Biodegradable composite films with antibacterial properties for packaging applications

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Acknowledgement

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Ending Plastic Waste Symposium
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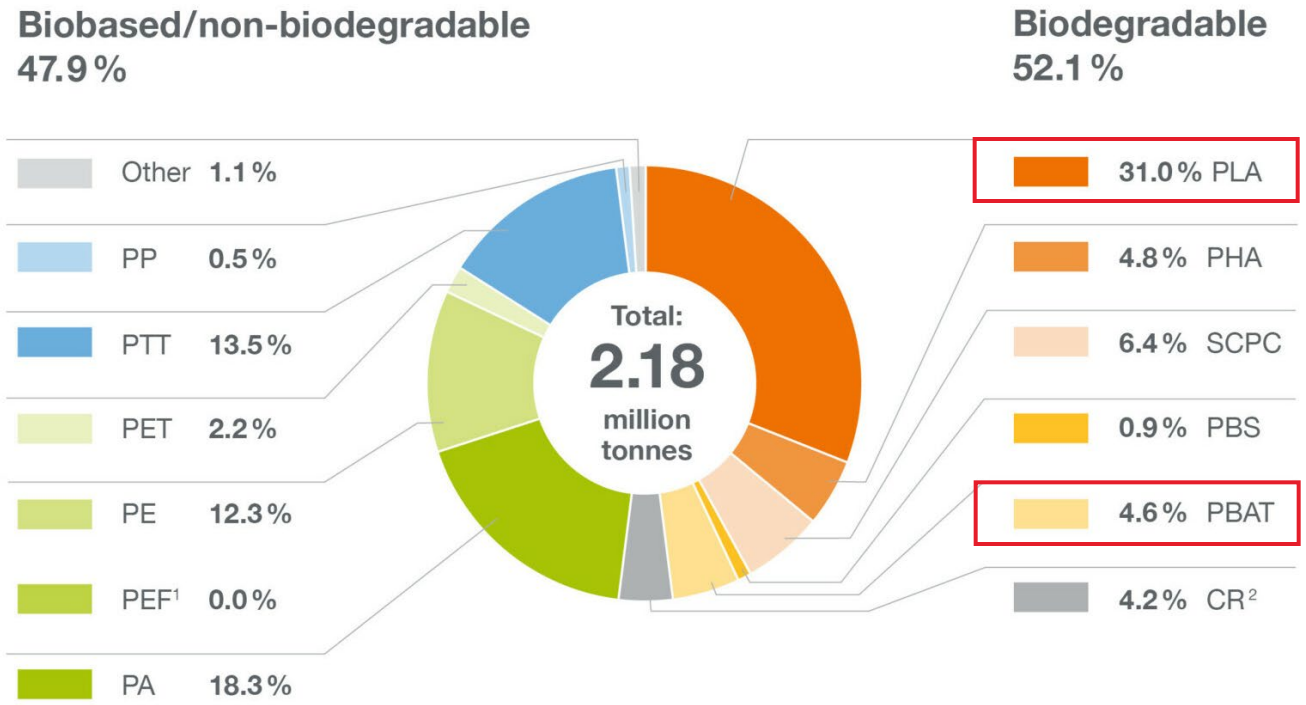
Global production capacities of bioplastics 2023



Source: European Bioplastics, nova-Institute (2023)

Market segment

Bioplastics used for food packaging

Polymers	Advantages for food packaging	Disadvantages for food packaging
Polylactic acid (PLA)	100% biodegradable. FDA approved for food contact. Bio-compostable. Transparent. Good processability. Renewable resources (plant sugars).	Rigid & brittle. Low heat resistance. Slow degradation rate. Moderate permeability to oxygen & moisture. Not suitable for long term food storage. No inherent antibacterial property.
Polybutylene adipate terephthalate (PBAT)	100% biodegradable. FDA approved for food contact. Bio-compostable. Transparent. Good processability. Flexible & tough. Fast degradation rate.	Fossil fuel resources. Relatively more expensive. Produces microplastics. Good heat resistance. High permeability to oxygen & moisture. No inherent antibacterial property.
PLA/PBAT blends	70% PLA optimal for strength & processability (20 °C). 40% of PLA good for chilled (4 °C) food packaging. 20% of PLA good for frozen (-25 °C) food packaging.	Poor antibacterial performance. High permeability to oxygen & moisture.

