SYNTHESIS AND CHARACTERIZATION OF ZnO NANOPARTICLES ENCAPSULATED IN PECTIN-PROTEIN COMPLEX: ANTIBACTERIAL AND ANTI-INFLAMMATORY PROPERTIES EVALUATION

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Bogor, October 2025

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RINGKASAN

PUTRI NUR ANGELINA. Sintesis dan Karakterisasi Nanopartikel ZnO Terenkapsulasi dalam Kompleks Pektin-Protein: Evaluasi Karakteristik Antibakteri dan Anti-inflamasi. Dibimbing oleh ZAENAL ABIDIN, TRIVADILA, dan IRMA ISNAFIA ARIEF.

Stunting merupakan salah satu masalah kesehatan utama di Indonesia. Asupan zink yang cukup sangat penting untuk mengatasi stunting karena zink berperan penting dalam pertumbuhan dan fungsi imun. Penelitian ini mengaplikasikan nanopartikel zink oksida (ZnO-NP) sebagai bahan tambahan pangan dalam yogurt untuk meningkatkan asupan zink dan pada akhirnya berpotensi mengatasi stunting. ZnO-NPs yang memiliki aktivitas antibakteri dan anti-inflamasi dienkapsulasi menggunakan bahan edibel, yaitu pektin dan protein, untuk meningkatkan karakteristik fisiknya dan meminimalkan kontak langsung dengan bakteri baik dalam yogurt. Proses enkapsulasi dioptimalkan dengan perlakuan pemanasan untuk memperkuat interaksi pektin-protein yang membentuk lapisan pelindung di permukaan nanopartikel. Keberhasilan proses enkapsulasi ditentukan melalui karakterisasi fisikokimia serta uji aktivitas antibakteri dan anti-inflamasi.

Proses enkapsulasi dilakukan dengan metode presipitasi sederhana. Material hasil sintesis dan enkapsulasi dicirikan menggunakan spektroskopi *Fourier Transform Infrared* (FTIR) dan *Scanning Electron Microscope* (SEM), serta diuji aktivitas biologinya. Spektrum inframerah material menunjukkan tidak adanya puncak vibrasi regangan ZnO yang membuktikan keberhasilan enkapsulasi. ZnO-NPs yang telah dienkapsulasi memiliki aktivitas antibakteri yang relatif sama dengan yogurt tanpa penambahan ZnO. Hasil tersebut mengindikasikan bahwa lapisan enkapsulasi efektif dalam mengurangi efek antimikroba langsung terhadap bakteri probiotik dalam yogurt. ZnO-NPs memiliki aktivitas anti-inflamasi yang terkategori sedang melalui penekanan produksi IL-6, TNF-α, dan iNOS. Sementara itu, ZnO-NPs terenkapsulasi memiliki aktivitas anti-inflamasi yang lebih rendah. Semua sampel tidak menunjukkan sitotoksisitas sehingga aman digunakan dalam pangan.

Berdasarkan hasil tersebut, dapat disimpulkan bahwa ZnO-NPs dapat dienkapsulasi secara efektif menggunakan kompleks pektin-protein sehingga stabilitas dan keamanannya sebagai bahan tambahan pangan meningkat. Meskipun proses enkapsulasi menurunkan aktivitas anti-inflamasi ZnO-NPs, karakteristik fungsionalnya tetap terjaga dan relevan untuk fortifikasi pangan. Hasil ini mendukung potensi penggunaan strategi fortifikasi berbasis ZnO untuk meningkatkan asupan zink dan berkontribusi dalam pencegahan stunting dengan optimasi lebih lanjut untuk meningkatkan bioaktivitas dan efektivitasnya.

Kata kunci: Antibakteri, anti-inflamasi, enkapsulasi, pektin-protein, ZnO.

SUMMARY

PUTRI NUR ANGELINA. Synthesis and Characterization of ZnO Nanoparticles Encapsulated in Pectin-Protein Complex: Antibacterial and Anti-Inflammatory Properties Evaluation. Supervised by ZAENAL ABIDIN, TRIVADILA, and IRMA ISNAFIA ARIEF.

Stunting remains a major public health concern in Indonesia. Adequate zinc intake is crucial in mitigating stunting, as zinc plays an essential role in growth and immune function. This study explored the application of zinc oxide nanoparticles (ZnO-NPs) as a food additive in yogurt to improve zinc intake and potentially address stunting. The ZnO-NPs, which possess antibacterial and anti-inflammatory activity, are encapsulated in edible materials like pectin and protein to enhance their physical characteristics and minimize contact with the beneficial bacteria in yogurt. The encapsulation process was optimized using heat treatment to strengthen the pectin-protein interaction, forming a protective coating around ZnO-NPs. This study evaluated the encapsulation layer formation through the physicochemical characterization and antibacterial and anti-inflammatory assays.

The encapsulation process was conducted using a simple precipitation method. The synthesized and encapsulated material was characterized using Fourier Transform Infrared (FTIR) spectroscopy and Scanning Electron Microscopy (SEM), and biological activity analysis was also performed. The FTIR analysis confirmed the absence of Zn-O peaks, indicating effective coating. Encapsulated ZnO nanoparticles displayed antibacterial activity similar to that of blank yogurt, suggesting that the coating effectively reduced the direct antimicrobial effects on probiotic bacteria. In contrast, bare ZnO exhibited moderate anti-inflammatory activity by suppressing IL-6, TNF-α, and iNOS expression, while encapsulated forms showed reduced anti-inflammatory effects. All samples were non-cytotoxic, confirming their safety for food use.

In conclusion, this study demonstrated that ZnO nanoparticles can be effectively encapsulated using a pectin-protein complex derived from yogurt, enhancing their stability and safety as a food additive. While encapsulation slightly reduced anti-inflammatory activity, it maintained beneficial properties suitable for food fortification. These findings support the potential use of ZnO-based fortification strategies to improve zinc intake and contribute to stunting prevention, with further optimization needed to enhance bioactivity and efficacy.

Keywords: *Antibacterial, anti-inflammation, encapsulation, pectin-protein, ZnO.*

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Thesis
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PREFACE

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May this scientific work be beneficial to those who need it and contribute to the advancement of knowledge.

Bogor, October 2025

Putri Nur Angelina

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