Finishing of Multifunctional Cotton Fabric using Tea Tree Oil-Loaded Urea-Formaldehyde Microcapsules Incorporated with Zinc Oxide Nanoparticles.

Oranuch Naprang

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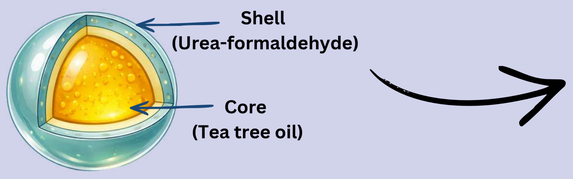
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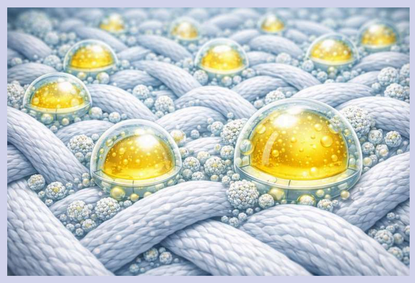
ABSTRACT

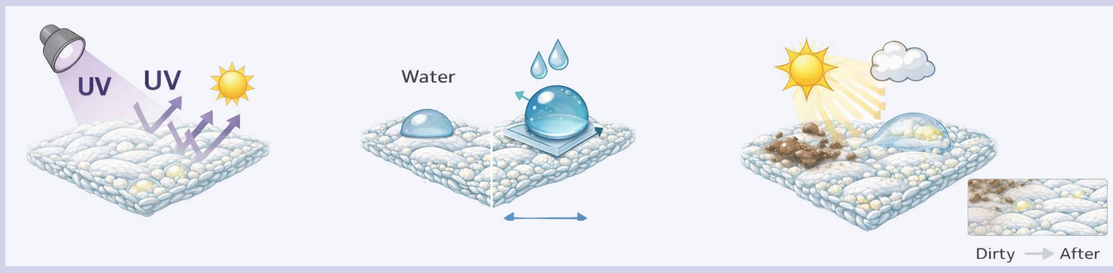
This research investigates the development of a multifunctional finishing process for cotton fabrics utilizing tea tree oil-loaded urea-formaldehyde microcapsules in combination with zinc oxide nanoparticles (ZnO NPs). The microcapsules were synthesized via in-situ polymerization, where the influence of stirring speed (250–1,250 rpm) on microcapsule formation was systematically evaluated. Morphological characterization using Scanning Electron Microscopy (SEM) and particle size distribution analysis identified 500 rpm as the optimal speed, yielding spherical microcapsules with smooth surfaces and a maximum encapsulation efficiency of 30.57%. The optimized microcapsules were subsequently incorporated with ZnO NPs and applied onto cotton fabrics using a padding–drying–curing method with an acrylic binder. The treated fabrics exhibited enhanced multifunctional performance. Improved surface hydrophobicity was achieved, with water contact angles ranging from 102.36° to 136.48°, confirming effective water repellency. Moreover, the synergistic interaction between the microcapsules and ZnO NPs significantly enhanced UV protection, resulting in a 35.5% improvement compared to untreated fabrics. Photocatalytic self-cleaning performance was also demonstrated through the degradation of organic coffee stains under D65 standard illuminant irradiation. These findings suggest that the integration of microencapsulation and ZnO NPs offers a high-potential strategy for advancing multifunctional textile finishing and functional coatings.

INTRODUCTION



Microencapsulation





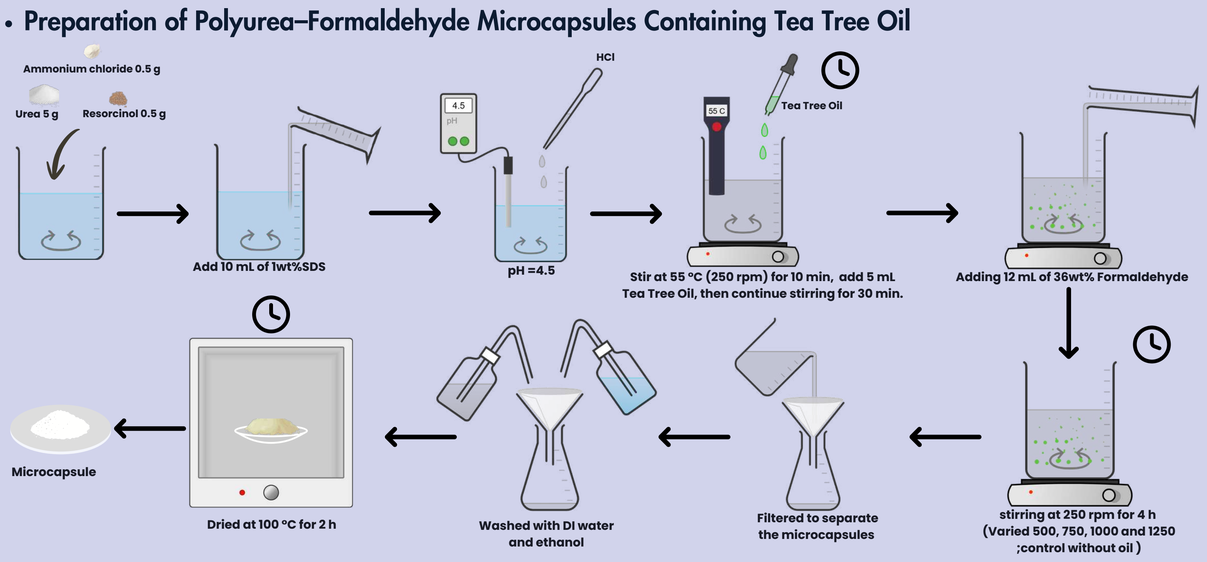
Natural textiles often lack multifunctional properties, limiting their added value. To address this, our research utilizes microencapsulation of tea tree oil combined with ZnO nanoparticles to provide multifunctional properties, including UV protection, antibacterial activity, water-repellent, and self-cleaning performance.

