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Effects of yeast-originating polymeric compounds on ethanol pervaporation

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ABSTRACT

During ethanol fermentation with in situ pervaporation, membrane fouling might occur due to polymers originating from yeast cell lysis. The aim of this study was to evaluate the influence of yeast cellular polymers on pervaporative membrane performance.

Lipids were identified as the most detrimental components among these cellular polymers causing 50% and 33% flux decrease in polydimethylsiloxane (PDMS) and polyoctylmethylsiloxane (POMS) membranes, respectively. This fouling was irreversible and might be due to hydrophobic interactions between lipids and membranes resulting in high lipid adsorption on membrane surface. The relatively hydrophobic model protein BSA also contributed to flux decrease in PDMS membrane but RNA and the model polysaccharide glycogen did not. The PDMS membrane selectivity for ethanol/water remained ~4.5 in all cases.

All the cellular components decreased the water flux through the POMS membrane. However, the ethanol flux through the membrane was not altered very much, resulting in increased membrane selectivity.

1. Introduction

Among the different biofuels, bioethanol is widely used as a fuel oxygenate and is believed to be an alternative renewable fuel to gasoline (Cardona and Sánchez, 2007; Vane, 2005). The concentration of bioethanol blended into gasoline ranges from 5% to 85% (v/v) and varies from country to country (Mustafa, 2011). This application of bioethanol as a transportation fuel leads to a worldwide increase in its production. Great efforts are being undertaken to improve ethanol productivity and minimize the overall production cost. To do so, different possibilities are explained in literature (Cardona and Sánchez, 2007; Vane, 2005). One of the ways to achieve these goals is to modify the process configuration and perform process integration.

Commercially, the recovery of ethanol from fermentation broth is dominated by distillation. For low ethanol feed concentrations (<5 wt.%) and small production scale, however, distillation is not economical and energy efficient (O'Brien et al., 2000; Vane, 2005). Alternative recovery processes are listed in the literature. Among these processes, pervaporation is suggested as viable option due to its potentially lower energy consumption and simplicity of operation requiring no additional chemicals (Chovau et al., 2011; O'Brien et al., 2000). Pervaporation may also be applied to the separation of other volatile organic compounds such as biobutanol (Claes et al., 2012; Dobrak et al., 2010; Fadeev et al., 2000; Yen et al., 2012). Industrial applicability of pervaporation (hydrophilic and hydrophobic) in bioethanol production is discussed in the literature (Jonquières et al., 2002; Vane, 2008).

Coupling ethanol fermentation and pervaporation has been explored by many researchers (Groot et al., 1992; O'Brien and Craig, 1996; Shabtai et al., 1991). This integration enables continuous operation while maintaining an ethanol concentration in the fermentation broth below inhibitory levels but still achieving an ethanol rich outlet stream (Lipnizki et al., 2000). However, industrial applicability of pervaporation coupled directly with fermentation is limited by fouling of the membranes.

The common ethanol fermentation is performed by *Saccharomyces cerevisiae*. Most of the fouling studies done so far address the effects of unconverted sugars and excreted metabolites such as acetic acid, succinic acid, glycerol on membrane performance during pervaporation (Aroujalian et al., 2006; Chovau et al., 2011; García et al., 2009; Nomura et al., 2002). For fermentation integrated with pervaporation, viability of the cells decreases with time due to the accumulation of non-volatile by-products and cell aging (Nakao et al., 1987). This cell lysis causes release of cellular components in the fermentation broth. Detailed studies of lysis of *S. cerevisiae* have been performed using retentostat cultures where the cell viability decreased by 13% after 22 days resulting in an increase in extracellular proteins (Boender et al., 2009). In Clostridial fermentation coupled with pervaporation, FT-IR analysis of fouled membrane demonstrated the presence of carbohydrates, proteins and amino acids on the membrane (Liu et al., 2011). Hence from these studies we can conclude that, in an integrated system, potential candidates for fouling, present in fermentation broth are cellular polymers such as proteins, lipids, polysaccharides and nucleic acids (RNA and DNA).

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