A Sustainable Chitin-Lecithin Plasticiser System for PLA Composites

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INTRODUCTION

Polylactic acid (PLA) is a bio-based, biodegradable polymer widely used in various applications. However, PLA is brittle and requires plasticisers to improve flexibility. Conventional plasticisers are often petroleum-based, non-biodegradable and can reduce thermal stability, which conflicts with the eco-friendly nature of PLA. **Lecithin**, a natural emulsifier and plasticiser, improves PLA flexibility but starts to migrate at 60 °C, preventing injection moulding. **Chitin**, a natural polymer derived from crustacean shell waste that is usually discarded, is explored here as a bio-based stabiliser for lecithin within the PLA matrix.

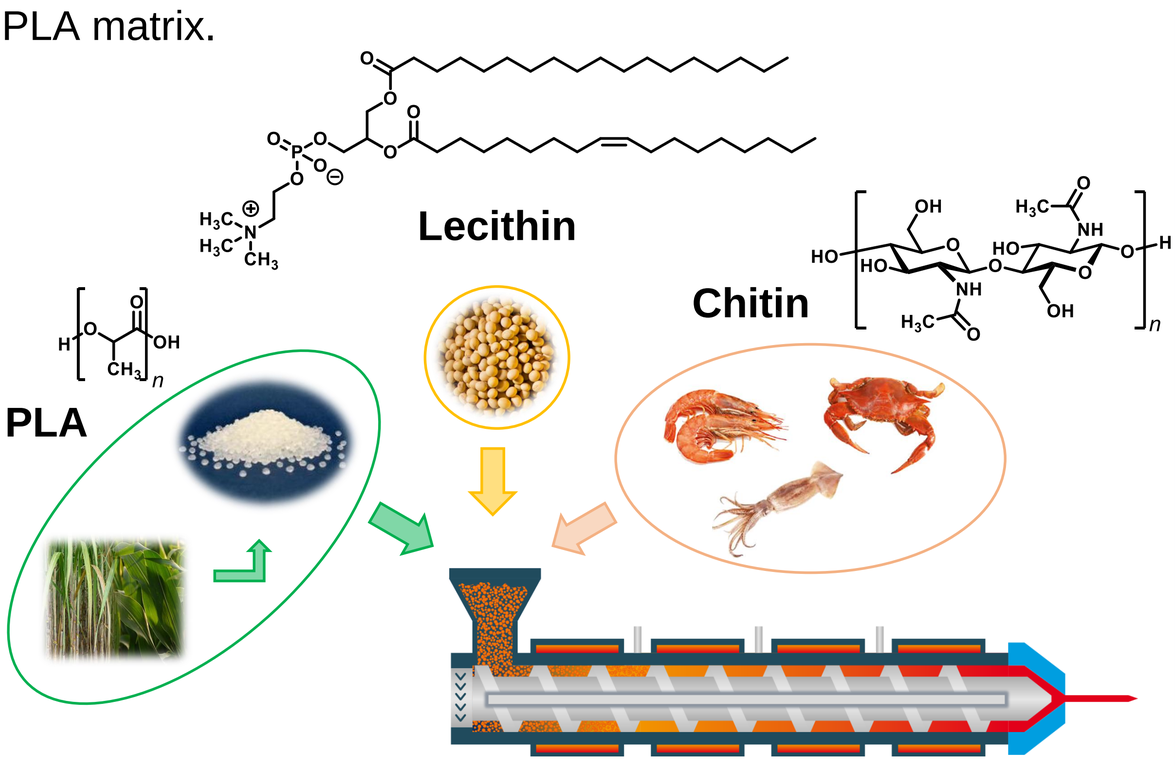

Figure 1. *Schematic illustration of the composition of the PLA composites.*

RESULTS AND DISCUSSION

- Chitin and lecithin were mixed in a laboratory kneader at various weight ratios.
- At a ratio of $x_{CHT/Lec} = 4$, the material was too inhomogeneous for further processing (Fig. 2A).
- A minimum ratio of $x_{CHT/Lec} = 3$ was required to obtain a homogeneous, kneadable material (Fig. 2B).
- At a ratio of $x_{CHT/Lec} = 1$, it was even possible to process the mixture by extrusion, producing a strand (Fig. 2C).
- Therefore, the ratio of $x_{CHT/Lec} = 3$ was chosen for incorporation into PLA at loadings up to 24 wt%, followed by injection moulding (Fig. 2D).