OBJECTIVES

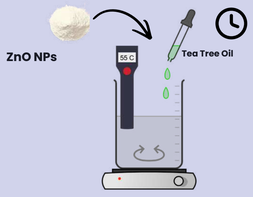
- To synthesize polyurea–formaldehyde (PUF) microcapsules containing tea tree oil and tea tree oil combined with ZnO NPs via in-situ polymerization.
- To investigate the physical properties and morphology of the prepared microcapsules.
- To evaluate the functional properties of fabrics finished with the microcapsules, including UV protection, water repellency, and self-cleaning performance.

EXPERIMENTAL

• Preparation of Polyurea–Formaldehyde Microcapsules Containing Tea Tree Oil

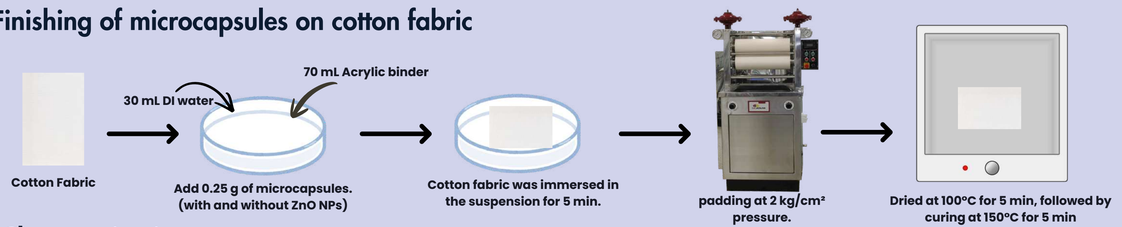


• Preparation of Polyurea–Formaldehyde Microcapsules Containing Tea Tree Oil and Nano-Zinc Oxide

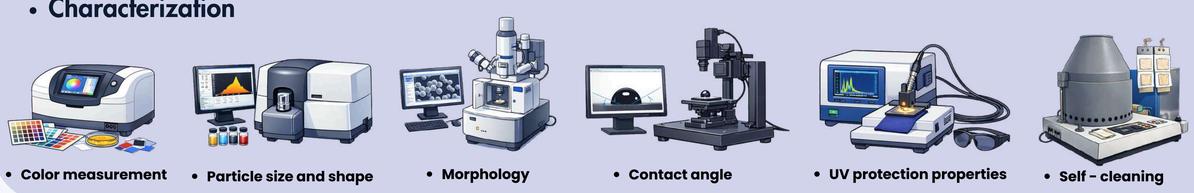


Microcapsules were prepared using the same procedure, with 5 g of ZnO NPs added to the emulsion after tea tree oil addition and stirred at 500 rpm.

• Finishing of microcapsules on cotton fabric



• Characterization



- Color measurement
- Particle size and shape
- Morphology
- Contact angle
- UV protection properties
- Self - cleaning

RESULTS AND DISCUSSION

• Optimization of Tea Tree Oil–Loaded Microcapsules

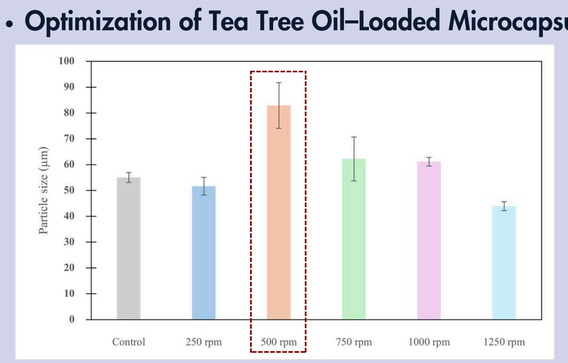


Fig.1 Particle size of Microcapsules Containing Tea Tree Oil

Table.1 Encapsulation yield of Microcapsules Containing Tea Tree Oil

Microcapsules	Encapsulation yield (%)
control	23.63
250 rpm	24.35
500 rpm	30.57
750 rpm	21.89
1000 rpm	24.72
1250 rpm	21.11

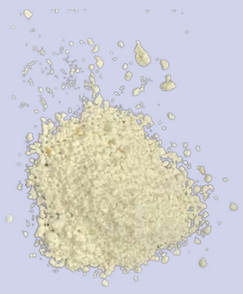


Fig.2 Synthesized microcapsules

A stirring speed of 500 rpm was identified as the optimal condition.

