



Fostering the Transition to Sustainable Food Systems:

Embracing Novelty and Overcoming Challenges

EFFoST

17–19 November
Porto, Portugal

2025 INTERNATIONAL
CONFERENCE

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Aim:

The demand for sustainable food packaging has driven the development of bio-based materials with active functionalities. Nanotechnology has gained increasing attention in this field due to its potential to improve material properties. Combining nanomaterials with bio-based matrices can extend food shelf life, enhance quality and safety, while contributing to reduce the plastic use. This study aims to evaluate the effectiveness of zinc oxide nanoparticles (ZnO NPs) with different morphologies incorporated into microfibrillated cellulose (MFC) films, contributing to the development of sustainable and innovative food packaging solutions. A real food model (melon) was used to assess microbial growth and zinc migration.

Method:

ZnO NPs were synthesized with three distinct morphologies (spherical, flower, and sheet shapes) and incorporated into MFC packaging films by the solvent casting method. Fresh-cut melon cubes were wrapped in each film and microbial growth and migration of zinc were monitored during storage at 4 °C. Mesophilic and psychophilic bacteria, enterobacteriaceae, yeasts and molds were monitored using standard enumeration methods over 1 week. Zn migration from the films into the melon was evaluated using microwave digestion followed by atomic absorption spectrometry (AAS) for zinc quantification. The pH of the melon was also measured during storage. A melon control was used for both microbiological and migration studies.

Results:

All MFC/ZnO NPs films significantly reduced microbial growth compared to the control. The MFC/ZnO-sheet film showed the highest antimicrobial efficacy, with microbial counts 2–3 log CFU/g lower than those observed in the control samples. The MFC/ZnO-spherical and flower-shaped films presented similar antimicrobial activity for the studied bacterial groups. Zinc migration increased progressively during storage, with the MFC/ZnO-sheet film showing the highest levels, which correlated with its superior antimicrobial performance. A gradual decrease in melon pH was observed over time, which may have contributed to both the enhanced antimicrobial activity and the increased zinc migration.

Conclusion:

MFC films incorporating ZnO NPs demonstrated effective antimicrobial properties for food packaging applications, with the sheet-shaped morphology presenting the best performance. The correlation between higher zinc migration and microbial inhibition suggests a morphology-dependent release behavior. These findings reinforce the role of nanomaterials design in optimizing the functionality of sustainable, bio-based active packaging.