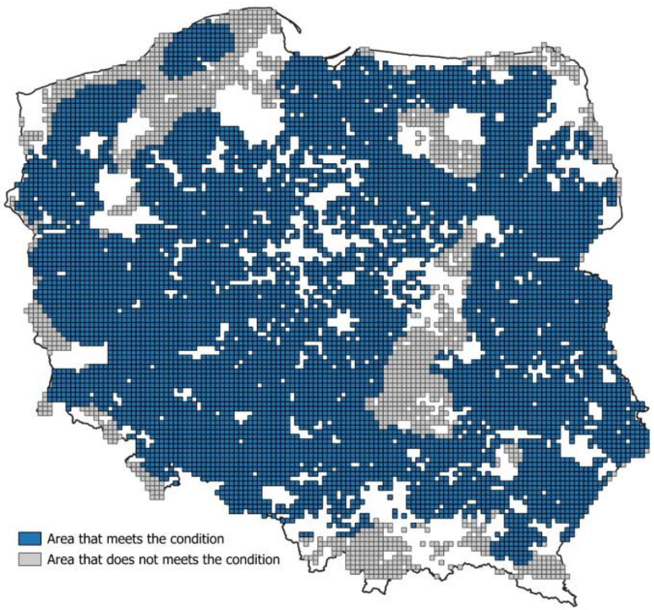


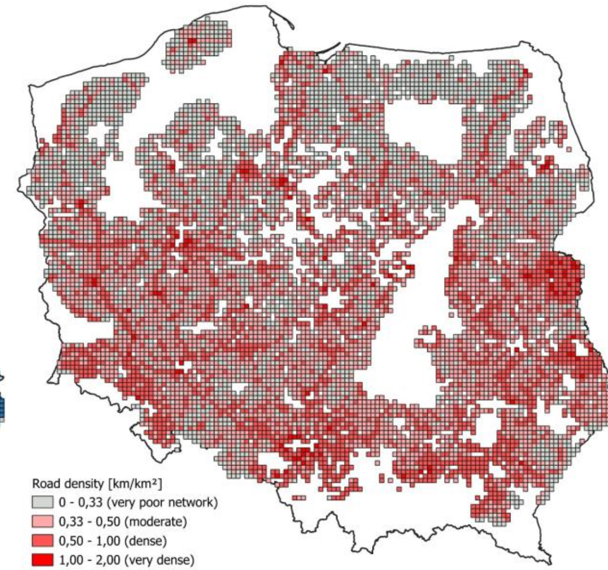
Area for the potential biomass torrefaction plants with all object

Sustainability-constrained maize straw potential from 2020 to 2025

Theoretical and technical maize straw potential

Year	Total area (ha)	Mean theoretical ($t\ ha^{-1}$)	Mean technical ($t\ ha^{-1}$)	Theoretical total (t)	Technical total (t)
2020	248,504.67	3.71	1.85	920,835.59	460,417.79
2021	247,189.04	4.52	2.26	1,118,489.88	559,244.94
2022	295,634.43	4.42	2.21	1,307,132.25	653,566.13
2023	225,801.72	3.51	1.75	792,385.06	396,192.53
2024	273,253.34	5.67	2.83	1,548,800.80	774,400.40
2025	175,917.00	4.66	2.33	819,354.68	409,677.34



