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Regenerated collagen fibers with grooved surface texture: Physicochemical characterization and cytocompatibility

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ABSTRACT

A novel type of protein fibers, regenerated collagen fibers (RC) from cattle skin, was prepared through wet-spinning. Due to the combined effect of solvent exchange and subsequent drawing process, the fibers were found to have a grooved surface texture. The grooves provided not only ordered topographical cues, but also increased surface area. Protein content of the RC fibers was confirmed by Fourier Transform infrared spectroscopy (FTIR) and ninhydrin color reaction. The fibers could be readily fabricated into nonwovens or other textiles, owning to their comparable physical properties to other commercialized fibers. Cell growth behavior on RC nonwovens suggested both early adhesion and prompt proliferation. The high moisture regain, good processability, along with the excellent cytocompatibility indicated that the RC fibers and nonwovens developed in this study might offer a good candidate for biomedical and healthcare applications.

1. Introduction

Regenerated protein fibers are usually prepared by means of wet-spinning [1,2]. The American Federal Trade Commission and Textile Fiber Products Identification Act use the term 'azlon' to define regenerated protein fiber, as "A manufactured fiber in which the fiber forming substance is composed of any regenerated, naturally occurring protein" [3]. Depending on the source of protein, regenerated protein fibers can be categorized into fibers from mammal sources and fibers from marine sources [4]. Among them, cattle skin offers an abundant resource of collagen with high quality [5].

Collagen is the main protein of connective tissue in mammals [6], which has been widely applied in a variety of biomedical fields [7–11]. It can be isolated from many sources, is highly conserved, and is relatively nonimmunogenic. The procedures used to regenerate collagen into an engineered material compromise many of its biological and physicochemical properties [12].

Currently, there are three ways to make collagen spinnable, namely, crosslinking, grafting and blending [13,14]. Intensive studies have been focused on the blending method, which often towards an easy processing. For instance, Sionkowska [15] studied the intermolecular interaction of collagen and chitosan blends. Through the measurement of X-ray diffraction (XRD), viscosity and Fourier Transform infrared spectroscopy (FTIR), they found that the hydrogen bond forces changed the triple helix structure of collagen and prompted collagen and chitosan blends to be miscible at molecular level. Chen [16] also analyzed the spinnability of collagen/chitosan blended solution through electrospinning. The results suggested that the optimal mechanical and biological properties of the fibers were achieved when the blending ratio of collagen/chitosan was 4/1. Ding [17] introduced a method to get biocompatible collagen/PVA blended fiber. Collagen was grafted by vinyl monomer, and mixed with polyvinyl alcohol. After a series of procedures including wet spinning, freezing, stretching and post-treatment, collagen/PVA blended fibers were formed.

Despite blending method is an effective way to produce collagen fibers, proportion of collagen in the current commercialized fibers is reduced by the addition of other polymers. Therefore, researchers have been devoted to the crosslinking modification of collagen [14,18]. In this way, fibers normally contain a higher content of collagen, while the addition of toxic agent is difficult to be avoided. For example, Amsaveni [19] offered a crosslinking method to get regenerated collagen fiber with ideal mechanical strength and thermodynamic performance. However, the direct use of high concentration glutaraldehyde as crosslinking agent hampered fibers from being used in medical and hygienic products.

Herein, we reported a novel type of regenerated collagen (RC) fibers from cattle skin. Fiber morphology and physicochemical properties were studied and compared with several commercialized fibers, including mechanical dissociated waste leather fiber (MDWL fiber), silk fiber, acrylic fiber and viscose fiber. RC fibers were further made into spunlaced nonwovens as substrates for cell culture. Cytocompatibility was studied by culturing rat fibroblasts (cell line L929). The RC fibers and nonwovens developed in this study might be utilized for various

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biomedical and healthcare applications, such as tissue engineered scaffolds, wound dressings and face masks.

2. Experimental section

2.1. Preparation of RC fibers

General procedure of fiber spinning was shown in Fig. 1A. The process can be divided into three parts, namely, collagen extraction, fiber spinning and crosslinking. In brief, skin from American cattle with good quality and little injury was selected as the source of collagen. To avoid rotten, the cattle skin was salted for 1 week. A combined method of alkali treatment and enzymatic binding was used to extract collagen [20]. Strips of cattle skin were stirred in 0.1 M NaOH solution for 12 h, then neutralized in 0.5 M acetic acid for 4 h. The supernatant was collected by centrifugation at 5000 g followed by soaking into 0.1% pepsin (Sigma-Aldrich) aqueous solution for 48 h. When using alkaline alone, the long reaction time (~2 days) might destroy the structure of amino acids and thus reduce the content of collagen in RC fibers. Although enzymatic method was environmentally friendly and

