PREPARATION AND CHARACTERISTICS OF ULTRAFILTRATION MEMBRANE FOR PROTEIN SEPARATION

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Abstract

Ultrafiltration membranes for separation of protein were prepared by immersing phase inversion method. Influence of preparation conditions on separation performance and characteristics of membranes has been investigated in terms of polymer concentration, solvent evaporation time and an additive amount in casting solution. The experimental results show that membranes prepared at a suitable condition could have a good possibility for separation of protein. And, separation capacity as well as characteristics of the formed membranes highly depends on the formation parameters, especially a casting solution composition.

1. INTRODUCTION

Membrane separation technique is one of the modern separation methods that have been used widely for many purposes. The advantages of this method is that it can separate the species which have a very different sizes, ranged from particles to ions but no need to phase transition, and separation process can be carried out at room temperature, not necessary to use further other chemicals, so that it allows to proceed the separation, purification and concentration processes simultaneously [1-5]. Ultrafiltration is a pressure driving force separation process, which can be used to separate the species that have a size varied from several to several hundred thousands of dalton. Ultrafiltration membranes have been used widely in biomedical equipments (for artificial kidney), biochemistry, pharmachemical industry, food industry and many other applications [6-9].

In this paper, ultrafiltration membranes have been prepared from cellulose acetate by immersing phase inversion method. Influence of the preparation conditions on membrane protein separation capacity and some membrane characteristics has been investigated and compared.

2. EXPERIMENTAL

Casting solutions were prepared by dissolving of cellulose acetate (molecular weight of 50000 dalton, Aldrich) and an additive (PG-1) in acetone. Solution then was cast onto a clean glass plate by casting knife, which could control a casting solution layer thickness of 300 μm. After evaporation of solvent, casting solution layer was immersed into a coagulation medium. The formed membranes was post-treated, washed by pure water and kept in a preserved solution. Protein solution that contains albumin (molecular weight of 45000 dalton) with concentration of 10 g/l was used as a feed solution. Concentration of protein in the feed and filtrate solutions was determined by spectrometer through an absorption capacity of complex between protein and biure reagent, which shows a maximum adsorption wave numbers at 550 nm. Influence of preparation conditions on membrane separation property has been investigated in terms of cellulose acetate concentration, solvent evaporation time and composition of additives in a casting solution. Separation experiments have been performed in laboratory membrane cell at a determined pressure of 5 bar using nitrogen gas cross-flow repressing through membrane. The protein retention $R = [(C_0 - C)/C_0].100$, (%), and membrane flux $J = (V/S.t)$, $l/m^2.h$, where C_0 and C are concentrations of protein in the feed and filtrate solutions, respectively; V is a filtrate solution volume; S and t are membrane area and separation time, respectively.

3. RESULTS AND DISCUSSION

3.1. Influence of cellulose acetate concentration in casting solution

In this experiment, a casting solution of cellulose acetate concentration varied from 5 to 11 wt% has been prepared with PG-1 amount of 12 wt% and evaporation time fixed at 120 s, coagulation procedure was carried out at room temperature. The experimental results are given in table 1.

Table 1: Influence of cellulose acetate (CA) concentration in casting solution

CA, wt%	Retention, %	Flux, $l/m^2.h$	Strength
5	28.6	57.0	Poor
7	89.0	37.5	Poor
9	99.6	22.0	Good
11	99.9	15.0	Good

The experimental results show that the separation capacity of membrane highly depends on cellulose acetate concentration in casting solution. The change in separation property of membranes is due to the change in structure of membranes formed at the different casting solution concentration, the higher the cellulose acetate concentration is, the denser structure could be formed. Therefore, membranes have a higher protein retention and lower flux. In this work, when cellulose acetate concentration increases from 5 to 11 wt%, membrane flux decreases from 57.0 $l/m^2.h$ to 15.0 $l/m^2.h$ and its protein retention increases from 28.6 % to 99.9 %. It can be seen that membranes formed from a casting solution contains 9 wt-% cellulose acetate could reject protein well, and, these membranes also have a rather good mechanical property.

3.2. Influence of solvent evaporation time

In this work, casting solutions with cellulose acetate concentration of 9 wt-% and PG-1 amount of 12 wt% were used for preparation of membranes, a solvent evaporation time varied from 30s to 120s. The experimental results given in a table 2 indicated that, the increasing of a solvent evaporation time affects on membrane separation property similarly to the cellulose acetate concentration increasing effect. However, the change in membrane separation property in this case seems more slowly. Namely, when evaporation time changes from 30 to 120s, membrane flux decreases from 26.0 $l/m^2.h$ to 22.0 $l/m^2.h$, meanwhile its protein rejection increases from 95.4 to 99.6 %. The further increasing of evaporation time for longer than 120s just makes membrane flux will be very low, but its protein retention is almost not improved.

