Valorisation of brewers' spent grain for manufacturing of wood polymer composites

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ALEKSANDER HEJNA, KRZYSZTOF FORMELA, MATEUSZ BARCZEWSKI

This Project is supported by the National Science Centre (NCN, Poland) in the frame of SONATINA 2 project 2018/28/C/ST8/00187

AIM OF THE PROJECT

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- Analysis of the lignocellulose fillers' modification *in situ* during reactive extrusion,
- Development of the continuous method for fillers' modification – reduction of the environmental impacts,
- Possibly, development of the one-step process including filler modification and manufacturing of polymer composites – cost reduction,
- Development of the utilization method for brewers' spent grain (BSG) – the biggest by-product of the brewing industry (Poland is the 2nd biggest European producer of beer),

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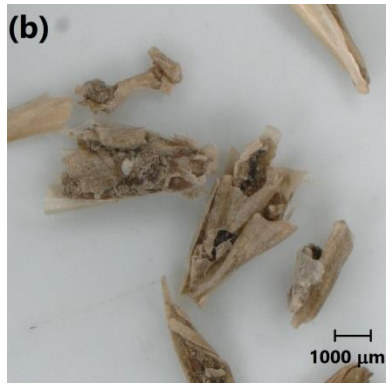
BACKGROUND

BREWERS' SPENT GRAIN

- The main by-product of brewing industry, ~85% of total by-products,
- Stand for ~31% of the initial malt weight – 6.2 kg per 100 l of beer,
- Over 2.5 milion tonnes annually in Europe,
- Currently rather perishable by-product than wholesome raw material,
- Mainly used for animal nutrition, given for free not to pay for utilization,
- Considering the chemical composition – promising candidate for filler in wood-polymer composites,



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BSG MODIFICATIONS

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REACTIVE EXTRUSION OF BSG

- One-step drying and grinding – Hejna A., Formela K., *Sposób suszenia i rozdrabniania młóta browarnianego*, Polish patent application P.430449.,
- Easy tailoring of final products' properties by extrusion parameters,
- Maillard reactions during modification – additional antioxidant activity,
- Possible color adjustment by changing the extrusion parameters – important for final recipients of WPCs,
- Modified BSG – promising candidate for WPCs production,

Hejna A., et al., *J. Cleaner Prod.*, 2020, 285, 124839.

