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Preparation and Characterization of Electrospun Polycaprolactone Nanofiber Webs Containing Water-soluble Eggshell Membrane and Catechin

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Abstract

The process of incorporating water-soluble Eggshell Membrane (S-ESM) into Polycaprolactone (PCL) electrospun nanofiber webs was investigated, utilizing the hydrogen bonding interaction between S-ESM and catechin. PCL was first electrospun with catechin, and S-ESM was introduced into the resulting PCL/catechin nanofibers by immersing the fibers in S-ESM solution. Morphological observation suggested that S-ESM was incorporated with catechin and formed S-ESM/catechin nanoparticles, distributed in the PCL nanofiber webs. Analysis of FTIR spectra indicated that hydrogen bonding interactions were generated between PCL and catechin as well as between S-ESM and catechin. The bulk compression property of electrospun nanofiber webs was measured and the results showed S-ESM and catechin had effect on modifying the mechanical property of PCL nanofiber webs.

Keywords: Water-soluble Eggshell Membrane; Catechin; Nanofiber; Compression

1 Introduction

In recent years, the electrospun nanofibers have attracted much attention due to the nano-scale diameter, high surface area to volume ratio, and unique physical properties, which make them suitable to widely potential applications. The nanofibers fabricated by using natural compounds have been investigated as good candidate for medical materials [1-2]. However, the electrospinning of natural materials is limited by their complex chemical contents which lead to difficulty in preparing efficient spinning dope. Furthermore, to achieve medical application of natural material nanofibers, the mechanical properties of nanofibers needs to be studied. Nevertheless, the characterization method for understanding the mechanical properties of nanofiber webs is not yet satisfied, since nanofiber webs are naturally soft, nano-scale in diameter, and few micrometers in thickness. The effective characterization method is required to evaluate the electrospun nanofiber webs.

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Eggshell Membrane (ESM), which contains collagen types I, V, and X, is a natural protein that is treated as waste. The ESM exhibits a fiber-like network structure resulting in adherence to skin texture and moisture retention properties which are suitable characteristics for medical applications [3]. The natural insolubility of ESM is a main obstacle to further application, and in particular, the production of ESM fibers. Rather than employing natural ESM, water-soluble ESM (S-ESM) from natural hen ESM has been considered. Nevertheless, the electrospinning of aqueous S-ESM is difficult due to the low viscosity. In our previous study, electrospinning of S-ESM was carried out by blending S-ESM with poly(ethylene oxide) (PEO) and poly(vinyl alcohol) (PVA) for the S-ESM fiber formation [4]. To maintain the fibrous structure of the soluble as-spun S-ESM/PEO and S-ESM/PVA fibers in water, the effect of incorporation of catechin with the S-ESM/PEO and S-ESM/PVA fibers was studied. Catechin is a non-toxic, polyphenolic antioxidant plant metabolite that belongs to the flavonoid family, and that has been shown to possess antibacterial, antioxidant, and other physiological functions. Furthermore, many studies have reported that the hydrogen bonding and hydrophobic interactions can be generated between protein and polyphenol [5-6], therefore, the interaction between S-ESM and catechin was examined to maintain the fibrous structure of S-ESM/PEO and S-ESM/PVA as-spun fibers in water. However, the result indicates only a few S-ESM/catechin precipitate with fibrous structures were observed because some of the S-ESM failed to interact with catechin and was probably dissolved in water with PEO or PVA. Moreover, the obtained S-ESM/catechin precipitate was also brittle in nature which leads to inefficient mechanical property. We therefore wished to determine if this process of fabrication of S-ESM nanofibers might be improved by adding S-ESM into a carrier electrospun polymeric nanofiber. For this purpose, polycaprolactone (PCL) was chosen as the base material of the polymer.

PCL is aliphatic polyester that has been widely considered as a candidate material for medical application, due to its excellent mechanical properties, biodegradability, and biocompatibility. Several processes have been reported for incorporating S-ESM with aliphatic polymers. In one of these processes, Lu et al. reported the process to entrap the Soluble Eggshell Membrane Protein (SEP) onto poly(D, L-lactic acid) PD-LLA membrane [7]. In order to explore an effective and simple process to add S-ESM into electrospun PCL nanofibers, catechin was considered to be used. Zhu et al. reported that an intermolecular hydrogen bonding interaction was generated between the ester carbonyl groups of the polyesters, and the phenol groups of catechin [8]. According to these results, as well as those of our previous study, it is possible to incorporate S-ESM with PCL nanofibers through the hydrogen bonding interaction between S-ESM/catechin and PCL/catechin.

In the present study, we aim to investigate using catechin as a key material for the fabrication of PCL-based S-ESM/catechin nanofiber webs, and investigate the effect of addition catechin and S-ESM on modifying the mechanical properties of PCL nanofiber webs. First, a process to prepare electrospun PCL nanofibers containing S-ESM and catechin was developed and analyzed. Secondly, the bulk compression property of electrospun nanofiber webs was measured using a modified compression tester (Kawabata evaluation system, KES-G5s) for understanding the fundamental mechanical property of PCL-based S-ESM/catechin nanofiber webs. The PCL-based S-ESM/catechin nanofibers could combine all the benefit properties of materials and have potential to be in medical application, such as wound dressing.