Innovations in antioxidant delivery systems for food preservation.

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Introduction

In the dynamic landscape of food preservation, the quest for innovative solutions has led to a significant focus on antioxidant delivery systems. Antioxidants play a pivotal role in preventing oxidative deterioration, which can affect the quality, safety, and shelf life of food products. Understanding antioxidant delivery systems: Antioxidant delivery systems refer to the methods and technologies employed to incorporate antioxidants into food products effectively. These systems are designed to protect sensitive bioactive compounds from degradation during processing, storage, and distribution, ultimately ensuring that the antioxidants fulfill their role in preserving the freshness and nutritional value of the final product [1,2].

Innovations in antioxidant delivery systems: Nanoencapsulation technology: Nanoencapsulation involves encapsulating antioxidants in nanometer-sized particles, providing several advantages in food preservation. The reduced particle size increases the surface area, enhancing the stability of antioxidants and allowing for controlled release. Nanoencapsulation protects antioxidants from environmental factors, such as oxygen and light, and improves their solubility, leading to better integration into food matrices. Liposome delivery systems: Liposomes are spherical vesicles composed of lipid bilayers, mimicking cell membranes. This technology allows for the encapsulation of both water-soluble and fat-soluble antioxidants. Liposomes offer protection to antioxidants during processing and storage and facilitate their controlled release. These delivery systems are particularly useful in products with high lipid content, such as oils and fatty foods [3,4].

Microencapsulation techniques: Microencapsulation involves coating active ingredients, including antioxidants, with a protective layer. This technology provides a barrier against external factors, preventing degradation and ensuring the controlled release of antioxidants. Microencapsulation can be achieved through various methods, such as spray drying, coacervation, and fluidized bed coating, offering flexibility in application across a wide range of food products. Edible coatings and films: Edible coatings and films have gained prominence as innovative antioxidant delivery systems, especially in the context of fresh produce. These coatings are made from natural polymers, such as proteins or polysaccharides, and can be infused with antioxidants. They create a protective layer around fruits and vegetables, reducing exposure to oxygen and moisture, thereby extending shelf life and preserving nutritional quality [5,6].

Supercritical fluid technology: Supercritical fluid technology involves the use of supercritical carbon dioxide (co2) as a solvent for extracting and delivering antioxidants. This method offers several advantages, including high selectivity, minimal residue, and reduced oxidation during extraction. Supercritical fluid technology is particularly suitable for extracting heat-sensitive antioxidants from botanical sources. Electrospinning: Electrospinning is a technique that produces nanofibers by applying an electric field to a polymer solution. This method has found applications in creating antioxidant-loaded nanofibers for use in food packaging. These nanofibers can be incorporated into packaging materials, providing a sustained release of antioxidants and creating an additional layer of protection against external factors [7,8].

Smart packaging systems: Advances in smart packaging involve integrating sensors and responsive materials into packaging to monitor and control the conditions of the packaged food. In the context of antioxidants, smart packaging can release antioxidants based on real-time assessments of factors like temperature, humidity, and oxygen levels. This responsive approach ensures that antioxidants are deployed when needed most, optimizing their efficacy. Incorporation of natural extracts: Utilizing natural extracts rich in antioxidants has become a popular approach in food preservation. Innovations involve finding effective ways to incorporate these natural extracts into food matrices without compromising their stability. Technologies such as microencapsulation or Nano emulsification help enhance the solubility and bioavailability of natural antioxidant extracts. Benefits of antioxidant delivery systems: Extended shelf life: The primary benefit of incorporating innovative antioxidant delivery systems is the extension of the shelf life of food products. By protecting antioxidants from environmental factors that contribute to oxidative reactions, these systems help maintain the freshness and quality of the product for a more extended period [9].

Preservation of nutritional quality: Antioxidant delivery systems play a crucial role in preserving the nutritional quality of foods. They protect sensitive vitamins, polyphenols, and other bioactive compounds from degradation, ensuring that the final product retains its nutritional value throughout its shelf life. Improved bioavailability: Some delivery systems, such as nanoencapsulation and liposome technology, can enhance the bioavailability of antioxidants. By improving solubility and

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stability, these systems facilitate the absorption of antioxidants in the body, potentially maximizing their health benefits for consumers. Reduced food waste: Antioxidant delivery systems contribute to reducing food waste by preventing premature spoilage and degradation. The extended shelf life allows for better inventory management, minimizing the likelihood of products reaching their expiration dates before consumption [10].

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