Trends in Food Science & Technology 2022, 125, 66-80; Polymers 2020, 12, 804.

Research Rationale

- Property limitations of PLA/PBAT blend films can be overcome by incorporating functional filler materials.
- Zinc oxide (ZnO) nanoparticles as filler has shown antimicrobial activity and improved mechanical strength, barrier properties, and thermal and shelf-life stability in PLA/PBAT blend films.
- Tetrapod ZnO (T-ZnO) microparticles have been recently applied in many advanced composite systems: linkers for joining polymers, self-healing/antifouling/antireflective coatings, vulcanizer for elastomers, …
- Cell toxic potency of T-ZnO whisker is found to be significantly lower than that of spherical ZnO nanoparticles.

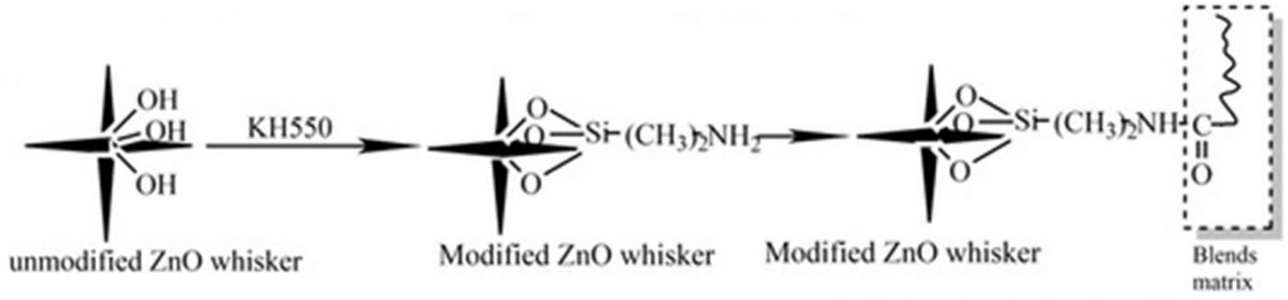
Objective

- To develop PLA/PBAT/T-ZnO whisker composite films for cold food packaging application.
- To study the effect of T-ZnO whisker content on the physicochemical properties of developed composite.

Materials Letters 2024, 372, 136960; Food Chemistry 2023, 405, 134798; Food Packaging and Shelf Life 2019, 21, 100327; Materials Today 2018, 21, 631-651.

Fabrication of composite films

- Polymer blend: PLA/PBAT (30/70)
- Compatibilizer: Joncryl ADR-4380 chain extender
- Filler: Tetrapod ZnO microparticles
- Surface treatment: Silane



Schematic of surface modification of T-ZnO whisker

Components pre-mixed in paddle type powder hot mixer

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Twin-screw melt extrusion & granulation