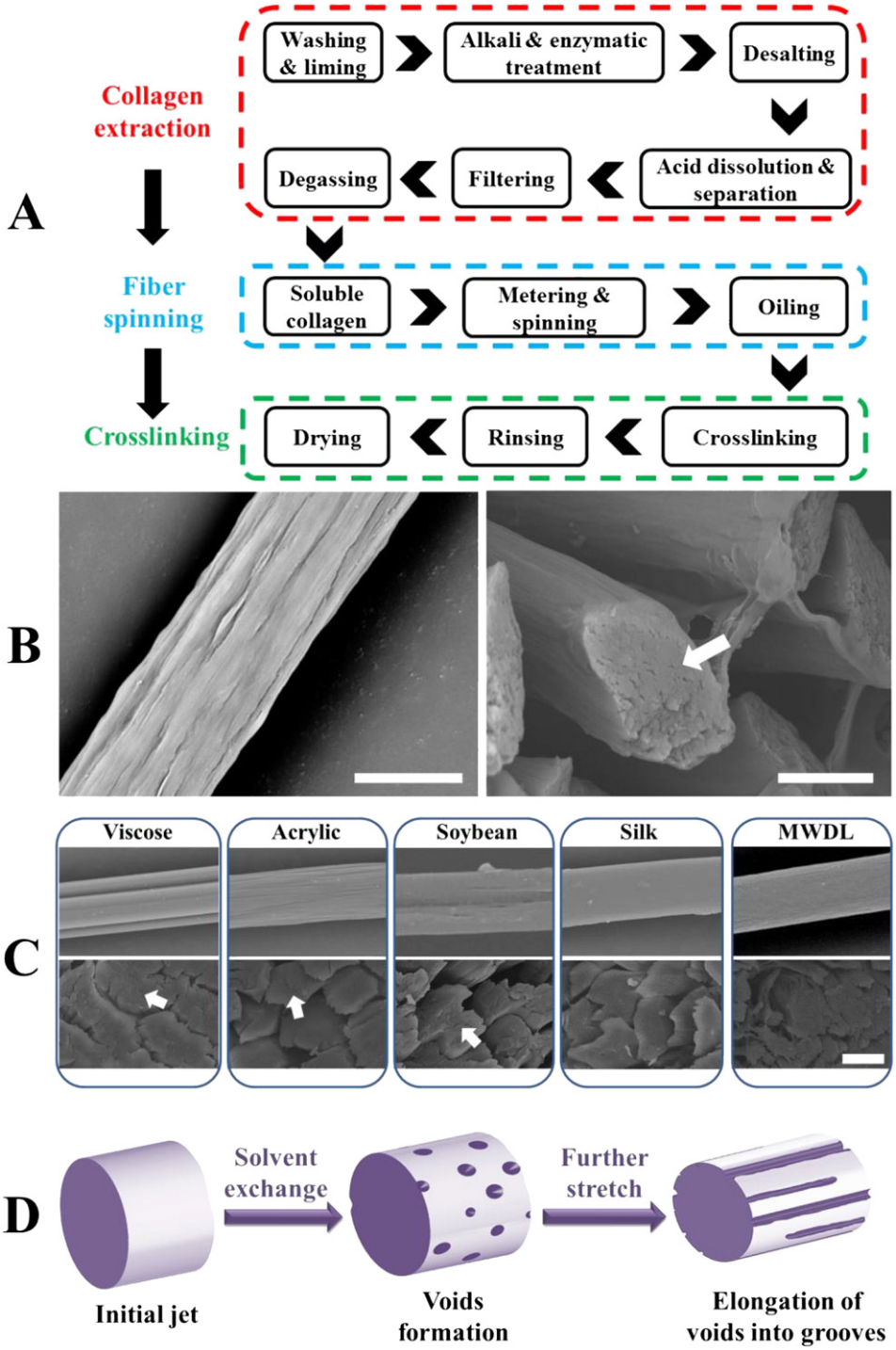

Fig. 1. A) Block diagram of collagen extraction and wet spinning of RC fibers, B) surface and cross-sectional SEM images of RC fibers, C) surface and cross-sectional SEM images of viscose, acrylic, soybean, silk and MWDL fibers and D) Proposed mechanism of groove formation on the surface of wet-spun fibers. Scale bar = 10 μm. Cracks of fibers are pointed by the white arrows.