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An enhancement on water absorbing and permeating abilities of acrylic acid grafted and chitosan/collagen immobilized polypropylene non-woven fabric: Chitosan obtained from *Mucor*

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ABSTRACT

The wound dressing of acrylic acid-grafted and chitosan/collagen-immobilized polypropylene non-woven fabric (PP–AAg–CCi) were produced. In this study, two kinds of chitosan obtained from the nourishment of *Mucor* (m-chitosan) and from commerce (c-chitosan) were used for comparison. It was found that the values of water absorbing and water diffusion coefficient for m-chitosan sample (PP–AAg–CmCi) were significantly higher than that for c-chitosan sample (PP–AAg–CcCi). The enhanced percentage on water absorbing value and water diffusion coefficient for PP–AAg–CmCi sample increased with the increasing of chitosan contained in the mixture of chitosan/collagen. The surface of the PP–AAg–CcCi sample was smooth; however, the surface of the PP–AAg–CmCi sample was rough and cracky/loose. The higher water adsorption and water diffusion properties were caused by the nature of agent for the PP–AAg–CmCi sample. The hydroxyl group contained on m-chitosan, which was prepared in this study, was higher than that contained on c-chitosan. The anti-bacterial properties of the PP–AAg–CmCi and PP–AAg–CcCi samples were all excellent. The products of the multi-layer material of PP–AAg–CmCi were expected to provide better services for wound dressing.

1. Introduction

Collagen is responsible for the functional integrity of such tissues as bones, cartilages, and skins. It emerges early during embryonic development and constructs the structural framework of most organs. Collagen, which is found to possess good biocompatibility [1], is accounting for about 30% of all proteins present in mammals [1–4]. Additionally, chitosan, partially de-acetylated from chitin, possesses good anti-bacterial activities and cell adhesiveness [5]. Chitosan was used to impregnate on the acrylic acids (AA) and N-isopropyl acrylamide bi-grafted polypropylene (PP) non-woven fabrics for dressing wounds to possess higher values of water vapor transmission rates as well as anti-bacteria [6]. The previous study [7] pointed out that collagen/nano-fibrous matrix was a very effective wound-healing accelerator in early-stage of wound healing. In the recent years, some of the products derived from collagen and chitosan for wound healing have been approved [8–10]. Our previous study [11] showed that the water absorbing ability and water diffusion coefficient of the AA-grafted and chitosan/collagen-immobilized PP non-woven fabric decreased with the increase of chitosan contained in the chitosan/collagen immobilizing agent. Nevertheless, the water absorbing and water permeating properties still exist in the products derived from chitosan and collagen. For a large open wound, the dressing material is required to prevent bacterial infection and preserve moisture [12–14]. Therefore, it is integral to develop a wound dressing with excellent water permeating/absorbing abilities and excellent anti-bacteria activities [15,16].

Previous studies [17] indicated that chitin had three types of conformation. The first one was formed by two parallel and symmetric polymer molecules with the inverse direction and was called "α-type". The conformation of the α-type was the most stable and the density of this type was the highest among the three types of chitin. This type of chitin was generally obtained from the insect and carapace. The second type was called "β-type" and was formed by two parallel polymer molecules with the same direction. The density of this type was the lowest among the three types of chitin. The third type was the mixture of α-type and β-type and was called "γ-type". The chitin obtained from the nourishment of *Mucor* is γ-type and the structural characterization and other physical and chemical properties of γ-chitin have been investigated by the previous studies [18,19]. Chitosan could be obtained from the de-acetylation of all the three kinds of chitin. In general, the conformation of chitosan hydrolyzed from the three kinds of chitin was only one type of "α-type". However, the source of chitosan might affect the water adsorption and permeating properties

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of the wound dressing. However, the wound dressing prepared from the chitosan de-acetylated from chitin, which was obtained from the nourishment of *Mucor*, is lacking.

