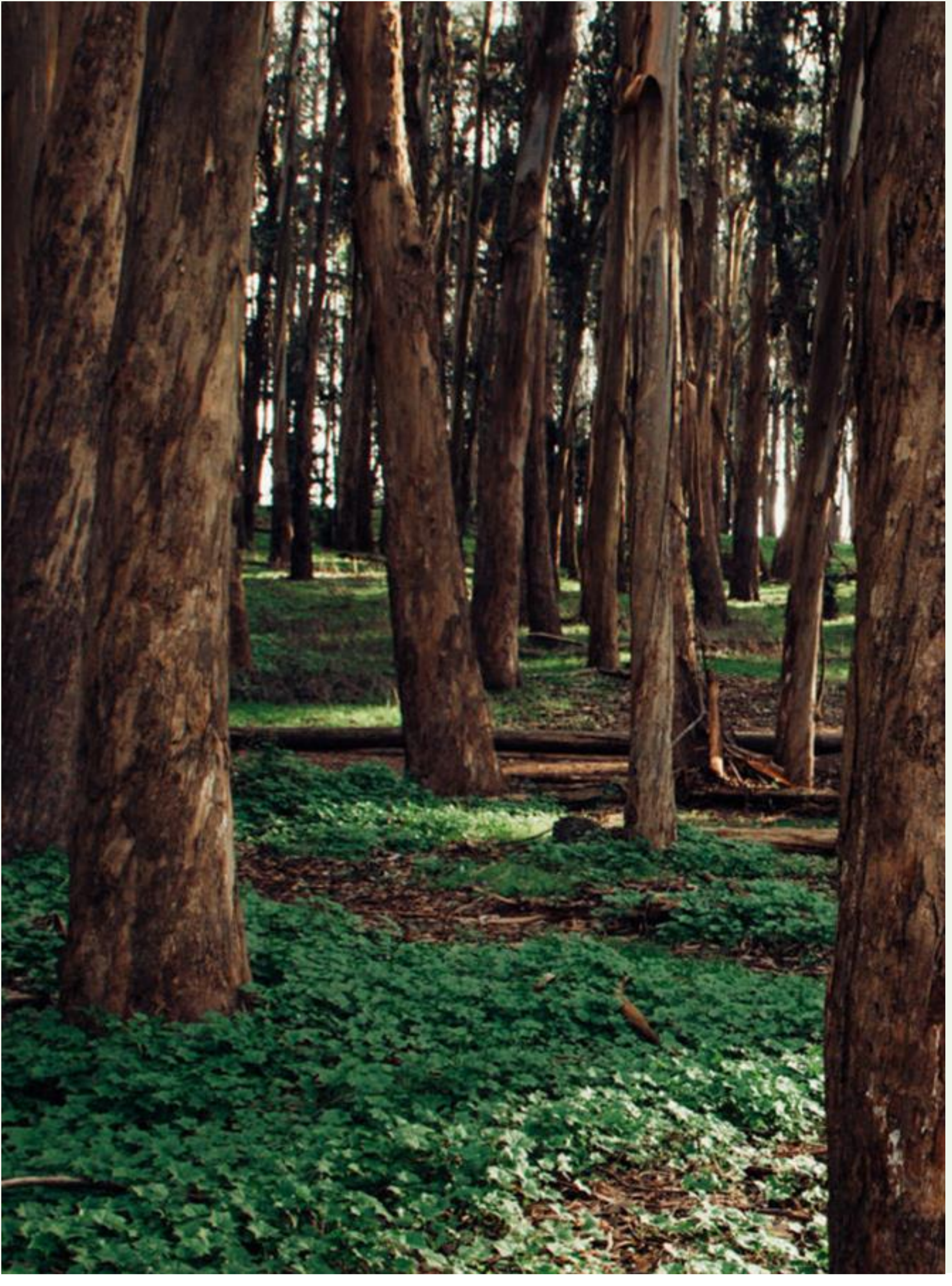

Impact of Cellulose Fiber and Microcrystalline Cellulose on the Performance of PLA Composites

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Due to low recyclability and the growing consumption of plastics, a significant portion of these materials ends up in landfills. As a result, the development of alternatives to fossil-based materials with equivalent functionality is being strongly encouraged at both national and international levels.

