Functional Biopolymer Films Based on Apple Flour for the Development of Biodegradable Capsules Supplemented With Beneficial Microorganisms for Agricultural Applications

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Modern agriculture faces two challenges: managing agro-industrial waste and reducing reliance on synthetic agrochemicals. The integration of materials science and agricultural biotechnology offers an innovative, eco-friendly solution. Apple flour, an abundant regional by-product, was used to create biodegradable biopolymeric matrices. This approach connects the circular economy with sustainable crop management and improved plant health. This research aims to develop and characterize functional, biodegradable capsules made from apple-flour biofilms. These capsules are designed to encapsulate, protect, and control the release of fungal microorganisms known as plant growth-promoters (PGP) at the soil-plant interface. Biopolymeric film-forming solutions were prepared with apple flour as the primary matrix and glycerol. Beneficial fungal species (Trichoderma sp., Beauveria bassiana, and Metarhizium anisopliae) were added before casting, forming functional capsules with seeds. The mechanical and barrier properties of the resulting bioplastics were evaluated. The viability of the encapsulated microorganisms, their release kinetics, colonization capacity, and PGP properties were also assessed under controlled conditions. The apple flour-based capsules demonstrated optimal structural integrity and protected the microorganisms from initial environmental stress. When applied to soil, the biodegradable matrix degraded in a controlled manner facilitating seed germination. The target plants inoculated with these capsules showed enhanced root development. By combining agro-industrial waste valorization with microbial biotechnology, this project provides a scalable, sustainable tool for agriculture. These functional bio-capsules reduce local agro-waste and enhance plant health.

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