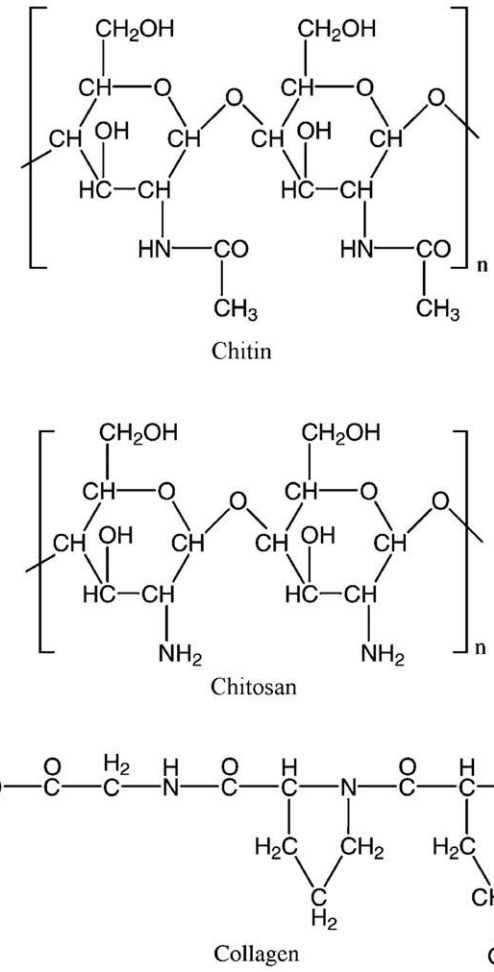
In this study, the chitosan obtained from *Mucor* (m-chitosan) was used to produce the wound dressing, which was expected to enhance the water absorbing and permeating properties. This study used the acrylic acid to graft on the surface of PP non-woven fabric and then the mixtures of chitosan/collagen (chitosan was obtained from commerce and *Mucor*, respectively) were employed to immobilize on the surface of AA-grafted PP non-woven fabric [11]. The parameters on water absorbing and water permeating properties and the anti-bacterial activity for those composite materials were examined. At the same time, the micro-photographs obtained from scanning electron microscope (SEM) of the AA-grafted and m-chitosan/collagen-immobilized polypropylene (PP–AAg–CmCi) were examined and AA-grafted and c-chitosan/collagen-immobilized polypropylene (PP–AAg–CcCi) were also analyzed for comparison. The aim of this study was to produce a non-antigenic wound dressing, which possessed high water absorbing/permeating properties and high anti-bacteria activities.

2. Experimental

2.1. Materials

Polypropylene non-woven fabric, 50 g/m^2, was supplied by Industrial Technology Research Institute, Taipei, Taiwan. The average denier of the melting blown fiber was about 0.4–0.5 and the fineness of the fiber was 7–8 μm. Glutaraldehyde was employed as a crosslinking agent. Glutaraldehyde and acrylic acid (AA) were obtained from Acros Organics, Geel, Belgium. Collagen and c-chitosan (Sigma H-6279) were from SIGMA Co., Louis, U.S.A. The degree of de-acetylation for this commercial product was 80%. Other chemicals used were all reagent grade.

Chitosan (m-chitosan) was obtained from the de-acetylation of γ-Chitin prepared by the method described by McGahren *et al.* [20]. The purity (the content of N-acetyl-D-glucosamine) of the γ-Chitin was 78.5% and was confirmed with the methods of thin layer chromatography (TLC) and Elson-Morgan reagent [19–21]. It was similar to the chitin obtained from Sigma. The degree of de-acetylation was about 80% for m-chitosan, which was also similar to that for c-chitosan obtained from Sigma. The chemical structures of chitin, chitosan (commercial) and collagen were listed in Scheme 1.



Scheme 1. The chemical structures of chitin, chitosan and collagen.

2.2. Methods

2.2.1. Preparation of dressing materials

The initial PP non-woven fabric samples were pre-treated with pure acetone and grafted with AA by the same method as used in the previous study of ours [11]. Then, the AA-grafted non-woven fabric samples were dried at 105 °C for at least 1.5 h to clear the residual water and toluene on the grafted samples, and weighed to obtain the grafting percentage as the following [11].

$$\text{Grafting percentage (\%)} = [(\text{dry weight after grafting} - \text{dry weight before grafting}) / \text{dry weight before grafting}] \times 100. \quad (1)$$

The grafting percentage of the AA-grafted PP non-woven fabric for this study was controlled at 15 wt.%.

2.2.2. Immobilizing percentage

The AA-grafted fabric samples were immersed in the glass dish containing specific concentrations of collagen, chitosan (c-type and m-type, respectively), and crosslinking agent at 4 °C for 18 h to immobilize the various mixed ratios (weight) of chitosan/collagen onto those non-woven fabric samples [11]. Those immobilized fabric samples were next fully washed with cold distilled water, neutralized with 1 wt.% sodium hydroxide at room temperature for 30 min, and washed with de-ionized water in the ultrasonic washing machine for 10 min to remove the un-immobilized agents. Those chitosan/collagen immobilized fabric samples were dried at 35 °C in a (40 Torr) vacuum drier for 24 h.

$$\text{Immobilizing percentage (\%)} = [(\text{dry weight after immobilizing} - \text{dry weight before immobilizing}) / \text{dry weight before immobilizing}] \times 100. \quad (2)$$

2.2.3. Anti-bacterial activity

Anti-bacterial property (bacteria inhibition percentage) of the various samples was examined by the method of AATCC Test Method 100-1998. The fabric samples were put into a jar, in which 1.0 *ml* standard bacterial liquid was contained. The top of the jar was screw tightly to prevent the evaporation of water molecules in liquid to proceed the incubation at 37 °C. In this study, *staphylococcus aureus* was employed. The bacteria inhibition percentage was calculated as following equation.

$$(B - A) \times 100 / B \quad \text{or} \quad (C - A) \times 100 / C \quad \text{or} \quad [(B + C) / 2 - A] \times 100 / [(B + C) / 2]. \quad (3)$$