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Chitosan and alginate polyelectrolyte complex membranes and their properties for wound dressing application

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Abstract This study investigated the characteristics and drug release properties of membranes of chitosan and alginate prepared via a casting/solvent evaporation technique. Membranes of chitosan and alginate with silver sulfadiazine as model drug incorporated in different concentrations and different membrane compositions were obtained. The polyblend solution viscosity reached to the highest at the composition polyblends of (1:1). This chitosan/alginate membranes showed pH- and ionic strength-dependent water uptake properties and had the WVTR rang from 442 to 618 g/m^2/day. The maximum value of the dry membrane of breaking strength was 52.16 MPa and the maximum value of the wet membrane breaking elongation was 46.28%. The results of controlled release studies showed that the silver sulfadiazine release rate was the fastest when the alginate content was 50%. On the basis of the requisite physical properties, the chitosan–alginate PEC membrane can be considered for potential wound dressing or controlled release application.

1 Introduction

Alginate are anionic block copolymers of α-(1-4)-L-guluronic (G) and β-(1-4)-D-mannuronic acid (M) and are usually presented as the sodium salt. The pKa values of M- and G-residues are 3.38 and 3.65, respectively [1]. The alginate as acidic linear polysaccharide, composed of cell wall and intercelluar cementing matrix algae, can be converted into hydrophilic gel. This hydrophilic gel provides a moist wound environment which promotes healing and epidermal regeneration. Alginate is chemically stable at pH values between 5 and 10.

Chitosan, obtained via deacetylation of the naturally occurring biopolymer chitin, is a polycationic polysaccaride consisting of β-(1-4)-2-acetamido-2-deoxy-β-D-glucopyranose and 2-amino-2-deoxy-β-D-glucopyranose and has a macro pKa value in the range of 6.3–6.5. Chitosan is also known as an antimicrobial polysaccharide having an amino group at the C-2 position of the glucosamine residue. It has excellent cell-adhesive properties, accelerates wound-healing, and has bacteriostatic effects [2]. The chitosan aqueous solution was reacted with polyanion aqueous solution, such as carrageenan [3], sodium alginate [4–6], gelatin [7], and poly (acrylic acid) [8]. The formation of polycation–polyanion (polyelectrolyte) complex is mainly driven by an electrostatic mechanism where charge neutralization and possible local overcompensation or bridging (such as hydrogen bounding, Coulomb forces, van der Waals forces, and transfer forces) [9]. Comparing with the constituent polymers, the polyelectrolyte complex (PEC) has advantages when applied as coating membranes and controlled release delivery systems [10, 11]. Currently, there is inadequate information on the characteristics of the PEC membrane that could be used in wound dressing. This method we used involved the mixing of chitosan and sodium alginate solutions under controlled conditions to yield fine coacervates suitable for casting into coherent membranes [12–14]. It may be expected that wound healing of chitosan/alginate PEC membrane will be promoted over chitosan or alginate itself. We envisaged the water-based systems to have potential for membrane application because this method did not require the use of noxious solvents to produce water-insoluble membranes of

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biodegradable polymers. This property makes them particularly attractive for biomedical applications.

The demonstration of membrane forming capability is important as it widens the application of the PEC to include membrane products that can be used for coating, dialysis, packaging and wound dressing [15–18]. Both the chitosan and alginate have excellent film forming properties. Drug loaded membrane of chitosan or alginate is being one of the applications by those membranes in pharmaceutical technology. In addition, numerous controlled or sustained-delivery systems have been described in the literature, whereby the active ingredient has been dissolved or dispersed within these films [19]. Chitosan, its less flexibility, is rarely used alone, being often used by modification through several methods, such as cross-linking, grafting and blending [20–24]. It is well known that blending is an effective and convenient method to improve the performance of polymer materials.

The conventional temporary wound dressing cannot be used in conjunction with antimicrobial cream and ointment. In these cases, it is difficult for wound dressing to adhere to the wound surface due to their delayed wound healing. Patients feel pain due to the frequent replacement of the wound dressing. Wound dressing must be both robust and flexible so as to allow adherence to the surface of the skin for a period time, while also maximizing patient comfort and convenience [25–27]. For the development of membrane devices to be used in wound dressing, we prepared chitosan/alginate blend membranes in the present study. To use these films in wound dressing application, it was essential to have an overall understanding of their properties. Silver sulfadiazine is an effective and widely used antibiotic for burn injuries in human [28]. Silver sulfadiazine has been found to effectively control Pseudomonas aeruginosa, Candida albicans, and other bacterial infection [29–32]. Using silver sulfadiazine as a model drug, we investigate some factors that may influence the drug release from chitosan/alginate membrane.

