Biowaste-based pellets as a promising feedstock for biochar production

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Bialystok University of Technology, Poland

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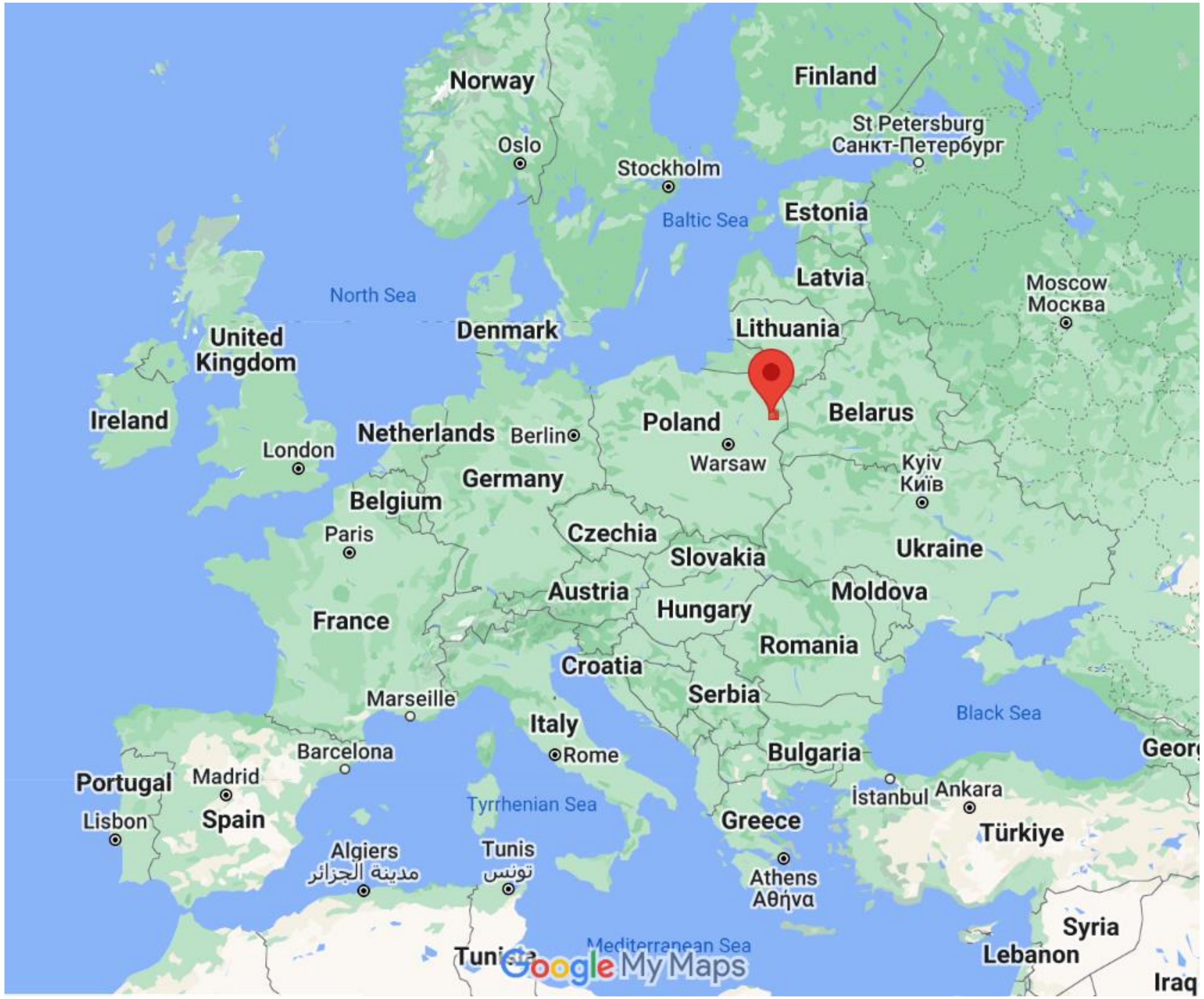

Source: pb.edu.pl

Dr Magdalena Joka Yildiz, *Asst. Prof.*

POLITECHNIKA BIAŁOSTOCKA

17 publications in SCI&SCI-E journals
11 proceedings
16 publications in international and national journals with peer review

h-indeks **8** (WoS: 159 citations)
8 (GoogleScholar: 212 citations)

Research interests:
Waste-to-Biochar
Renewable Solid Fuels
Thermochemical Process Technologies
Solids Pre-treatment Technologies

2019 Environmental Engineering, Mining and Energetics, PhD

2014 Mechanics and Construction of Machinery, MSc

2013 Agri-Food Engineering, BSc

2012 Biomedical Engineering, BSc

Research visits

5.2023 The University of Natural Resources and Life Sciences, Vienna, Austria

1-3.2023 UKBRC, The University of Edinburgh, Scotland, United Kingdom

5.2022 EBRI, Aston University, England, United Kingdom

energies — Reviewer Board Member

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ROLKA Rolnicze Koło Akademickie — Head of Students' Science Club ROLKA

Participation in projects founded by:

Ministerstwo Edukacji i Nauki

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BRISK2 BIOFUELS RESEARCH INFRASTRUCTURE

European Funds Regional Programme

NARODOWE CENTRUM NAUKI

Pellets

according to EN ISO 17225-2:2021
is a **cylinder** with:

