Ultrafiltration of polysaccharide–protein mixtures: Elucidation of fouling mechanisms and fouling control by membrane surface modification

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ABSTRACT

This work describes the fouling behavior of polysaccharide–protein mixture solutions by investigation of adsorptive and ultrafiltration fouling. Alginate, dextran, myoglobin and bovine serum albumin were used as model foulants. Three commercial poly(ether sulfone) (PES) ultrafiltration (UF) membranes with nominal cut-off of 10, 30 and 100 kg/mol and a PES-based thin layer hydrogel composite (TLHC) membrane, synthesized by photo-initiated graft copolymerization of poly(ethylene glycol) methacrylate (PEGMA) and having a cut-off of 10 kg/mol were used. The effects of pH, foulant concentration, ionic content and proportion of protein to polysaccharide in the solution on fouling were investigated. The results showed that significant water flux reductions and changes in membrane surface property were observed after static adsorption for PES membranes for all feed solution conditions. This water flux reduction decreased with increasing the pH of the solution. Addition of monovalent ions could either increase or decrease the water flux reduction. Synergistic effects between polysaccharide and protein with respect to forming a mixed fouling layer with stronger reduction of flux than for the individual solutes under the same conditions have also been verified for PES UF membranes. UF experiments using a stirred dead-end UF suggested that both reversible and irreversible fouling have contributed to the overall fouling. The antifouling efficiency of the TLHC membrane with respect to both adsorptive and ultrafiltration fouling has been demonstrated for the strong foulant alginate as well as for polysaccharide–protein mixtures.

1. Introduction

Because membrane processes are increasingly used for separations of mixtures with high complexity, the focus of fouling studies in ultrafiltration (UF) has also been shifted from using well-studied foulants such as proteins to more complicated and less-defined substances such as humic acids or polysaccharides. In the last years, polysaccharides have been used as models for effluent organic matter to be treated with reverse osmosis [1,2], but they are also relevant for fouling in wine microfiltration (MF) [3]. Interactions of ultrafiltration membranes with polysaccharides have been investigated during processing of bioproduct or food streams [4–6], and also as model for marine biofouling [7]. However, the strongest motivation is certainly based on the success of membrane separations and membrane bioreactors (MBR) for water and wastewater treatment [8]. MBR has proven as a more efficient technique for wastewater treatment compared to other conventional (biological) processes. MBR delivers a better product quality of treated water, meeting the need for saving water, and contributing to less volume-demand for a treatment plant. However, beside the obvious advantages of MBR, further improvement of its performance is now challenging researchers. The complex characteristics of the feed and the high solid content including biomass promote to exacerbate the problem of membrane fouling [9,10]. Many attempts have been devoted to overcome these problems and can be generally classified into: (1) foulant identification and characterization, (2) investigation of fouling mechanisms, and (3) minimizing or control of fouling.

With respect to foulant identification, it has been reported that exctracellular polymeric substances (EPS) are the key components affecting fouling in MBR [6,9,11,12]. Polysaccharide, protein and natural organic matter have been identified as the main constituents of EPS [6,11–16]. Wang et al. [17] also reported that the organic matter in the supernatant and the EPS of the bulk sludge and the cake sludge consist mainly of polysaccharides, proteins and humic acid.

Numerous fouling mechanism studies have been performed using various foulant models to describe fouling in MBR. Beside protein, an already very well known foulant, polysaccharides have

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