Preparation and Application Possibility of Sodium Alginate/Chitosan Polyelectrolyte Membrane

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Keywords: Chitosan, Sodium alginate, Polyelectrolyte complex, Drug release.

Abstract. As two excellent natural polymers, sodium alginate has excellent biocompatibility and chitosan has good chemical stability and fine bio-availability. They are eco-friendly and easily absorbed by human body. For this reason alginate and chitosan have been widely used in daily life and production, and some efforts were made to improve their application. In this paper a kind of polyelectrolyte membrane made from these two raw materials was prepared and its properties and possible application were studied. The results showed that the sodium alginate/chitosan (SA/CS) polyelectrolyte membrane is sensitive to pH and it hardly has swelling ability in acidic and alkaline solutions but swells easily in phosphate buffer saline (PBS) solution. Meanwhile, the SA/CS membrane has a high rate of water absorption and retention showing that it has a wonderful hydrophobicity and biocompatibility. The drug loading experiment showed than this SA/CS membrane has a smooth release rate of drug like ciprofloxacin hydrochloride indicating that it can be used as a drug carrier material and has a wide application prospect in biomedical material.

Introduction

Polyelectrolyte complexes are often used as a protein carrier in drug delivery systems and microcapsules are prepared by using of polycation and polyanionic complexes to manufacture encapsulated polypeptide proteins [1-4]. The polyelectrolyte complex has attracted extensive attention in the field of drug-controlled release and have made great progress in the stimulus response of drug-controlled release, cell immune isolation transplantation, peptide protein drug-controlled release, gene therapy, artificial vaccines and other fields.

Sodium alginate/hydroxyethyl methacrylate semi-polyelectrolyte hydrogel was prepared by Devendra et al. and Tokifumi et al. studied the immobilization of α-lactase by calcium alginate/chitosan blends [5,6]. Alginate were prepared into a calcium alginate/(poly N-isopropylpropylene phthalamide) polyelectrolyte hydrogel using interpenetrating polymer network technology. Guy et al. prepared a kind of hyaluronic acid/sodium alginate semi-poly electrolyte scaffolds which has a wide application prospect in the field of tissue engineering and membrane separation using glycerol ether and calcium chloride as a cross-linking agent.
However, in microcapsules, microspheres or coatings, this complex formed in situ is difficult to separate and characterize.

In this paper, chitosan and sodium alginate were used as substrate to compose a polyelectrolyte complex and to make a kind of membrane whose potential functions in drug-sustained release were measured as well.

**Preparation of Polyelectrolyte Membrane**

Firstly, the sodium alginate solution and the chitosan solution were mixed with a volume ratio of 2: 1, 1: 2, 1: 1 in flasks and stirred them well. Next, 5 % CaCl₂ solution was added and kept for 1 h then membrane formed. After rinsed with Milli-Q water products were dried at 50 °C for 6 h and the sodium alginate/chitosan (SA/CS) polyelectrolyte membrane were obtained. Pure alginate membrane and pure chitosan membrane were obtained by the same methods. These membranes were labeled with AC a-b. Wherein A represents sodium alginate and C represents chitosan, and a and b represent the mass ratio of sodium alginate to chitosan, respectively. Ciprofloxacin hydrochloride (CH) tablets first mashed to powder then dissolved completely in water. The sodium alginate was dissolved by water containing the medicine and then the ciprofloxacin hydrochloride/sodium alginate/chitosan (CHSA/CS) polyelectrolyte membrane was prepared in the same methods as SA/CS polyelectrolyte membrane. The formation of chitosan and sodium alginate poly-electrolyte membrane can be shown in Fig. 1.

![Formation of chitosan and sodium alginate poly-electrolyte membrane](image)

**Figure 1.** Formation of chitosan and sodium alginate poly-electrolyte membrane. In this figure G unit represents Guluronic acid, M unit represents Mannuronic acid. CHI and ALG are shortened form of chitosan and alginate.

**Swellability**

Appropriate amount of acetic acid solution and sodium hydroxide solution were adjusted with water to pH = 4 to 9 respectively. 0.2 mol/L disodium hydrogen phosphate solution and 0.2 mol/L sodium dihydrogen phosphate solution were compounded. Two solutions were prepared by mixing the two solutions at a volume of 4: 1 and then the phosphate buffer solution (PBS) with a pH of 7.4 were obtained.