The **From Fossil to Forest** (FF2F) Project aims to develop cellulose-based materials capable of replacing fossil-derived components in packaging solutions. When combined with other materials (thermoplastic matrices, preferentially bioplastics), cellulosic fibres can form new compounds that are processable through injection/moulding, thermoforming, extrusion, lamination or 3D printing. These compounds can then be used to produce a wide range of products, including rigid packaging, films and filaments. In the form of monofilaments, they may also be used in sustainable textile-based products for application in flexible or rigid packaging.

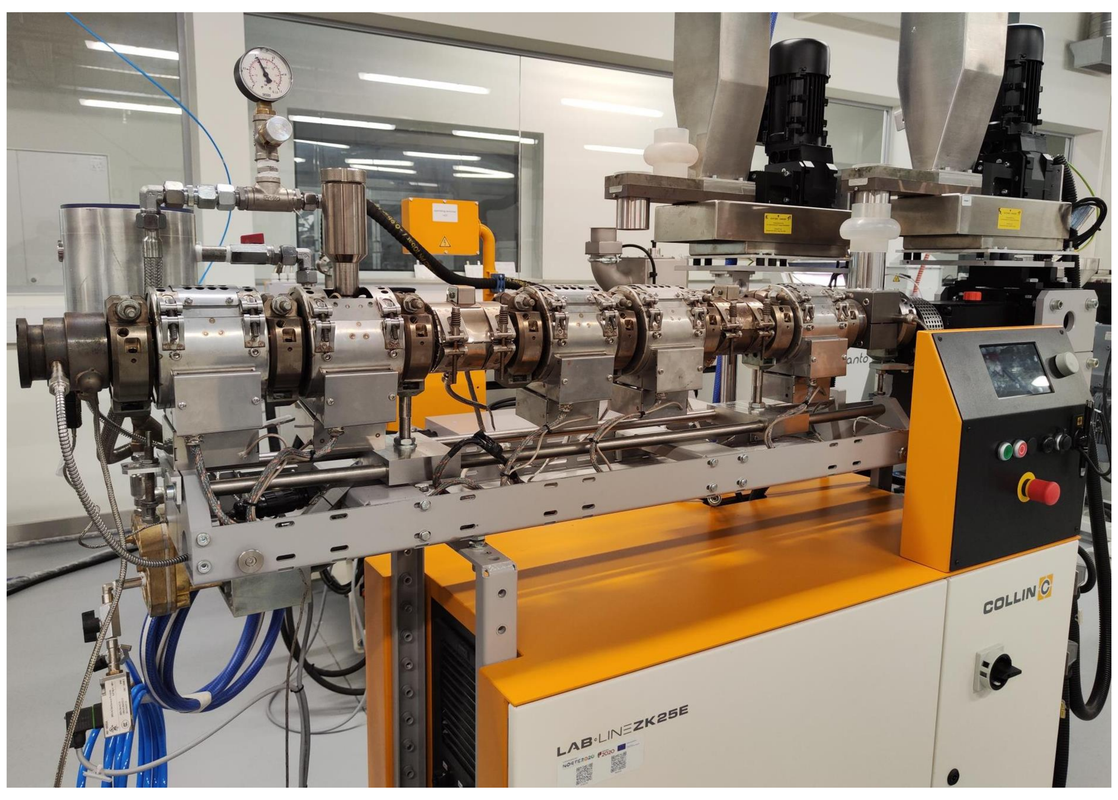
This study explores the incorporation of cellulose fibres and microcrystalline cellulose at varying loadings into a poly(lactic acid) (PLA) matrix, focusing on their impact on the mechanical, thermal, and rheological behaviour of the resulting composites. Understanding these effects will support the optimisation of PLA-cellulose composites for melt spinning processes, paving the way for more sustainable textile and packaging solutions.