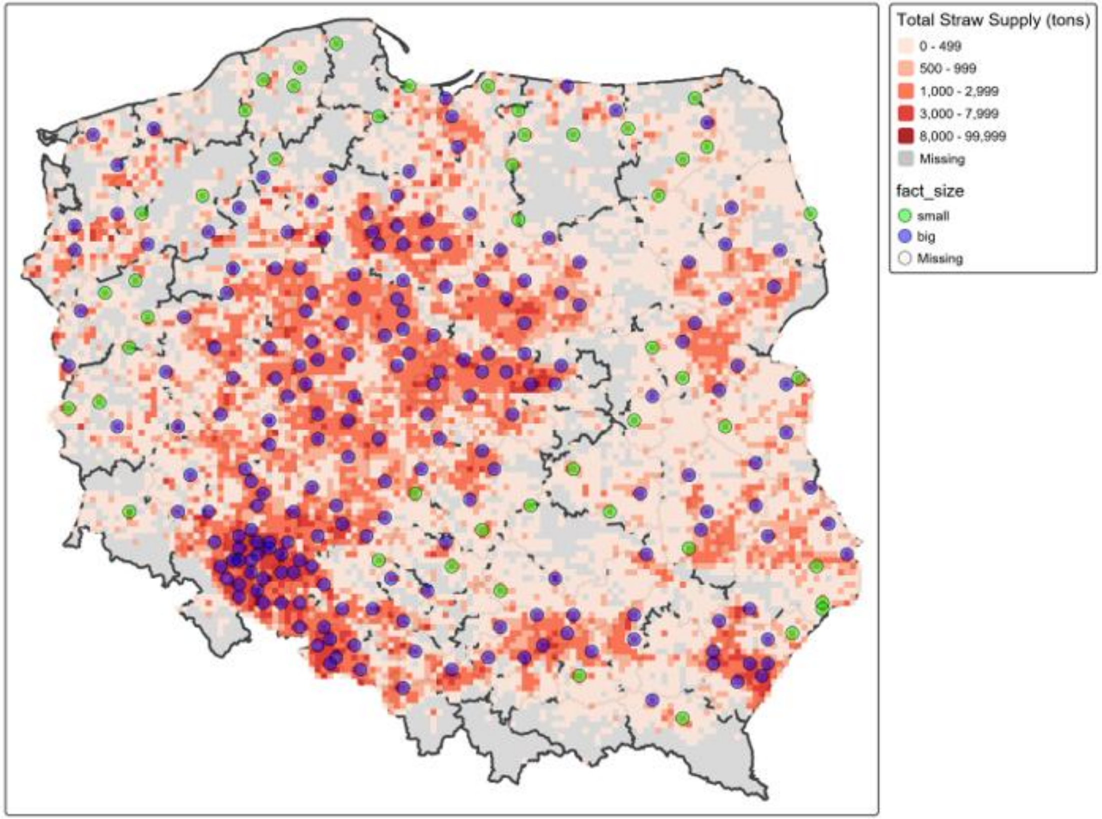


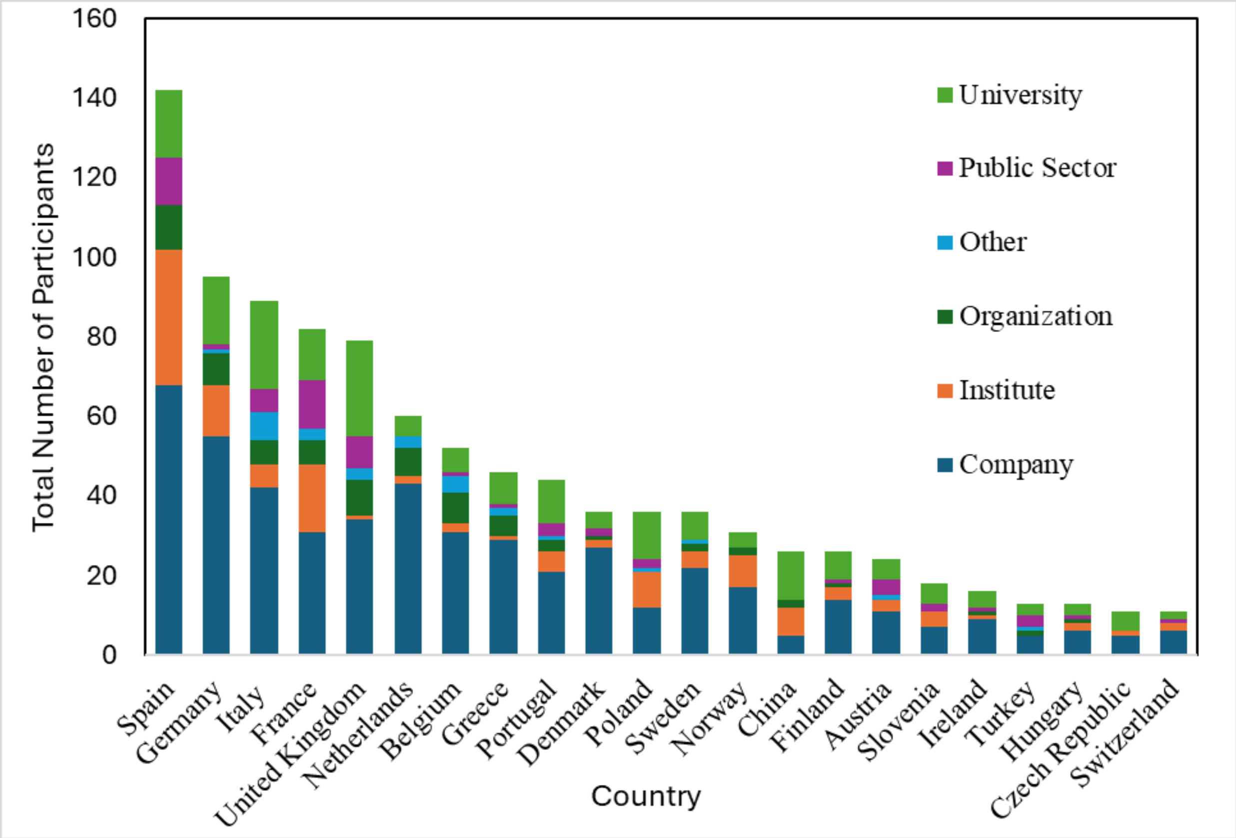
Type Road	Weight
Highways	1.00
Expressways	0.85
Main expressways	0.65
Main	0.45
Collective roads	0.25
Local	0.12
Access roads	0.06
Other	0.06

Area that meets the condition 30,000 tones

Road density in the facility (taking into account weight)

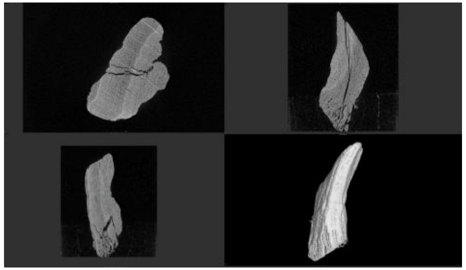
Facility locations – straw_100_s1_b1 | straw_price=100, s_Fact=1, b_fact=1

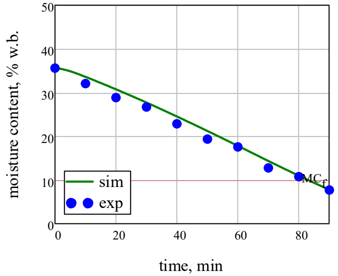


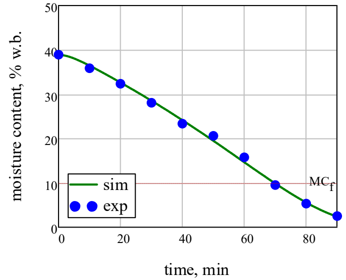


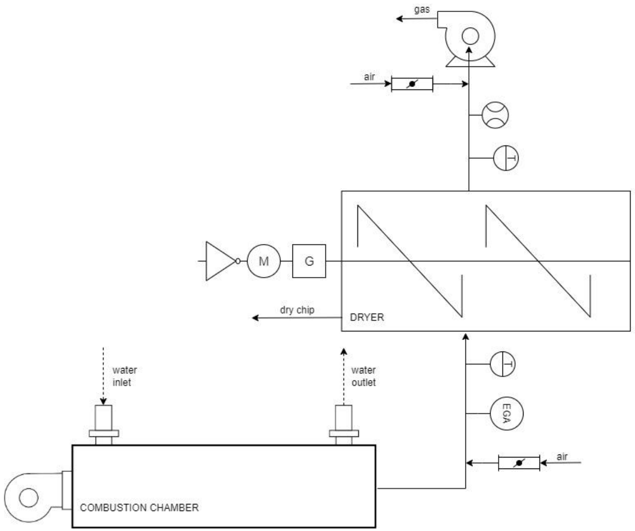
Total Number of Participants
0
20
40
60
80
100
120
140
160
University
Public Sector
Other
Organization
Institute
Company
Spain
Germany
Italy
France
United Kingdom
Netherlands
Belgium
Greece
Portugal
Denmark
Poland
Sweden
Norway
China
Finland
Austria
Slovenia
Ireland
Turkey
Hungary
Czech Republic
Switzerland
Country

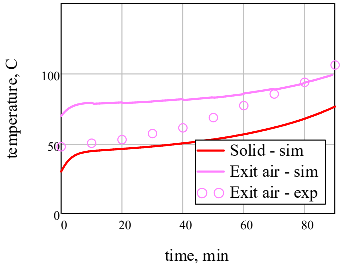
Szufa S.; Piersa P.; Junga R., Sobek S., Unyay H., Siczek K., Pakowski Z., Kostyniuk A., B. Likozar, ***"Batch rolling-bed dryer applicability for drying biomass prior to torrefaction"***, **RENEWABLE ENERGY**,

