



A review of applications of electrospun nanofibers in food packages

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Abstract

Functional food packaging materials have become a topic of interest due to the increasing public awareness of food safety and environmental protection. Nanofibers are a popular choice for packaging materials because of their unique one-dimensional structure, high aspect ratio, and large specific surface area. Electrospinning is a simple and efficient method for producing nanofibers. It can create nanofibers with various structures, such as aligned, core-shell, and porous structures, by adjusting the process parameters and modifying the devices. By selecting the right raw materials and structural design, nanofibers can be endowed with different functions, such as antimicrobial activity, antioxidation protection, and response to pH. This paper aims to provide a comprehensive review of the application of electrospun nanofibers in functional food packaging. Additionally, it highlights the progress and development prospects of electrospun nanofibers in functional food packaging..

Keywords: “environmental, electrospinning, devices, antioxidation, protection, nanofibers, functional, response”.

Introduction

Food packaging is used to create a barrier between the food and the environment, and also to inhibit microbial growth, and maintain food safety and quality. Edible packaging can prevent waste of packaging and reduce environmental pollution [1, 2].

Plastic packs are non-degradable, so because of the increasing demand for environmental protection and food safety, the application of natural and biodegradable packaging materials has increased. The use of some bioactive substances in intelligent food packages has improved antioxidant, antibacterial, and other properties that inhibit food deterioration, maintain food safety, improve food quality attributes, and enhance the shelf life of food products [3, 4].

Due to active bioactives' structures, these compounds may be affected by high temperatures, oxidation, hydrolysis, or enzymatic reactions during processing and storage time. Recently, several researches on the use of nanotechnology in food packaging have been done. Nanoparticles indicate better chemical, physical, mechanical, optical, and catalytic characteristics, which makes them good choices in food packaging applications. In general, the use of antioxidants in packaging materials will reduce the loss of sensorial and quality properties [5-9].

It is well known that polymers are the best substituents for biodegradable food packaging due to their functional features such as their ability to incorporate bioactive agents. The evaporation of active agents during electrospun high-voltage conditions makes injection directly of them impossible. To solve this problem, the electrospinning (ES) method can be used in food packaging techniques [10-13].

Electrospinning technique

In this technique, a high-voltage power supply is connected to a metallic nozzle and a metallic collector. The high voltage between the solution and metallic collector causes forming a conical droplet at the tip of the nozzle which is named the Taylor cone. This droplet is affected by the electrostatic force and then a liquid jet is deposited onto the collector in the form of the nanofiber nets [14].

The process occurs when the solution or melt overcomes its surface tension and solidifies after solvent evaporation or melt cooling. The traditional single-needle ES has three parts - the reservoir area, spinning area, and collector. Due to its low efficiency, the use of single-needle electrospinning is limited in industry. However, multi-needle electrospinning increases nanofiber production by utilizing multiple needles arranged in various shapes such as linear, circular, or oval [15-19].

Electrospun and food packaging

Synthetic polymers and natural polymers as raw materials for electrospun are commonly used for food packaging [20-22]. For preventing of environmental pollution, biodegradable polymers are an appropriate choice for food packaging by ES technique [55-57], and different compounds also can be used into the base materials to improve the antioxidant, antimicrobial and mechanical properties of packages [1, 23-25].

Samples of biopolymers applied in electrospun technology

1. Zein

Most proteins do not spin well, resulting in the inability to produce nanoscale fibers with good morphology due to low conductivity or high viscosity of the spinning solutions. Additionally, proteins typically have poor mechanical properties and hydrophobicity, making them unsuitable for packaging alone. However, zein, an alcohol-soluble protein from maize, has excellent barrier properties for transporting gases, water vapor, or solutes, and also it shows excellent biodegradability properties. Although it's impossible to electrospin nanofibers at a zein concentration of less than or equal to 10%, zein films have been used as edible coatings on nuts and tomatoes to delay rancidity and color changes, and maintain firmness during storage [26]. Zein-based NFMs prepared by ES have been widely used in food packaging. In a study, H. Azizi et al. electrospun Gluten/zein, where with a decrease in the level of zein in the nanofibers, the Tg dropped from 177.7 to 162 °C proving that this mixture is more flexible vs. the pure zein fiber [21].

2. Starch

Starch is a natural polysaccharide that is cost-effective, renewable, and easy to process. Starch-based food films have the potential to be used as biodegradable food packaging materials, which can reduce the overuse of traditional petroleum-based plastics. However, starch molecules have many hydrophilic hydroxyl groups, which can limit their performance as a food packaging material. To improve starch-based films, cross-linking, self-assembly, and grafting techniques can be used. To make electrospun starch films less hydrophilic, Cai et al. coated them with stearic acid



(STA) through solution immersion. This coating increased the water absorption capacity (WAC) of the films from 0 to 134.7 [27].

Fillers

• Bioactive Compounds

Aromatic herbs are effective antioxidants and antimicrobial agents, which isolated from plants and containing components such as flavonoids, quinine, saponins, alkaloids, terpenoids, phenols, coumarins, tannins, and, etc. These compounds. There are many studies have focused on the extraction of these agents from plants to be used in packaging [28-31].

Essential oils with the advantages such as biodegradability, antioxidant antibacterial and properties, are widely applied in food packaging. These oily compounds are able to partition into the cell membranes and changing cell permeability thus preventing the absorption vital molecules and ions by the microorganisms, thus results to cells death [32] However, the use of essential oils in food packaging have been limited because of their strong smell, volatility, uncontrolled released and other problems. ES is an important way to solve these problems [30].

Conclusions

Electrospinning (ES) is a simple and efficient method used to prepare functional nanofibers that can control the morphology, structure, property and function of nanofibers by modifying devices, adjusting process parameters, and loading various functional substances into nanofibers. This makes electrospun NFMs with a large specific surface area and high porosity show great potential in the field of food packaging. Nature offers many reliable, safe and biodegradable raw materials that can be used for food packaging through ES technology, and various fillers can be loaded into the base materials to enhance the mechanical, optical, pH sensitive, antimicrobial, and antioxidant properties of food packaging. This helps to obtain food packaging with different functions. To obtain antibacterial and antioxidant packaging, various active drugs or NPs (such as antibiotics and antioxidants) are encapsulated in nanofibers through ES, which effectively extends the shelf life of food. The text summarizes the application of functional packaging based on electrospun nanofibers in different foods. However, there are limitations to the commercial application of electrospun nanofibers in food packaging. Currently, the application of electrospun nanofibers in food packaging is still mainly concentrated in the laboratory due to its low productivity. In addition, although natural biopolymers are green, safe, and non-toxic, they are hydrophilic, and their barrier properties are weakened at high humidity, which limits their application in food packaging. Moreover, the small-sized nanofibers may cause migration of their components into food products during packaging, which may lead to environmental contamination and even affect human health. Therefore, a systematic risk assessment is necessary. Various functional nanofibers have been widely studied in food packaging, but based on the aforementioned shortcomings, electrospun nanofiber-based packaging still needs further development in the future.

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