CHITOSAN HOLLOW FIBERS FOR TISSUE ENGINEERING

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Abstract

Taking advantage of the physicochemical and biological properties of chitosan, we elaborated chitosan hollow fibers samples in order to be used for nerve or blood vessels tissue engineering. Chitosan hollow fibers were performed by wet spinning process. A chitosan solution was placed into a syringe and extruded into a coagulation bath of NaOH (1.0 M) where a hydrogel of chitosan was formed. The neutralization process was controlled to form an outer membrane or "shell" and an inner solution or "core" and by mechanically removing the core it was possible to elaborate hollow tubes of chitosan. In the present work, the processing parameters, the mechanical properties and the morphological characteristics were determined.

Introduction

There has been a considerable interest in developing chitosan hollow fibers due to several biomedical applications, particularly for tissue engineering[1] and for membrane separation purposes[2,3].

Chitosan has the ability to form a continuous and stable macrofilament owing to its high viscosity in aqueous acetic acid solution[4]. As a result of this property, chitosan hollow fibers could be elaborated by the wet spinning process.

Complex methods in forming chitosan hollow fibers by the wet spinning technique have been reported, i.e. the wet method in the vertical system where the spinning solution was forced into a coaxial tube spinneret, while a core liquid was delivered through the inner tube[2,3,5]. In the present work, we elaborated hollow fibers samples by controlling the neutralization process in the initial stage in order to form an outer membrane or "shell" and an inner solution or "core". Because of the distinct boundary between these two parts, it was possible to elaborate hollow fibers by mechanically removing the core.

The objective of this work was to profit the physicochemical properties of chitosan for elaborating chitosan hollow fibers samples with potential to be used for nerve or blood vessels tissue engineering.

Material and Methods

The material used for chitosan solution was from Mahtani Chitosan (batch No. 113). This chitosan (Mw 516 800 g/mol, %DA=1,5) was dissolved in 2% (w/w) in presence of a specific amount of acetic acid necessary to achieve the stoichiometric protonation of the $-NH_2$ sites. The coagulation bath used was sodium hydroxide (1.0 M).

Preparation of samples. Chitosan solution was placed into a plastic syringe and then extruded by a metering pump. As coagulating bath, a solution of 1.0 M NaOH was used. The spinneret was maintained in air distance from the surface coagulation bath. After extrusion, the tubes were washed

and the "core" mechanically removed. Finally, in order to obtain dry fibers, a teflon rod was placed into the wet hollow fibers.

Characterization samples. The samples were frozen in liquid nitrogen and cross-sectioned by a razor blade. The internal and external diameters were determined by a light microscope (magnification: 20X).

Mechanical properties. The mechanical behaviour strength was measured on samples using an Adamel-Lhomargy DY22 tensile testing machine with a load cell of 10 N. The cross-head speed of 2 mm/min and a gauge length of 1.20 cm. Mechanical properties were evaluated on: 1) wet chitosan tubes as produced, 2) wet hollow fibers, 3) dry hollow fibers and 4) dry and rehydrated hollow fibers by immersing in distilled water during 24 h.

Cryo-SEM. Images of surface and internal surface of hollow fibers were obtained after immersing the samples into liquid nitrogen and coating samples with gold-palladium prior examination under a Hitachi (S800) Scanning Electron Microscope (SEM) at 15 KV

Result and Discussion

Chitosan hollow fibers elaboration

During the neutralization process, a gel is first formed at the periphery of the tube. The neutralization is not totally accomplished because it is controlled and stopped by a water washing step. Then, the inner chitosan solution slowly collapses into the performed gel. Finally, the polymer concentration progressively decreases, resulting in the formation of a second gel of low density that was separated from the outer shell.

Mechanical properties

The results show differences between wet and dry samples as a result of water presence which acts as plasticizer. Additionally, small-diameter and soft fibers with low Young's modulus were obtained. Mechanical properties of wet chitosan hollow fibers are appropriate for the tissue engineering application, i.e. spinal cord tissue (0.2-0.8 MPa)[6].

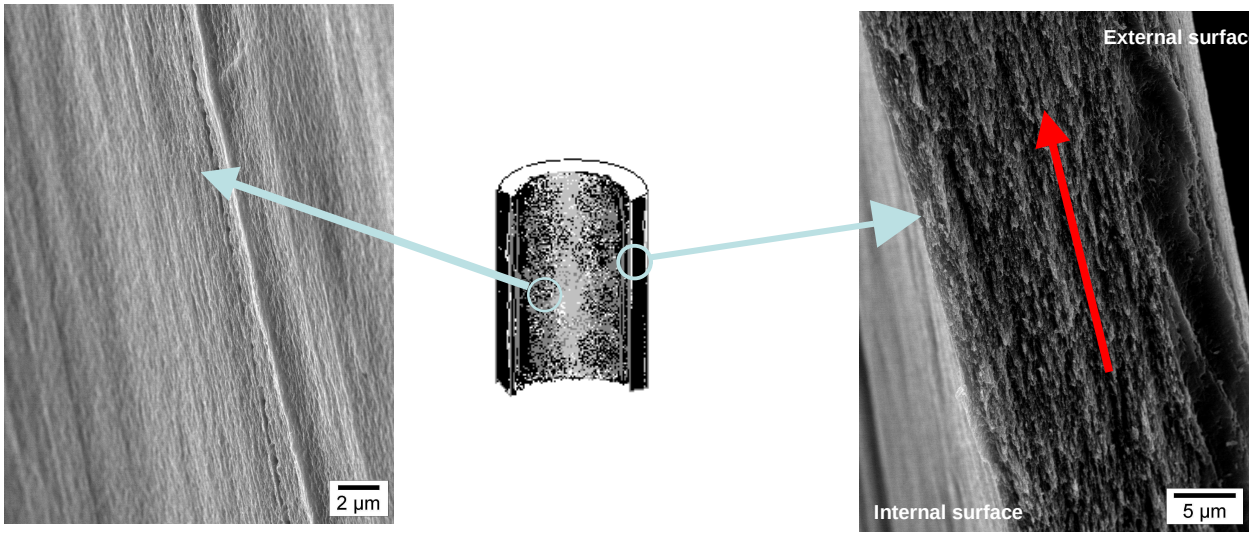
Morphology

Cryo-SEM images of chitosan hollow fibers revealed: a) an sponge-like inner surface with an axial orientation induced by the shear stress during the mechanical "core" remotion and b) a micro laminar overlap of chitosan chains evidences the radial neutralization of chitosan solution.

Table 1: Mechanical properties of different fibers obtained by wet-spinning (Polymer concentration= 2 % (w/w) Mw= 516 800 g/mol), %DA=1.5).

Sample	External diameter (mm)	Internal diameter (mm)	Young modulus (MPa)	Stress at break (MPa)	Elongation at break (%)
Wet tubes	1.9	1.6	0.66	0.23	45.78
Hollow wet fibers	1.9	1.6	1.57	0.71	59.68
Dry hollow fibers	1.4	1.3	13.44	2.46	25.92
Dry and rehydrated hollow fibers	1.4	1.3	6.25	1.04	26.23

Figure 1 : SEM photographs of a) internal surface of chitosan hollow fibers (Polymer concentration= 2 % (w/w) Mw=516 800 g/mol), %DA=1.5 and b) cryo-facture surface.



a) b)

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