2 Materials and methods

2.1 Materials

Chitosan (Mv 7.3 × 10^5 and 90% deacetylated) was supplied by Qingdao Hai-hui Bio-Tech Co., Ltd. (China). Sodium alginate was provided by Shanghai San-pu Chemical Co., Ltd. (China). The viscosity of a 1% sodium alginate was approximately 200 cp at 25°, which was determined by Brookfield digital viscometer. Silver sulfadiazine was donated from Er-Kang Pharmaceutical Co., Ltd. (Hunan, China).The deionized water was made by EDI (electrodeionization) technique in our institute. All other reagents were analytical grade.

2.2 Preparation of chitosan/alginate complex membranes

Chitosan/alginate drug loaded films were produced by a casting/solvent evaporation technique. Chitosan powder was dissolved with stirring in deionized water containing 0.5% (v/v) acetic acid. Undissolved solids were filtered through a medium-pore-size glass funnel to yield a chitosan solution (0.4%, w/v).The pH was adjusted to 5.0 with the addition of 1 M NaOH. Sodium alginate was dissolved in deionized water to form homogeneous solution of 0.4 wt% polymer. Twenty-five milliliters of chitosan solution were added dropwise to 25 ml sodium alginate in water employing a mechanical stirring rate of 1,000 rpm at ambient temperature for 10 min. The viscosity of the prepared formulations was measured with angular velocity being at 100 rpm by a rotary viscometer (DV-I, Brookfield, USA) at 25°C.

20 mg of silver sulfadiazine was dispersed, under stirring, in 50 ml of each one of these three resulting solutions to make them completely homogeneous. After that, these suspensions were left to stand still for deaeration, cast into 85-mm polyethylene Petri dishes and dried for 30 h under 40°C to yield the homogeneous membranes. The film thicknesses were measured by thickness gauge. The measure of every sample was repeated 10 times and the average value was taken as the thickness of the film.

These dried membranes were cut into 1 cm × 1 cm sections for tests. The several chitosan/alginate drug loaded membranes, prepared with different proportions to obtain final alginate amounts of 30, 50 and 70 wt%, were designated as CA-1, CA-2 and CA-3. The blank matrix membrane, without the drug, was marked with CA. Following the above method, 10 mg and 30 mg of silver sulfadiazine were dispersed in a suspension of chitosan and alginate (50:50 wt%), producing drug loaded membranes designed as CAS-1 and CAS-2, respectively.

2.3 Characterization of membranes

The surface and cross-sectional morphologies of the samples were observed under scanning electron microscope (SEM) (JEOL, JSM-6700F, Japan). FT-IR spectra of these membranes were recorded with KBr pellets on a FT-IR spectrophotometer (Thermo Nicolet 380, USA) coupled to a PC with OMNIC software analysis. The X-ray diffraction patterns of chitosan, alginate, silver sulfadiazine, CA and CA-2 membranes were measured on a Rigaku D/max 2,500 V/pc automated X-ray diffractometer (XRD) at 40 kV and 150 mA.

2.4 Mechanical properties

The mechanical properties of the membranes were measured using an INSTRON-5865 strength tester (Canada). The test was performed in ambient temperature and humidity of 50%. A film strip (dimensions 5.0 cm × 1.0 cm) was held between clamps and pulled by top clamp at rate of 5.0 mm/min. The stress and elongation were measured when the film broke off. The value was the average of eight experiments. The film thickness was measured by thickness gauge.

2.5 Water uptake and water vapor transmission rate studies

The water sorption capabilities of blank PEC membranes CA-2 were determined gravimetrically, whereas the weights of the completely dried samples were measured directly. The blank matrix membranes (1 × 1 cm^2) were suspended in glass vessels containing 10 ml of medium and incubated on a shaking bed (SHZ-88, China) at 32°C, 100 rpm for 24 h. Then the membranes were retrieved from the medium, blotted with filter paper and weighed immediately.