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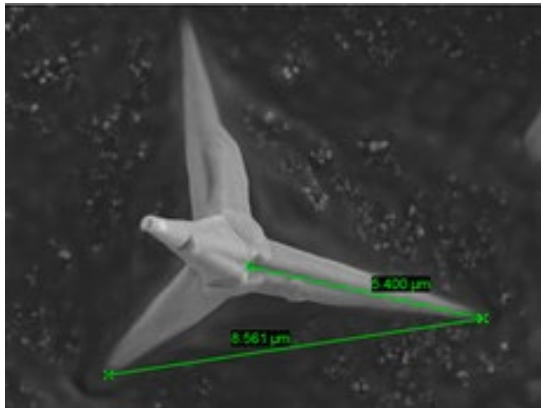
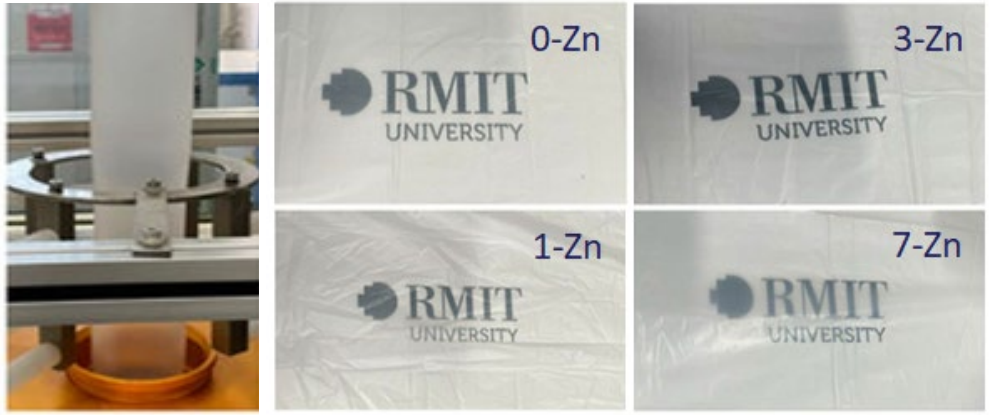
Film blowing & characterization