- ✓ a diameter of 6 to 8 mm
- ✓ a length of between 3.15 and 40 mm

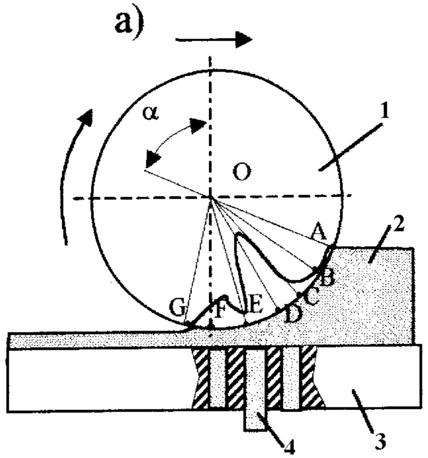
Pelletization

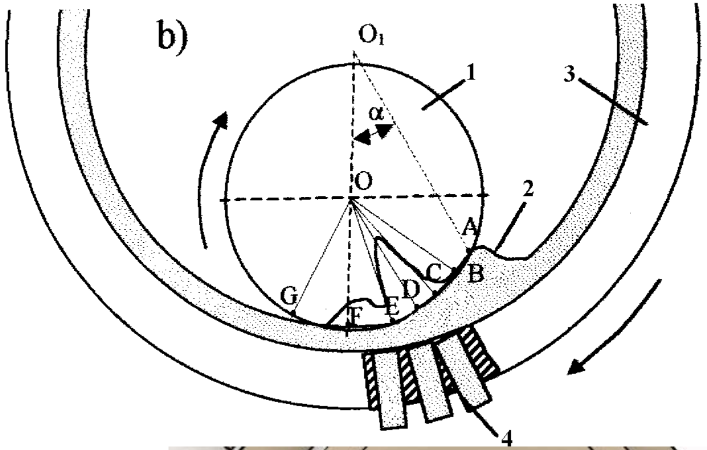
- ➢ pressure agglomeration of previously comminuted materials

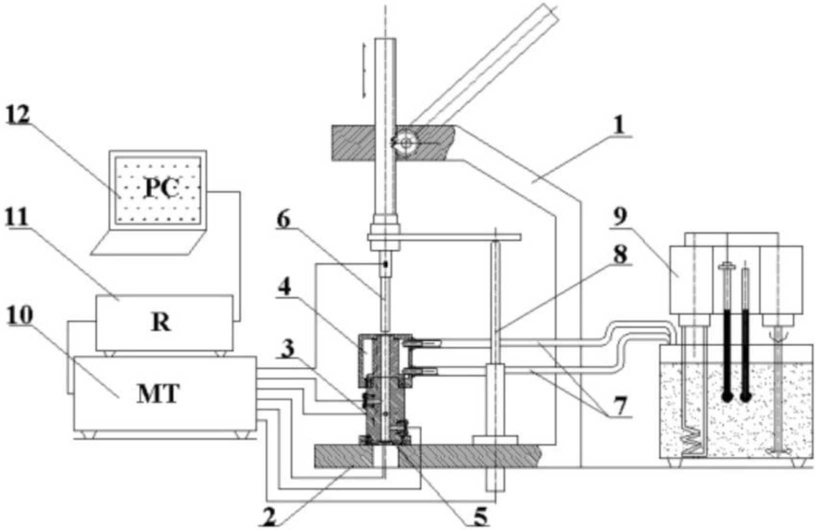
Pelletization

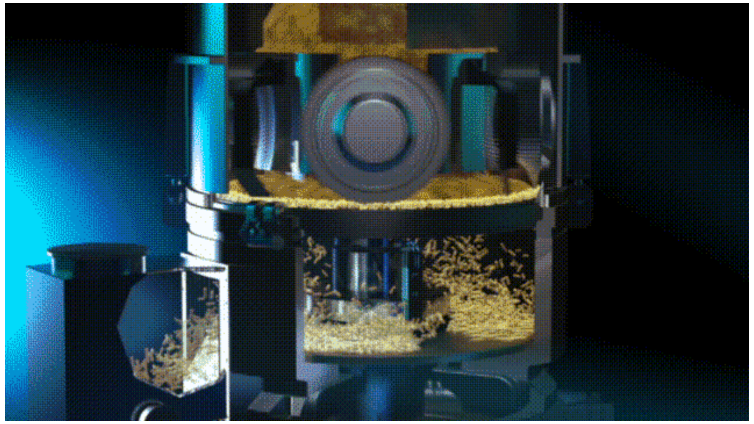
Pelletization

- in the working system of the granulator: as a result of external and internal forces, a given material is compacted into a specific, constant geometric form

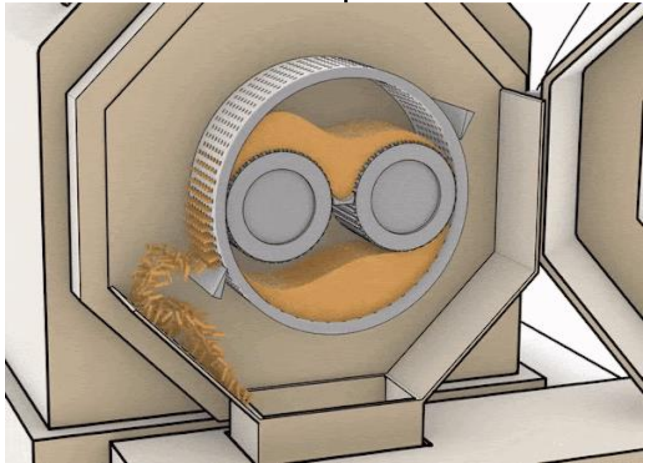








Source: www.lcicorp.com



Source: www. biomass-energy.org

Fig. 1. Working systems [Czaban 2000, Hejft 1991, Melnikov 1978]:
a) **flat matrix** - compacting rollers,
b) **ring matrix** - compacting rollers: 1 - compacting roller, 2 - material, 3 - matrix, 4 – agglomerate

c) single-pellet press

Biochar

porous, carbonaceous material that is produced by pyrolysis of plant biomasses and is applied in such a way that the contained carbon remains stored as a long-term C sink or replaces fossil carbon in industrial manufacturing.