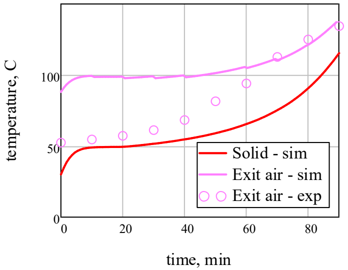












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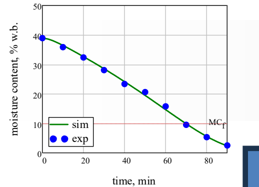
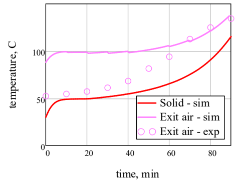
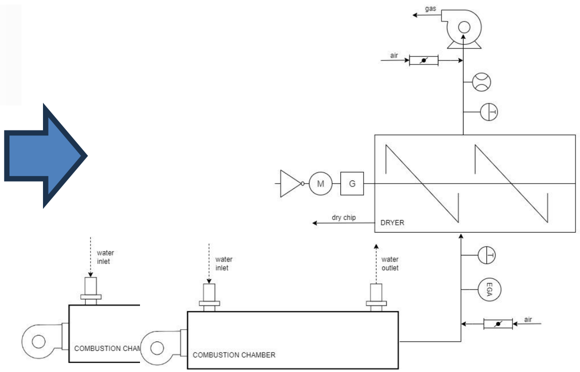
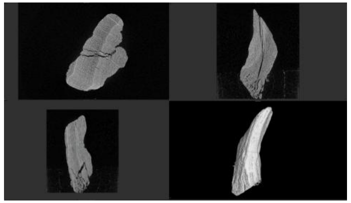
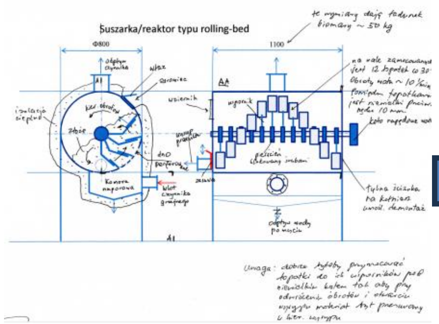
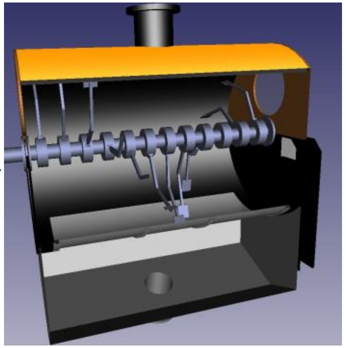


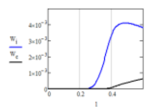




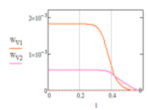








Rys. 4 Profil natężenia przepływu (kg/s) prod. pośredniego i węgla



Rys. 5. Profil natężenia przepływu (kg/s) substancji lotnych

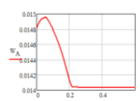
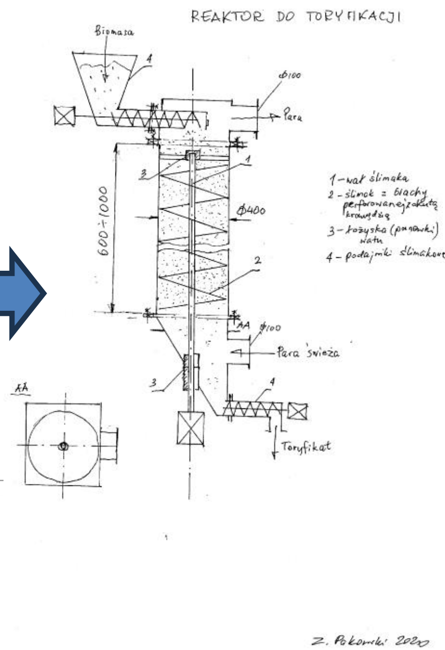
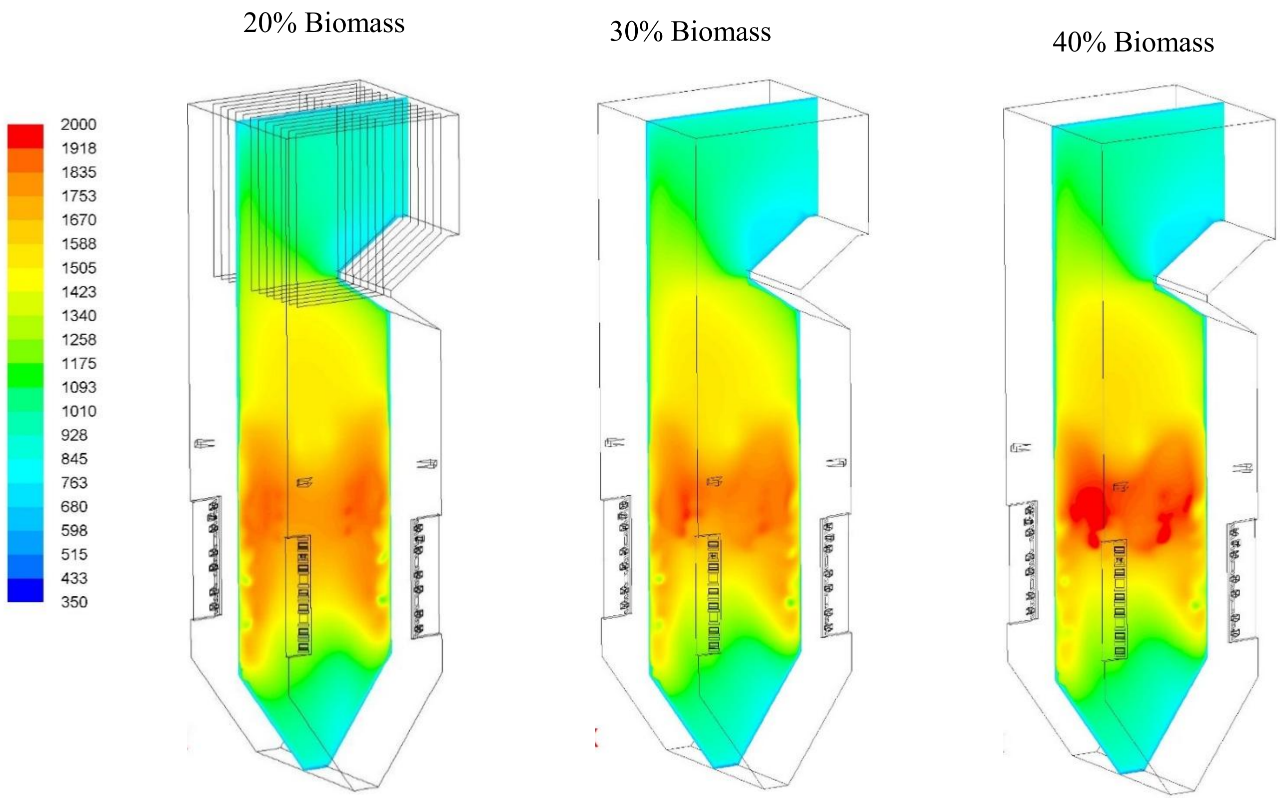


Fig. 6 Profil natężenia przepływu fazy gazowej (kg/s)