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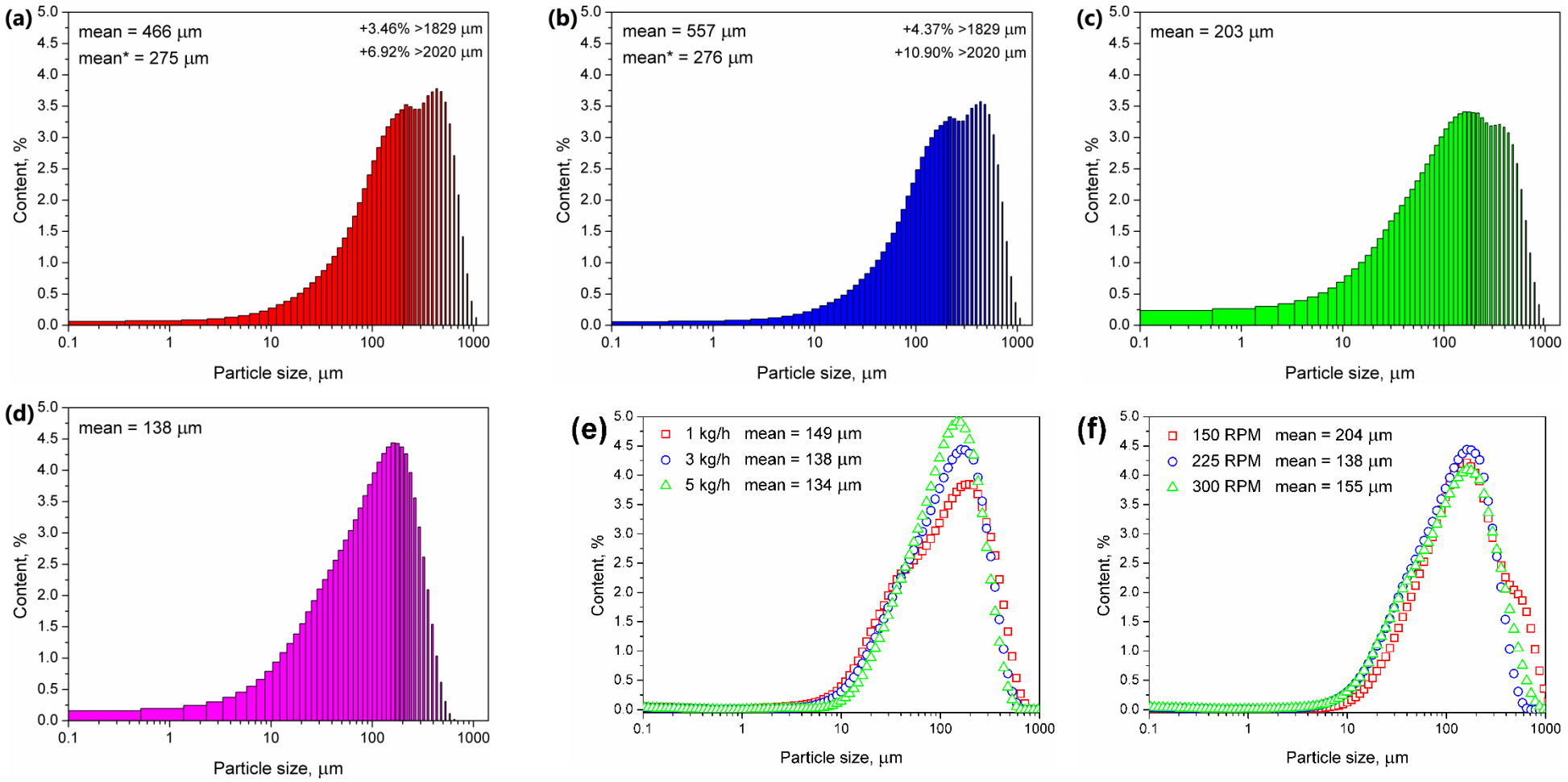

Particle size distribution of brewers' spent grain extruded with a screw speed of 225 rpm and throughput of 3 kg/h at (a) 30 °C, (b) 60 °C, (c) 120 °C and (d) 180 °C, as well as the impact of (e) throughput and (f) screw speed.

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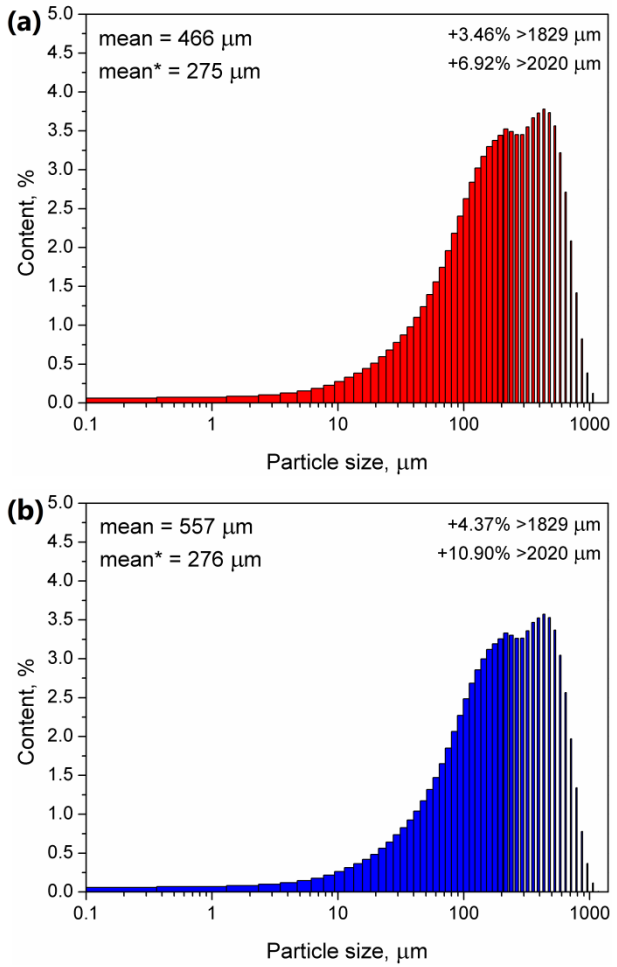

