Journal of the Indian Chemical Society 101 (2024) 101122

Contents lists available at ScienceDirect

Journal of the Indian Chemical Society

journal homepage: www.journals.elsevier.com/journal-of-the-indian-chemical-society

The use of factorial design for levulinic acid extraction via hollow fiber supported liquid membrane

Vikneswary Rajendaren, Syed M. Saufi *, M.A.K.M. Zahari

Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuhraya Persiaran Tun Khalil Yaakob, 26300, Gambang, Kuantan, Pahang, Malaysia

A R T I C L E I N F O

Keywords:
Supported liquid membrane
Levulinic acid
Factorial design

A B S T R A C T

Supported liquid membrane (SLM) is an effective method to separate a high-demand levulinic acid (LA) from an aqueous or biomass hydrolysate solution. Several factors can influence the separation of LA using SLM. In this study, three hollow fiber (HF) SLM (HFSLM) operation parameters, such as carrier concentration (0.1–0.5 M tri-n-octylamine, (TOA), stripping concentration (0.25–0.75 M sodium hydroxide (NaOH), and feed concentration (10–30 g/L LA) was analyzed by using a 2^3 full factorial design (FFD). The results showed that all three factors significantly impact the extraction of LA. The order of contribution effects towards LA extraction was LA feed concentration > NaOH stripping concentration > TOA carrier concentration. The design proposed a valid condition of factors such as 0.5 M TOA, 0.75 M NaOH, and 10 g/L of LA with LA extraction of 69.6 ± 2.16 %. The result proved that FFD effectively improved the LA extraction in the HFSLM process by considering all the factors involved.

1. Introduction

Levulinic acid (LA) is a bio-organic acid in high demand across various industries, including chemicals, pharmaceuticals, agriculture, food production, plasticizers, and cosmetics [1,2]. In the production of bio-organic LA, a significant challenge revolves around efficiently separating LA from other biomass-derived compounds. This separation constitutes a substantial portion of the production cost, accounting for 50 %–70 % [3]. Moreover, the separation of LA from the biomass substrate is crucial in sugar fermentation within biorefineries. It's important to note that LA can inhibit the microorganisms involved in sugar fermentation [4]. As a result, removing LA becomes essential to reduce its concentration in the biomass substrate to below 4.6 g/L [5].

Supported liquid membrane (SLM) offers a practical approach for the simultaneous separation and recovery of LA from aqueous solutions within a single operational setup [6]. This method employs a minimal quantity of liquid membrane (LM) infused into a supporting membrane, resulting in a remarkably selective medium for extracting specific solutes from biomass solutions. Consequently, SLM exhibits great promise for the efficient extraction of LA during biorefinery processes. SLM has been successfully applied in the past for the extraction of various chemicals and metals, including acetic acid [7], fumaric acid [8], pentachlorophenol [9], chromium (III) [10], and nickel [11].

The effectiveness of the SLM process for separating LA relies heavily on selecting the appropriate operating parameters [6]. It is essential to minimize the development of a boundary layer during SLM operations. A boundary layer is a thin layer of viscous fluid that comes into contact with a moving feed or stripping phase, and its flow velocity varies from zero at the membrane support. This layer disrupts the interaction and transport of solutes between the different SLM phases, ultimately leading to a reduction in the desired solute extraction yield [12]. In instances where the boundary layer becomes thick, it generates a high osmotic pressure near the membrane's surface, causing solutes to repel away from the membrane support and towards the bulk solution [13]. The concentration of the aqueous solutions emerges as a pivotal factor influencing the formation of the boundary layer. In accordance with Poiseuille's Law, an increase in solution viscosity results in a reduction in the stream's flow rate [14]. When the flow rate is insufficient and remains low, it fails to effectively prevent the formation of the boundary layer during the SLM process [7].

Wongkaew et al. [15] demonstrated that the presence of highly concentrated platinum (IV) in the feed phase of HFSLM leads to the accumulation of platinum (IV) at the interface between the feed and LM phases, resulting in fouling. This fouling disrupts the transportation of

* Corresponding author.
E-mail address: smsaufi@umpsa.edu.my (S.M. Saufi).

https://doi.org/10.1016/j.jics.2024.101122
Received 10 September 2023; Received in revised form 7 December 2023; Accepted 5 January 2024
Available online 6 January 2024