It is not made to be burnt for energy generation (EBC).

I. Pellets to pyrolysis

Pellets are compacted forms of biomass or other materials that are cylindrical in shape and have a diameter of 6 to 8 mm and a length between 3.15 and 40 mm (EN ISO 17225-2:2021).

The integration of pellets into pyrolysis brings several **advantages**:

Consistency: Pellets provide uniform and consistent feedstock, reducing variability in pyrolysis reactions.

Efficiency: Faster heating rates and longer residence times in the reactor improve pyrolysis efficiency.

Energy Density: Pellets offer higher energy density, resulting in more energy-rich products.

Handling and Transportation: Pellets are easier to store and transport due to reduced volume.

Environmental Benefits: Pellets can lead to lower emissions and repurposing waste materials.

Scalability and Viability: Suitable for small and large-scale applications, enhancing economic viability.

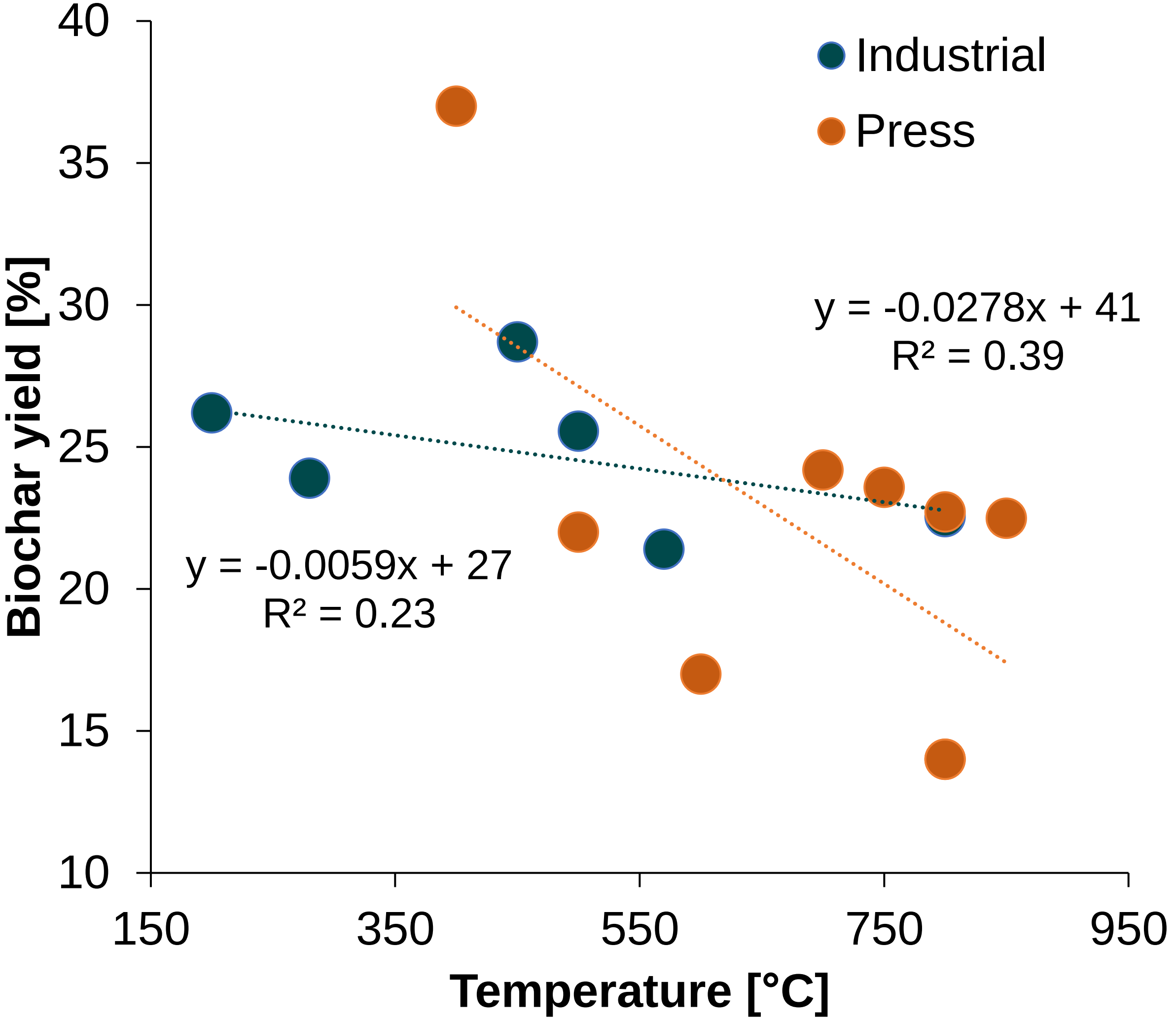
Versatility: Pellets can be made from diverse biomass sources and tailored for specific applications.