Particle size distribution of brewers' spent grain extruded with a screw speed of 225 rpm and throughput of 3 kg/h at (a) 30 °C, and (b) 60 °C.

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- Color changes as a result of non-enzymatic browning, mainly Maillard reactions,
- Maillard reactions products – melanoidins, except color enhance antioxidant activity (they are highly valued in food chemistry and technology),
- Possible color adjustment by changing the extrusion parameters – important for final recipients of WPCs,
- Enhanced thermooxidative stability of WPCs by the addition of modified BSG,

Temperature, °C	Throughput, kg/h	Rotary speed, rpm	Color	Antioxidant activity, %	Specific mechanical energy, kWh/kg
Reference sample				36	-
30	3	225		49	0.652
60				49	0.550
120				54	0.306
180				71	0.298
180	3	150		73	0.398
		225		71	0.298
		300		65	0.293
180	1	225		63	0.400
	3			71	0.298
	5			72	0.278
120	1	150		54	0.361
180	3	150		73	0.398

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MODIFIED BSG IN PCL-BASED COMPOSITES

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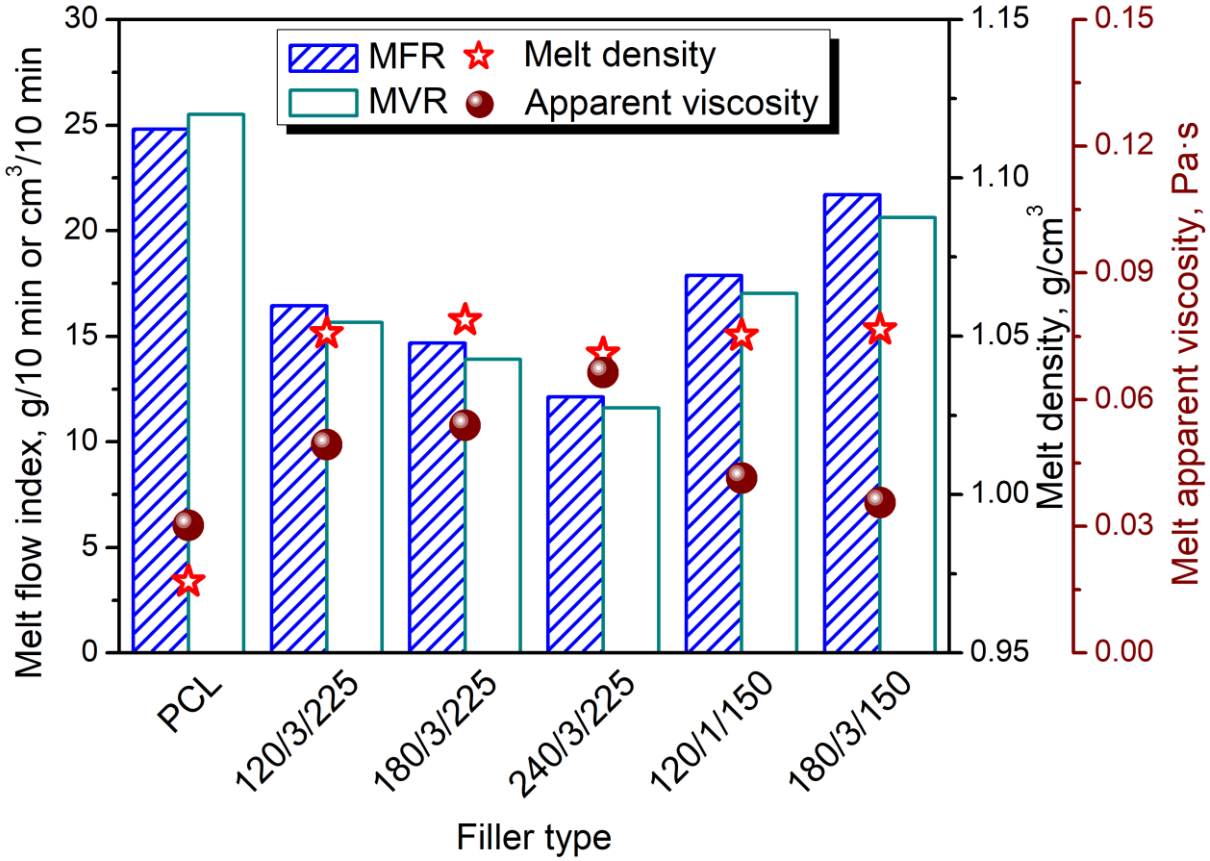

