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Popular Article

Encapsulated Biocontrol Agents for Precision Plant Protection

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Abstract

Biological control of insect pests and diseases has been showing promise in sustainable agriculture long time and it is the key factor in IPM and organic farming. It has huge potential in reducing usage of chemical pesticides, which are responsible for today's soil and ground water pollution along with hazardous pesticides residues in food, due to their indiscriminate use by the farmers. But the major concerns in the mass production and widespread usage of biocontrol agents are, their short shelf life and sensitivity to environmental conditions when they are applied in the field, which is greatly reducing their efficacy and applicability. The encapsulation method provides significant solutions to biocontrol agent application challenges through protective outer layers surrounding biological agents to protect them from field conditions which lead to enhanced biocontrol agent performance for sustainable farming.

Keywords: Biological control, Encapsulation, Pest management, Sustainable agriculture

Introduction

Successful crop pest management depends on two essential elements which include the right choice of biocontrol agent (BCAs) for the problem and extending their active presence to the target site. In nature, without human intervention beneficial insects and microbes are playing crucial role in combating pests but it is not enough for preventing crop losses. There by there is necessity to augment biocontrol agents' population in the field so as to achieve effective pest control. However, their mass production and widespread use by the farmers is limited by their short shelf life and vulnerability to harsh environmental conditions. Here comes the role of encapsulation of biocontrol agents which offers a breakthrough solution by enclosing these microbes and their bioactive compounds in a protective coating, which can significantly boost their stability, effectiveness and longevity. There are several techniques in encapsulating BCAs in a protective coat which can offer key advantages like protecting the BCAs from heat, moisture and UV radiation, ensuring their viability until they reach the target site (Figure 1). Additionally, controlled and gradual release mechanisms make these bioagents more efficient over time, reducing the need for repetitive applications (Riseh *et al.*, 2022).

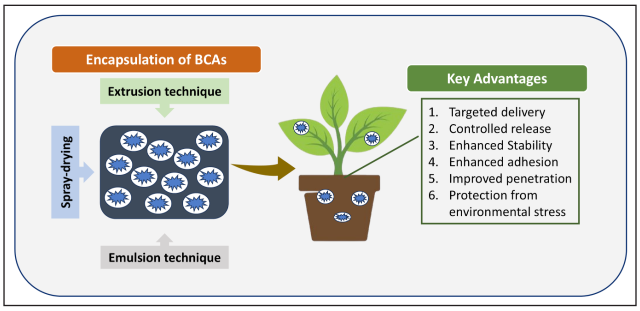

Figure 1: Encapsulated biocontrol agents for precision plant protection

Multiple industries apply encapsulation techniques in their operations starting from pharmaceuticals through food processing industries although their use in pest and disease biological management remains at an initial stage. The field keeps advancing to create affordable user-friendly formulations that farmers can easily use. At its core, encapsulation is powerful technique, it involves trapping active agents inside a carrier material, forming protective capsules that range from microscale (1-1000 µm) to nanoscale (1-several hundred nanometers), depending on the method used (Levic *et al.*, 2015). This precision delivery

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system not only enhances the performance of biocontrol agents but also ensures their sustained and targeted action, making biological control a more practical and scalable alternative to chemical pesticides.

BCAs Encapsulation Techniques

1. Extrusion Method

The extrusion technique is a simple yet highly effective method for encapsulating beneficial microbes, making it a popular choice for agricultural applications. It involves application of high pressure to shape a protective coating around the microbes, when used with hydrogel-based biopolymers, extrusion greatly improves the stability and delivery of biocontrol agents, helping them thrive in the soil. In this technique, a specialized device dispenses the bacterial suspension through an inner channel, while the outer channel releases the protective material, forming a continuous rod with bacteria at its core. As the rod spins, it breaks into uniform droplets, which solidify into protective capsules. One of the biggest advantages of this method is its ability to shield the microbes from oxidation, extending their shelf life and ensuring better field performance.

2. Spray-Drying Technique

In this method the biocontrol agents and protective coating agents are blended well to form a homogenised emulsion. This mixture is sprayed onto a heated chamber where the liquid quickly evaporates, leaving behind the encapsulated biocontrol agents in dry pelleted form. This technique is widely used in producing encapsulated formulations, as it is cost effective and creates high quality and stable encapsulated BCAs. For this process to work efficiently, the wall materials used must be slightly viscous, highly water-soluble and capable of drying effectively at high concentrations. The biggest advantages of spray-drying include low production costs, excellent capsule quality, fast solubility and strong stability, all while keeping the microcapsules compact and easy to handle. However, since this method involves exposure to high temperatures, it may not be suitable for encapsulating heat-sensitive bacteria, which could lose viability during the process.

3. Emulsion Technique

One widely used method in creating microcapsules is the water-in-oil emulsion technique, which helps encapsulate active ingredients effectively. This technique involves mixing small amounts of a biopolymer suspension such as alginate (ALG), gums, or gelatin with pure oil to create an emulsion. The size of the resulting microcapsules varies depending on the type of emulsification process and the agitation speed used. For instance, Pour *et al.* (2019) utilized ALG to form emulsions with soybean oil for encapsulating *Pseudomonas fluorescens* VUPF5. ALG was chosen primarily due to its superior water solubility compared to other biopolymers, as well as its ability to effectively emulsify oil-in-water suspensions, making it an ideal candidate for encapsulation processes.

Key Advantages in BCAs Encapsulation

• *Protection from Environmental Stresses*: The coating agent shields the biocontrol agent from harsh environments like UV radiation, temperature extremes and stomach acid, ensuring its viability and activity upon reaching the target site.

• *Targeted Delivery*: The coating agent can be designed to specifically target the pest or pathogen, allowing for more precise application and minimizing off-target effects.

• *Controlled Release*: The encapsulation can regulate the release of the bioactive compound, providing a sustained and prolonged control effect, unlike conventional biocontrol agents which may rapidly degrade.

• *Enhanced Adhesion*: The micro and nano-sized particles can better adhere to plant surfaces, increasing the contact between the biocontrol agent and the target organism.

• *Enhanced Stability*: Encapsulation protects biocontrol agents from environmental stressors such as UV radiation, temperature fluctuations and desiccation which ensure their viability for longer periods, both during storage and after application.

• *Improved Penetration*: Micro- and nano-particles can penetrate plant tissues easily and reach infection sites that might be inaccessible to traditional treatments. This increases the likelihood of the biocontrol agent direct contact with the pathogens, enhancing their effectiveness.

Conclusion

Encapsulation of biocontrol agents is offering a promising solution for the concerns in applicability of BCAs. Along with the natural efficacy of biocontrol agents' addition of encapsulation has improved the efficacy of BCAs drastically with the enhanced viability. This technology now has the ability to transform biological control to the next level, which can even reduce the sole dependency on chemical pesticides for the quick and effective pest management. With the further refinements in this technology, a new era of biological control can be witnessed throughout the world, paving the way for a more sustainable and resilient agriculture, which is leading to eco-conscious farming landscape.

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