Development of Banana Peel Fiber-Based Zn Nano-Carriers to Enhance Zn Bioavailability

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ABSTRACT

Introduction: Zinc deficiency is a pervasive global health concern, with disproportionate severity observed in developing nations. Billions of people are facing a wide range of problems, like increased morbidity, stunted growth in children, and decreased immunity (Hussain *et al*., 2022). This can be overcome by fortification, but the binding of Zn with antinutrients like phytates directly reduces the bioavailability of Zn (Wang *et al*., 2020). Additionally, promising techniques such as nanoemulsions have limitations, such as thermal instability, phase inversion, and oxidation (Kumar *et al*., 2019). However, the utilization of banana peel fiber as a nanocarrier for Zn not only protects it but also prevents material oxidation. Fiber-based nano-carriers are excellent for enhancing the bioavailability of desired nutrients, are cost-effective, and are more stable than emulsions.

Objective: The primary objective of this study is to develop and characterize a novel Zn nano-carrier derived from banana peel fiber and incorporate it into bread to evaluate its physical and chemical stability.

Methodology: For the extraction of lignocellulosic residue, banana peel was treated with potassium hydroxide and $NaClO_2$ (Hoque & Janaswamy, 2023). Subsequently, Zn nanoparticles were synthesized and characterized using UV-Visible Spectroscopy, SEM, ATR-FTIR, and XRD to analyze dispersion stability and bonding interactions (Al-Khaial *et al*., 2024). The nanocarrier was incorporated into bread at levels of 20, 40, and 60 mg Zn/kg to evaluate physicochemical properties and bioavailability using a Simulated Gastrointestinal Digestion Model (Milinčić *et al*., 2024).

Result: The study successfully yielded banana peel fiber, which acted as an effective host for Zn-carrier. Characterization through SEM and XRD confirmed that the Zn particles were stabilized at the nano level without agglomeration. In the bread application, the nanocarriers demonstrated superior physical and chemical stability against oxidation and thermal processing compared to conventional $ZnSO_4$ fortification. The physicochemical properties of the bread, including moisture content, texture profile, and color (L*, a* b* values), remained stable and comparable to the control group. Crucially, the nanocarriers prevented the binding of Zn with phytates, directly addressing the problem of antinutritional activities.

Key Findings: The banana peel fiber-based nanocarrier exhibited no phase inversion, proving more stable than emulsion-based systems. An in vitro study showed a significant difference in bioaccessibility, with the nanocarrier system releasing a higher percentage of soluble Zn compared to standard fortification. The fiber successfully protected Zn from environmental barriers and oxidation during storage and processing.

Conclusion: This approach targeted a cost-effective system by utilizing the waste of bananas to increase bioavailability and overcome the limitations of existing technologies.

Keywords: Zinc Bioavailability, Nanocarriers, Nanoencapsulation, Food Fortification.

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