The impact of BSG type on the melt flow performance of PCL-based composites.

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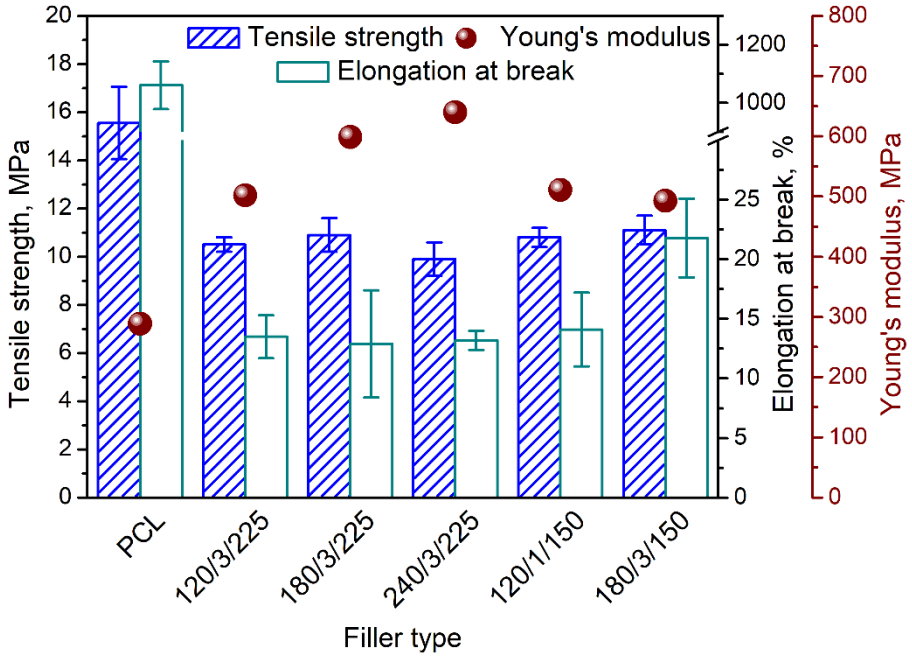

