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Characterization of CuO NPs-Reinforced Bio-Nanocomposite Films from Taro Starch and Aloe Vera Gel Blend

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INTRODUCTION & AIM

Can locally available taro starch and Aloe vera be developed into biodegradable films, and how does the addition of copper oxide nanoparticles (CuO NPs) improve their functionality for sustainable food packaging?

Plastic pollution remains one of the most urgent global challenges, with single-use plastics dominating the food packaging industry. These materials are persistent in the environment, threaten ecosystems, and rely heavily on non-renewable fossil resources. Developing sustainable and biodegradable packaging is therefore essential to reduce environmental impact while ensuring food quality and safety.

In this study, taro starch and Aloe vera gel were used as the biopolymer matrix, with CuO NPs incorporated to enhance optical, mechanical, barrier, and antimicrobial properties.

Aims

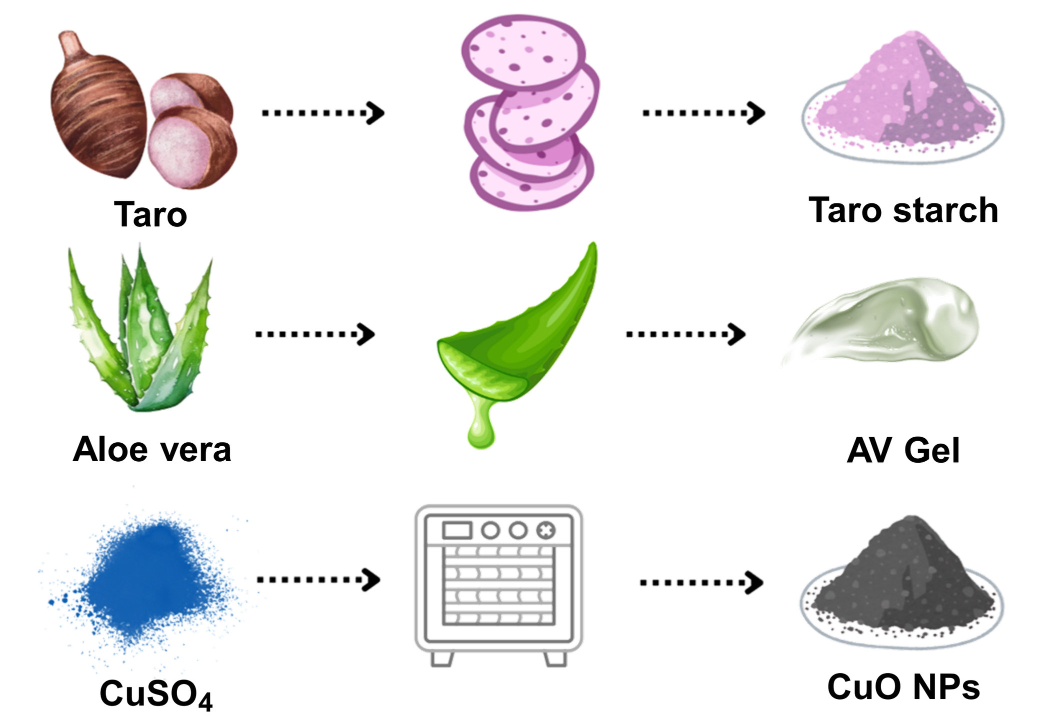
- To synthesize and incorporate different concentrations of CuO NPs into taro starch–Aloe vera gel films.
- To characterize the optical, mechanical, thermal, physical, antimicrobial, and antioxidant properties of the developed bio-nanocomposite films.
- To evaluate the potential of CuO NP-reinforced films as active biodegradable food packaging material.