• Morphology of Microcapsules

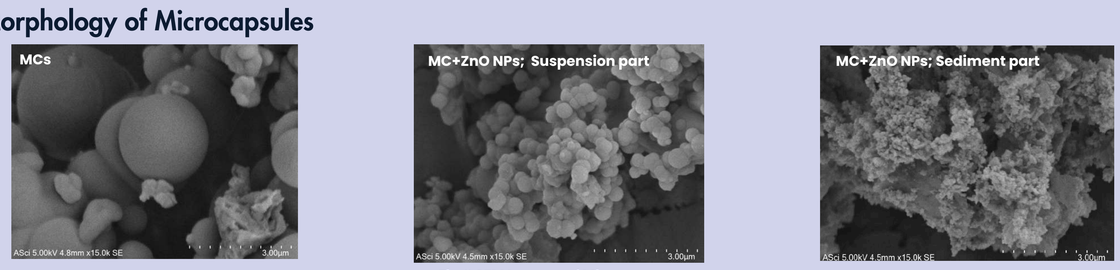


Fig.3 SEM Images of Microcapsules

MCs were round in shape and did not clump together significantly, while adding ZnO NPs leads to smaller, grape-like clusters in the suspension and dense, irregular agglomeration in the sediment.

• Morphology of Cotton Fabrics Finished with Microcapsules

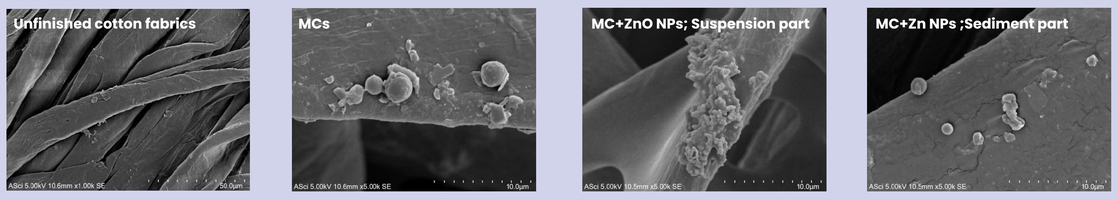


Fig.4 SEM Images of cotton fabrics

The attachment of tea tree oil-loaded microcapsules and ZnO nanoparticles onto the cotton fiber surfaces was found.

• Multifunctional Properties

Self-Cleaning Performance

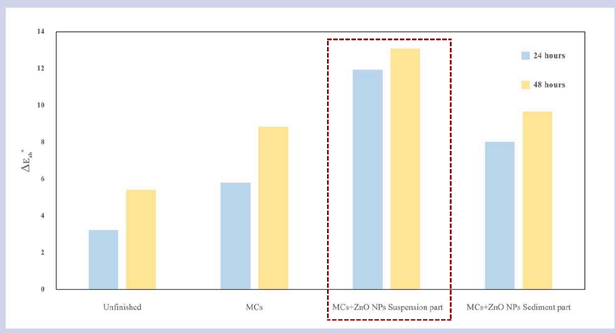
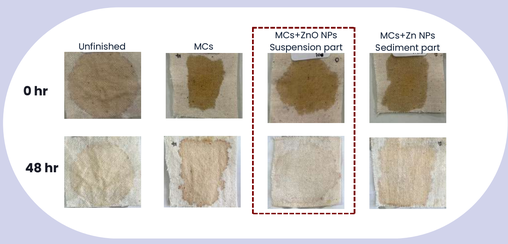


Fig.4 Color Different of coffee stain on finished cotton fabrics at 24 and 48 hours



The cotton fabric finished with MCs containing tea tree oil and ZnO NPs exhibited the best self-cleaning performance.

Water-repellent



Fig.5 Contact angle of cotton fabrics

The finished cotton fabric exhibited a contact angle > 90°, indicating hydrophobic behavior

UV-Protection

Table.2 UV radiation power and %UV protection improvement ofsamples

Finished Cotton Samples	UV Radiation Power (µW/cm2)	% UV Protection improve
Unfinished	23949	0
MCs	20544	14.2
MCs+ZnO NPs Suspension part	17254	26.8
MCs+ZnO NPs Sediment part	15447	35.5

The finished cotton fabric containing MCs and ZnO NPs showed improved UV protection

CONCLUSION

- The microcapsules exhibited a spherical morphology with slight agglomeration.
- A stirring speed of 500 rpm was determined to be optimal, yielding the highest encapsulation yield with well-defined spherical microcapsules and minimal agglomeration.
- The finished fabric exhibited self-cleaning, hydrophobic, and UV-protective properties.

Reference: Mohamed AL, El-Zawahry M, Hassabo AG, Abd El-Aziz E. Encapsulated lemon oil and metal nanoparticles in biopolymer for multifunctional finishing of cotton and wool fabrics. Industrial Crops and Products. 2023;204:117373.