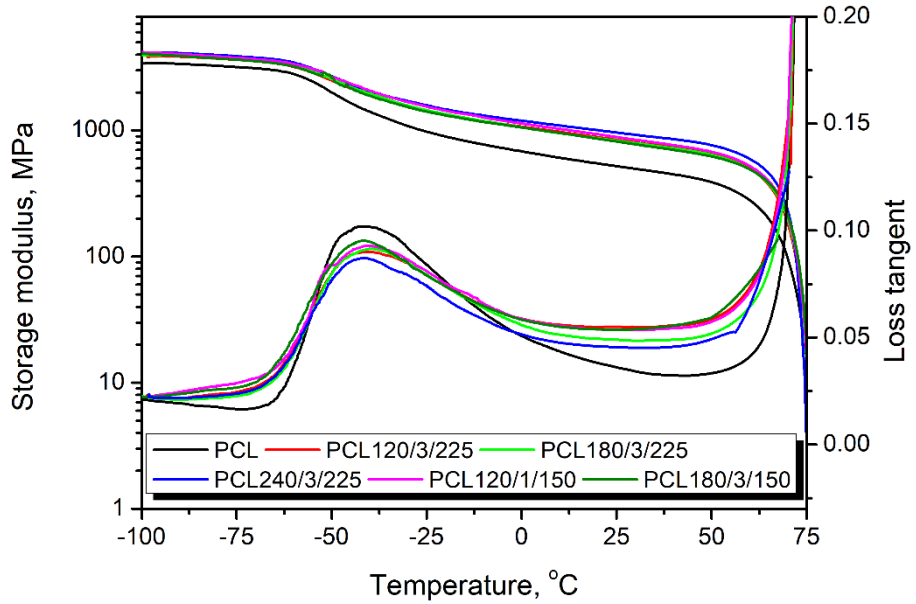

The impact of BSG type on the mechanical performance of PCL-based composites.

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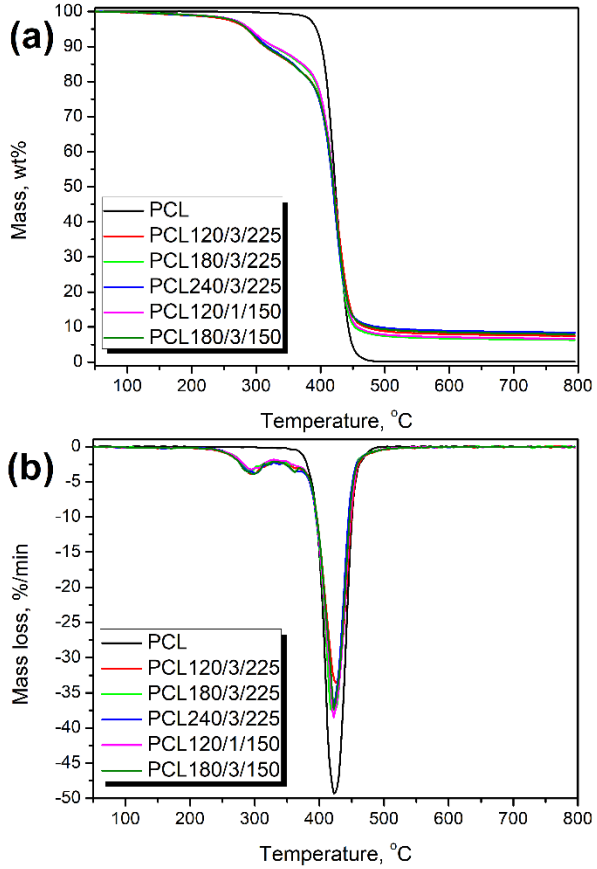
Sample	ΔH_c, J/g	T_c, °C	ΔH_m, J/g	T_m, °C	X_{cr}, %	ΔT_{sc}, °C
PCL	-66.9	24.8	73.6	57.3	52.8	32.0
PCL120/3/225	-54.0	29.5	55.4	58.7	56.8	29.2
PCL180/3/225	-57.6	29.3	59.9	58.3	61.3	29.0
PCL240/3/225	-57.8	28.8	60.7	57.7	62.1	28.9
PCL120/1/150	-65.7	29.3	67.1	57.7	68.7	28.4
PCL180/3/150	-59.1	28.4	60.5	57.5	61.9	29.6



The impact of BSG type on thermal performance of PCL-based composites.