The percentage water uptake of blank PEC membranes CA-2 were then calculated from the formula:

$$E_w = \left[\frac{W_e - W_o}{W_o}\right] \times 100\% \quad (1)$$

here E_w is the percentage water uptake of membranes at required time. W_e and W_o denotes the weights of wet and dry membranes, respectively.

The rate of water vapor transmission (WVTR) through the PEC membranes was determined according to the dessicant method of the ASTM E96-95 (1995b) [33]. Film discs (φ16 mm) were each mounted onto a plastic container containing 19–20 g of activated silica gel to within 6 mm of the sample. Periodic weighings of the container determined the rate of water vapor movement across the sample into the desiccant. The experiment was performed in fabric water vapor transmission instrument (YG601, China) under controlled conditions of 32°C and relative humidity of 50%. WVTR was calculated from the equation:

$$\text{WVTR} = W/t \cdot A \quad (2)$$

where W is the weight of water vapor transmitted through a membrane sample of areas A (7.54 cm^2) at time t. All the experiments were performed in triplicates.

2.6 Release studies

The release of AgSD from the AgSD-impregnated PEC membranes composed of chitosan and sodium alginate was carried out in 5 ml of phosphate buffered saline (PBS, pH = 7.4), and incubated on a shaking bed at 32°C, 100 rpm. At appropriate time intervals the solutions were withdrawn and the amount of AgSD release from the membranes was determined by UV spectrophotometer (Shimadzu, model UV-1700) at 256 nm. Then, an equal volume of the same dissolution medium was added back to maintain a constant volume. All the experiments were done in triplicates.

3 Results

3.1 Structure and morphology characterization of the membranes

Figure 1 shows the FT-IR spectra of individual polymers, blank matrix membrane CA, silver sulfadiazine and drug-loaded membrane CA-2. The characteristic absorption bands of chitosan at 1652, 1598, and 1320 cm^{-1} represent the amide I band, amide II and amide III band, respectively. The characteristic absorption bands at 1,652 and 1,598 cm^{-1} overlap each other. The FT-IR spectrum of blend membrane (chitosan/alginate 1:1) revealed difference with pure chitosan and sodium alginate membrane. In Fig. 1c, the amide I absorption margined with characteristic absorption band of amide N–H group and showed a wide absorption at 1,635 cm^{-1}. For alginate in Fig. 1b, the absorption bands at 1,620 and 1,416 cm^{-1} were due to the respective asymmetric and symmetric stretching vibrations of carboxylate anions. The absorption band at 1,620 cm^{-1} shifted to 1,635 and 1,416 cm^{-1} shifted to 1,403 cm^{-1} after alginate reacted with $–NH_2$ groups via hydrogen bonds which shown in Fig. 1c. The amide III at 1,320 cm^{-1} disappeared. Chitosan, alginate and their blend displayed characteristic absorption bands between 3,400 and 3,450 cm^{-1}, which represented the –OH and $–NH_2$ groups in free as well as in amide form in chitosan. The –OH and $–NH_2$ groups in chitosan may form hydrogen bonds with –C=O and –OH groups of alginate. The characteristic absorption band 3,423 cm^{-1} in chitosan membrane shift to 3,435 cm^{-1}. In Fig. 1e, the characteristic absorption bands at 1,354 and 1,597 cm^{-1} of silver sulfadiazine were due to the asymmetric stretching vibration of –S=O bond and the stretching vibration of phenyl framework conjugated to $–NH_2$, respectively; the stretching vibration of C–H from the phenyl framework at 3,074 cm^{-1} was observed; two characteristic absorption bands at 3,391 and 3,343 cm^{-1} were detected and attributed to the asymmetric stretching vibration and symmetric stretching vibration of $–NH_2$ group.

The cross-sections of pure membranes were homogeneous as shown in Fig. 2. Comparing with these pure