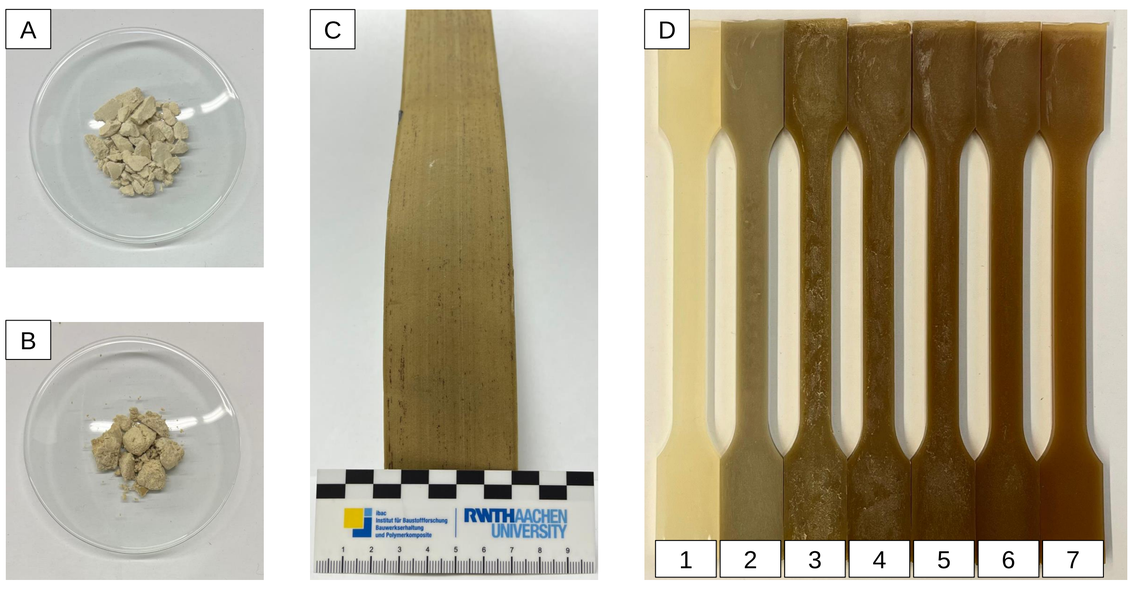

Figure 2. *Chitin-lecithin blends at weight ratios of (A) $x_{CHT/Lec} = 4$ and (B) $x_{CHT/Lec} = 3$. (C) Extruded strand at $x_{CHT/Lec} = 1$. (D) Injection-moulded specimens: (1) neat PLA, (2) PLA + 20 wt% chitin, (3–7) PLA + chitin-lecithin ($x_{CHT/Lec} = 3$) with additive content from 24 wt% (3) to 8 wt% (7).*

- Samples containing lecithin appeared brown, due to the lecithin itself and not degradation.
- A PLA film containing 6 wt% lecithin was prepared by solvent casting.

- Migration tests (DIN EN 13130-1, 70 °C, 2 h, aqueous medium) using the injection-moulded specimens and the solvent-cast film (Fig. 3A).
- After heating, the solvent-cast film bent and showed visible lecithin migration (Fig. 3E).

