Effect of PLLA/Keratin Ratio on Mechanical and Physical Properties of Electrospun Nonwoven Fibrous Membrane

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Abstract: Mechanical and physical properties are potentially very important for biomaterials to be used as scaffolds. To investigate the effect of adding keratin to polylactic acid (PLLA) on the mechanical and physical properties of electrospun nonwoven fibrous membranes, a series of experiments were conducted, with PLLA/keratin mass proportions of 1:0, 2:1, 1:1, 1:2, 1:4 and 1:8 respectively. Measured mechanical and physical properties include tensile property, compressional property, water vapor permeability, moisture content and moisture management property. The results show that with an increase in the keratin content, tensile property of above membranes decreased; while moisture content and hydrophilicity are increased; compressional property and water vapor permeability, however, are not influenced significantly. It could be concluded from the experimental results that adding keratin into PLLA would significantly change some important mechanical and physical properties of electrospun nonwoven fibrous membranes, which could influence their performances as scaffolds for tissue engineering.

Keywords: polylactic acid, wool keratin, electrospinning, membrane, mechanical properties, physical properties

1. Introduction

In recent years, electrospun nanofiber technology (electrospinning) has been developed and applied widely. Using this technology, we developed a series of PLLA and wool keratin composite nonwoven fibrous membranes, and aimed at applying these membranes to cell-culture domain [1, 2]. So far, these kinds of membranes are highly eco-friendly products as wool keratin is abstracted from waste natural wool fiber while PLLA also has good bio-compatibility and degradability.

This paper reports an investigation in which a series of PLLA/keratin electrospun nonwoven fibrous membranes (shortened as PLLA/keratin membranes) were prepared at the outset, with different PLLA/keratin mass proportions consisting of 1:0, 2:1, 1:1, 1:2, 1:4 and 1:8. The investigation was planned with an application goal, and thus we characterized the mechanical and physical properties, such as tensile, compressional and moisture–related properties, of these membranes. All the specimens were cut from the center of each sample and preconditioned for more than 24 hours to ensure approximate moisture equilibrium in a standard atmosphere according to ASTM D 1776 [3].

2. Testing Item and Methods

Characterization items for PLLA/keratin electrospun nonwoven fibrous membranes and testing facilities have been listed in Table 1. Detailed testing methods and parameters were itemized as follows.

2.1 Tensile Property

When measuring tensile properties of these membranes, the specimen size had been set at 10mm ×80mm. The specimen was clamped and elongated by two clamps of tensile tester. The distance between top and bottom clamps was 50mm. Elongating speed was 10 mm/min [4, 5].

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Table 1 Characterization item

No	Characterization item	Facilities
1	Tensile property	Instron 4411 tensile tester
2	Compressional property	KES compression tester
3	Moisture content	Oven, Balance
4	Water vapor permeability	Balance, wide-mouse cups
5	Moisture management capacity	MMT Tester

2.2 Compressional Property

Compressional property of these membranes was tested by KES Compression Tester automatically. The specimen size was 200mm×200mm. Tester initial pressure was 0.5 gf/cm^2 and maximum pressure was 50 gf/cm^2. Compressional velocity was 50 mm/sec [6].

2.3 Moisture Content

The specimen of PLLA/keratin electrospun nonwoven fibrous membranes was dried at 80°C for more than 24 hours until it was mass-constant. The mass at the end was marked as m^0. Then dried specimen were put in the standard atmosphere for more than 24 hours, until is the specimen were mass-constant and the mass was marked as m^t. Moisture content has been calculated by Equation 1 as follows;

Moisture content = $(m_0 - m_t) / m_0 \times 100\%$ (1)

2.4 Water Vapour Permeability

Water vapour permeability has been expressed by mass-loss per unit area of water vapour permeated from PLLA/keratin membrane during 24 hours in standard atmosphere [7].

2.5 Moisture Management Properties

Moisture management property was measured by MMT Tester automatically. The specimen size was 8mm×8mm. Pumping time of testing water was 20s, and measuring time was 120s.

Mechanism of moisture management testing consisted of firstly dropping definite water on specimen top surface and then calculating relative indices of water 's spreading status on both top and bottom surfaces. Excellent moisture management capacity of a specimen would result in all the dropped water transporting automatically from top surface to bottom surface and being absorbed by the bottom surface; while the top surface would be keeping dry all the time.

3. Results and Discussion

3.1 Tensile Property

The morphology of PLLA/keratin membranes with different PLLA/keratin mass proportions are shown in Figure 1 Tensile properties of these membranes include two indices – maximum load and maximum strain. Tensile testing results are shown in Figure 2 and Figure 3 Results of nonparametric test have been listed in Table 2, in which P value (Asymp Sig.) is less than 0.05. It means, at 5% confidence level, PLLA/keratin membrane's tensile strength and elongation are influenced by the keratin content significantly. Figures 2 and 3 indicate that as we increased keratin content, maximum load and maximum strain of PLLA/keratin membranes decreased sharply. When PLLA/keratin mass proportion reaches 1:8, its Max. Load and Max.Strain are only about 16% and 12% of pure PLLA membrane respectively.

From Figure 1 we can see, without keratin particles, the electrospun PLLA fibers are continuous and smooth. Once keratin was added, the keratin particles dispersed along the PLLA fibers. Because the average diameter of keratin particles is larger than that of PLLA fibers, PLLA fibers were unable to hold the whole keratin particles totally. In fact the