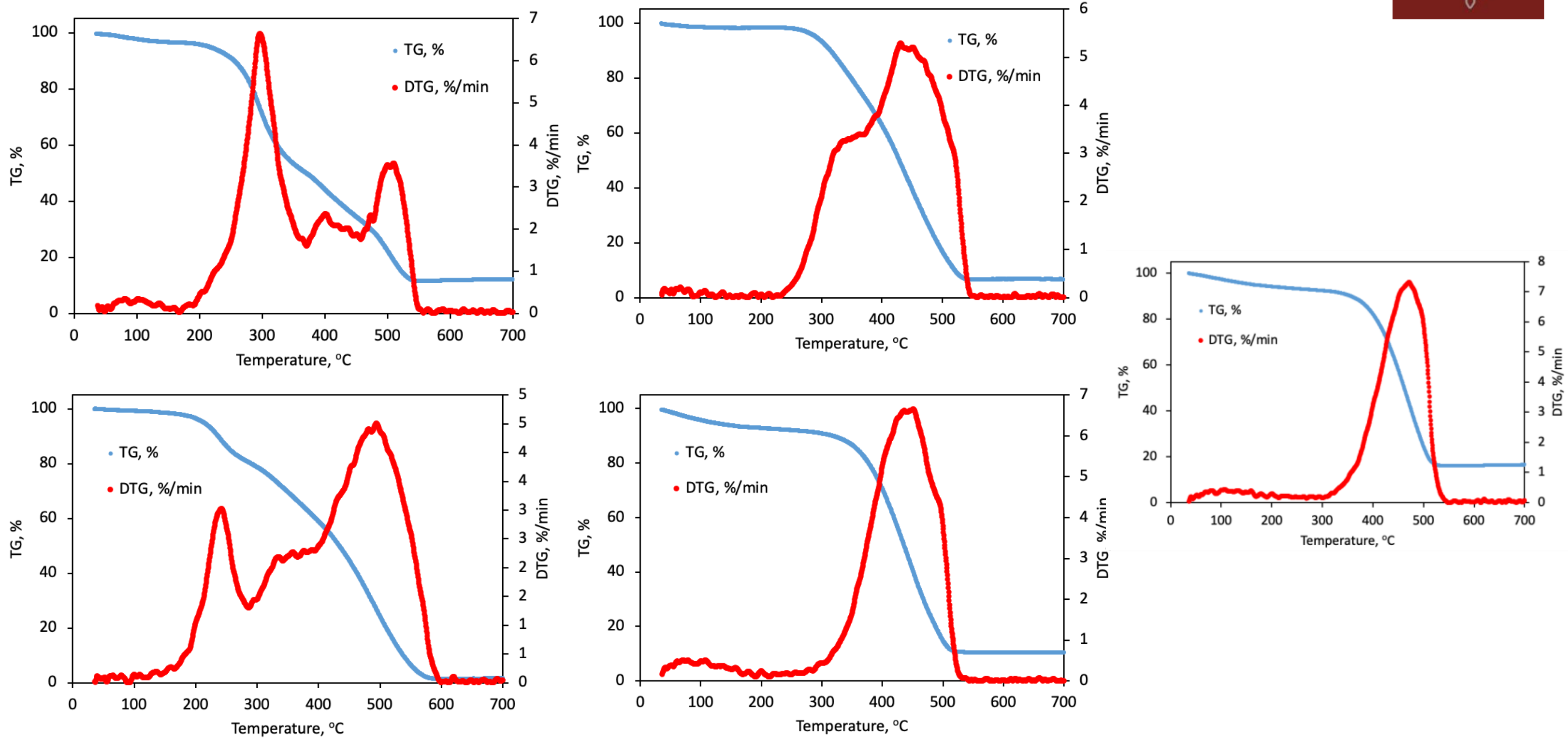
Z. Pakowski - v.1.0 dn. 17.12.2020



Solid Biofuels



Temperature fields (K) in the boiler axis

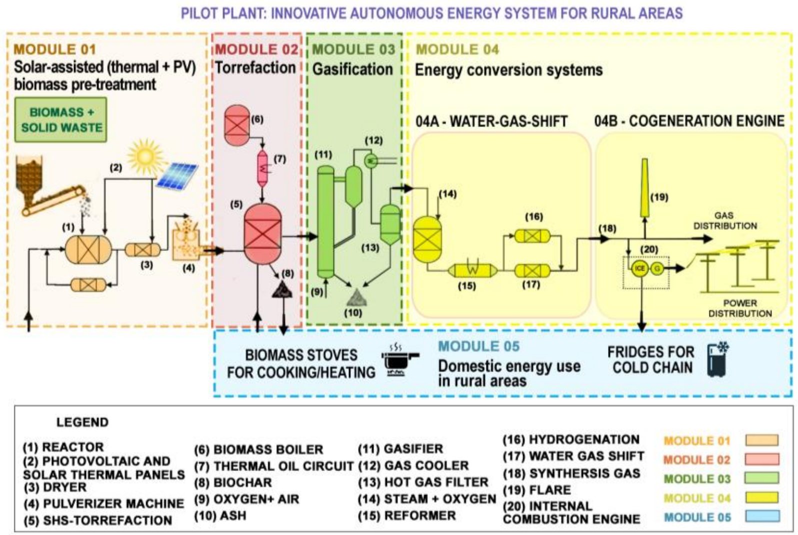


Thermogravimetric analyses of the oxy-combustion of spent coffee grains at heating rate 10 K/min: a) raw SCG, b) T- char, c) HTC char, d) P-char 600, e) P-char 800

- Comprehensive comparison of the combustion behavior of spent coffee grounds (SCG) subjected to torrefaction, pyrolysis, and hydrothermal carbonization (HTC) under oxy-fuel combustion conditions. The results clearly demonstrate that the selected **thermochemical pretreatment method significantly influences the physicochemical properties, combustion reactivity, and performance indices of the resulting biochars.**

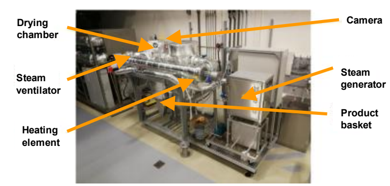
- Among the evaluated biochars, HTC-char exhibited the most favorable fuel characteristics - achieving the highest higher heating value (30.2 MJ/kg), the greatest energy yield (77.5%), and the highest flammability (C) and comprehensive combustion (S) indices.

Biomass Torrefaction combined with gasification process



„Hydrogen-rich SYNGAS production using Innovative gasification system towards a Circular Economy in rural area"

(a) Lab-scale superheated steam (SHS) batch unit for process specifications at IGB (Germany)



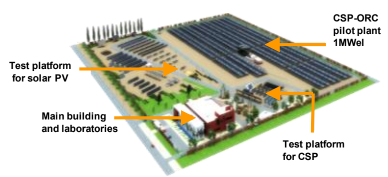
Gasification pilots at LERMAB Laboratory, UL (France)

(c) Lab-scale dense fluidized bed gasification reactor

(d) Pilot-scale dense fluidized bed gasification reactor in Epinal

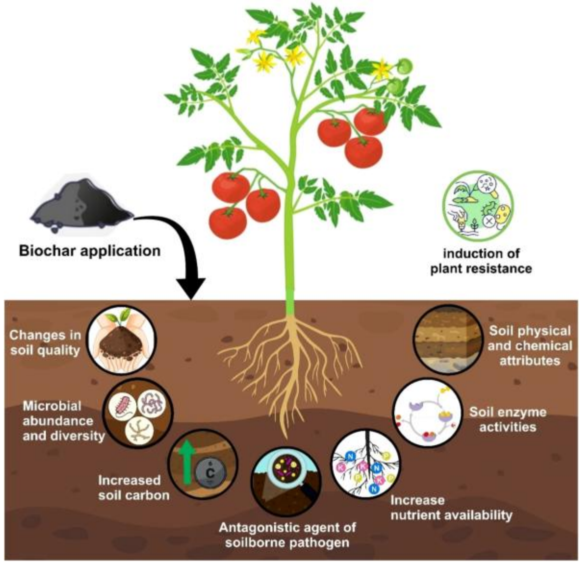
(b) Pilot-scale SHS drying unit to be upgrated as torrefaction unit at IGB (Germany)

