Journal Pre-proof

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PII:	S0260-8774(19)30451-0
DOI:	https://doi.org/10.1016/j.jfoodeng.2019.109807
Reference:	JFOE 109807
To appear in:	*Journal of Food Engineering*
Received Date:	17 May 2019
Accepted Date:	03 November 2019

Please cite this article as: Helen Julian, Felly Yaohanny, Anita Devina, Ronny Purwadi, I.G. Wenten, Apple juice concentration using submerged direct contact membrane distillation (SDCMD), *Journal of Food Engineering* (2019), https://doi.org/10.1016/j.jfoodeng.2019.109807

Apple juice concentration using submerged direct contact membrane distillation (SDCMD)

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Abstract
The applicability of SDCMD technology using polypropylene membrane for apple juice concentration was explored in this study. The effect of feed temperature, draw solution flowrate, and draw solution concentration against the permeate flux and nutrient content were investigated. The results suggested a noticeable trade-off between the permeate flux and nutrient content. Severe temperature polarization was occurred during the SDCMD operation due to poor feed hydrodynamic and mixing condition in submerged configuration with stagnant feed. Therefore, the temperature difference of the feed and draw solution flow resulted on negligible driving force. The optimum SDCMD operation condition for apple juice concentration in this study were 3 mL/s draw solution flowrate, 630 g/L draw solution concentration, 14°C draw solution temperature and 30°C feed temperature. To avoid excessive heat treatment and prolong operation time, the advantage of membrane modularity was highlighted. Apple juice concentration to up to 35°Brix could be achieved with excellent nutrient preservation.

Keywords: membrane distillation; juice concentration; Vitamin C; phenolic compound; temperature polarization; concentration polarization

1. Introduction

Fruit juice concentration is of interest in food industry as it serves not only as a preservation method but also reduces the transportation and storage cost. Current method for fruit juice concentration is water evaporation in a multiple effect evaporator (Kozák et al., 2009; Quist-Jensen et al., 2016). To avoid disadvantages, such as non-enzymatic browning and antioxidant degradation, the operation is conducted at vacuum pressure and intermediate temperature of 60°C (Falguera and Ibarz, 2014). However, the reduction of nutrient content and overall concentrated fruit juice quality were still observed due to the excessive heat treatment during the evaporation process (Bahçeci et al., 2015; Gunko et al., 2006; Kujawski et al., 2013). Fruit juice concentration by using Membrane Distillation (MD) technology has attracted much attention (Bhattacharjee et al., 2017; Calabro et al., 1994). As the driving force in MD is the vapor pressure difference across the hydrophobic membrane (Lawson and Lloyd, 1997), MD is capable to be operated at relatively low feed temperature, in the range of 30°C to 50°C (Brazinha et al., 2013). Among four MD configuration, namely direct contact membrane distillation (DCMD), vacuum membrane distillation (VMD), air gap membrane distillation (AGMD), and sweep gas membrane distillation (SGMD), DCMD is the most studied as it offers set-up simplicity (Ashoor et al., 2016; He et al., 2011; Johnson and Nguyen, 2017).

The antioxidant and phenolic compounds in fruit juice are sensitive to heat, hence the concentration process should be conducted at low temperature (Réblová, 2012). At that particular condition, the vapor pressure difference between the feed and permeate solution in