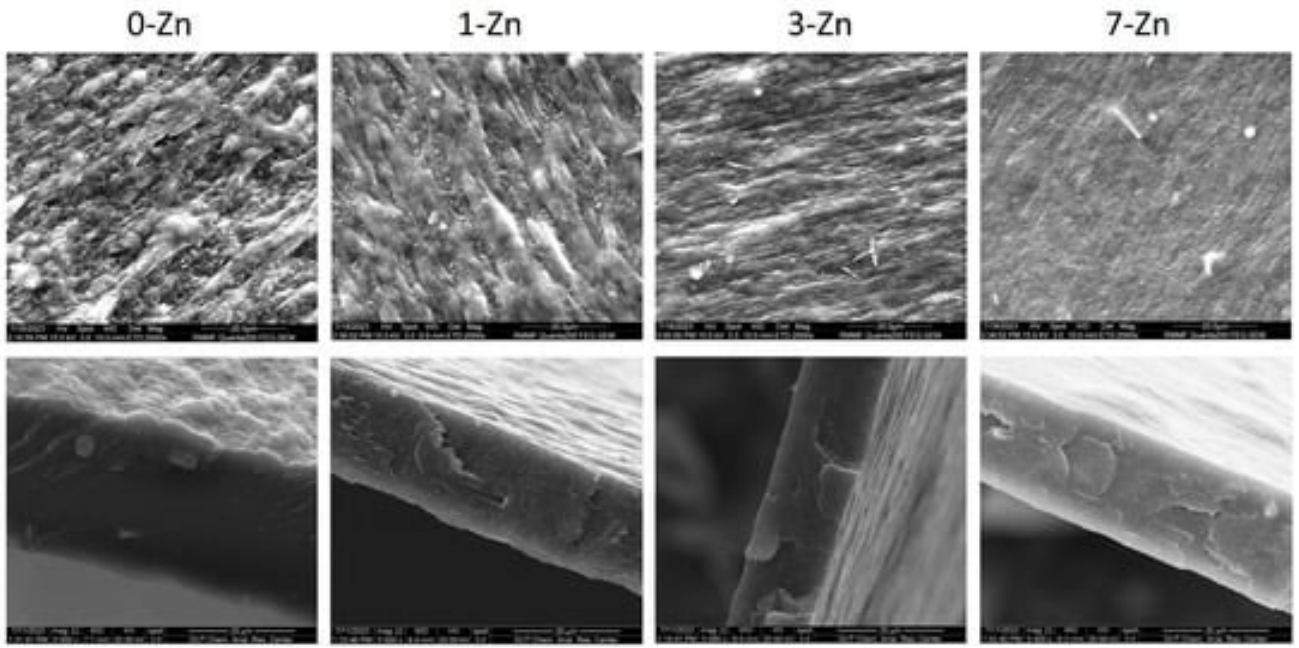
SEM image of T-ZnO whisker



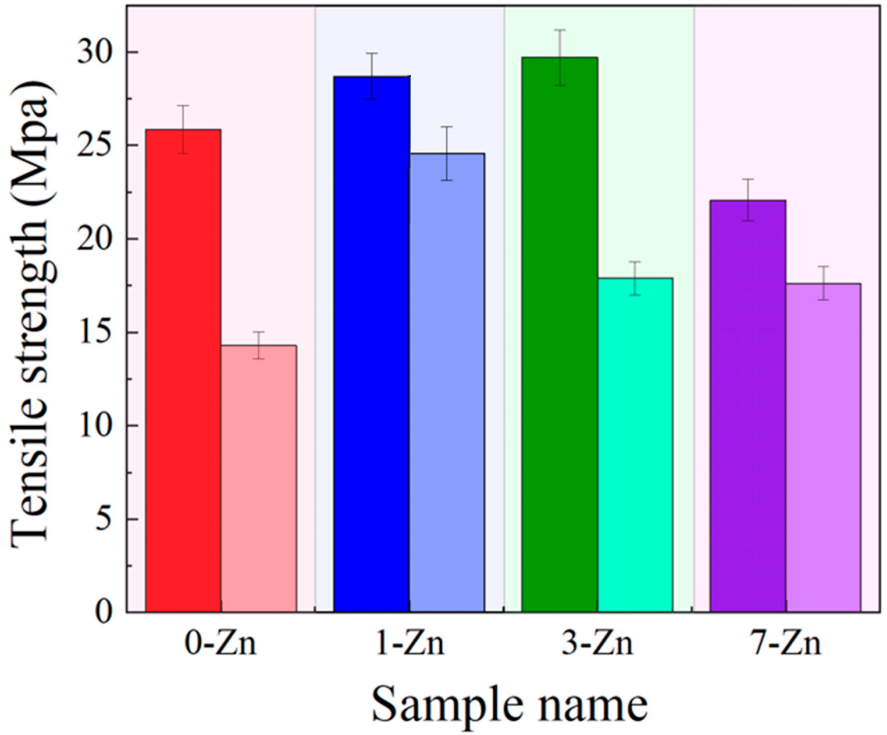
Film blowing and transparency pictures of fabricated composite films