Table 2: Influence of solvent evaporation time

Evaporation time, s	Retention, %	Flux, $l/m^2.h$	Strength
30	95.4	26.0	Poor
45	95.8	24.0	Poor
60	97.3	23.5	Fair
90	98.4	23.0	Good
120	99.6	22.0	Very good

The increasing of membrane retention and the decreasing of membrane flux in this case is also due to a change in membrane structure. The longer evaporation time, the thicker and denser top-layer will be formed, and thus, the membrane protein retention increases, meanwhile its flux reduces because of the higher mass resistance of membrane itself.

3.3. Influence of additive composition in casting solution

In this experiment, casting solutions of cellulose acetate concentration of 9 wt% were prepared with the different PG-1 compositions, which changed from 12 to 30 wt%. Solvent evaporation time fixed at 120s. The experimental results (table 3) showed that, the increasing of PG-1 amount leads to the sharp increasing of membrane flux. However, when PG-1 amount reaches to about 22 wt%, the mechanical property of the formed membrane becomes rather poor, and, the protein retention of membranes also reduces.

Scanning electronic microscope (SEM) images showed that, the membranes formed from casting solution with higher PG-1 amount could have a higher porosity in comparison with that of the membranes formed from casting solution with lower

PG-1 amount. For example, figure 1 shows the SEM images of the membranes prepared with the amounts of PG-1 of 22 wt% (left) and 12 wt% (right).

Table 3: Influence of an additive amount in casting solution

PG-1 amount, %	Retention, %	Flux, l/m^2.h	Strength
12	99.6	21.5	Good
15	99.3	26.5	Good
18	99.0	38.0	Fair
22	99.0	45.5	Poor
30	96.0	54.5	Poor

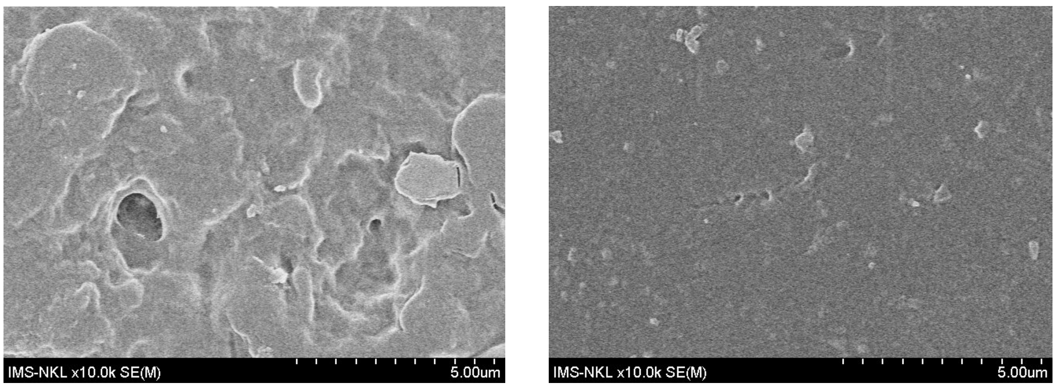

Fig. 1: SEM images of membranes prepared with the PG-1 amounts of 22 wt-% (left) and 12 wt-% (right) in casting solution

Membrane porosity is defined as a free volume inside a porous structure of membranes. Comparatively, membrane porosity (ε) can be estimated based on the differences in membrane weights before and after drying to remove water contained in membrane, that is, $\varepsilon = [(m_1 - m_2) / m_1]$ x100 (%), where m_1 and m_2 are the wetted and dried membrane weights, respectively. Table 4 shows the porosities of some membranes prepared with the concentration of cellulose acetate of 9 wt% and different additive amounts in casting solution.

Table 4: Porosity of membranes prepared at the different PG-1 amount in casting solution

PG-1 amount, %	Porosity, %
12	57.9
15	65.3
22	82.7

Generally, the higher PG-1 composition in casting solution could make the porosity of membranes higher and its flux increased. However, when membrane porosity reaches a certain limiting value, the strength as well as the protein retention of membrane would be reduced simultaneously; this approach is also a good agreement with the separation experimental results present above.

4. CONCLUSION

Ultrafiltration membranes prepared from cellulose acetate by immersing phase inversion method have a good capacity for separation of protein. Separation property and membrane characteristics such as strength and porosity highly depend on the membrane preparation conditions, especially on the casting solution composition. The experimental results showed that the membranes formed from a casting solution that contains cellulose acetate concentration of 9 wt%, and PG-1 amount of about 15 wt% could have an excellent selectivity for protein with an acceptable flux and good mechanical property.

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