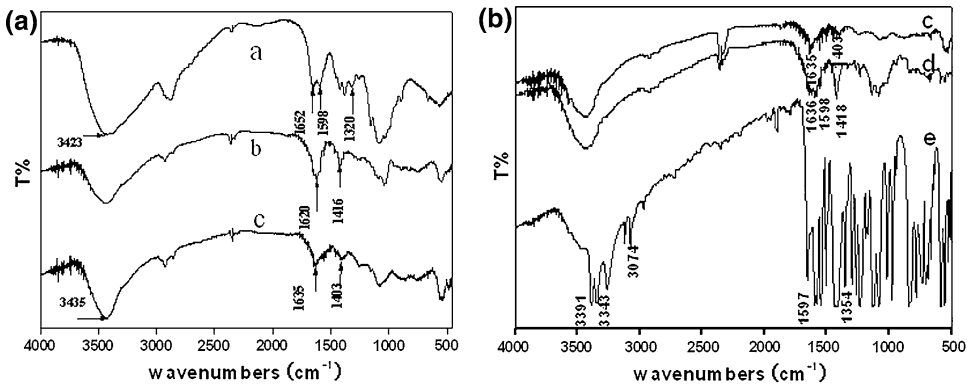

Fig. 1 IR spectra of chitosan (*a*), alginate (*b*), blank matrix chitosan/alginate membrane CA (*c*), drug-loaded membrane (*d*) and Silver sulfadiazine (*e*)

membranes, blank chitosan/alginate membrane CA and drug loaded membrane CAS-2 had irregular surfaces with fibrillate structure distributed throughout with no apparent pores. Comparing the cross-sections of CA and CAS-2 (Fig. 2e, f), it was possible to observe that the rough and heavily striated cross-section was still existed after addition of the drug to the matrix membrane. Addition of silver sulfadiazine did not destroy the packing of the molecules of CA membrane to form the rigid and compact structure as shown in Fig. 2f.

The chitosan membrane showed two peaks at 18.7° and 22.5° related to the hydrated and anhydrated crystals, respectively (data no shown). The diffractogram of alginate membrane consisted of two crystalline peaks at 15.2° and 22.5° (data no shown). After complexing, the typical peaks of chitosan disappeared, the diffraction peaks of alginate disappeared at 15.2° and intensified at 22.5° and the PEC showed an amorphous morphology. This can be explained by the strong interactions between chitosan and alginate which had destroyed the close packing of the chitosan or alginate molecules for the formation of regular crystallites.

3.2 Mechanical properties

The mechanical properties of the wet PEC membranes were shown in Fig. 3. The blank matrix membranes were suspended in glass vessels containing 10 mM NaH_2PO_4–Na_2HPO_4 buffered solution with pH 7.4 and ionic strength of 0.145 M and incubated on a shaking bed at 32°C, 100 rpm for 24 h. The ionic strength of buffered solution can be adjusted to a relatively level by adding an appropriate amount of NaCl. Then the membranes were retrieved from the medium, blotted with filter paper and measured immediately. The mechanical data of the wet sodium alginate membranes were not obtained because the sodium alginate was highly soluble in water. As shown in Fig. 3b, when increased the content of alginate, the maximum stress of blank membrane, especially the membranes containing alginate of 50 and 70%, decreased clearly. This phenomenon was related to medium pH value. In the alkaline medium, deprotonation followed by the repelling action of residual carboxyl groups in the PEC membranes caused membrane expansion. However, the wet membrane elongation increased and got the maximum at the alginate content of 50%. The elongation profile of the membrane with alginate content of 30 and 50% showed greater maximum elongation values than the chitosan alone and alginate content of 70% ($P < 0.05$). The maximum value of the dry membrane breaking strength was 52.16 MPa and the maximum value of the wet membrane breaking elongation was 46.28% ($P < 0.05$).

3.3 Water uptake and WVTR studies

The water uptake of CA-2 membranes, in four different buffered solutions with pH 5.0, 6.2, 7.4 and 8.0, were studied. The ionic strength of those solutions was all adjusted to 0.145 M by adding an appropriate amount of NaCl. These buffered solutions had pH of 5.0, 6.2, 7.4 and 8.0, and water swelling ratio of 134 ± 27%, 95 ± 8%, 274 ± 37% and 295 ± 9%, respectively. Water swelling ratio of blank matrix membrane reached to the lowest value at pH 6.2. It was apparent to observe that the chitosan/alginate membrane CA exhibited pH-dependent water uptake in aqueous media and the wet thickness of the membrane was remarkably greater than that of dry membrane.

