Manufacturing of Functional Gelatin/Chitosan Composite Membrane

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Abstract. Biodegradable materials have gained more and more attention, especially in biomedical fields. Because of their degradability, biomedical products made of these biodegradable materials can reduce the deleterious impact to the environment. Among other biodegradable polymers, gelatin has been used in wound dressing to accelerate wound healing due to its biocompatibility, film formability and hemostatic activity. In this study, we used gelatin as the matrix for our dressing. As gelatin is prone to degrade/dissolve in water at body temperature, it has to be cross-linked or stabilized with other compounds to enhance its lifetime. Chitosan, another biodegradable polymer, is also widely used in wound healing due to its biocompatibility and antibacterial properties. In this study, we mixed gelatin solution with chitosan solution at a variety of ratios and tested the effectiveness of UV irradiation on cross-linking the two polymers. The composite membranes were fabricated and underwent tests of swelling, stability in water, water contact angle to evaluate their stability and hydrophilicity. Our results showed that the composite membrane made of gelatin/chitosan (90:10) treated with UV irradiation for ten min has the optimal stability in water.

Introduction

Gelatin is a hydrolyzed product of collagen and generally extracted from skin, bone, and tendons of animals. Gelatin is a fat-free, high protein containing no cholesterol [1]. The energy in ultraviolet light can break the hydrogen bonds between the amino acids of a gelatin molecule, producing dislocation binding, which further results in a changed helical structure. In addition, the peroxidation caused by ultraviolet light can induce changes in amide bonds leading to cross-linking between proteins [2]. Because of its membrane formability and hydrophilicity, gelatin has many medical applications such as drug carriers and wound dressing. As gelatin is prone to degrade/dissolve in water at body temperature, it has to be cross-linked or stabilized with other compounds to enhance its lifetime. Chitosan is produced by deacetylation of chitin with varying degrees of deacetylation. It is basically a linear polysaccharide composed of randomly distributed D-glucosamine and N-acetyl-D-glucosamine. The amino groups in the chitosan can form hydrogen bonds with carboxyl groups in the gelatin, resulting in a stable network [3-4]. A stable gelatin/chitosan composite increases its potential to be used in numerous applications such as a coating of the wound dressing. In fact, a series of functional wound dressing based on composite matrix have been developed [5-7].

In this study, we investigated the effects of addition of chitosan and UV irradiation on the physical properties, such as water absorption, stability in water, and hydrophilicity, of the gelatin/chitosan composite membrane.

Materials and Methods

Manufacturing process

Gelatin (Sigma, U.S.A.) was dissolved in deionized water on a hot plate stirrer to prepare 10% (w/v) gelatin solution. Chitosan (VAEG, Taiwan) was dissolved in 1 % (v/v) acetic acid on a hot plate stirrer for 24 hours to prepare 3% (w/v) chitosan solution. The gelatin and chitosan solutions were then mixed for a variety of ratios (gelatin soln.: chitosan soln.=98:2, 96:4, 94:6, 92:8, 90:10) and agitated with heat for another 24 hours. The mixtures were either irradiated with ultraviolet light for 10 minutes or without UV treatment. The mixtures were poured into a custom-made mold and dried in a oven ending up the gelatin/chitosan composite membranes.

Properties examination

Swelling ratio

A given weight of gelati/chitosan composite membrane was placed in the deionized water at room temperature for an hour. At certain intervals, the sample was removed from water and weighted. The swelling ratio was calculated using Equation (1):

$$Sw(\%) = \frac{Wt - Wo}{Wo} \times 100 \qquad (1)$$

where W_o is the dried weight of the sample, W_t is the dried weight of the sample after t hours in water.

Stability in water

A given weight of gelatin/chitosan composite membrane was placed in the deionized water at 37℃ and 50 rpm for 1, 3, 5 hour, respectively. At certain intervals, the sample was removed from water and placed in oven 37˚C at 24 hour. The water stability was calculated using Equation (2) :

$$S(\%) = \frac{Wo - Wn}{Wo} \times 100 \qquad (2)$$

where W_o is the dried weight of the sample, W_n is the dried weight of the sample after n day, and n= 1, 3, 5 hour.

Wetability

In this test method, drops of water are placed on the surface of a membrane sample, and the contact angle values are measured and then averaged.

Results and Discussion

Swelling of Composite Membrane

Figure 1 showed that as the proportion of chitosan in the composite increased, the swelling of the composite membrane decreased significantly. This may be due to the hydrogen bonds formed between gelatin and chitosan, which not only stabilizes the structure but also makes the composite more compact. It appeared that UV irradiation also reduced the swelling of the composite. It is not surprising as UV has been shown to create covalent bonds in gelatin solution alone.[ref] Similarly, the formed covalent bonds can significantly stabilize the structure of the composite and limit its ability to absorb water.