Compounding

Evaluation of cellulose fibre and microcrystalline cellulose effects - FORMULATIONS:

Sample	PLA (wt.%)	Pre-mixture (PLA/40 wt.% Cellulosic Fibres) (CF)	Microcrystalline cellulose (MC) (wt.%)	Melt strength enhancer (MSE) (wt.%)	Compatibilizer (C) (wt.%)
2.5 CF	83.75	6.25 (2.5 wt.% cellulose)		5	5
5 CF	77.5	12.5 (5 wt.% cellulose)			
10 CF	65	25 (10 wt.% cellulose)			
20 CF	40	50 (20 wt.% cellulose)			
2.5 MC	87.5	0	2.5		
5 MC	85	0	5		
10 MC	80	0	10		
20 MC	70	0	20		

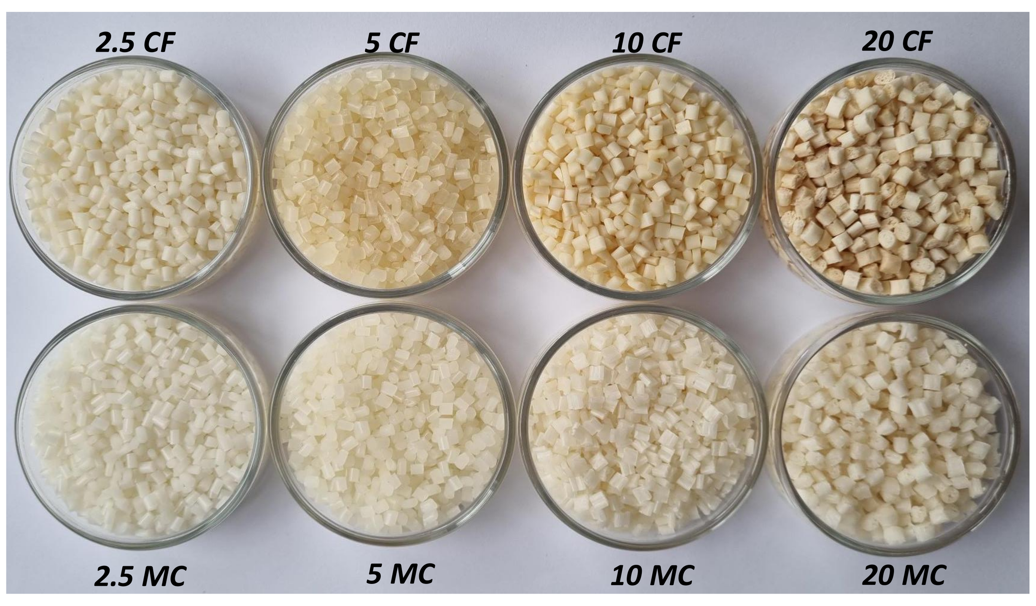
Twin screw-extruder Collin ZK25 @ CeNTI



Evaluation of cellulose fibre and microcrystalline cellulose effects – CHARACTERISATION:

- **CELLULOSIC FIBRE (CF) / MICROCRYSTALLINE CELLULOSE (MC)**

Pellets obtained from the compounding process for CF and MC

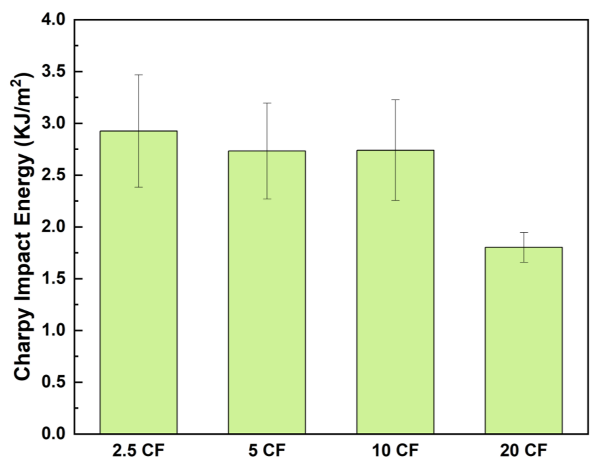


Mechanical properties from tensile testing

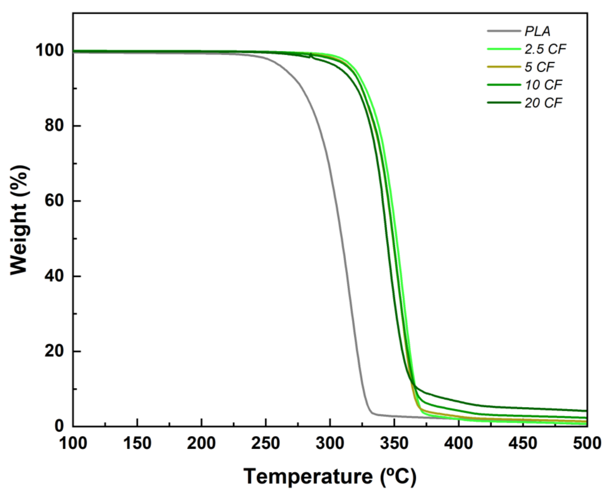
Sample	Young's Modulus (GPa)	Ultimate Tensile Strength (MPa)	Elongation at Break (%)
2.5 CF	3.79	68.57	2.93
5 CF	4.19	70.62	2.47
10 CF	4.53	73.90	2.39
20 CF	6.78	62.02	1.16
2.5 MC	3.82	66.20	3.30
5 MC	4.28	68.56	3.06
10 MC	2.97	68.08	2.32
20 MC	-	-	-

