Development and Optimization of Biodegradable Chitosan Beads Encapsulating Olive Stone Wooden Residues Ash for Application as Controlled Release Fertilisers

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Introduction

The development of controlled release fertilisers (CRFs) has gained significant attention as a sustainable strategy to enhance nutrient use efficiency and reduce environmental impact. In this study, biodegradable chitosan-based coatings were developed and optimized encapsulating Olive Stone Wooden Residues (OSWR) ash as a functional additive. The system aims to combine waste valorisation with fertiliser delivery through a bio-based encapsulation approach.

Materials and Methods

Chitosan of varying molecular weights was dissolved in 2% (v/v) aqueous acetic acid to form the polymer matrix. OSWR ash was incorporated in the solution at optimized loading (2% w/v) and mixed for 2 hours to ensure homogeneity. Capsule formation was achieved via dropwise addition into a NaOH–water–methanol solution, inducing gelation. The resulting capsules were filtered and washed until neutral pH.

To enhance mechanical stability, a cross-linking step using glutaraldehyde was applied. Glutaraldehyde forms covalent imine (Schiff base) bonds with chitosan amino groups, improving structural integrity. The optimized formulation utilized higher molecular weight chitosan (200–600 mPa·s) at 1% w/v, followed by freeze-drying as the preferred drying method.

The elemental composition of the materials and final capsules was analyzed using Atomic Absorption Spectroscopy (AAS). Nutrient release behavior was assessed through controlled release studies focusing on K, Na, Ca, Mg, and other essential ions.

Results and Discussion

AAS analysis revealed that OSWR ash is rich in potassium and calcium (~5000–7000 ppm), with moderate concentrations of Fe, Cu, and Mn, whereas chitosan exhibited negligible mineral content (<0.3 ppm), confirming its high purity. The optimized chitosan–OMW capsules effectively retained essential nutrients such as K, Na, Ca, and Mg, indicating successful encapsulation. The use of higher molecular weight chitosan improved capsule stability, while glutaraldehyde cross-linking significantly enhanced mechanical strength through the formation of stable chemical bonds. Release studies, conducted using a method adapted from EN 13266, were performed on beads produced under optimized conditions. The results, determined via atomic absorption spectroscopy, demonstrated a gradual and controlled release profile of K, Na, Ca, and Mg, supporting the functionality of the developed system as a controlled-release fertilizer (CRF).

Conclusions

The study demonstrates the successful development of biodegradable chitosan-coated fertilisers incorporating OSWR ash as a nutrient source. The optimized system provides enhanced encapsulation, mechanical stability, and potential for controlled nutrient release. This approach promotes the valorisation of agro-industrial waste and contributes to sustainable agricultural practices by improving fertiliser efficiency and reducing environmental impact.

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References

Atalay, S., Sargin, I., & Arslan, G. (2022). *Slow-release mineral fertilizer system with chitosan and oleic acid-coated struvite-K derived from pumpkin pulp*. **Cellulose, 29**, 2513–2523. https://doi.org/10.1007/s10570-022-04453-5

Govil, S., Long, N.V.D., Escriba-Gelonch, M. and Hessel, V., 2024. Controlled-release fertiliser: Recent developments and perspectives. *Industrial crops and products*, *219*, p.119160. https://doi.org/10.1016/j.indcrop.2024.119160