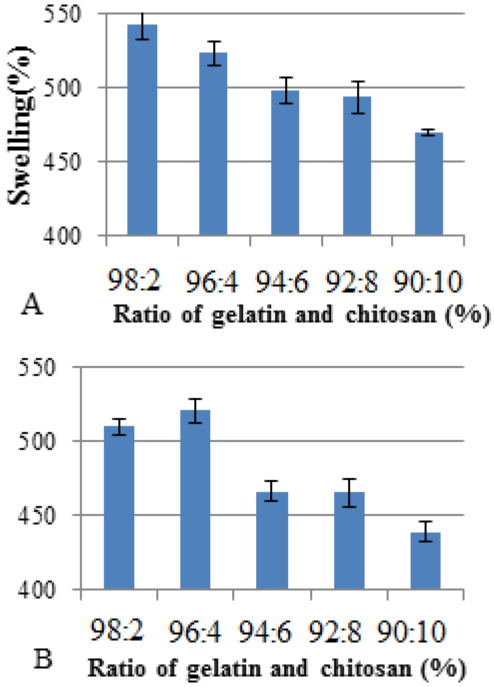

Figure 1. Swelling of composite membranes made of different ratios of 10 wt% gelatin solution and 3 wt% chitosan solution. The gelatin/chitosan solutions were not treated with UV (A) whereas solutions were treated with UV for 10 min (B).
98:2, 96:4, 94:6, 92:8, 90:10

Water Stability of Composite Membrane

As expected, the weight loss in all the groups increased with the incubation time (Figure 2). The figure also showed that as the proportion of chitosan in the composite increased, the weight loss measured at 5 hours decreased. The introduction of chitosan to gelatin appeared to enhance the stability of the composite in water in comparison with pure gelatin, which is basically water-soluble. UV irradiation, which can create cross-linking between molecules and strengthen the structure, was also shown to increase the stability of the composite. Note that it seems that UV irradiation has more influence than addition of chitosan in terms of stability in water if we compared Figure 2A and 2B.

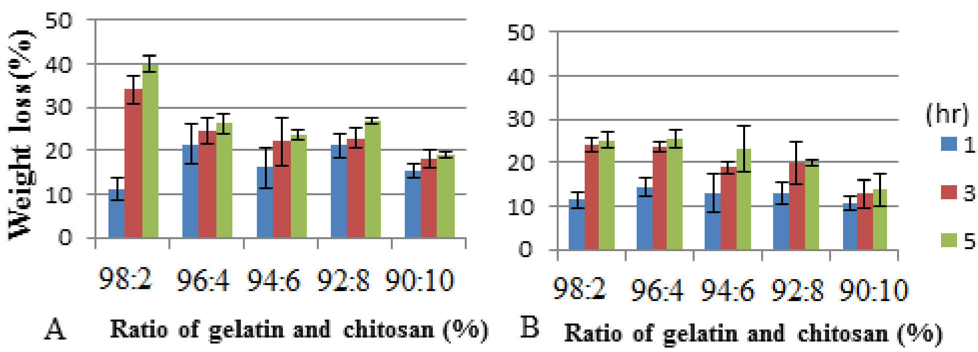

Figure 2. Weight loss of composite membranes made of different ratios of 10 wt% gelatin solution and 3 wt% chitosan solution after placed statically in water for one hour (blue bars), three hour (red bars), and five hours (green bars). The gelatin/chitosan solutions were not treated with UV (A) whereas solutions were treated with UV for 10 min (B).

Contact angle of Composite Membrane

Table 1 showed that contact angles of the composite membrane do not change significantly in all groups. This demonstrated that both chitosan and UV treatment did not change the hyrdophilicity of the composite. As all the contact angles were less than 90°, the composite membrane is hydrophilic and can be used as in wound healing.

Table 1. Wetability of gelatin/chitosan composite with different ratios of gelatin and chitosan. The gelatin/chitosan solutions were not treated with UV (A) whereas solutions were treated with UV for 10 min (B).

Chitosan (°)	0 min	10 min
0	68 ±1	70 ±1
2	65 ±4	65 ±2
4	63 ±2	64 ±2
6	64 ±4	65 ±6
8	66 ±1	64 ±2
10	66 ±1	62 ±1

Conclusion

We successfully developed a gelatin/chitosan composite membrane which could be used in fuctional wound dressing. Results showed that stability in water increased and swelling decreased as the proportion of chitosan in the composite increased. UV treatment can be used to reduce the swelling and enhance the stability. Indeed, UV irradiation has been shown to promote formation of covalent bonds [2], which can provide additional structural strength and decrease swelling. This study provides optimal manufacturing parameters to make a gelatin/chitosan composite membrane as a potential matrix for wound dressing.

Acknowledgement

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