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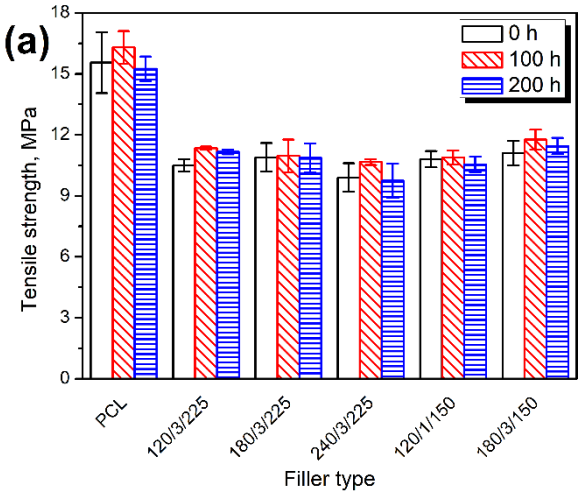

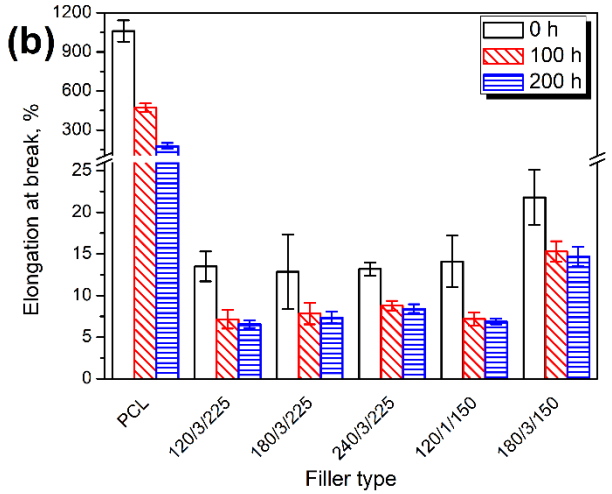

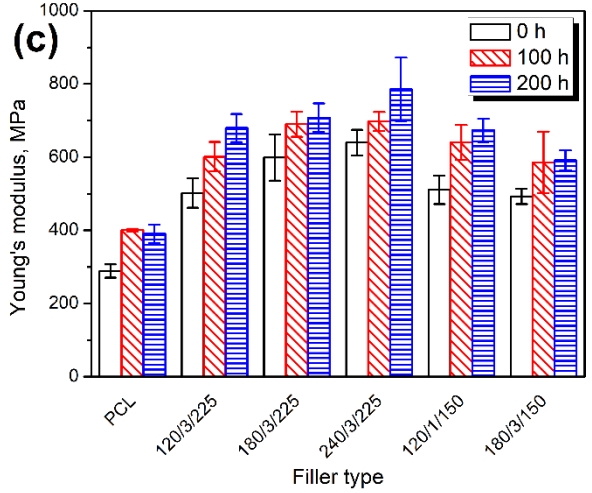

The impact of photo-oxidative aging on the mechanical performance of PCL-based composites.

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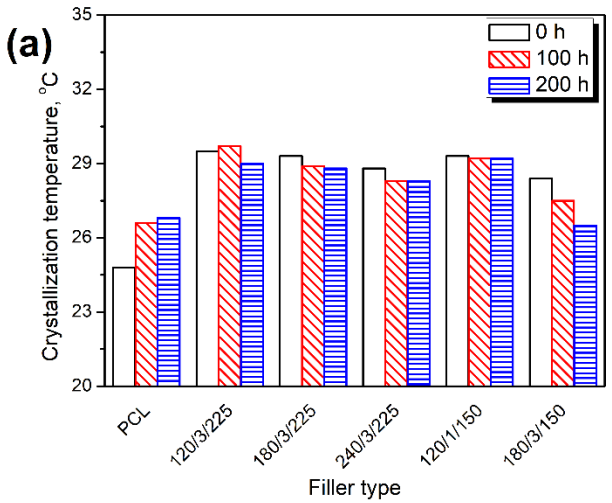