(e) Pilot platform at Green Energy Park (GEP) Morocco

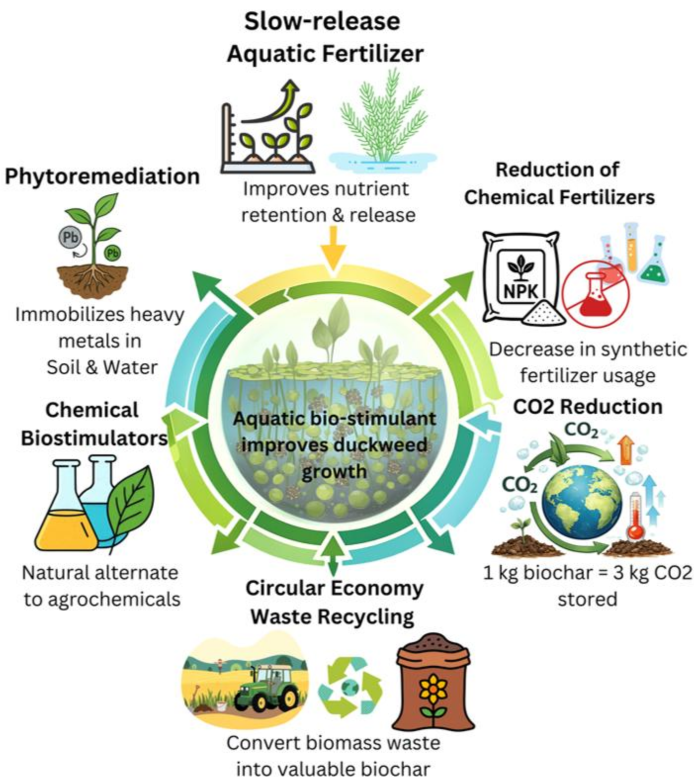


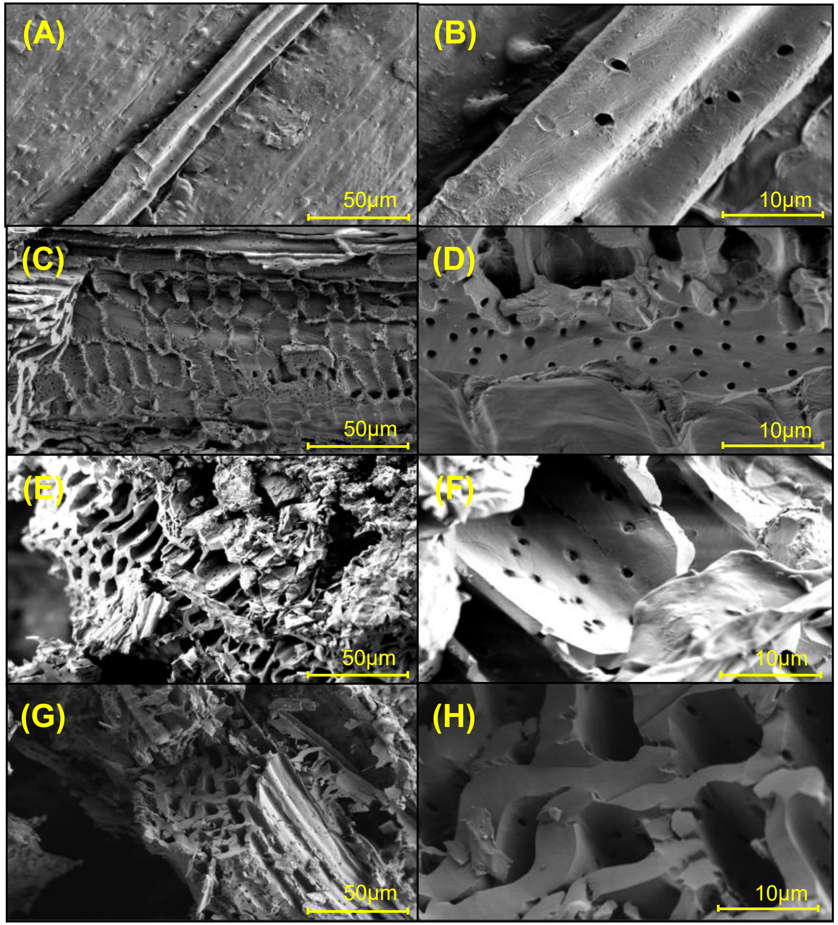
BIOCHAR FOR PLANTS GROWTH STIMULATOR

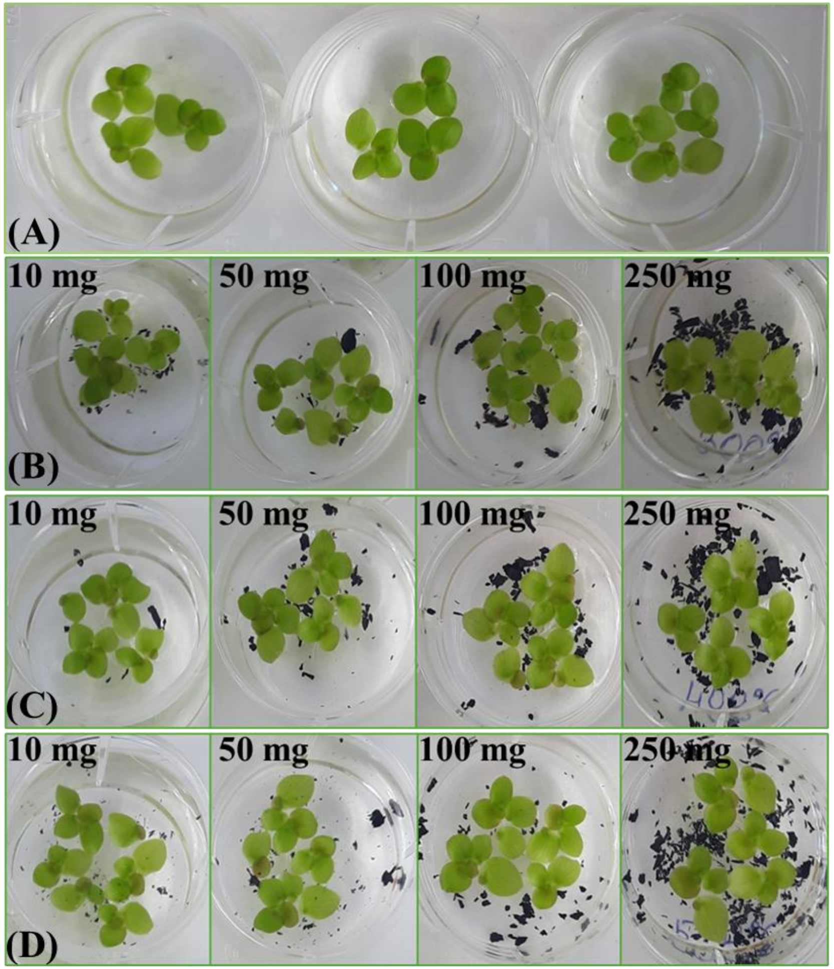
Aplication of biochar for stimulating growth of plants application of biochar for stimulating growth of plants. **Biochar stimulates plant growth by significantly transforming the physical, chemical, and biological properties of the soil**. This highly stable, carbon-rich material acts as a lifelong soil amendment that creates a fertile, moisture-rich environment tailored for optimal root development



