Encapsulation of hydrolyzates from waste high-protein materials in a hydrogel matrix - a solution for sustainable agriculture

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Introduction

Precision agriculture has long been an object of scientific interest for efficient plant fertilization. This study used hydrolyzates based on mealworm larvae as a rich protein source, 3.68-22.32 g/100 g (Grau et al., 2017). Larvae have been used as a potential solution to the problems of plastic accumulation in the environment because of their unique bacterial flora capable of degrading many polymers (Billen et al., 2020). Organisms after the consumption period usually die without reaching the maturity stage, which shows a potential source of organic waste that needs to be managed. The chemical hydrolysis process has been suggested as a cheap and easy-to-apply solution to extract amino acids having a biostimulatory effect on plant growth (Etemadian et al., 2020). These compounds were encapsulated in a hydrogel matrix to slow down the release of biostimulant compounds into the environment. In this study, hydrogel matrices based on sodium alginate were used. Alginate is commonly used to immobilize microorganisms (Berninger et al., 2016) or control the release of fertilizers and pesticides (Rudzinski et al., 2002).

Material and methods

The encapsulated fertilizer was obtained by mixing an acid hydrolyzate (a mixture of phosphoric acid 30% and citric acid 5%) with an alkaline hydrolyzate based on potassium hydroxide 10% at a ratio of 1:2.4 (pH 5). Sodium alginate (concentration 2-6%) and hydrolyzate were mixed in a mass ratio of 1:1, then matrix additives (starch, bentonite at conc. 1-5%) were included at appropriate rates. The mixture was introduced with a syringe into calcium chloride solution 2% (Berninger et al., 2016) to form spherical beads that were placed in chitosan solution (1-2%) for 24 h to create an extra coating. Chitosan forms a thin film on the surface of the oppositely charged alginate through electrostatic interactions (Kopplin et al., 2021), allowing for a limited exchange of the hydrolyzate with the environment. Optimizations were performed based on the nitrogen release rate determined by C/N analysis. The efficacy of the final product was tested on cucumber seeds in germination tests and pot trials.

Result and discussion

The obtained results of matrix optimization allowed for the selection of the optimal matrix composition for further studies. Fertilizer doses were chosen based on the nitrogen content of the hydrolysate and the optimized matrix. In order to evaluate the effectiveness of the controlled release, trials were also performed on the standard fertilizer, distilled water and the unencapsulated hydrolyzate. The study confirmed the efficacy of slow-release and indicated the possibility of using fertilizer with higher content of bioavailable forms. The issue of premature release of the hydrolysate was addressed by using chitosan coating, which showed good barrier properties.

Conclusions

The work presented here shows the use of alginate matrices as a method of controlled release of innovative smart hydrogel fertilizer is more effective than standard application methods. Slow-release prevents over-fertilization and targets different stages of plant development by distributing fertilization over time. The rate of release can be controlled by the appropriate choice of matrix parameters. Storage and application problems were solved by chitosan encapsulation, which eliminates the exchange of hydrolyzate with the environment. The results presented provide a vision of a closed-loop controlled-release fertilizer production cycle. The next stage will be an attempt to increase the scale and estimate the cost of hydrogel fertilizer production.

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