To better understand the structure and water absorbability, a further analysis was carried out. Blank PEC membrane CA was used in this experiment. Adding an appropriate amount NaCl to the 10 mM PBS with pH 7.4 produced four solutions of different ionic strength. The concentrations of NaCl for the four solutions were 0, 0.1, 0.2 and 0.3 M, respectively. Corresponding to the four solutions, the water swelling ratio of the blank matrix membranes in these medium were 267 ± 15%, 240 ± 17%, 174 ± 11% and 183 ± 2%, respectively. Comparison of the concentration of NaCl of 0.2 and 0.3 M groups showed no significant differences. However, the other groups showed statistically significant differences with the

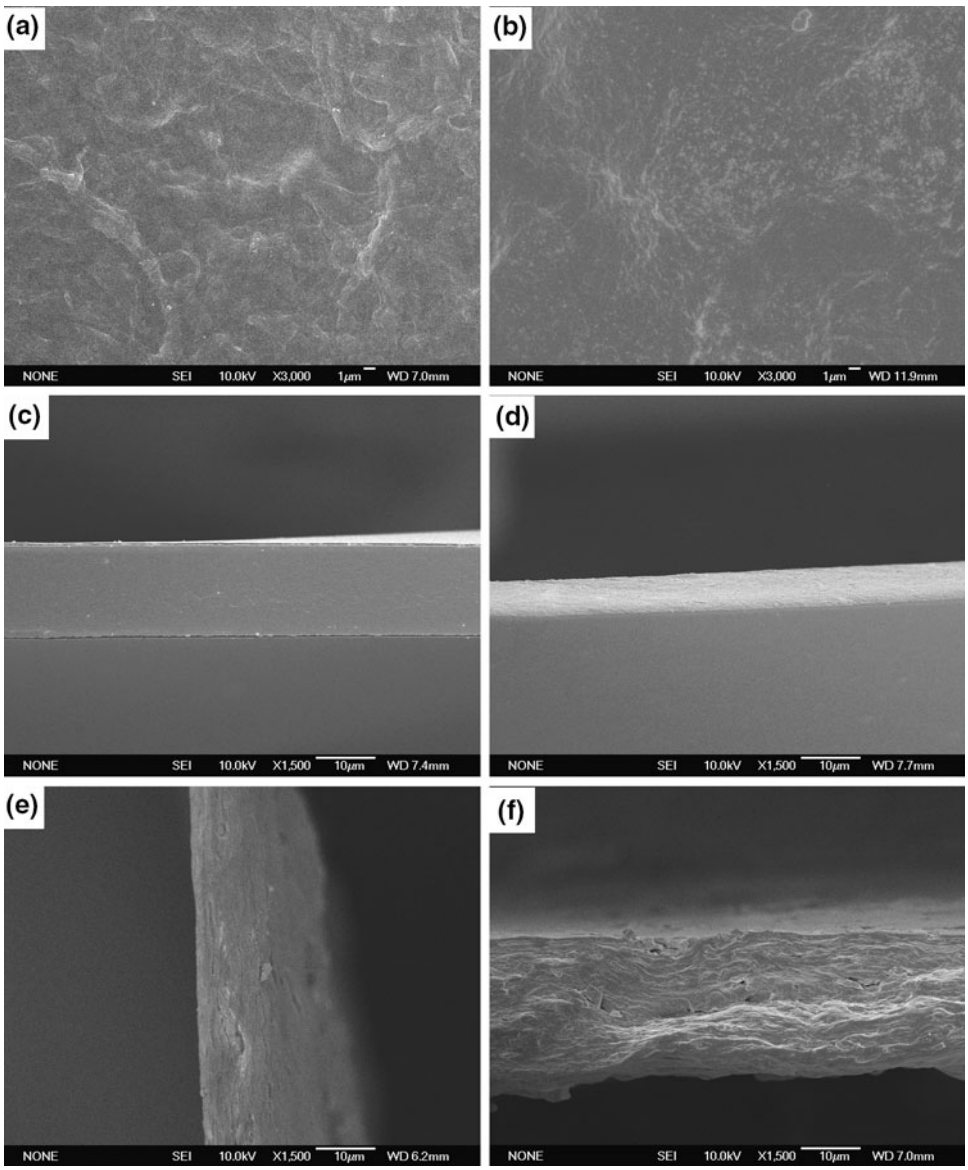

Fig. 2 SEM images of the outer surfaces of CA-2 (**a**) and CAS-2 (**b**); the cross-sections of the chitosan membrane (**c**), alginate membrane (**d**), CA-2 (**e**) and CAS-2 (**f**)