I. Pellets to pyrolysis

Tab. 1. Wood pellets pyrolysis literature data

Pelletizing system	Diameter [mm]	Length [mm]	Moisture content [%]	Ash content [%]	HHV [MJ/kg]	Temp. [°C]	Biochar yield [%]
Press	8	25	3,69	0,65		700	24,18
Press	8	25	3,69	0,65		750	23,57
Press	8	25	3,69	0,65		800	22,71
Press	8	25	3,69	0,65		850	22,48
Press	8	9		1,15		400	37
Press	8	9		1,15		500	22
Press	8	9		1,15		600	17
Press	8	9,5		1,02		800	14
Press	8	9,5		1,02		800	14
Industrial	8	40	6,19	0,85	17,79	500	25,55
Industrial	8	40	6,19	0,85	17,79	800	22,54
Industrial						200	26,2
Industrial						280	23,9
Industrial						570	21,4
Industrial			7,7	1,11		500	30
Industrial	6	20	7	3,6	18,2	450	28,5
N/D	6	12,5	6,3	0,3		800	21,3
N/D	8	11,75	5,6	0,3		800	21,5
N/D	8	11,75	5,6	0,3		450	28,7
N/D	8	11,75	5,6	0,3		800	21,5

Fig. 2. Comparison of wood pellets pyrolysis depending on the process temp. and their fabrication method



II. Addressed questions

- How does the bulk and particle density of biomass pellets change after pyrolysis?
- Is there a correlation between the bulk and particle density of pellets undergoing pyrolysis?
- What impact does the biomass type have on the mechanical properties of pyrolyzed pellets?

III. Materials

Tab. 3. *Pellets' composition*




No.	**Main component**	**Binder, 10%*wt***
1	Buckwheat husks	Potato pulp (PP)
2	Buckwheat husks	Coffee grounds (CG)
3	Hemp harl	Potato pulp (PP)
4	Hemp harl	Coffee grounds (CG)
5	Hemp harl	-
6	Giant miscanthus	Potato pulp (PP)
7	Giant miscanthus	Coffee grounds (CG)
8	Giant miscanthus	-
9	Hazlenut shells	Coffee grounds (CG)
10	Hazlenut shells	


III. Methods – pelletization and pyrolysis

Pelletization – fixed die-rotating rolls

Die hole ϕ6 mm
Feedstock flow 30÷60 kg/h
Rolls rotation speed 125 rpm
Power 12 kW

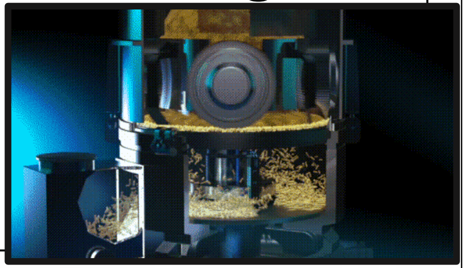


Fig.3. Pellet production line at the Bialystok University of Technology [labecotech.pl/]

Pyrolysis – Auger reactor

Split-tube furnace ϕ100 mm
Nitrogen flow 1 L/min^{-1}
Feeding rate ca. 500 g/h^{-1}
Process temperature 550°C and 700°C

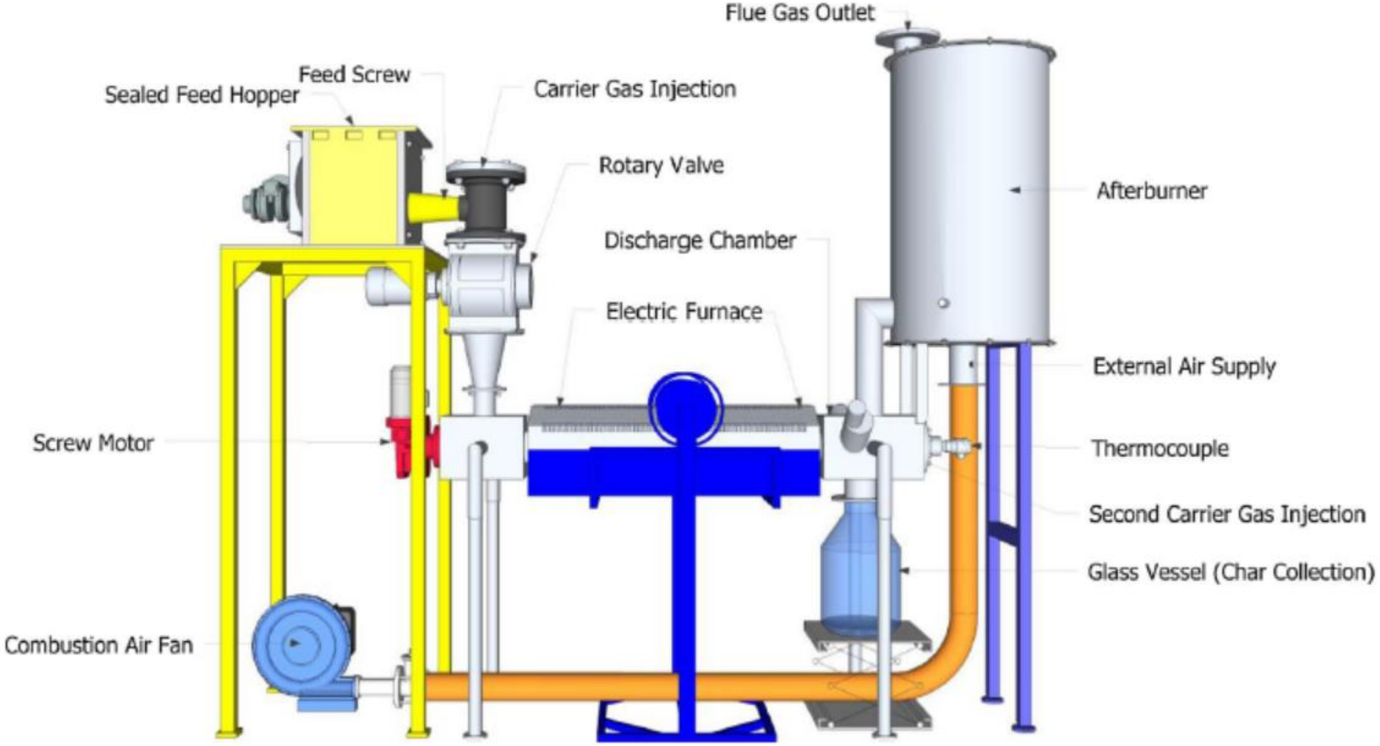
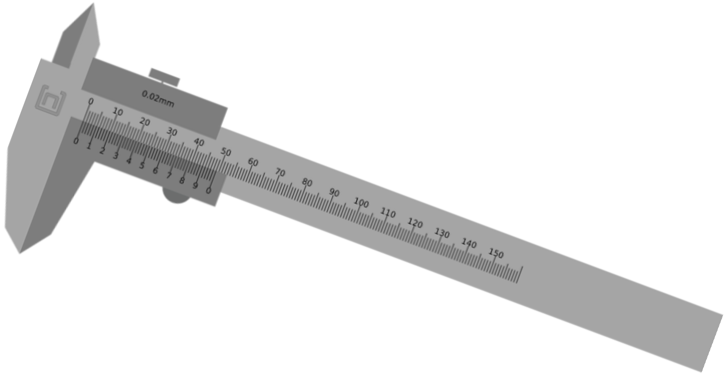