Relevance to the SDGs

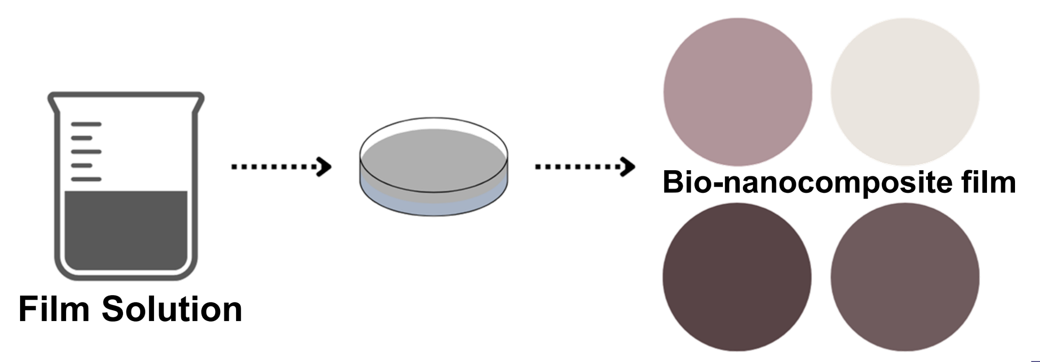
METHOD

Biodegradable film components were derived from natural and renewable resources—taro starch and Aloe vera gel—while copper oxide nanoparticles (CuO NPs) were synthesized in the laboratory using analytical-grade reagents.

Raw Materials Preparation



Film Formation



Film Characterization

Optical properties	Mechanical properties	Physical properties	Structural analysis	Bioactivity
-Opacity -transparency -Color	-thickness -tensile strength -elongation at break	-moisture content -water vapor transmission rate (WVTR)	-FTIR (functional groups) -SEM (surface morphology) -DSC (thermal transitions).	-Antimicrobial (disc diffusion) -Antioxidant (DPPH scavenging, FRAP assay).

RESULTS & DISCUSSION

A Optical & Barrier Properties

- Increasing CuO nanoparticle (NP) concentration resulted in progressively **darker films**, reflected by increased *opacity* and reduced *transparency*.
- UV–Vis spectroscopy confirmed that higher CuO loading enhanced **UV light blocking capacity**, suggesting potential for **retarding photooxidation in packaged foods.**

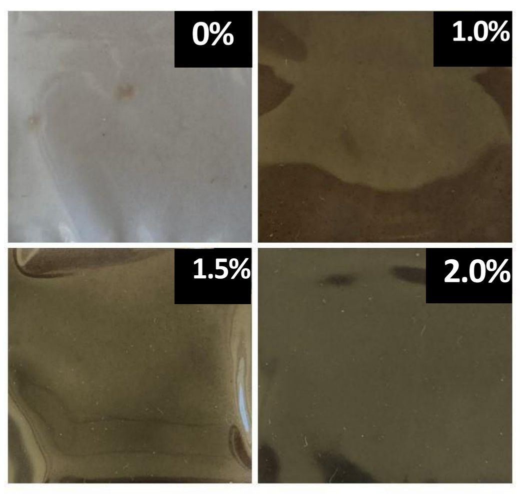


Fig. 1. Visual Appearance

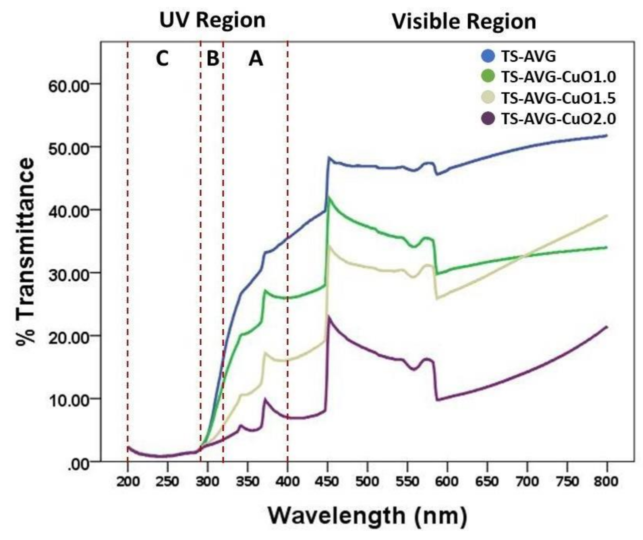


Fig. 2. UV/VIS transmittance spectra

B Mechanical & Physical Properties

Moisture Content

- Decreased with CuO addition, especially at 1.0%. This reduction indicates **less water binding capacity**, enhancing film stability and reducing microbial spoilage risk.

Water vapor transmission rate

- Lowest at 1.0% CuO, confirming **improved moisture barrier** due to tortuous path effect created by nanoparticles.