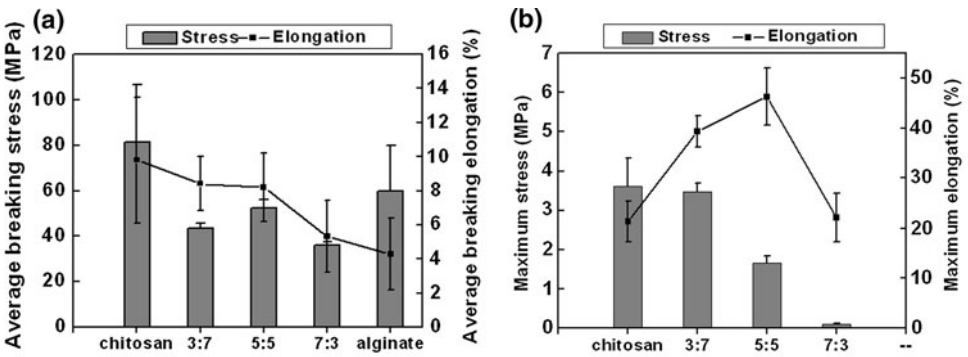

Fig. 3 Texture analysis data showing **a** the average breaking stress and elongation for dry membranes of different composition and **b** the maximum stress and elongation for wet membranes of different composition

increase of ionic strength ($P < 0.05$). Therefore, the membrane CA exhibited ionic strength-dependent water uptake in aqueous media.

The complex membranes had alginate content of 30, 50, 70%, and WVTR of 514 ± 10 g/m^2/day, 618 ± 7 g/m^2/day, 442 ± 18 g/m^2/day, respectively. The WVTR values had statistically significant differences in all cases ($P < 0.05$). The blank matrix membrane at the composition polyblends of (1:1) was more permeable than other mixed systems.

The WVTR of the PEC membrane CA prepared from the stored suspension of chitosan–alginate coacervates under 4°C stored temperature were also investigated. The stored coacervates, deposited for 2 months, however, were able to yield decreasing WVTR value from 618 ± 7 g/m^2/day to 262 ± 1 g/m^2/day.

3.4 Release studies

The influence of the different composition ratios of chitosan and alginate in the drug loaded membranes CA-1, CA-2, and CA-3 (30, 50 and 70 wt% of alginate, respectively) was investigated in this experiment as shown in Fig. 4. The release medium condition was 10 mM NaH_2PO_4–Na_2HPO_4 buffered solution with pH 7.4. Figure 4a showed total amounts of AgSD released from AgSD-impregnated composite membranes. The cumulative release amount of CA-2 could reach 75% of total amount within 3 days. In addition, the releasing rate for CA-2 was significantly higher than that for CA-1 and CA-3.

Membranes CAS-1, CA-2, CAS-2 with different drug loaded content (5, 10 and 15%) were investigated in the same release medium. It is interesting to note that we can not get a more persistent release by increasing the drug loaded amount. When the drug loaded content reach to 15%, the drug diffusion rate decreased significantly as shown in Fig. 4b, which may be related to the drug diffusion coefficient.

4 Discussion

The membranes we prepared were asymmetric membranes and the thickness of the composite membrane was approximately 15 μm. In membrane forming process, the hot air evaporated water from the outermost region of the nascent membrane to induce phase to coalesce and ultimately fused to form dense skin. With the increase of evaporation time, the underlying phase separation region tended to coalesce and fused with dense skin to increase the thickness of dense skin. The upper surface of the membrane provided several functions such as control of water loss through evaporation, inhibition of body fluid loss, and protection from external contamination.

Coacervation between chitosan and alginate occurred by electrostatic attraction between the two oppositely charged polymers. In polyblend solutions, the existence of thermodynamical interaction (attraction or repulsion) between polymer chains will induce the nonideal mixing, resulting in the changes of blend solution viscosity. At the composition polyblends of (4:6), the viscosity of the blended solution increase significantly (data no shown), which may be involved with the change in the electrostatic potential during the neutralization inducing the formation of polyion. With the continuing addition of the alginate, the polyblend solution viscosity reached to the highest at the composition polyblends of (1:1). The charge density of microdomains of two oppositely charged polyelectrolytes reducing much resulted in comprising significant amounts of insoluble PEC, which led to the greatest viscosity [11]. Both of our FTIR and XRD results confirmed that chitosan and alginate polyelectrolyte complexes formed and the PEC showed an amorphous morphology, which may be due to the strong interactions between cationic polysaccharide chitosan and anionic –COO-group in sodium alginate. Additionally, ionic bonds may be formed between chitosan and sodium alginate.