Fig.4. Auger reactor (Stage II) at the UKBRC, University of Edinburgh [Mašek O. et al. (2018) JAAP, 132.]

III. Methods – physical and mechanical properties

Physical properties by mass and dimensions measurements:

- Bulk density
- Particle density



Mechanical properties by measuring the force at break

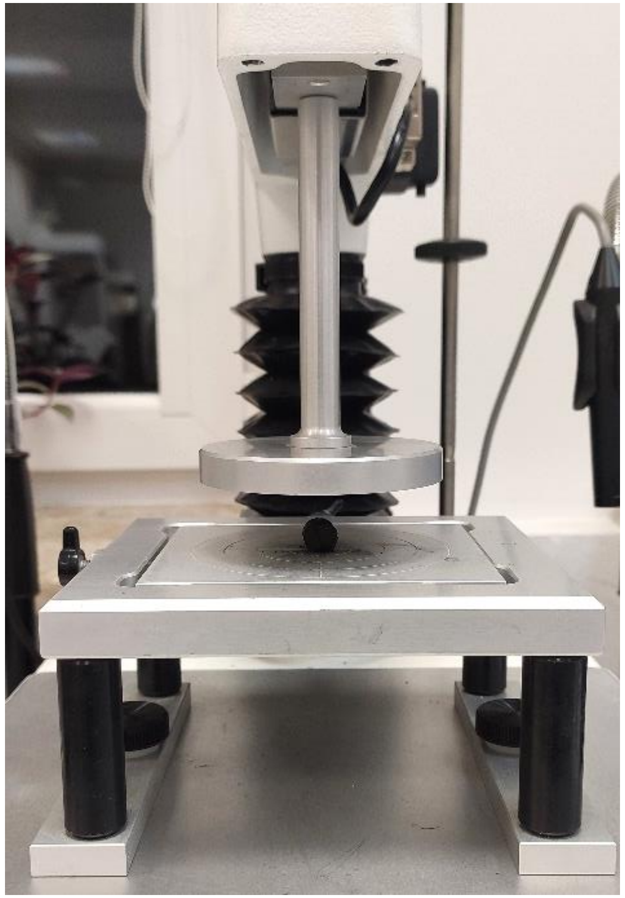


Fig.5. TA.XTplus Texture Analyser

Stress was calculated as follows:

$$\sigma_n = \frac{2F}{\pi d h}$$

where

F is the maximum force at break,

d is the pellet diameter,

h is the pellet lenght.

