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# Encapsulation of bioactive compounds for food preservation: Methods and future prospects.

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## Introduction

Food preservation is essential for maintaining food quality, extending shelf life, and ensuring consumer safety. One of the emerging techniques in this domain is the encapsulation of bioactive compounds, which protects and enhances their efficacy while preventing degradation. Encapsulation technology has gained significant attention for its ability to improve the stability and controlled release of bioactive compounds in food matrices. This article explores various encapsulation methods used in food preservation and examines future prospects for this innovative technology [1].

Encapsulation involves entrapping bioactive compounds within a carrier material to protect them from environmental factors such as heat, light, oxygen, and enzymatic degradation. Several methods are used for encapsulating bioactive compounds in food preservation, including:

Spray Drying Spray drying is a widely used technique for encapsulating bioactive compounds due to its cost-effectiveness and scalability. In this process, an emulsion containing the bioactive compound and a carrier material (such as maltodextrin or gum arabic) is sprayed into a hot chamber, where rapid evaporation of the solvent results in the formation of dry microcapsules. This method is suitable for encapsulating essential oils, antioxidants, and probiotics [2].

Coacervation Coacervation involves phase separation to form a polymer-rich coating around the bioactive core. This method can be simple or complex, depending on the nature of the polymer used. Coacervation is particularly effective for encapsulating volatile and sensitive compounds such as flavors, antimicrobials, and polyphenols, ensuring their stability and controlled release in food systems.

Liposomal Encapsulation Liposomes are spherical vesicles composed of phospholipid bilayers that can encapsulate both hydrophilic and lipophilic bioactive compounds. They provide excellent protection against oxidative degradation and enhance the bioavailability of encapsulated compounds. Liposomal encapsulation is widely used for preserving vitamins, antioxidants, and antimicrobial peptides in food applications [3].

Emulsification Emulsification is a technique where bioactive compounds are dispersed in an oil-in-water or water-in-oil emulsion, stabilized by surfactants or biopolymers. This method enhances the solubility and bioavailability of hydrophobic bioactives such as curcumin and carotenoids, making it an effective approach for food preservation.

Electrospinning and Electrospraying These novel encapsulation methods use an electric field to generate fine fibers or particles containing bioactive compounds. Electrospun fibers have a high surface area and tunable release properties, making them ideal for incorporating natural

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preservatives such as plant extracts and antimicrobial peptides into food packaging materials [4].

The future of bioactive compound encapsulation in food preservation lies in the development of novel carrier materials, smart delivery systems, and sustainable approaches. Innovations such as nanotechnology, biopolymer-based carriers, and stimuli-responsive encapsulation systems offer exciting possibilities. Additionally, the integration of encapsulated bioactives in active packaging and edible coatings can revolutionize food preservation by providing controlled release of antimicrobial and antioxidant agents [5].

## Conclusion

As research continues to advance, encapsulation will play a pivotal role in reducing food waste, enhancing food safety, and meeting consumer demand for natural and minimally processed foods. This promising technology is set to reshape the landscape of food preservation in the coming years.

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