In fact, the oppositely charged ions complexes often have insufficient ion pairing. The mixing of chitosan and alginate solutions gave rise to a suspension of fine fibrous chitosan–alginate coacervates, also containing unreacted chitosan and alginate molecules, which in accordance with the procedure adopted, were not removed. On casting and drying, the sodium alginate molecules or chitosan molecules provided a supporting matrix for the water-insoluble coacervates to give a coherent and flexible membrane. If the coacervates was isolated, membranes prepared from this teared easily, which may be due to the coherence was

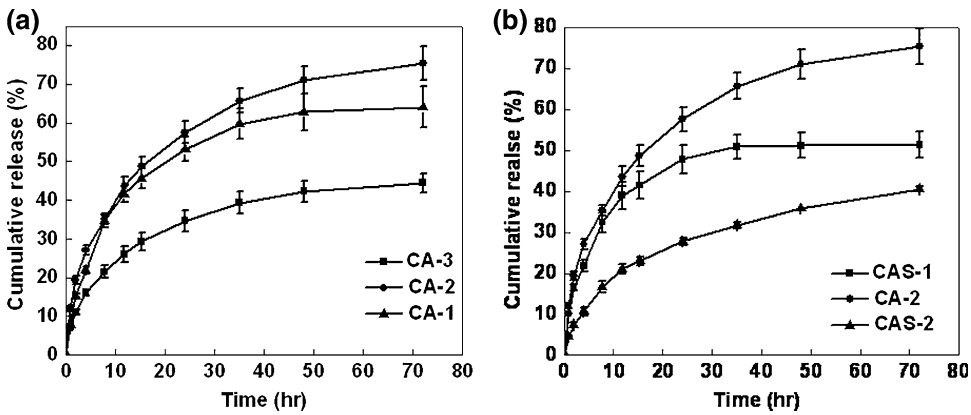

Fig. 4 **a** Influence of the composition of the drug loaded chitosan/alginate membranes on the drug controlled release process; **b** Influence of the amount of drug loaded in chitosan/alginate membranes on the drug controlled release process

destroyed. We investigated the viscosity of blended solutions and mechanical properties of different composition. The correlation between the mechanical properties and polyblend solution viscosity is our interest as it indicated that while the polyblend solutions showed increasing viscosity, the dry membranes appeared to be more rigid and the wet situation had a relatively high flexibility as shown in Fig. 3. As discussed by Christopoulou et al. [34], there is a very close relation between their behavior in solution and in the solid state. This phenomenon is called "memory effect" [35, 36]. In our studies, it may be seen that the blended solution reached to the greatest viscosity value of 224 cps when the content of alginate was 50 wt%, which was more involved with the significant amounts of insoluble PEC. Meanwhile, the maximum breaking stress value of dry mixed membranes and the maximum elongation of wet membranes were both observed at this point.

To better understand the polyelectrolyte forming characterization, the WVTR experiment and drug release model were designed. The WVTR for normal skin is from 279 ± 26 g/m^2/day for a first degree burn to 5,138 ± 26 g/m^2/day for a granulating wound. The material we prepared had the requisite WVTR rang from 442 to 618 g/m^2/day, although it is probably not suit in heavily exudative wounds because of its relatively low WVTR. The blank matrix membrane at the polyblends composition of (1:1) was more permeable than other mixed systems, which can be further elucidated that the membrane comprised significant amounts of insoluble and porous PEC. For steric hindrance and conformational restriction, not all amino and carboxylic groups in the two polymers were available for reaction. Fresh coacervates thus had a large volume-to-surface ratio with many interstices. However, the bulked chitosan and alginate molecular chains rotated and increasingly extended, which facilitated unreacted functional groups react on storage. As a result, the membrane CA prepared from the stored coacervates had greater extent of bounding occurred, which results in lower membrane permeability to water vapor. Drug release results indicated that the total release of AgSD from composite membranes was dependent on the complex composition. The releasing rate for CA-2 was obviously higher than that for CA-1 and CA-3 which could reflect the three-dimensional structure of PEC membrane. CA-2 had the highest amounts of insoluble PEC that facilitated drug release. In contrast, CA-1 and CA-3 had insufficient ion pairing, the matrix were more continuous and homogenous than CA-2 which probably confined the release of the drug. The repelling action of residual carboxyl groups of CA-3 membranes in pH7.4 medium caused membrane expansion, which facilitated water sorption and restricted the drug release.