IV. Results – bulk density of BC pellets and raw biochar

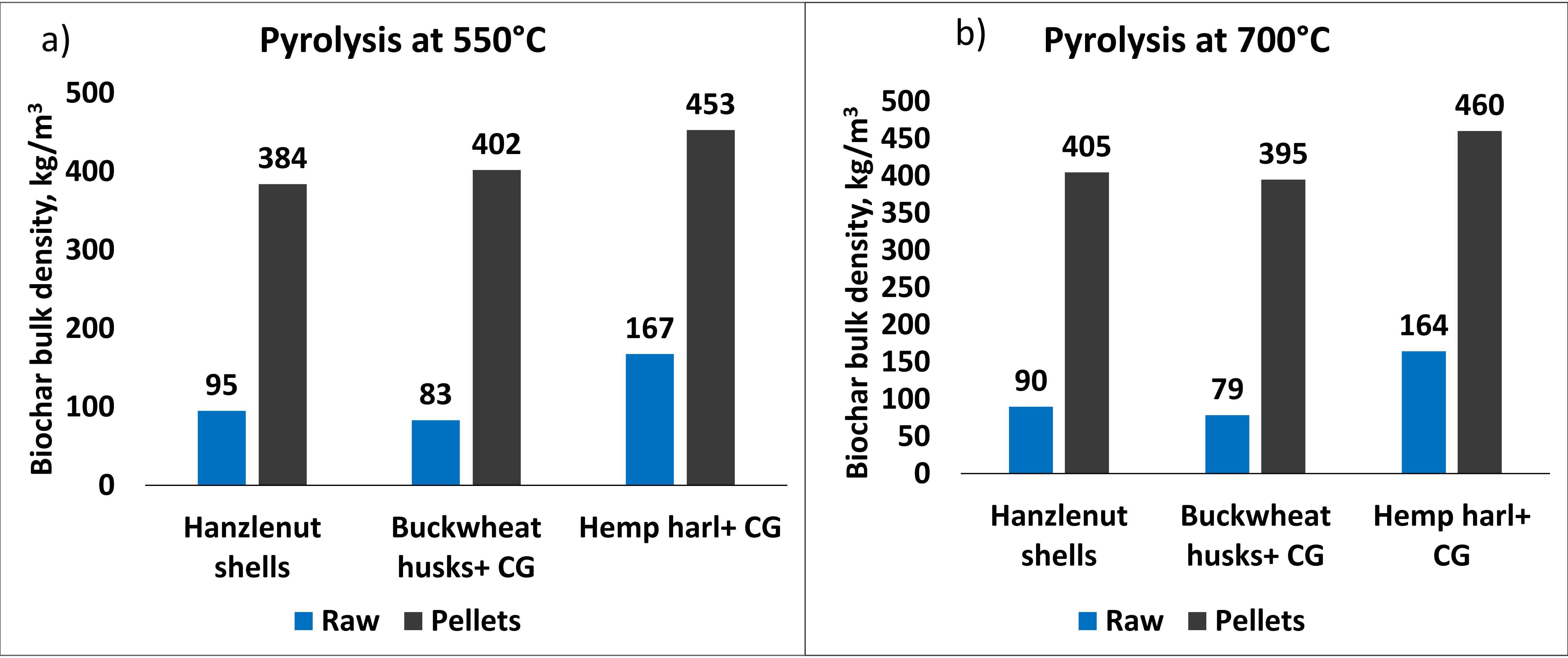


Fig.5. *Bulk density of biochar obtained from unprocessed biomass and pellets at a) 550 °C and b) 700 °C*

IV. Results – bulk density

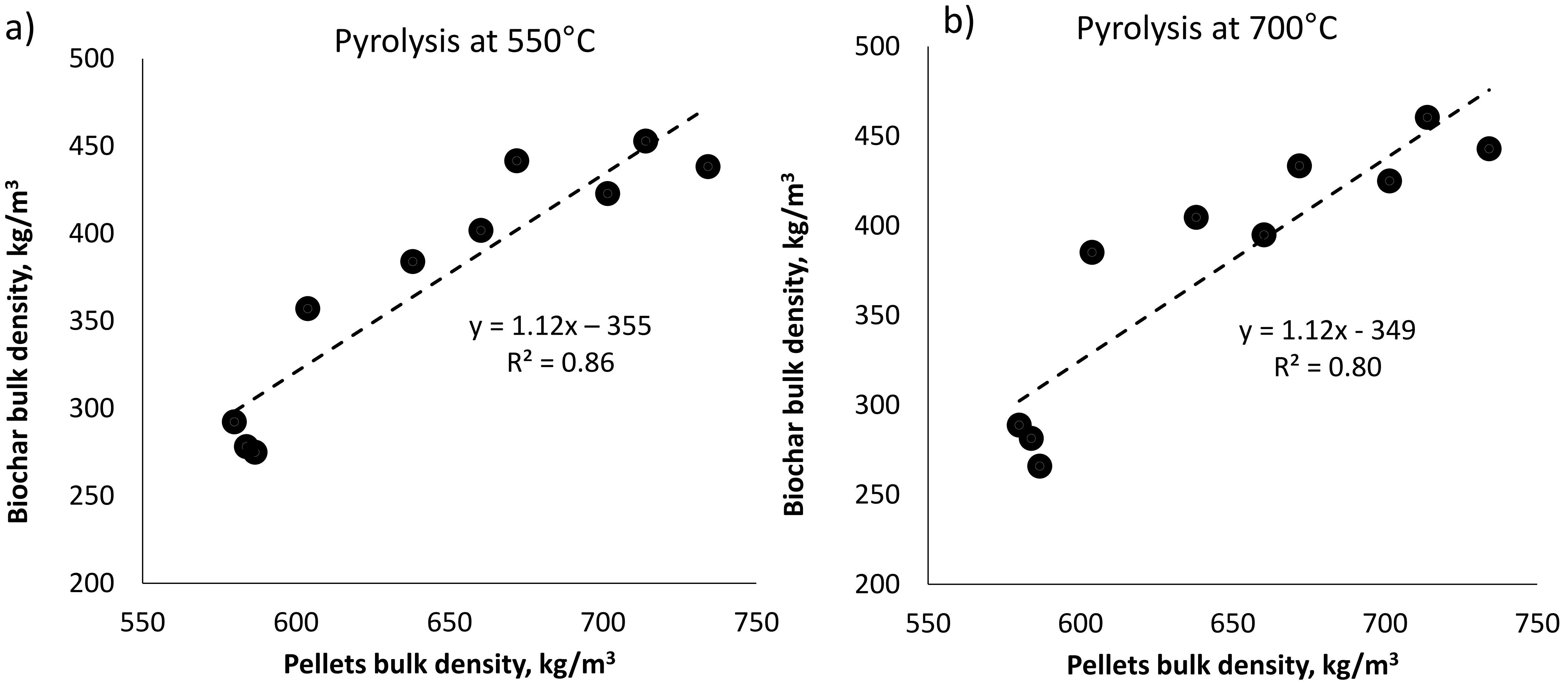


Fig.6. *Correlation between the pellet bulk density before and after pyrolysis at a) 550 °C and b) 700 °C*