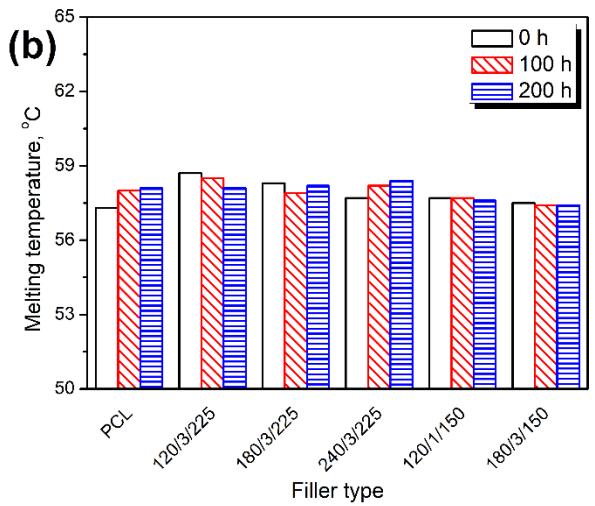

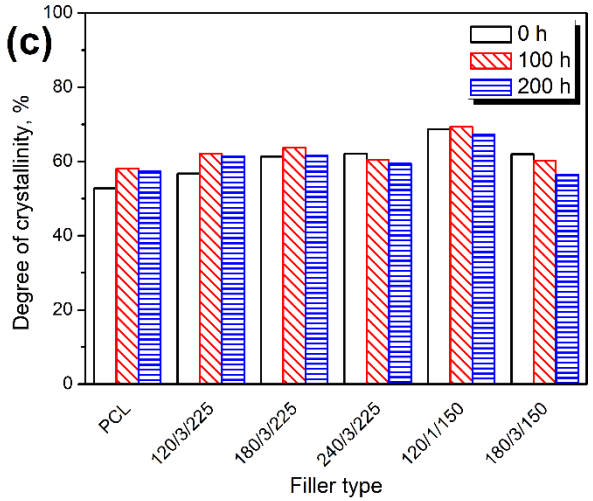

The impact of photo-oxidative aging on the thermal performance of PCL-based composites.

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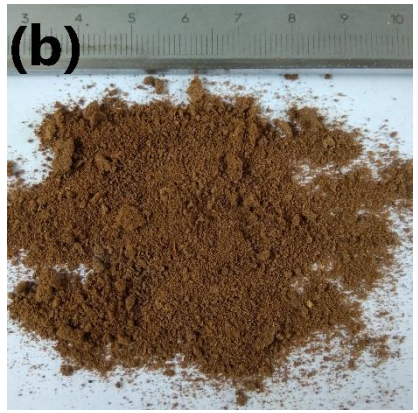
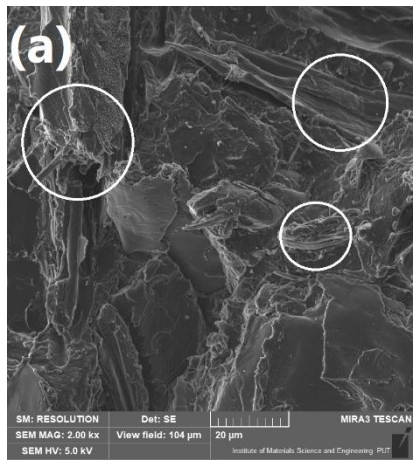
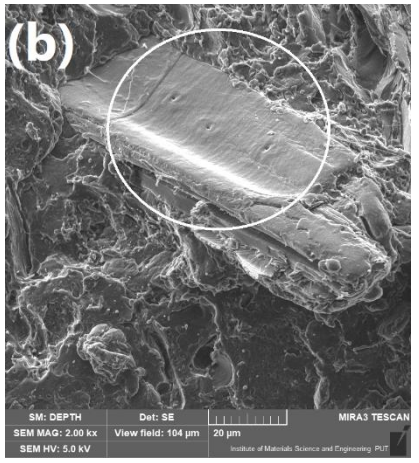
- Modified BSG as a substitute for beech wood flour (25, 50, 70, 100 wt%),
- Increased melt flow index, from 3.23 to 10.56 g/10 min,
- Reduced viscosity, from 1.018 to 0.303 Pa·s,
- Presence of proteins, lipids, which may act as plasticizers of polymer matrices.







Hejna, A., et al., *Polymers,* 2021, 13, 893.