The samples of pure alginate and SA/CS polyelectrolyte membrane were weighed and placed on a balance to record the initial mass (M₀). Then the samples were placed at different
pH (Mₙ, x = 1, 2, 3) and the mass of the surface of the membrane was blotted out by weighting the filter.

The initial data obtained was processed to calculate the mass growth rate, denoted as the swelling rate. Swelling rate of the samples at a given time was calculated from the formula (1),

\[ \text{Swelling rate} = \frac{M_x - M_0}{M_0} \times 100\% \]  

(1)

Where \( M_x \) is the weight of the sample (moist) at a given time and \( M_0 \) is the initial weight of the sample.

**Hydrophilic**

The SA/CS polyelectrolyte membrane with different mass ratio was cut to 1cm×1 cm size, and the mass was measured and recorded as \( Ma \). Then some membrane was placed into water and soaked 24 h, then took out and dried, weighed and recorded as \( Mt \). The water absorption can be calculated by formula (2). Then weighed the membrane into the 3000 r/min centrifuge centrifuged for 5 min. After that removed, weighed, and recorded as \( Md \). The water retention rate can be calculated by formula (3).

\[ \text{Hydrophilic rate} = \frac{M_t - M_a}{M_a} \times 100\% \]  

(2)

\[ \text{Water retention rate} = \frac{M_d - M_a}{M_a} \times 100\% \]  

(3)

**Drug Release**

The ciprofloxacin hydrochloride/alginate membrane and the CHSA/CS polyelectrolyte membrane were placed in the PBS buffer solution to determine the release rate of CH. To simulate the human environment, the buffer solution was placed in a water bath at 37 °C. Took samples in 5, 10, 30, 60 min and measured the concentration of CH with a method of spectrophotometry.

**Results and Discussion**

**Morphology**

The appearance of SA/CS polyelectrolyte membrane were shown in fig. 2. As can be seen from Fig. 2 (a) to (c) that with the addition of CH, CH/SA/CS membrane was getting darker and darker. The addition of drug did not affect the smoothness of the membrane surface, and CH drugs in sodium alginate had good solubility. So, SA/CS membrane can be used as a drug delivery material in the field of biomedicine.

**Swelling Properties**

The quality change and swelling rate of sodium alginate (SA) membrane, chitosan (CS) membrane and SA/CS polyelectrolyte membrane were tested in different pH and ratio of SA and CS. The data were shown in fig. 3.
Figure 2. The appearance of SA/CS polyelectrolyte membrane. AC1-1 indicates that the mass ratio of sodium alginate to chitosan is 1:1; AC2-1 indicates that the ratio is 2:1, AC1-2 indicates the ratio is 1:2.

Figure 3. Swelling rate with time. Here A is the lines when pH = 4.0, B is pH=7.4, C is pH=9.0. ■ is the polymeride with a ratio of 1: 1 between SA and CS, ● is 2: 1, ▲is 1:2; ▼is pure CS and ◆ is pure SA respectively.

As can be seen from fig. 3 (A), the swelling rate of the SA/CS membrane and the pure CS membrane in acidic solution varied within a very small range however the pure alginate membrane in acidic solution swelled largely. Meanwhile SA/CS have some stability in human gastric juice. Using this property, this modified material can be used as a drug carrier to control the release of drugs to avoid damaging to human’s stomach.

As can be seen from fig. 3 (B), in the buffer solution at pH 7.4, the quality of all SA/CS polyelectrolyte membranes raised sharply and the higher the mass of SA, the faster the mass increase, until the membrane dissolved in solution. The pH of fluid in human body is about 7.4, by simulating human body fluid, it can be seen that SA/CS polyelectrolyte modified material has its excellent performance as a drug carrier to the human body. It also can be seen from fig. 3 (A), SA/CS polyelectrolyte modified materials in the acidic environment has a stable properties. To ensure that the oral drug conditions the drug will not be lost in the stomach and avoiding damage to the stomach. In other words, when the drug-loaded SA/CS polyelectrolyte modified material to body fluids, will soon be absorbed to ensure the effective use of drugs.
As can be seen from fig. 3 (C), SA/CS polyelectrolyte membrane was very stable in alkaline environment, after a small amount of swelling, its quality remains essentially unchanged and the higher the mass proportion of sodium alginate in the membrane, the greater the mass increase, in other words, the higher of the swelling rate and the longer the time required for quality to reach stability. In alkaline environments, when the mass ratio of SA to chitosan in the SA/CS polyelectrolyte membrane was 2:1, it is the most stable. The solution in the small intestine of the human body is alkaline, simulating the humeral environment of the small intestine of the human body. It shows that SA/CS polyelectrolyte modified materials have a good application possibility.

