Rheological Characterization of Thermoplastics Derived from Biopolymers: An Investigation of Additive-Induced Property Modification

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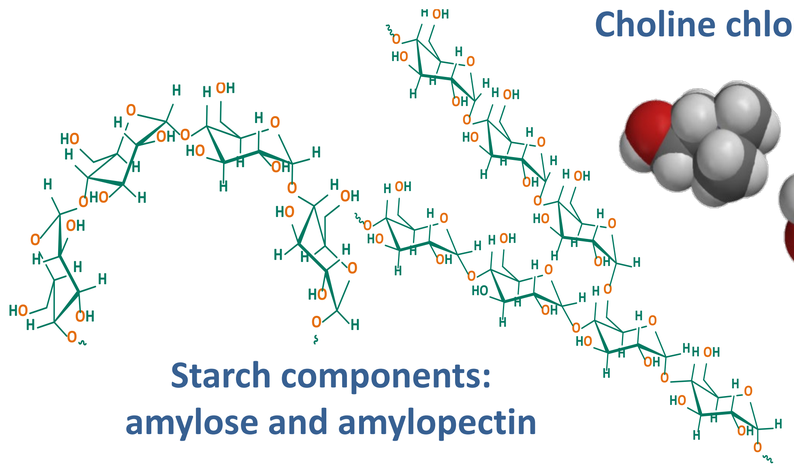
Introduction

Biopolymers such as starch, cellulose, and chitosan are gaining attention as sustainable alternatives to petroleum-based plastics, though their extensive hydrogen bonding poses processing challenges. This study investigates how tailored plasticizers and five bio-based fillers (eggshell, wood flour, silk, zein, and lignin) affect the rheological, mechanical, and thermal properties of starch-based thermoplastics. Notably, silk, with its proteinaceous structure, improves elasticity and thermal resistance, making it particularly suitable for flexible applications. Additives and processing conditions are shown to significantly influence the viscoelastic behavior and structure-property relationships of the materials. Results demonstrate that optimized formulations can be processed using conventional techniques such as extrusion, compression molding, thermoforming, and injection molding, offering a viable route to high-performance, thermoplastic starch (TPS).

Materials & Methods



Starch components: amylose and amylopectin

Choline chloride

Urea

injection molded TPS

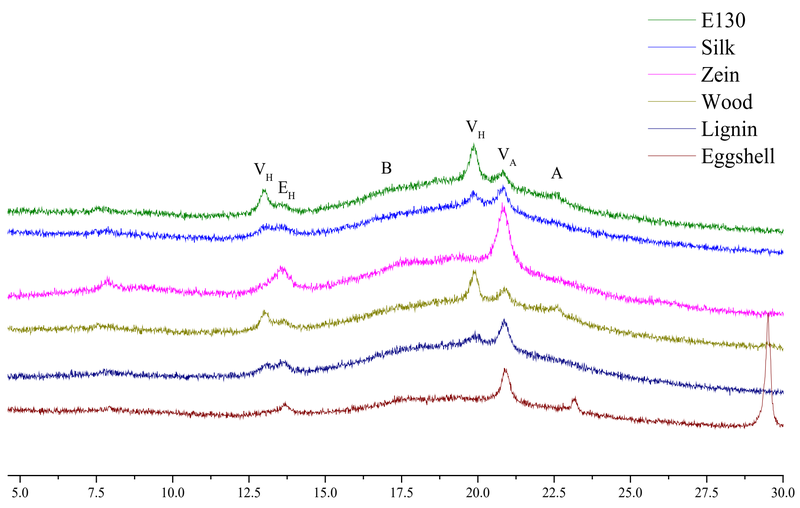
Sheet of Extruded TPS

Samples of TPS with composites from the natural waste

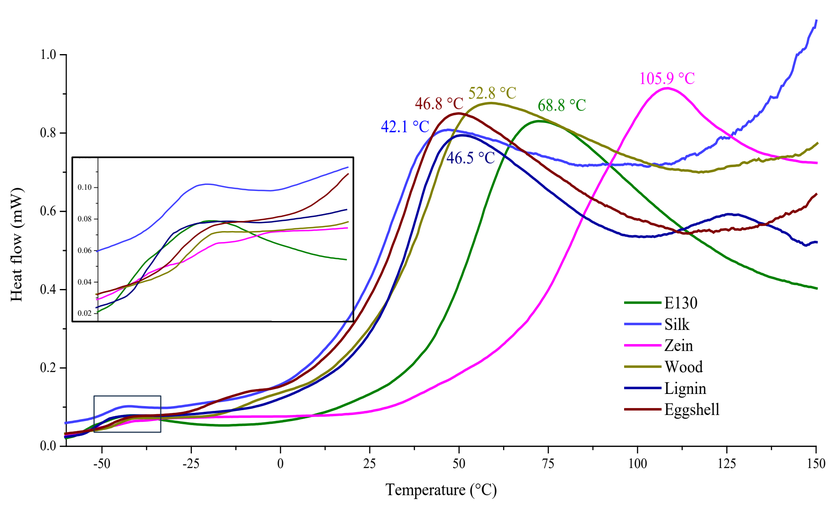
Results

Melt flow rate of samples, run at 150 °C with 21.6 kg force.

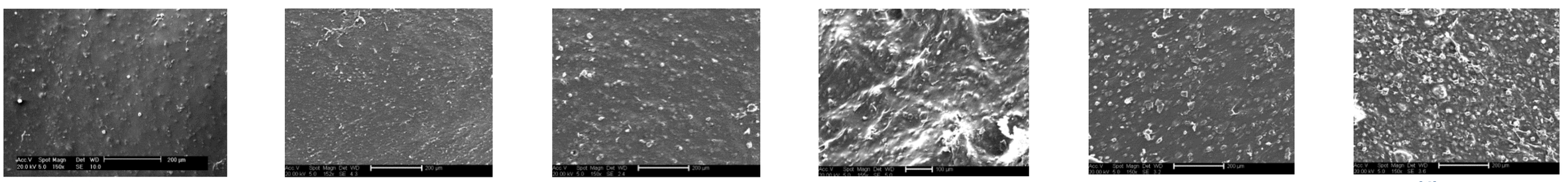
	MFR (g/10 min)
E130	14.35 ± 0.17
Silk	67.48 ± 2.89
Zein	0.83 ± 0.14
Wood	58.44 ± 2.46
Lignin	17.34 ± 0.53
Eggshell	10.55 ± 0.86



XRD data of TPS with bio-additives



DMTA data of TPS with bio-additives



(a) (b) (c) (d) (e) (f)

SEM images,of extruded pellets of blank TPS (a), and with 10 wt % content of silk (b), zein (c), wood (d), lignin (e) and eggshell (f).

Conclusion

This research demonstrated that TPS composites can be effectively tailored using various biofillers, influencing their structural, thermal, and mechanical properties. Filler type, particle size, and content significantly affected performance, with eggshell enhancing flexibility and wood improving strength. Biofillers modified the glass transition temperature, crystallinity, and phase structure, as revealed by DMA analyses. Morphological and rheological studies showed varying surface uniformity and melt flow behavior, highlighting the complex interactions between starch, plasticiser, and different biofillers.

References

1- Abbott, A. P., Abolibda, T. Z., Davis, S. J., Emmerling, F., Lourdin, D., Leroy, E., & Wise, W. R. (2014). Glycol based plasticisers for salt modified starch. Rsc Advances, 4(76), 40421-40427.

2- Abolibda, T.Y. Physical and Chemical Investigations of Starch Based Bio-Plastics. Ph.D. Dissertation, University of Leicester, Leicester, UK, 21 August 20.