Polymers, 2024; https://doi.org/10.3390/polym16081039

Morphology and mechanical strength analysis



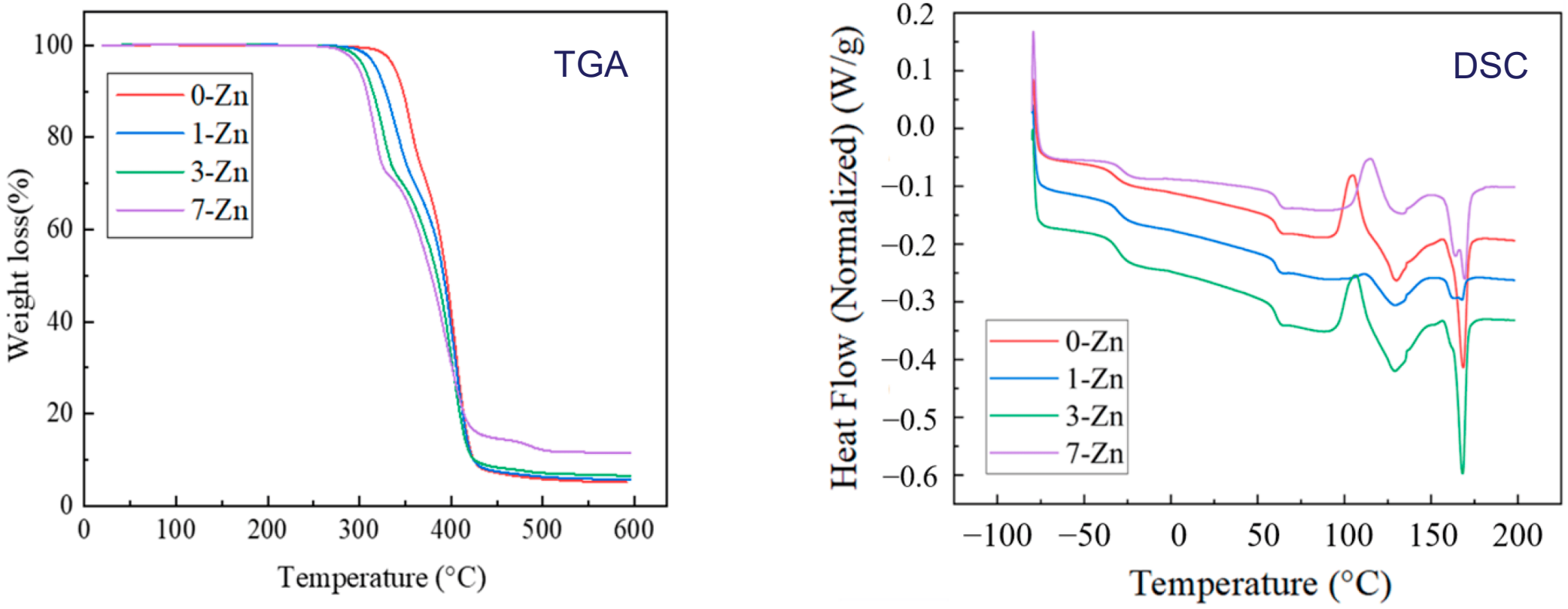
SEM images of the surface (top) and cross-sectional (bottom) morphology of fabricated composite films. Scale bar is 20 µm.



