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Impact factors to regulate mass transfer characteristics of stable alginate membrane performed superior sensitivity on various organic chemicals

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Abstract

Calcium alginate membrane has great potential for membrane separation technology. The polymer frameworks of the membrane were successfully regulated by the mass fraction of homopolymeric blocks of α -L-guluronic acid (F_{GG}) in the entire molecular chain of alginate and the additive CaCl_2 as a cross-linker. The mechanical strength can be controlled by regulated the F_{GG} and CaCl_2 concentration. Selected mass transfer of saccharides (Glucose, G, 180 Da; Maltose, M, 324 Da; Raffinose, R, 504 Da) was achieved. The mass transfer flux of saccharides was strongly changed and inversely proportional to the 4.4th power of molecular volume. The mass transfer flux of saccharides was inversely proportional to the 2nd power of F_{GG} at prepared 1 M CaCl_2 . The mass transfer flux of urea (60 Da) was clearly decreased with increasing CaCl_2 concentration. Especially, in higher F_{GG} range, effect of CaCl_2 concentration remarkably appeared on its effective diffusion coefficient (D_{eff}). The volumetric water fraction with calcium concentration was very slight, regardless of F_{GG} . The tortuosity increased linearly with increasing additive CaCl_2 concentration. In higher CaCl_2 concentration, the effect of F_{GG} on the tortuosity remarkably appeared. Obtained empirical equation was anticipated as a guideline to estimate the effective diffusion coefficient of the alginate membrane. High permeability was performed by low F_{GG} (0.18) membrane performed high permeability than high F_{GG} (0.56) membrane. The water permeation mechanism was obeyed by Hagen-Poiseuille flow regardless of F_{GG} .

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Keywords: Calcium alginate; α -L-guluronic acid; egg-box junction; membrane; effective diffusion coefficient

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1. Introduction

Recent years, the membranes from biological polymer are anticipated for biocompatible materials for practical application in separation technology. Biological polymers produced from bioresources are expected as environmental friendly polymers. They have great potential as alternatives to various artificial polymers produced from petroleum.

The application of a membrane separation in food industry, medical devices and water treatment has attracted in attention of biochemical engineering. Membrane separation processes reduced effectively energy cost and CO₂ production. In addition, interest in using natural materials has increased due to their biocompatibility and their lack of environment load upon disposal. Biopolymer membranes made by cellulose, [1-2], gelatin [3] and chitosan [4] were anticipated for use in biocompatible separation processing.

Alginate is abundantly produced by marine biological resources, especially brown seaweed. It has been conventionally applied in the food industry and the industrial applications as thickeners, suspending agents, emulsion stabilizers, gelling agents, and film-forming agents [5]. Sodium alginate is well known as a typical hydrophilic polysaccharide. It consists of a linear copolymer composed of two monomeric units, 1,4-linked β -D-mannuronic acid (Fig.1a) and α -L-guluronic acid (Fig.1b), in varying proportions (Fig.1c). Alginate molecular chain was constructed by three type polymeric blocks. They have been described previously: homopolymeric blocks of mannuronic acid (M-M block), guluronic acid (G-G block), and blocks with an alternating sequence in varying proportions (M-G block) [6].

The physical properties of sodium alginate are very susceptible to physicochemical factors (pH, total ionic strength, etc.). At near-neutral pH, the high negative charge of sodium alginates due to deprotonated carboxylic functional groups induces repulsive inter- and intra-molecular electrostatic forces. Sodium alginate rapidly formed into a gel structure by the presence of divalent cations such as Ca²⁺, resulting in a highly compacted gel network [7]. The basic ability for gelling properties of alginate is its specific ion binding characteristics [8]. Regions of G-G blocks chelate the alkaline earth metal ions because of the spatial arrangement of the ring and hydroxyl oxygen atoms and thus create a much stronger interaction [9]. These G-G block zones are mainly constructed of a cross-linked area called an “Egg-box,” where the Ca²⁺ ions are located as the “Egg” components (Fig. 2) [10].

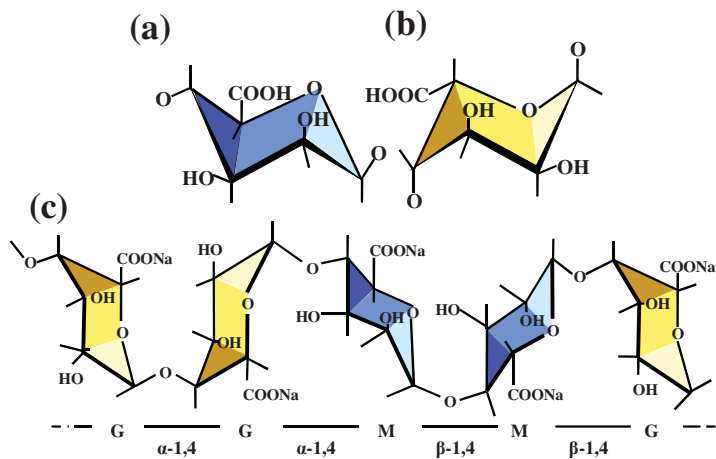


Fig. 1. Alginate composition. (a) β -D-mannuronic acid. (b) α -L-guluronic acid. (c) Structural formula of sodium alginate molecule.

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