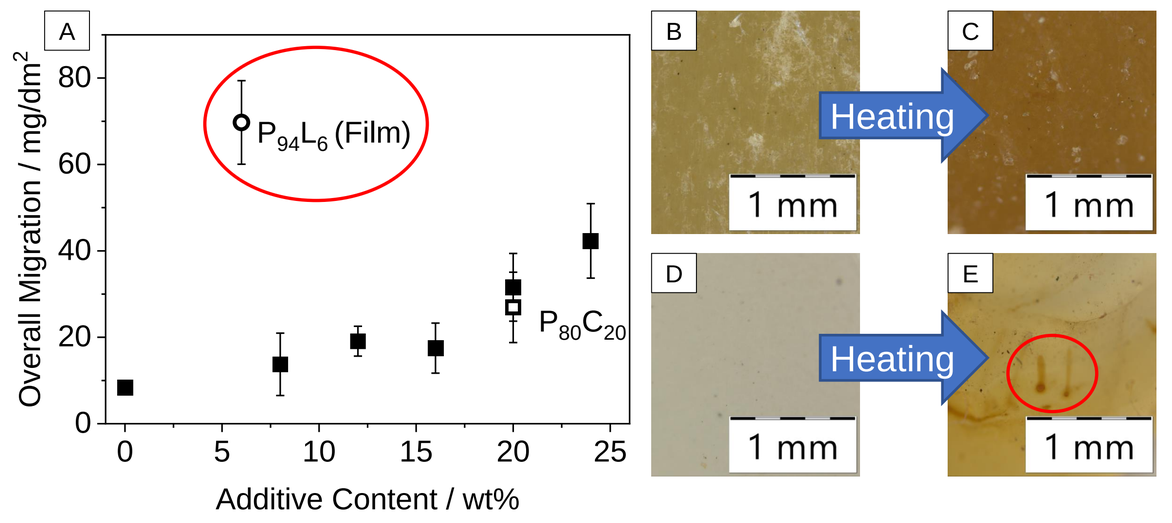

Figure 3. *(A) Overall migration as a function of additive content for injection-moulded specimens and the solvent-cast film. Optical micrographs (5×) of an (B, C) injection-moulded specimen (24 wt% chitin-lecithin) and (D, E) solvent-cast film (6 wt% lecithin).*

- Overall migration is 65 % higher in the solvent-cast specimen (lecithin only) than in the injection-moulded specimen containing both lecithin and chitin.

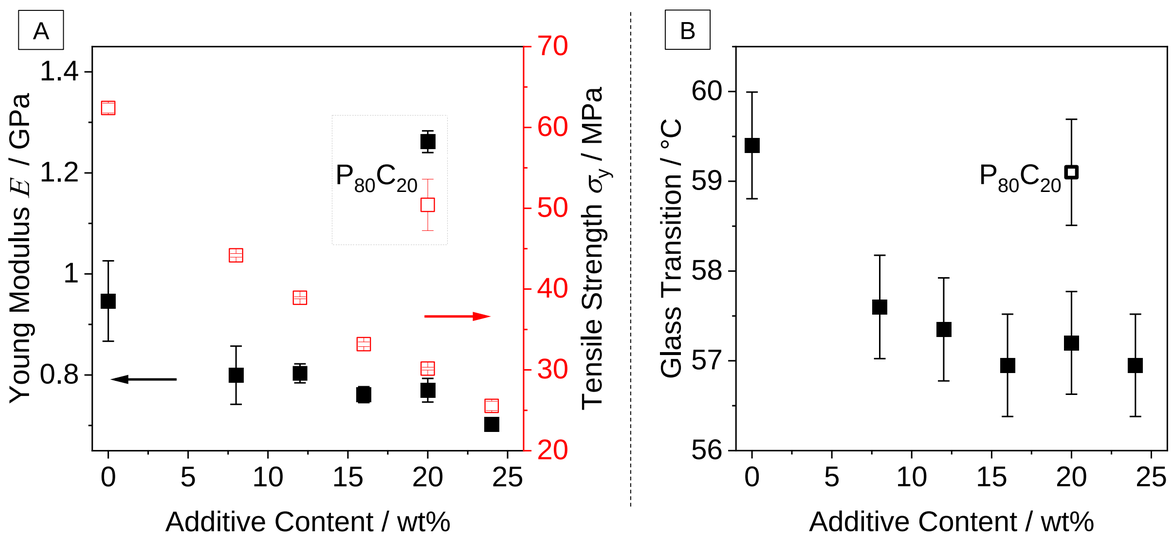

Figure 4. *(A) Young modulus, tensile strength, and (B) glass transition as functions of additive content in the injection-moulded specimens.*

- Addition of chitin alone increases stiffness without improving tensile strength or affecting the glass transition (Fig. 4).
- Increasing chitin-lecithin content decreases the Young modulus by 26 % and tensile strength by 59 % (Fig. 4A).
- Glass transition temperature decreases slightly by 2.4 °C (4%) with additive addition (Fig. 4B).
- Furthermore, impact strength increases by 16 %, and fracture strain rises by 300 %.

CONCLUSION

- Lecithin acts as a plasticiser for PLA, enhancing chain mobility and ductility in the PLA composites.
- Chitin supports lecithin incorporation by reducing its migration, resulting in a stable ternary system and balancing the softening effect of lecithin.
- Higher chitin-lecithin contents reduce stiffness and strength, but significantly increase toughness and ductility.
- At the highest additive content (24 wt%), glass transition temperature decreases by only 2.4 °C, indicating minimal impact on thermal behaviour at room temperature.

REFERENCES

Marten, P.; Weichold, O. *A Bio-Based Chitin-Lecithin Plasticiser System for PLA Composites*, submitted to *Polymers*.

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