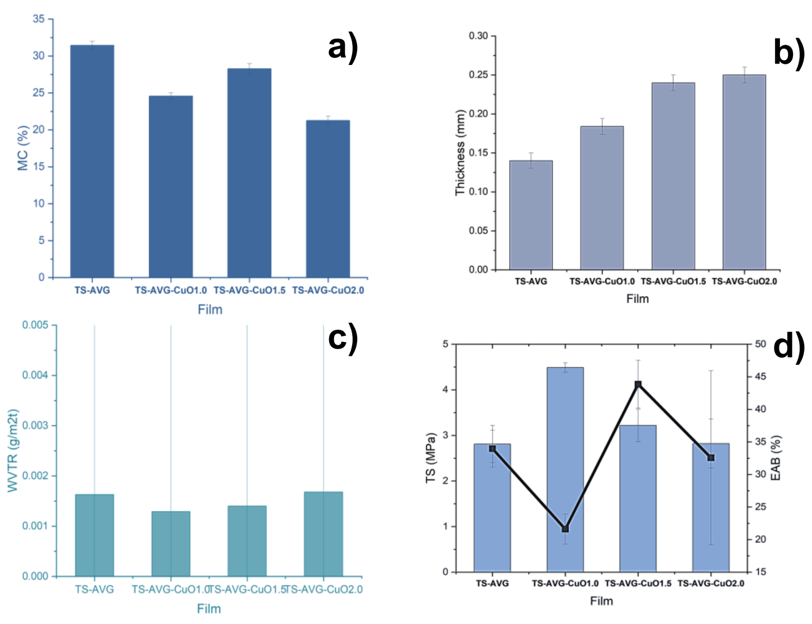


Fig. 3. a. MC (%); b. WVTR; c. Thickness; d. TS and EAB

Thickness

- Increased proportionally with CuO concentration due to denser nanoparticle incorporation.

Tensile strength and EAB

- Highest at 1.0% CuO (optimum dispersion → stronger polymer–filler interaction).
- Declined at higher loadings (1.5–2.0%) because of **nanoparticle agglomeration.**
- Decreased as CuO loading increased, showing stiffer and less flexible films in EAB.

C Structural & Morphological Characterization

- **FTIR spectra** showed no formation of new chemical bonds, indicating that CuO NPs acted as a **physical reinforcing agent** within the polymeric matrix rather than chemically modifying the biopolymers.
- **SEM micrographs** revealed smooth and homogeneous surfaces in control and 1.0% CuO films, while clustering and surface roughness were observed at 2.0%, confirming agglomeration at higher NP loading.
- **DSC analysis** demonstrated increases in glass transition (Tg) and melting temperature (Tm) with CuO addition, suggesting **restricted polymer chain mobility** and improved **thermal stability** of the films.