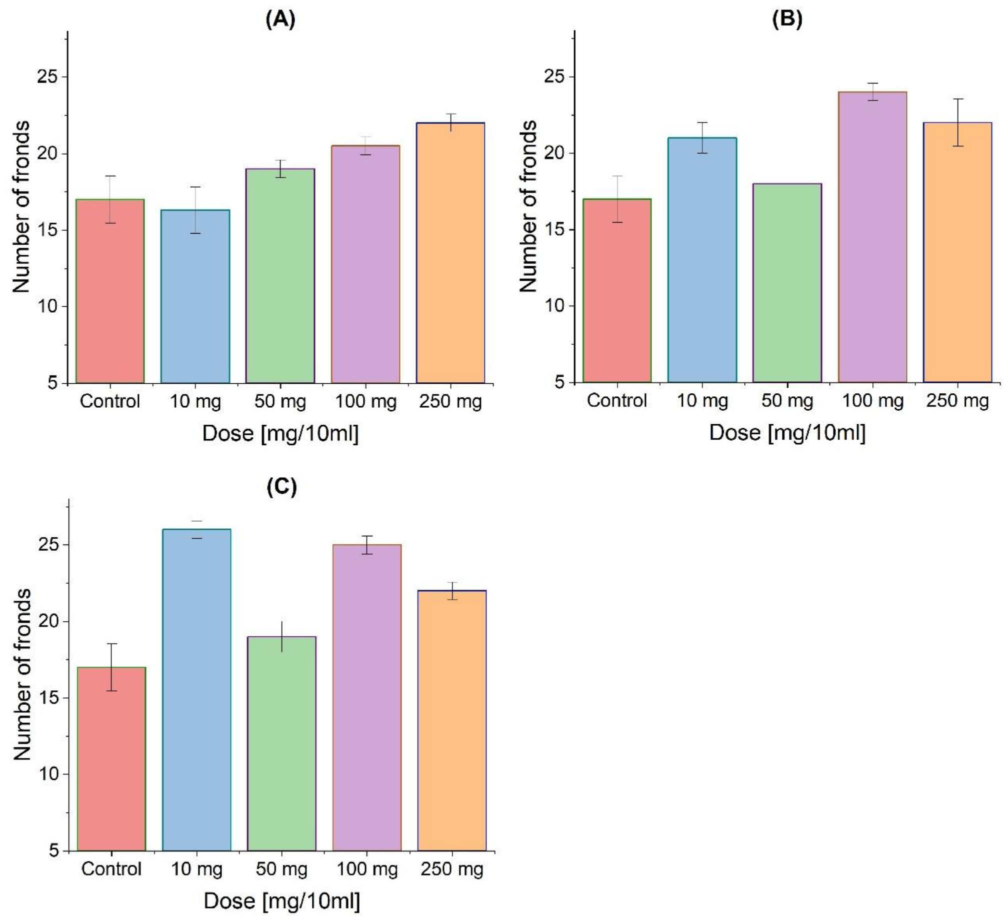
SEM views of (A, B) - raw material; (C, D) – 300 °C; (E, F) – 400 °C; (G, H) – 500 °C



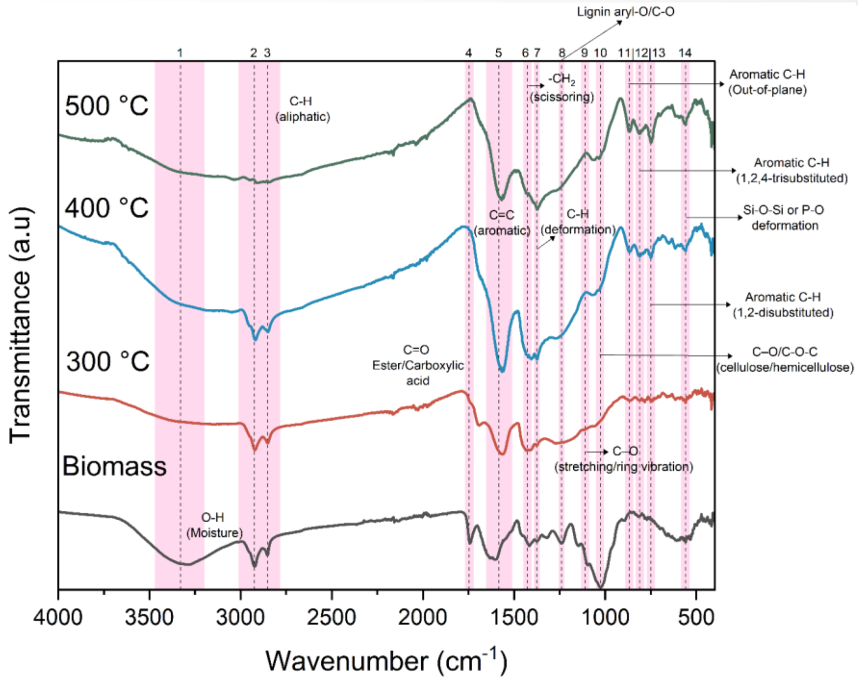




Growth of Spirodela polyrhiza plants. Variation in frond number among the samples on the final day of the experiment: (A) control sample, (B) biochar pyrolyzed at 300 °C, (C) biochar pyrolyzed at 400 °C, and (D) biochar pyrolyzed at 500 °C