**Hydrophilic Properties**

The hydrophilic properties of different kinds of SA/CS polyelectrolyte membrane were shown in fig. 4.

![Figure 4. The histogram of water absorption rate and water retention rate of different kinds of membrane.](image)

![Figure 5. The release curve of CH on SA/CS polyelectrolyte membrane in PBS.](image)

From fig. 4 we can see that the water absorption of SA/CS polyelectrolyte membrane increased with the proportion of chitosan in the membrane, and its water absorption increased first and then decreased. When the mass ratio of sodium alginate to chitosan was 1:2, the water absorption capacity of SA/CS polyelectrolyte membrane was the best and reached to 133%. Under the same conditions, when the mass ratio of sodium alginate to chitosan was 1:1, the SA/CS polyelectrolyte membrane was the worst and it would be about 59%. These data showed that the water absorption of the membrane was affected by both its own water absorption and the membrane composition. On the one hand, sodium alginate itself is a macromolecules network polymer and its molecule contains hydrophilic groups so water molecules can be easily go into the polymer mesh structure inside. So with the increase in the concentration of sodium alginate, sodium alginate increased the number of molecules conducive to increased water absorption, but the water absorption of polymer can also cause hollow space reduction and network shrinkage elasticity. On the other hand, sodium alginate and chitosan blends, the formation of polyelectrolyte membrane pores of the larger air radius, the higher the water absorption. So it can be explained that the pore size of polyelectrolyte membrane was the largest when the mass ratio of sodium alginate to chitosan was 1:2 and the radius of air dispersion was the smallest when the mass ratio was 1:1. The change rule of water retention rate was basically consistent with the water absorption rate. When the mass
ratio of sodium alginate to chitosan was 1: 2, the water retention of the membrane was the best and it could be about 114 %. This experiment showed that the SA/CS polyelectrolyte membrane has a good hydrophobicity and good biocompatibility. So it can be used as biomedical materials for development and application.

**Drug Release**

The release percent of CH on SA/CS polyelectrolyte membrane in PBS were studied and the data were shown in fig. 5. It can be seen from fig. 5 that the release of CH from SA/CS membrane increased rapidly in the first 30 min and then gradually became stabilized. At the time of about 120 min, the drug released rate was nearly steady and the cumulative release of drug release was about 55 %. Compared with CH on SA/CS polyelectrolyte membrane, the cumulative release rate of CH from alginate membrane drug was 80 %. When the mass ratio of sodium alginate to chitosan was 1: 2, the cumulative release of drug was small and it has the best biocompatibility.

Further analysis showed that pure SA drug release rate was very fast, it cannot guarantee the effective use of drugs in the human body, resulting in a waste of drugs, but also may cause harm to the human body. However, CH on SA/CS polyelectrolyte released rapidly at first so the drugs can obtain its effects. With the progress of time the drugs continued to release slowly so as to the pesticide effects of those drugs can be maintained.

**Conclusions**

Through above work, we got different kinds of membranes and their properties were tested respectively. By comparing the swelling rate of SA/CS polyelectrolyte membrane in three different pH solutions, it can be seen that the polyelectrolyte membrane with a SA: CS mass ratio of 1: 2 can be used as a drug carrier material by using its sensitivity to pH and non-toxic to human body and has wide application potential. Through the study of membranes’ ability of drug release showed that the cumulative release of drug was small and it has the best biocompatibility when the mass ratio of SA to CS was 1: 2. It follows that the polyelectrolyte polymer has good biocompatibility and it has a wide application prospect as a biomedical material.

**Acknowledgement**

This work was supported by the Fundamental Research Funds for the Central Universities (201713059) and a National Key Research and Development Program (2016YFC1402101).

**References**