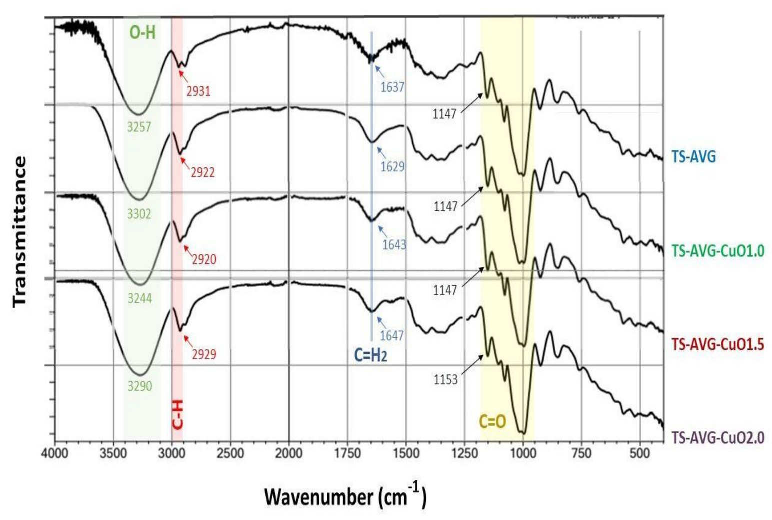


Fig. 4. FTIR Spectra

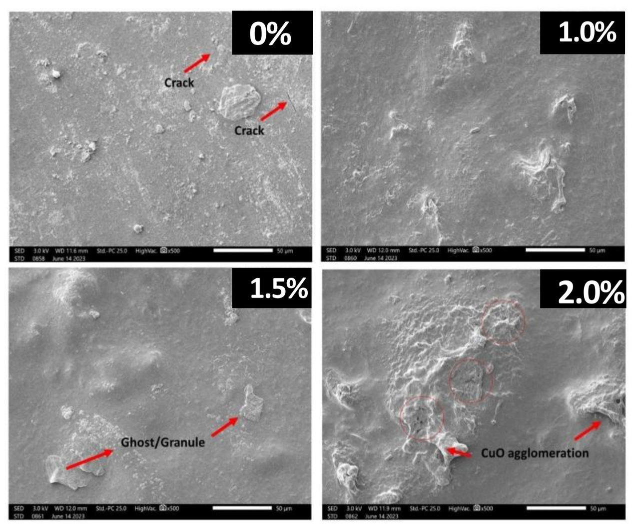


Fig. 5. SEM images

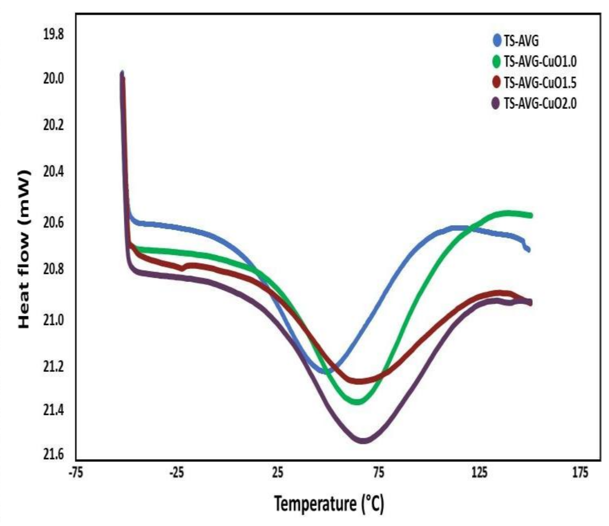


Fig. 6. DSC thermogram

D Antimicrobial & Antioxidant Activities

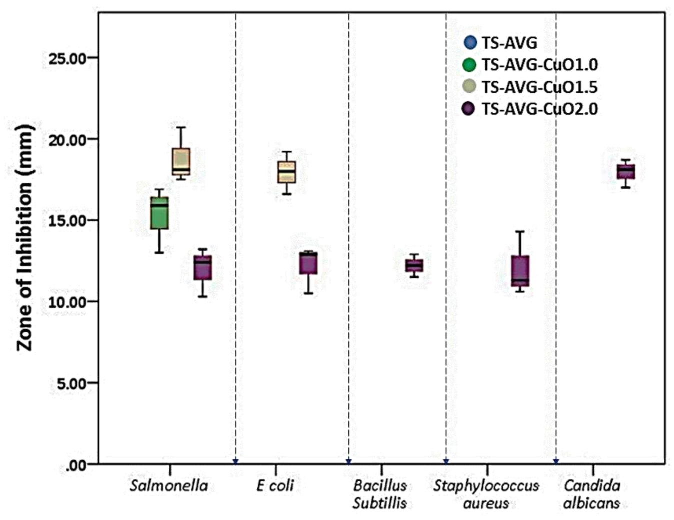


Fig. 7. Antimicrobial activities

Antioxidant Properties of Biocomposite Film with CuO Nanoparticles

Film	FRAP (µmol Fe2+ / g sample)	DPPH (% Inhibition)
TS-AVG	574.38 ± 37.421[a]	76.15 ± 0.09[ab]
TS-AVG-CuO1.0	525.00 ± 9.26[a]	76.26 ± 0.09[a]
TS-AVG-CuO1.5	543.52 ± 33.39[a]	75.19 ± 0.67[b]
TS-AVG-CuO1.5	531.17 ± 5.35[a]	75.40 ± 0.42[ab]
p -value	*p=0.165*	*p=0.026*

- **Antimicrobial Activity**: CuO-incorporated films exhibited dose-dependent inhibition against *E. coli, S. typhi, S. aureus, B. subtilis, and C. albicans.*
- **Antioxidant Activity**: Minimal contribution from CuO; activity primarily attributed to Aloe vera phenolic compounds.

CONCLUSION

- Taro starch and Aloe vera gel are effective renewable sources for biodegradable film production.
- CuO nanoparticles improved UV barrier, thermal stability, and antimicrobial activity of the films.
- Optimal properties were achieved at 1.0–1.5% CuO NPs, balancing strength and flexibility.
- Higher CuO concentrations caused agglomeration, reducing mechanical performance.
- The developed films show strong potential as active, eco-friendly food packaging to reduce plastic waste.

REFERENCES

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