- **CELLULOSIC FIBRE (CF)**

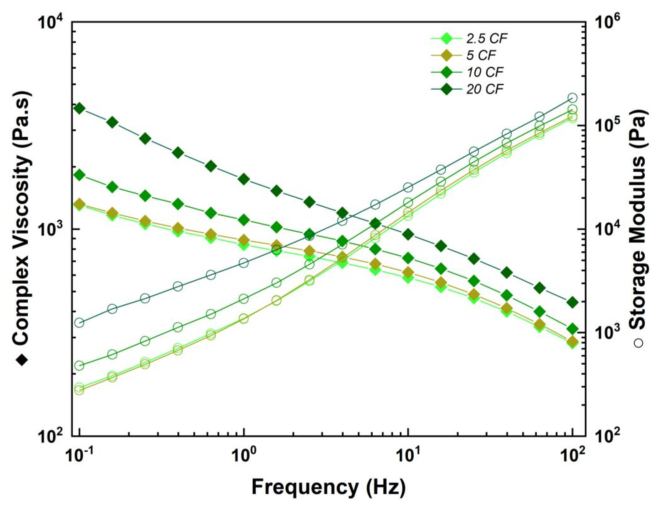
Impact Strength



Thermal analysis – TGA

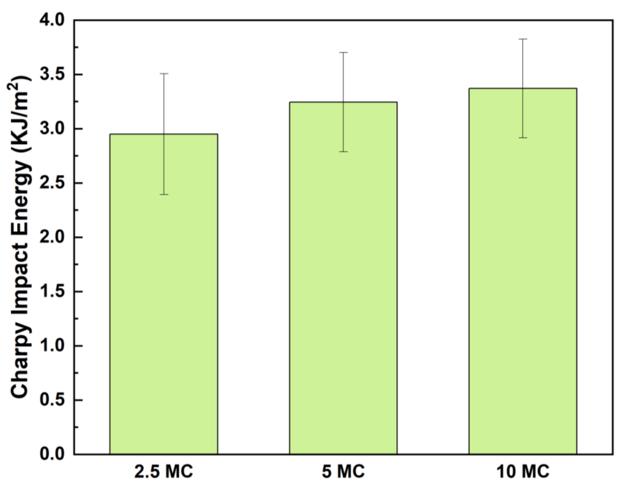


Complex viscosity and storage modulus

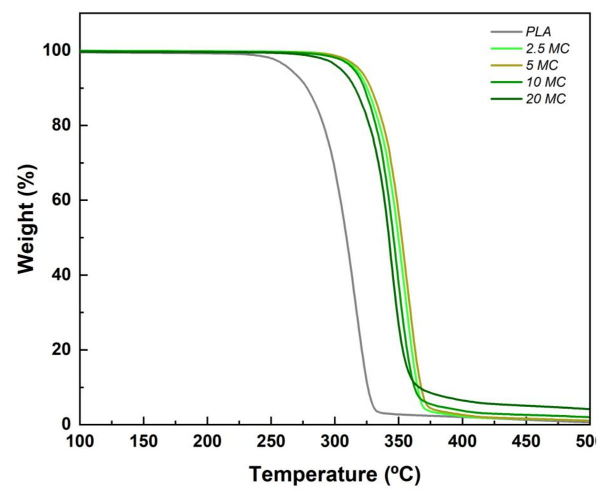


- **MICROCRYSTALLINE CELLULOSE (MC)**

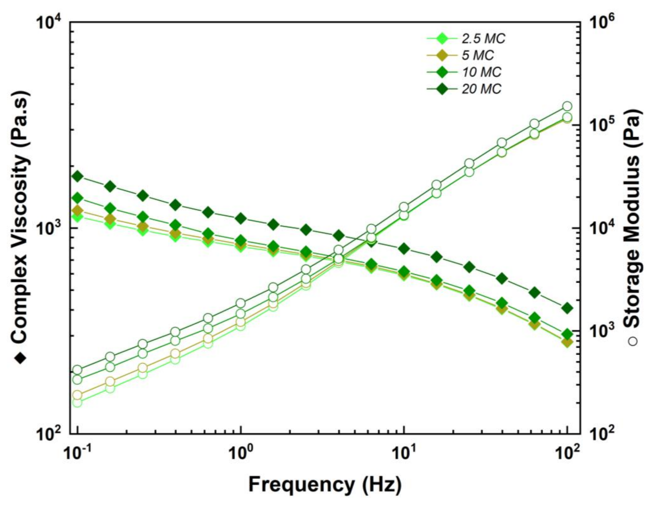
Impact Strength



