Shape-dependent migration and antimicrobial activity of zinc oxide nanoparticles in nanocellulose-based food packaging

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Abstract (max 2500 caracteres incluindo espaços)

The application of nanotechnology in food packaging has attracted significant attention due to its potential to improve thermal, barrier and mechanical properties, offering active and intelligent systems. Combining nanomaterials with bio-based packaging materials extends the shelf life of food products, ensuring quality and safety, while contributing to reduced plastic use. Zinc oxide nanoparticles (ZnO NPs) are widely studied in food packaging due to their diverse sizes and morphologies and high surface area, which provide unique properties such as antimicrobial activity, UV absorption, and safety, supported by positive evaluations from European Food Safety Authority (EFSA) and US Food and Drug Administration (FDA). The incorporation of ZnO NPs into different matrices has been explored to develop active packaging. When combined with nanocellulose (NC), ZnO NPs are reported to exhibit outstanding properties such as mechanical strength, UV protection and antibacterial activity. Despite the abundant literature research focusing on the use of ZnO NPs as an antimicrobial component in packaging materials, the effects of Zn migration, whether in ionic form (Zn^{2+}) or as whole particles (ZnO NPs), into food systems remain underexplored.

This project focuses on developing NC bionanocomposites incorporating distinct shapes of ZnO NPs for food packaging applications to control microbial hazards and understand the impact of Zn migration. ZnO NPs with spherical, flower and sheet morphologies were synthesized and characterized through scanning electron microscopy, X-ray powder diffraction, and nitrogen adsorption–desorption for specific surface area determination. Antimicrobial activity of the NPs against *E. coli* and *S. aureus* at 4 and 22 ºC was also determined by viable cell count assay. The ZnO NPs were incorporated in NC by solvent casting method. The release of Zn from NC/ZnO films into food simulants (distilled water and 10% ethanol) was evaluated over 35 days at 6, 23 and 60 ºC using atomic absorption

spectrometry, following the separation of fractions containing ZnO NPs and Zn^{2+} ions. The results indicate that Zn migration from the NC/ZnO films into food simulants is influenced by the shape and size of the ZnO NPs. Furthermore, differences between total and ionic zinc migration suggest the migration of ZnO in nanoform. Further research is required to accurately quantify nanoparticle migration and assess its safety in food packaging applications.

Keywords: ZnO nanoparticles, shape and size, nanocellulose, migration, antimicrobial activity, food packaging.