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Process Intensification of Propionic Acid Extraction and its Recovery by Distillation in Microchannel

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ABSTRACT

Extraction in microchannels has been studied extensively. However, the recovery of the solute and the solvent from the extract in microchannels has not been part of any reports. Hence, in this work, extraction of propionic acid (PA) using n-hexane and toluene and its subsequent recovery by distillation (flash) in microchannels is reported. Moreover, a total annual cost comparison between microchannels and conventional extraction and distillation units has been made. Microchannel extraction and distillation were conducted in a serpentine microchannel. The maximum percentage extraction is 36.3% with toluene. The maximum extraction efficiency is 99.6% with toluene and 98.4% with n-hexane. The overall K_La is in the range of 0.01-0.25 s^{-1}. Distillation was conducted in the presence of nitrogen gas. The solvents n-hexane and toluene were recovered with high percentage recovery of 98% and 73% respectively at 0.01 mL/min feed rate. The maximum power requirement is in the range (2.7-3.8) kWh. The overall pressure drop for the distillation is about 3.4 kPa for both the systems. The hexane, toluene and PA mole fractions agree well with the ASPEN Plus results. The total annual cost (TAC) analysis indicates that microchannel can lead to significant capital and operating cost benefits.

1. Introduction

Propionic acid (PA) is one of the carboxylic acids that have widespread applications in perfume base, fruit flavour, antifungal agents, etc. [1–5]. PA is majorly produced by chemical synthesis method [5]. But the interest in producing carboxylic acids especially through fermentation process is growing substantially [6–9]. The commercial production of some of the carboxylic acids in large scale by fermentation include acetic, D/L-lactic, succinic, itanoic, citric, d-gluconic acid. The industrial implementation of PA production is at present in the design stage [10]. Typically the cost of downstream processing (DSP) is about 30-40% of the total production cost [10,11]. In such a case, process intensification in the downstream processing may contribute to the total annual cost savings. Thus the successful recovery from the broth relies on choosing the efficient separation techniques or by intensifying the existing techniques.

Several separation techniques are used to isolate PA from the fermentation broth namely, reactive extraction, solvent extraction, reverse osmosis, ultrafiltration, electrodialysis, pervaporation, distillation etc. [3,8,10]. However, solvent extraction is still an economical option than the others [3,10]. PA is recovered from the solvent phase (extract) by distillation. The choice of the solvent for PA extraction has general selection characteristics as required by other carboxylic acid separation. The solvent should be immiscible with the feed, it should have high selectivity, high distribution coefficient, a high degree of extraction, low viscosity, non-corrosive, non-toxic, less expensive etc., [6,7,10]. For physical extraction, wide range of non-reacting hydrocarbons and substituted hydrocarbons are used which may be having low or high boiling point [12]. Solvents like hexane, heptane, paraffin liquid, benzene, toluene, butyl acetate, ethyl acetate, 1-octanol, 2-octanol, 1-decanol, MIBK fall in this category [3,13]. Solvents having low boiling point are advantageous as they can be evaporated from the organic acid thus avoiding the back extraction step [10,12]. In the present work, n-hexane and toluene are used as solvents despite its well known unsatisfactory performance. This is because these solvents have a low boiling point as mentioned above which can be easily recovered by distillation [10].

Process intensification (PI) in chemical industries (separation processes and reactions) has become a principal research focus in recent years [14,15]. PI aims to reduce the cost of operation, equipment cost by

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