IV. Results – particle density

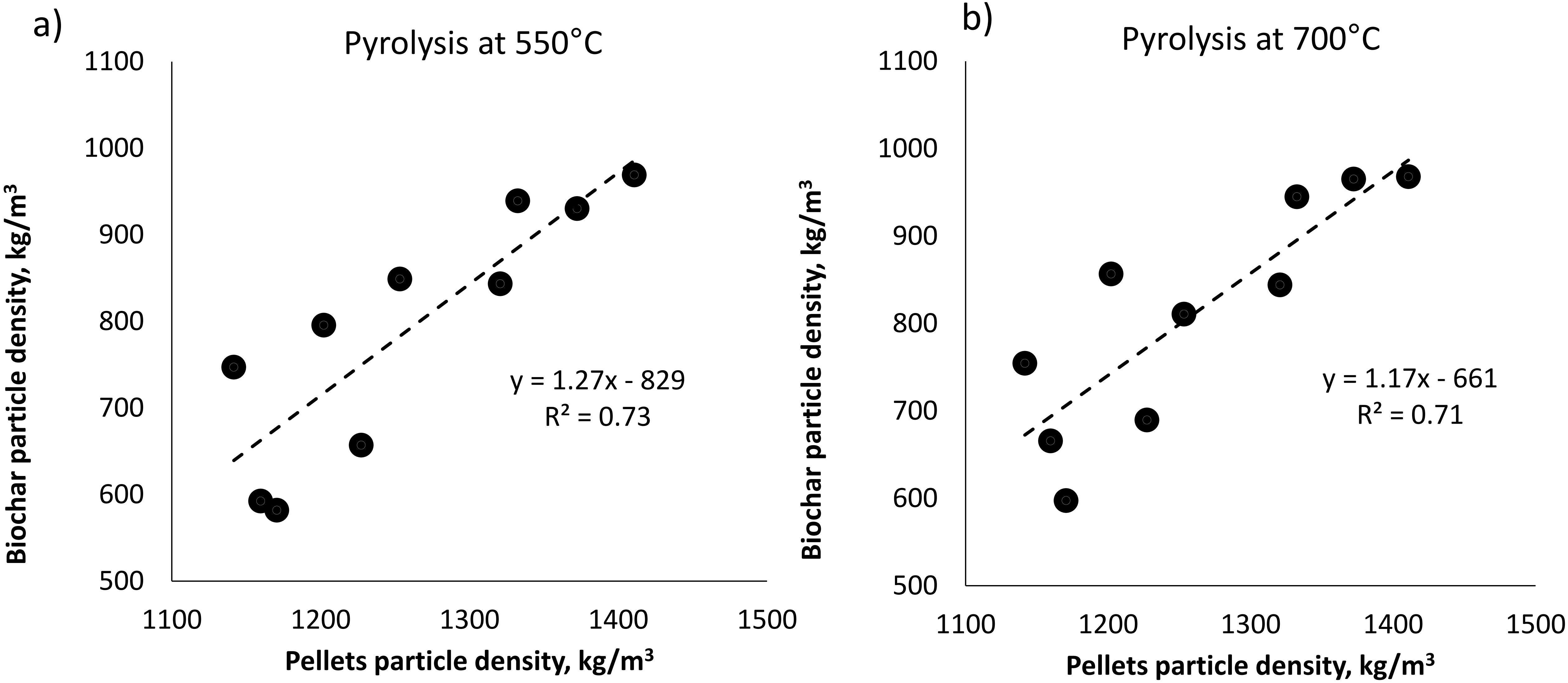


Fig.7. *Correlation between the particle density before and after pyrolysis at a) 550 °C and b) 700 °C*