Thermal analysis – TGA



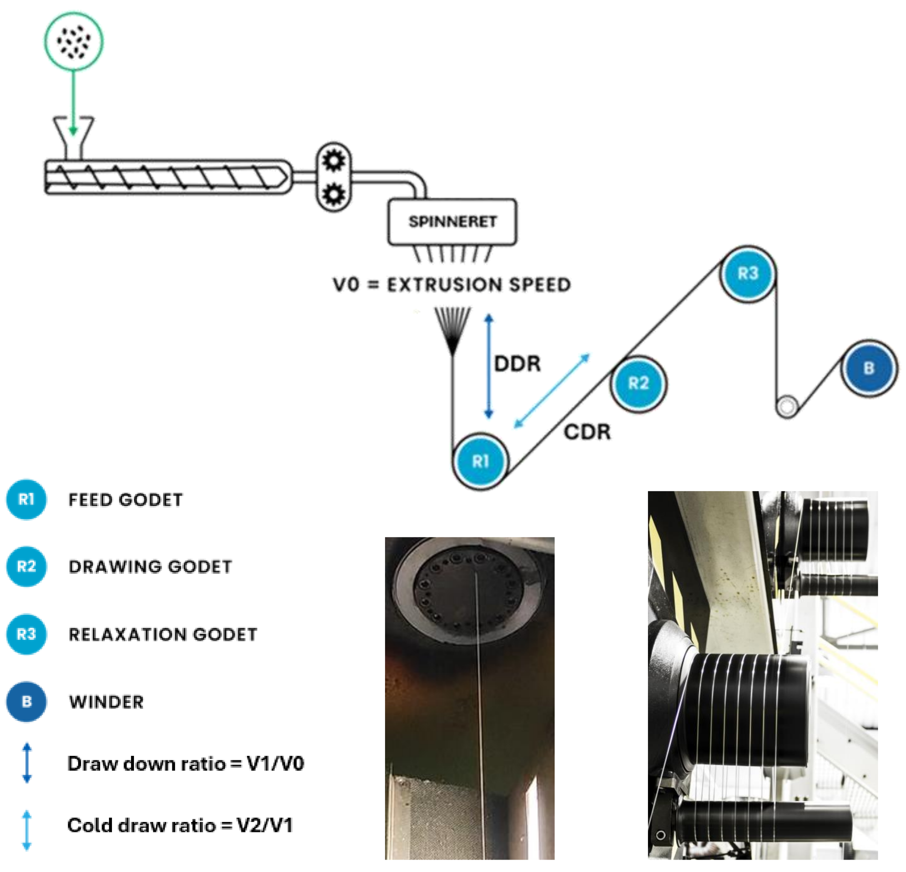
Complex viscosity and storage modulus



Monofilament (melt-spinning)

Extrusion scheme, spinneret and Drawing godets

- PLA and formulations 5 CF and 5 MC were selected for melt spinning trials.
- Monofilament spinneret with a diameter of 1.5 mm was used.