Tensile strength (dark bars—MD; light bars—TD) of fabricated composite films

Polymers, 2024; https://doi.org/10.3390/polym16081039

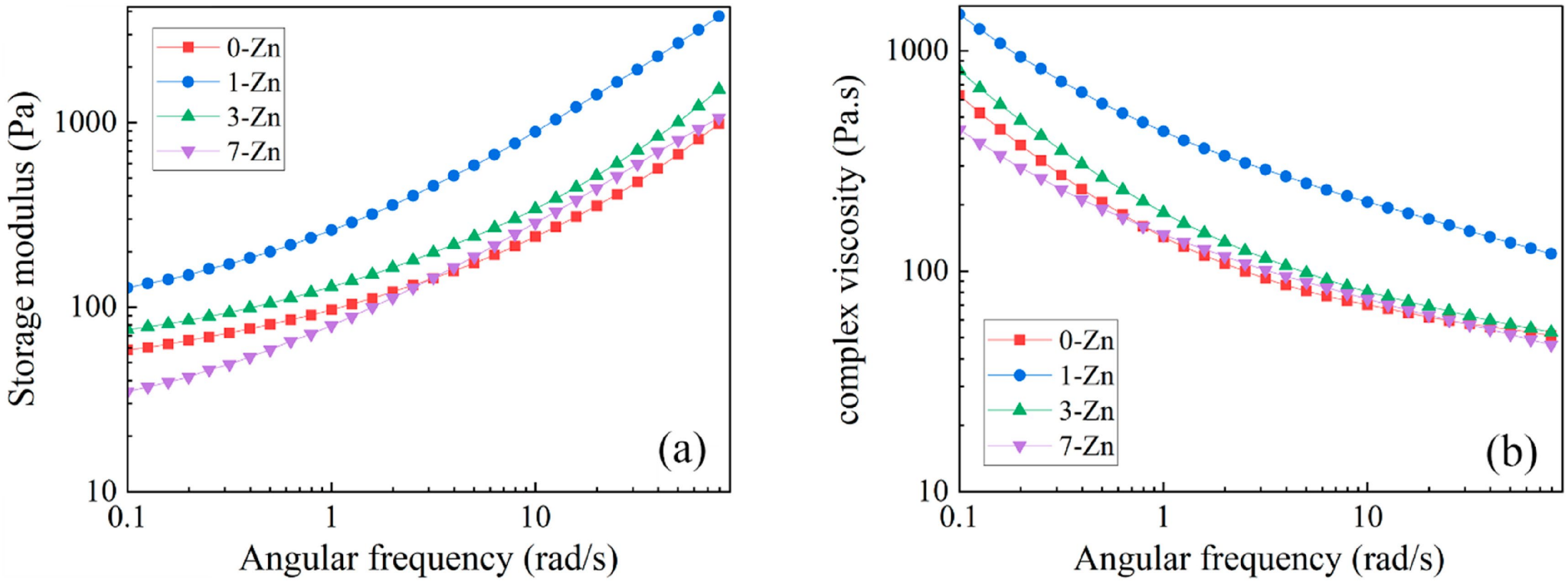
Thermal analysis



TGA and DSC thermograms of fabricated composite films

Polymers, 2024; https://doi.org/10.3390/polym16081039

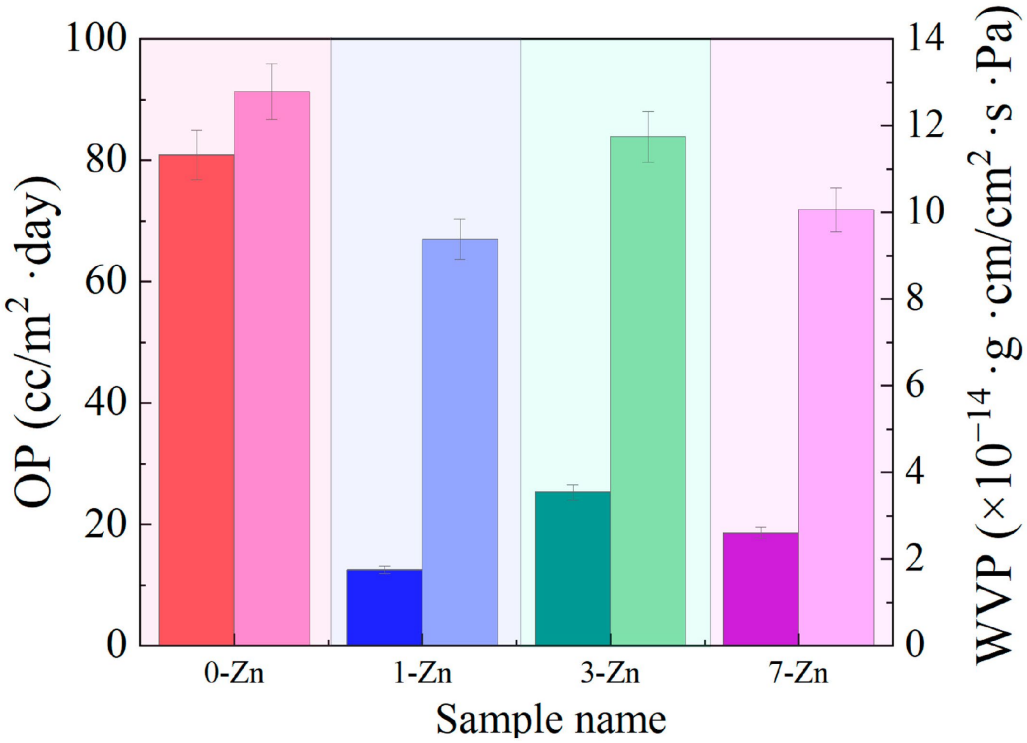
Rheological investigation



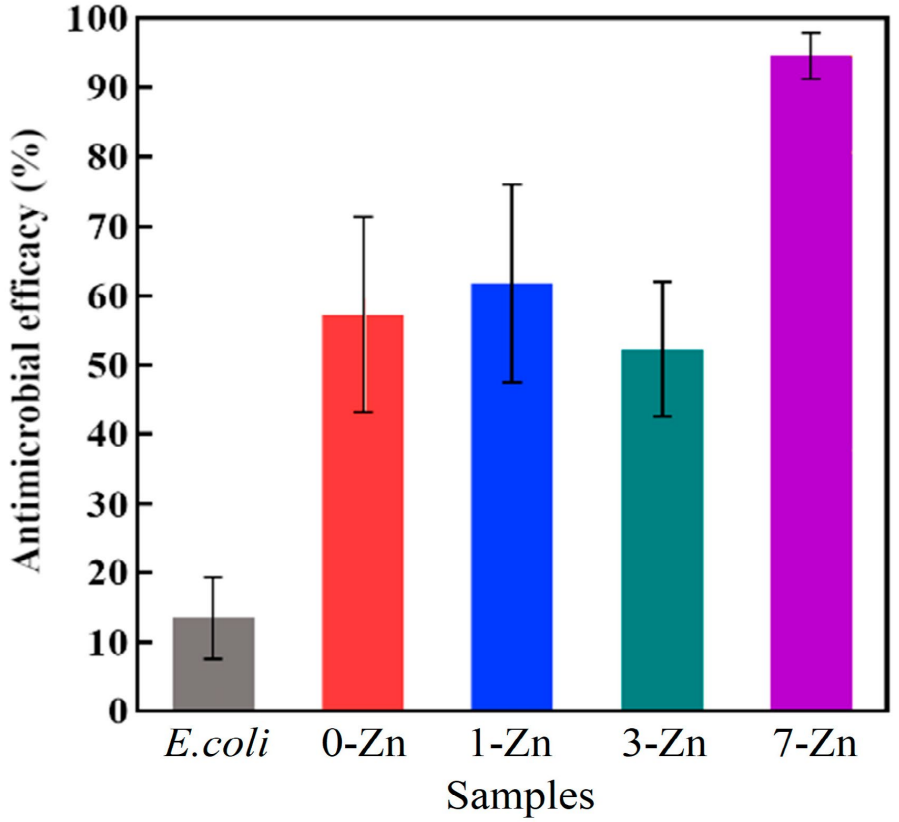
Rheology of composite melts measured as a function of angular frequency.

Polymers, 2024; https://doi.org/10.3390/polym16081039

Barrier properties and Antimicrobial efficiency investigation



Barrier performance (dark bar—OP; light bar—WVP) of fabricated composite films



Antimicrobial efficacy of fabricated composite films

Polymers, 2024; https://doi.org/10.3390/polym16081039

Conclusion

- ✓ Incorporation of T-ZnO whisker enhanced the crystallinity of PBAT/PLA films, whereas affected the optical properties.
- ✓ Composite with 1 wt.% T-ZnO whisker exhibited improved rheological and barrier properties.
- ✓ Composite with 3 and 7 wt.% T-ZnO whisker exhibited enhanced strength and antibacterial activity.
- ✓ The developed PBAT/PLA/T-ZnO whisker composite films can be used as potential antibacterial packaging material.

Research Outcome (Journal Article)

1. Poly(butylene adipate-co-terephthalate)/Polylactic Acid/Tetrapod-Zinc Oxide Whisker Composite Films with Antibacterial Properties. *Polymers*, 2024; https://doi.org/10.3390/polym16081039.

THANK YOU