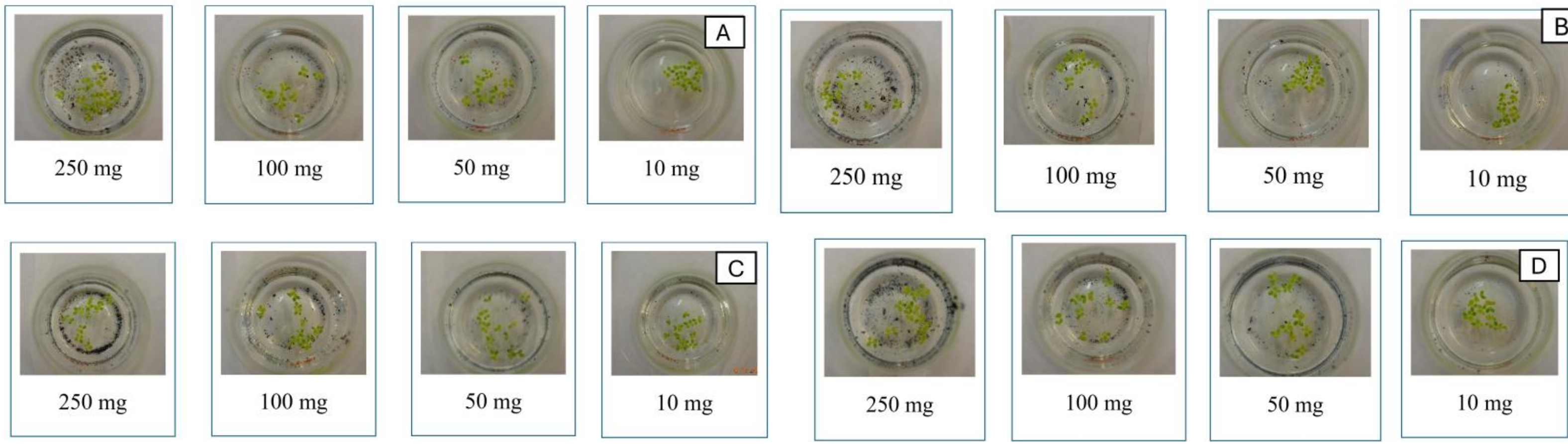
Effect of biochar produced at (A) 300 °C, (B) 400 °C, and (C) 500 °C on Spirodela polyrhiza growth in terms of the number of fronds



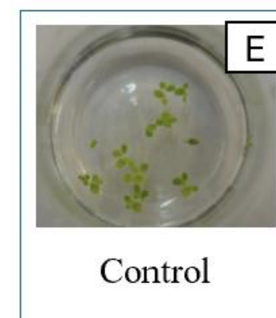
The ATR-FTIR spectra of the raw biomass and the pyrolyzed samples (300, 400, and 500 °C)

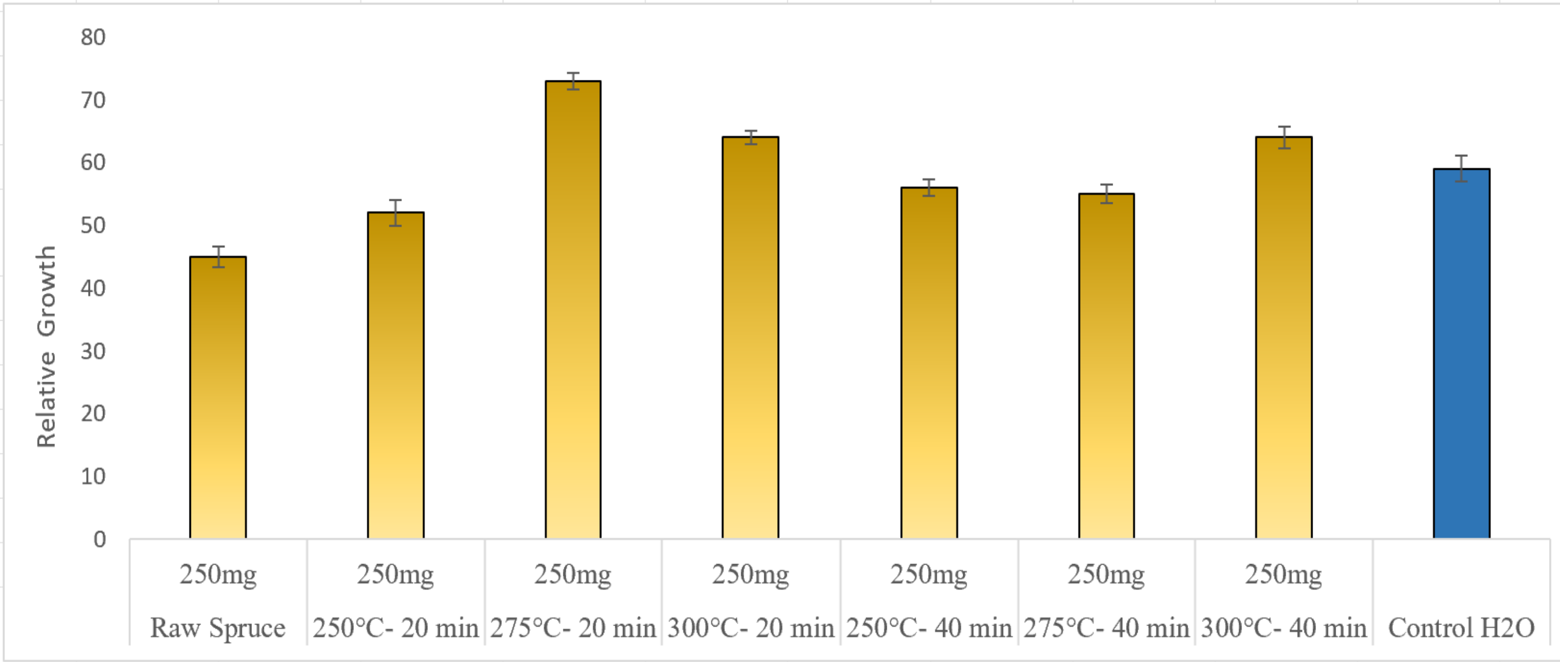
Material	Surface area (m^2/g)	BJH Surface area (m^2/g)	Pore Volume (cm^3/g)	Pore Diameter $D_v(d)$ (nm)
Raw biomass	0	0.756	0.001	3.070
Biochar 300 °C	0.849	4.923	0.0188	3.088
Biochar 400 °C	0.577	3.914	0.013	3.049
Biochar 500 °C	1.124	19.603	0.118	24.114