Aiming to meet the necessary requirements of the PEC membrane for use as wound dressing, the appropriate mechanical properties were needed. The tensile strength for skin is normally 2.5–16 MPa. The mechanical properties of the membrane we prepared could be regulated through different composition. In dry state, the tensile strength and elongation of the membranes were 36–52 MPa and 5.3–8.4%, respectively. For the wet membranes, the values were 0.1–3.47 MPa and 22–39%, respectively. In addition, formulations prepared with 50% alginate concentration had the highest elasticity of 46.3% and lower mechanical strength of 1.66 MPa in wet state, while in dry state, the membrane reached the higher elasticity and highest mechanical strength. Findings demonstrated that formulations prepared with 50% alginate concentration had the ideal mechanical properties for wound dressing. Apparently, the use of either of the polysaccharides alone or the polyblend systems afforded the operator a range of options with regard to mechanical properties. To summarize, polymer concentration, composition and deposited time of coacervates were key factors that influenced the stress and flexibility of membranes. Appropriate mechanical properties of the materials could maintain its integrity and comfort during use. The membranes we prepared were reasonably transparent in either dry or wet state, which potentially allows effectively observation of the wound bed during skin recovery.

Besides the aspect of material preparation, the application environment also affected the membrane properties because the PEC membrane exhibited pH- and ionic strength-dependent water uptake in aqueous medium. Thus, in order to specifically identify the pH influence on the water uptake property of CA-2 without the effect of ionic strength, we adjusted all the buffered solutions' ionic strength to 0.145 M of isotonic saline solution by adding an appropriate amount of NaCl. The water uptake of CA-2 membranes, within working pH ranged from 5.0 to 8.0 of PBS in our system, was studied. The pKa value of chitosan is about 6.3, and the pKa of mannuronic acid and guluronic acid of alginate are 3.38 and 3.65, respectively. As the amount of amino groups on chitosan were almost equivalent to the amount of carboxyl groups on alginate, in the blank matrix membrane CA at pH 6.2, dehydration of polymer chains and increase of hydrophobic inter-chain interactions induced a notable shrink. Meanwhile, the equilibrium balance between the amount of amino groups and carboxyl groups was broken at low pH and high pH. In low pH medium, protonation followed by the repelling action of residual amino groups in the PEC membranes facilitated water sorption which caused membrane expansion. In contrast, for high pH, water diffused into the matrix membrane more conveniently which may be contributed to large ionization of the carboxyl groups in alginate and macromolecules conformation of alginate. Additionally, the matrix membrane was resistant to dissolve in water,

aqueous acids and bases. On the other hand, the wet matrix membrane could be seen as ionic gel. Considering its potential application in wound dressing, we employed PBS of pH 7.4 because the normal pH value of human blood plasma is between 7.34 and 7.45. Generally, swelling of ionic gels is driven by osmotic pressure because of the ionic solutes in the gel and in the surrounding solution. The result was possibly related to the decrease of osmotic pressure inside the membrane with increasing of the salt concentration. However, the osmotic pressure difference reached an equivalent value when the concentration of NaCl was 0.2 M and continuously increasing the ionic strength could not significantly change the water absorbability of blank matrix membrane CA.

5 Conclusions

Blended membranes and drug loaded membranes based on chitosan and alginate were produced by a casting/solvent evaporation method. AgSD was employed as a model drug to be incorporated into the PEC membranes. The chitosan–alginate PEC membranes showed an amorphous morphology through X-ray diffraction analysis. This PEC membranes had higher degree of surface roughness compared to the chitosan or alginate alone membranes. At the composition polyblends of (5:5), the breaking strength reached the maximum value was 52.16 MPa of dry membrane and the wet membrane got the maximum breaking elongation value of 46.28%. In addition, the viscosity of the blending solution also had the maximum value. The special properties determined its related drug cumulative release profiles, water uptake and WVTR properties. Requisite physical properties, controllable release behavior, pH-dependent water uptake, ease of formulation and biodegradability added to its advantages for the development of membrane devices to be used in wound dressing or drug controlled release.

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