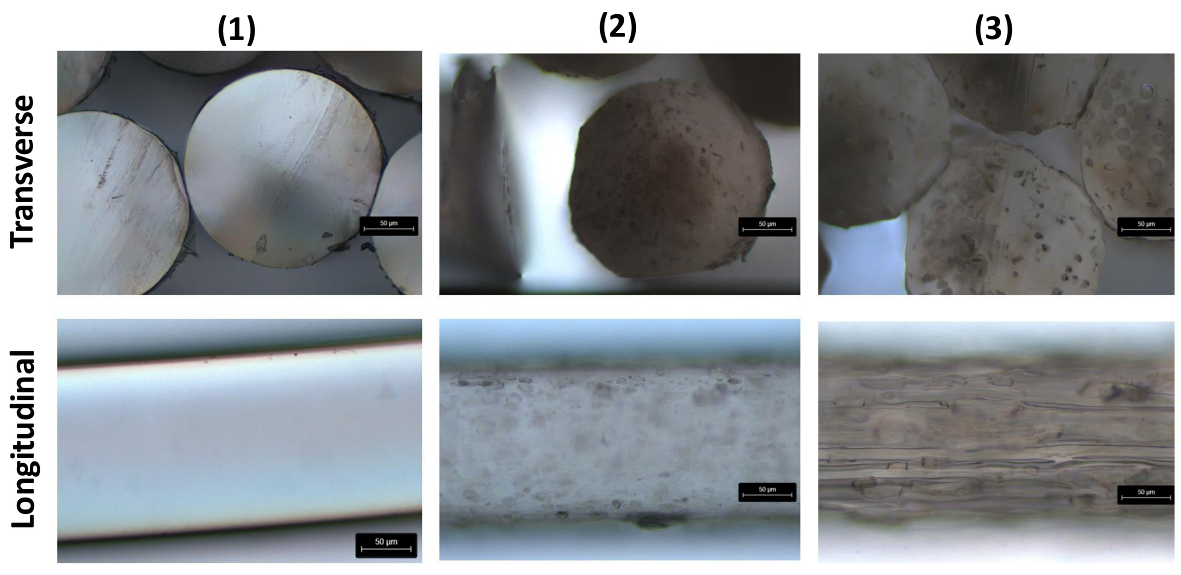
Spools of obtained monofilament:

(1) PLA

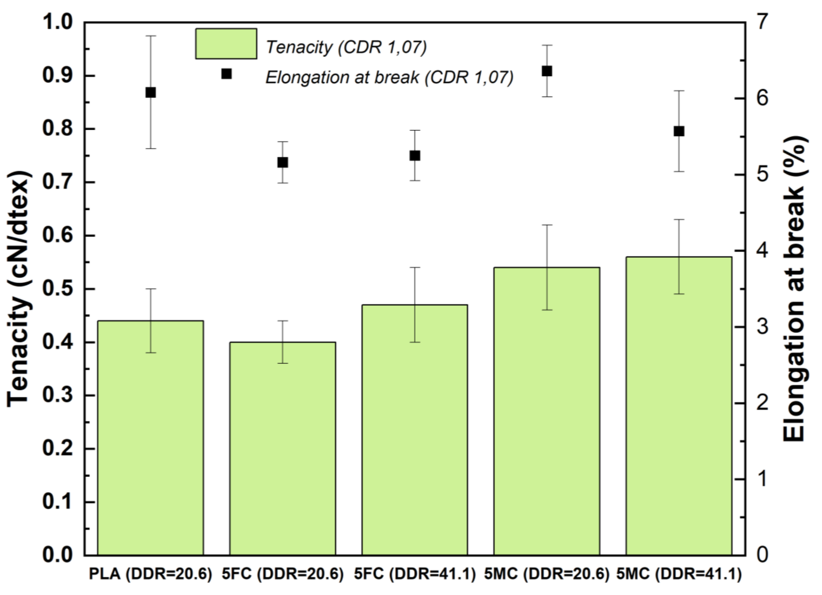
(2) 5 CF

(3) 5 MC

Optical microscopy images of the fibres



Mechanical properties from tensile testing



Final Remarks

- PLA was successfully compounded with both cellulosic fibers (CF) and microcrystalline cellulose (MC) up to 20 wt.%, showing distinct effects on properties.
- CF significantly increased stiffness (up to 6.78 GPa) but reduced ductility and impact resistance.
- MC offered a more balanced performance, maintaining better elongation at lower loadings (≤ 5 wt.%).
- Viscosity and storage modulus increased with filler content, indicating stronger matrix-filler interactions.
- **Monofilaments were successfully produced from formulations with up to 5% CF or MC, demonstrating good processability and suitability for sustainable textile and packaging applications.**

WP4 Consortium

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