IV. Results – bulk and particle density

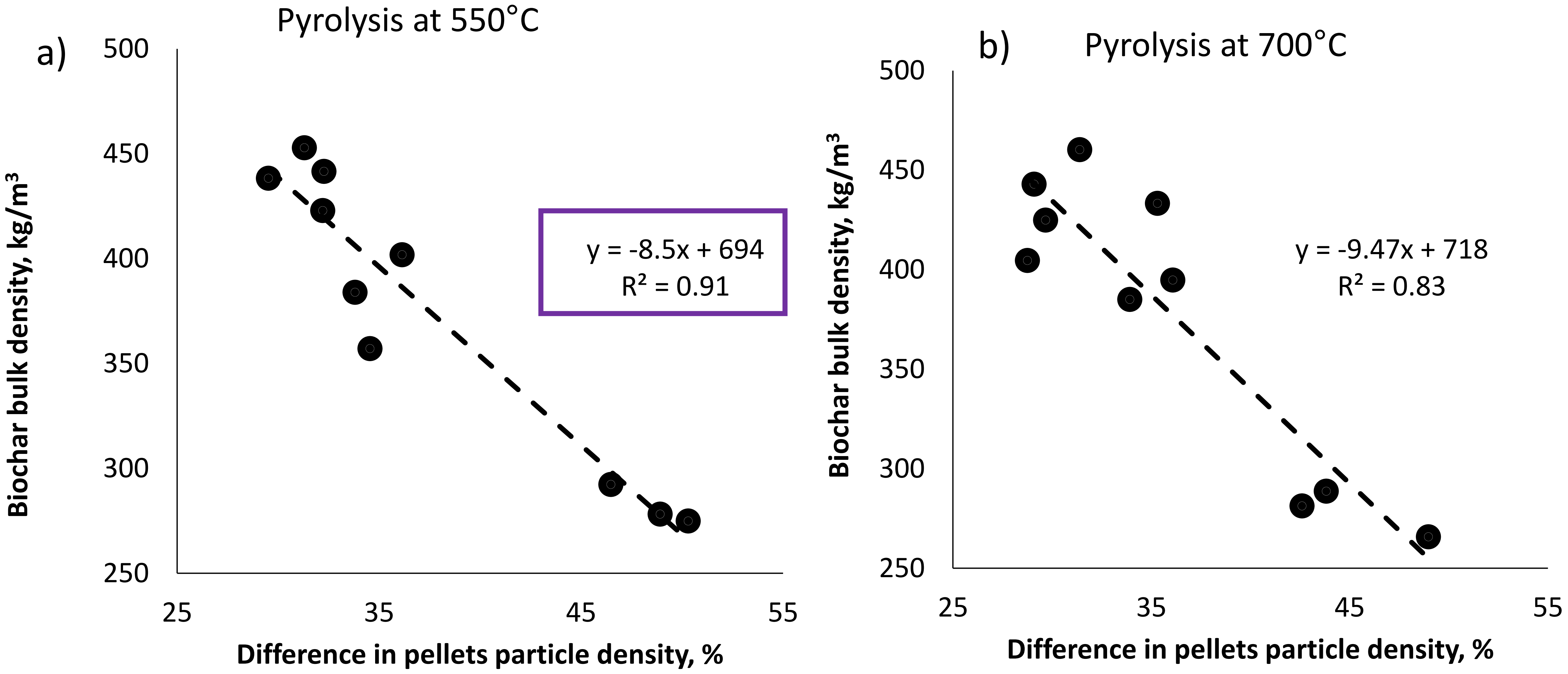


Fig.8. *Correlation between the difference of pellet particle density before and after pyrolysis and biochar bulk density at a) 550 °C and b) 700 °C*

IV. Results – mechanical properties

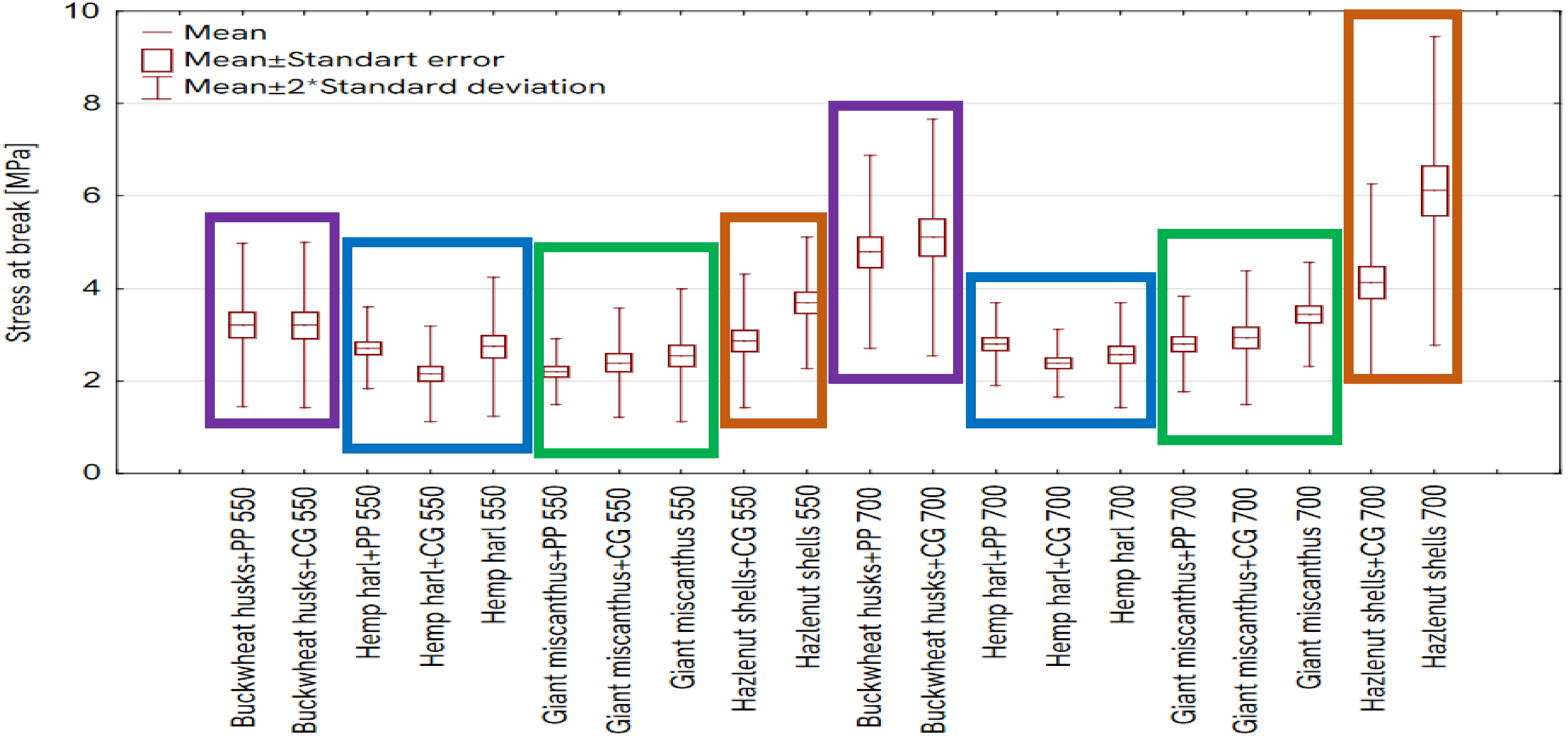


Fig.9. *Stress at break of pyrolyzed pellets*

V. Summary

- Biomass pellets are valuable feedstocks for pyrolysis allowing to reach an improved bulk density of biochar.
- Pelletization as a pre-treatment step in the production of biochar can improve co-pyrolysis of various biomass types.
- A strong positive correlation is evident between the bulk density of pellets undergoing pyrolysis and the characteristics of the resultant biochar. This correlation is more pronounced when pyrolysis is conducted at lower temperatures. Furthermore, the particle density of pyrolyzed pellets is directly proportional to that of the untreated pellets.
- Production of biochar is a promising technology to transform waste biomass into a value-added product having the ability to long-term carbon storage.

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