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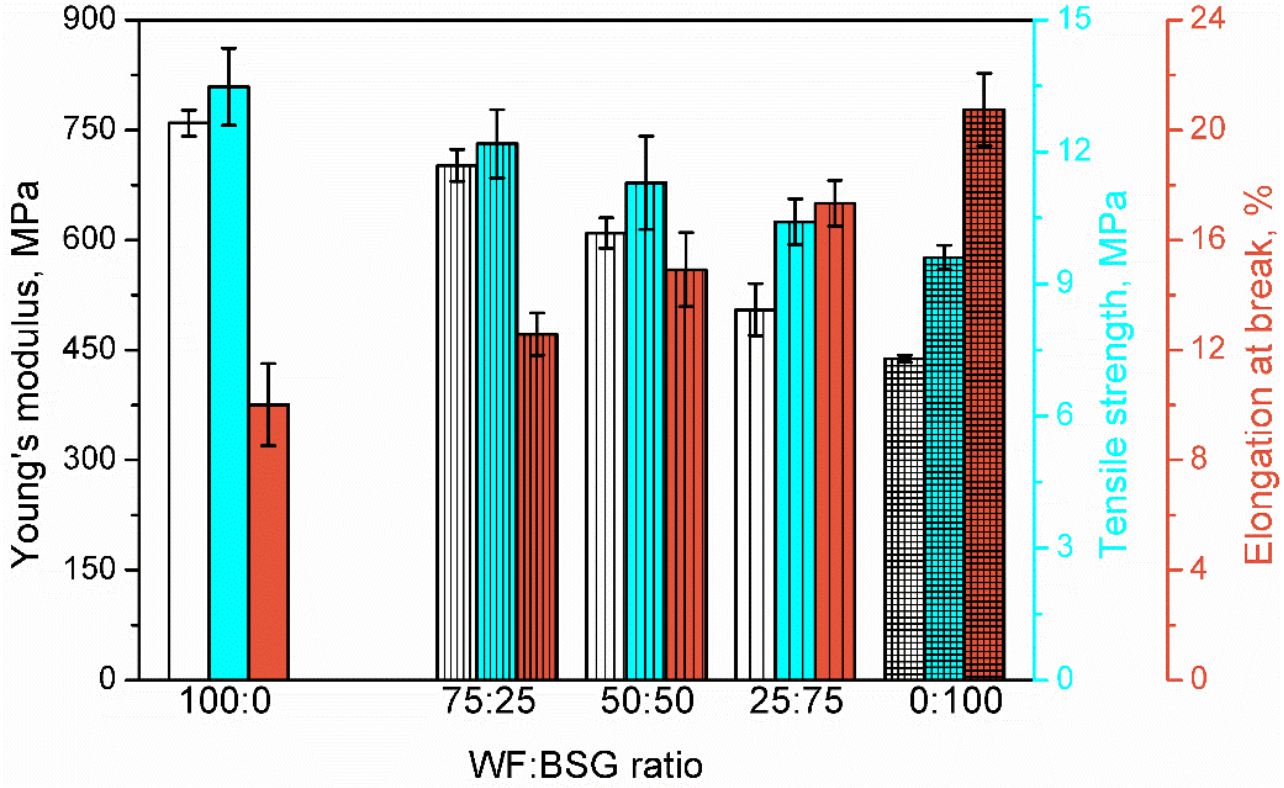
- Reduced stiffness and tensile strength,
- Increase in elongation at break,
- Possibility to engineer materials with desired properties.



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CONCLUSIONS

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- Parameters of the BSG modification, hence extent of Maillard reactions and melanoidin content affect the processability, appearance, but also the mechanical performance of composites,
- Higher modification temperature – lower composites porosity, better interfacial adhesion,
- Adjustment of BSG modification parameters could be used to tailor the mechanical performance of polymer composites,
- BSG modified at higher temperatures was found more effective in hindering the photo-oxidative degradation of PCL matrix,
- Thermo-mechanically modified BSG should be considered an auspicious substitute for the conventional lignocellulose fillers,
- Presented method also allows introduction of additional chemical modifiers,

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