Brunauer-Emmett-Teller (BET) Surface Area Analysis results

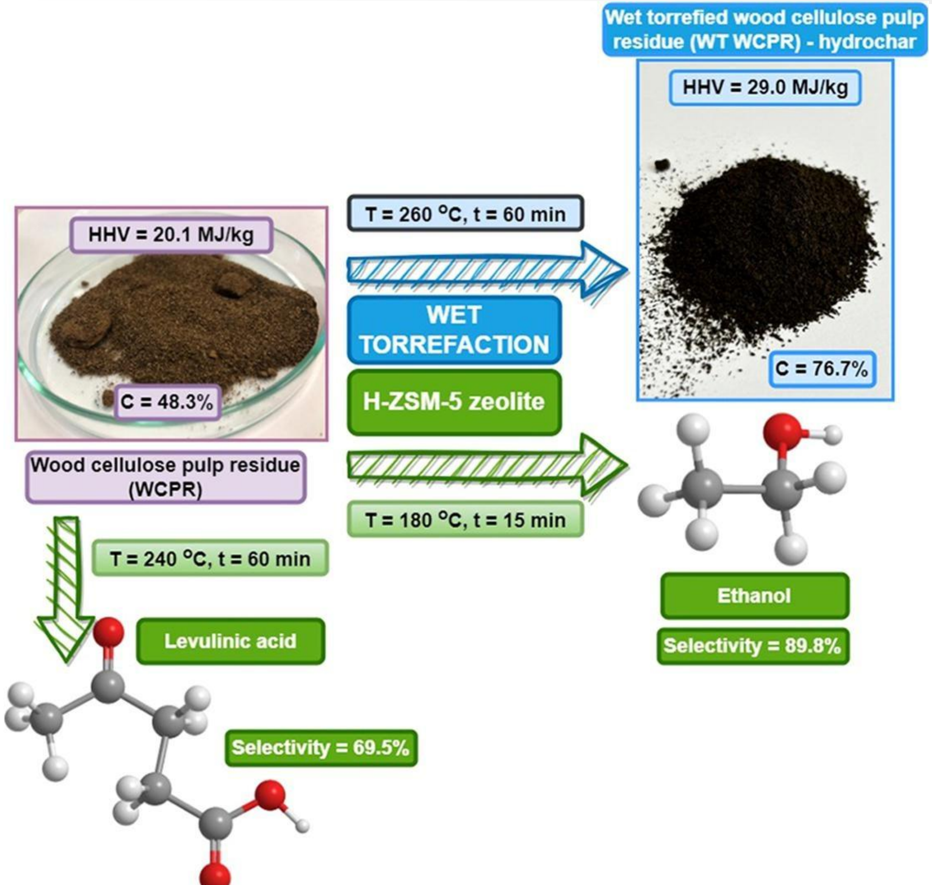


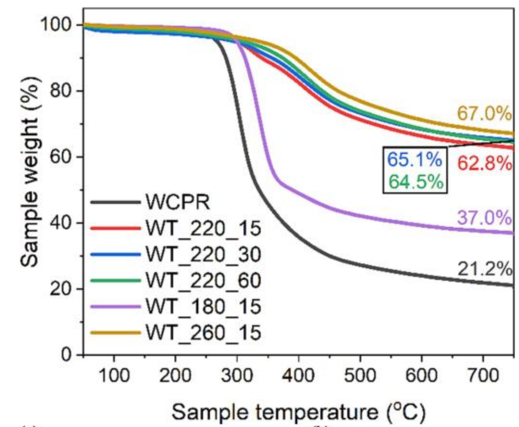
Growth kinetics of duckweed: Lemna minor L (after 10 days) grown on different concentrations and different conditions of torrefied spruce A) 275 ˚C-20 min residence time B) 250 ˚C- 40 min residence time C) 275oC -40 min residence time D) 300 ˚ C- 40 min residence time E) Control (Lemna minor L. plants grown only in tap water – absence of biochar)

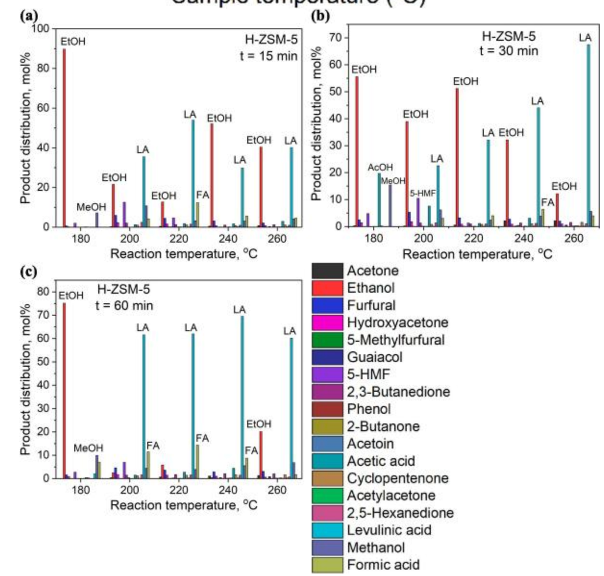




Relative Growth
80
70
60
50
40
30
20
10
0
250mg Raw Spruce
250mg 250°C- 20 min
250mg 275°C- 20 min
250mg 300°C- 20 min
250mg 250°C- 40 min
250mg 275°C- 40 min
250mg 300°C- 40 min
Control H2O


Wet torrefied wood cellulose pulp residue (WT WCPR) - hydrochar
HHV = 29.0 MJ/kg
C = 76.7%
HHV = 20.1 MJ/kg
C = 48.3%
Wood cellulose pulp residue (WCPR)
T = 260 °C, t = 60 min
WET TORREFACTION
H-ZSM-5 zeolite
T = 180 °C, t = 15 min
T = 240 °C, t = 60 min
Ethanol
Selectivity = 89.8%
Levulinic acid
Selectivity = 69.5%


Sample weight (%)
Sample temperature (°C)
WCPR
WT_220_15
WT_220_30
WT_220_60
WT_180_15
WT_260_15
67.0%
65.1%
64.5%
62.8%
37.0%
21.2%


(a)
H-ZSM-5
t = 15 min
(b)
H-ZSM-5
t = 30 min
(c)
H-ZSM-5
t = 60 min
Product distribution, mol%
Reaction temperature, °C
EtOH
MeOH
LA
FA
AcOH
5-HMF
Acetone
Ethanol
Furfural
Hydroxyacetone
5-Methylfurfural
Guaiacol
5-HMF
2,3-Butanedione
Phenol
2-Butanone
Acetoin
Acetic acid
Cyclopentenone
Acetylacetone
2,5-Hexanedione
Levulinic acid
Methanol
Formic acid

Porus carbon for anode for sodium-ion batteries;

Porus carbon for anode for sodium-ion batteries;

KPI	**Baseline**	**Target**	**Validation**
Carbon yield	Direct pyrolysis	Increase by ≥15%	Mass balance
AAEM removal	Feedstock dependent	>50%	ICP-OES
Ash content	Biomass dependent	<1 wt.%	Ash analysis
O/C ratio	Untreated biomass	Reduced after pretreatment	CHNS
BET surface area	Variable	Optimized for SIB	N_2 adsorption
Closed pore volume	Not optimized	Maximized	CO_2 adsorption
ICE	80–85%	≥90%	Half-cell tests
Reversible capacity	300–350 mAh g^{-1}	>350 mAh g^{-1}	Electrochemical testing
Batch reproducibility	Not defined	<5% deviation	QC protocol
Liquid-product identification	Limited	>95% carbon identified	GC-MS/HPLC/TOC

Dry torrefaction optimization; Hydrothermal carbonization (wet torrefaction). Steam torrefaction -> Comprehensive characterization by NIC (XRD, Raman, BET, CO_2 adsorption, SEM/TEM, XPS, TGA). Selection of the optimum pretreatment route.

https://cordis.europa.eu/project/id/101086411/pl

https://biotrainvalue.eu/

https://www.zycieuczelni.p.lodz.pl/pl-koordynuje-projekt-biotrainvalue

https://www.youtube.com/watch?v=t0ZsMgQoNXo

Nauka dla gospodarki cyrkularnej

References:

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