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# Process Intensification of Propionic Acid Separation – Effect of Channel Geometry on Microchannel Distillation

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ABSTRACT

A considerable number of microchannel distillation studies have been reported. However, they are confined to the efficiency evaluation in a single-stage microchannel. The effect of geometry on microchannel distillation has been studied to a significantly little extent. In our previous work, simultaneous extraction and distillation in microchannels were conducted to study the separation of propionic acid. In this work, the effect of microchannel inlet angles, channel width and length on percentage distillation, ΔP, power requirement was studied. Four Y-junction angles (30°, 45°, 60°, 90°), and four 90 mm long T-junction channels of different widths and depth 0.75 mm were utilized. Y-junction channel with 90° angle produced the maximum separation. T-junction microchannel yielded a separation of 88.3% and 42.3% for hexane and toluene respectively. The ΔP increased with the increase in Y-junction angle lying in the range of 0.01-0.021 kPa. Power consumption decreased with the increase in Y junction angle which ranges from 7.9 to 4 kWh for the hexane system. The maximum separation for the PA-hexane system varied in the range of 98.2-65.3% and 74.2-32.6% for the PA-toluene system. An empirical model has been developed to predict percentage separation. The predicted results are in good agreement with the experimental data.

## 1. Introduction

Propionic acid (PA) is used in the food, pharmaceutical and chemical industries [1,2]. It also has various applications in other industries such as perfume, fruit flavor, antifungal agentsand so on [3]. The salts of propionic acid are also used in the pharmaceutical industries as wound antiseptic and anti-arthritic drugs. Numerous synthesis routes have been proposed in the literature [4-6] for the production of propionic acid. This includes Reppe and Larson process wherein PA is produced from the petroleum feedstock [7]. PA can also be produced from the fermentation process using *propionibacterium* [8]. They are majorly produced from petroleum feedstock but fermentation-based production is desired as they depend on renewable sources [2,9]. The interest in PA production by the latter method is growing in recent years [10]. The PA obtained from the biological methods accounts for merely 5-10% while the remaining portion is occupied by water. Hence, the separation of PA is a challenging problem, which leads to 30-40% of the downstream process of the total production cost. Therefore, an efficient separation process for propionic acid separation is important to reduce the overall production cost. Separation processes like pervaporation, physical or chemical solvent extraction, reverse osmosis, ultrafiltration and electrodialysis, are used [2]. Among these processes, solvent extraction is more economical owing to its ease of operation and less energy requirement [11]. In this method, a solvent (physical extraction) is used for the extraction of the solute selectively (propionic acid) [12]. The solute i.e. PA is later recovered from the solvent by distillation in general [7]. Process intensification of the carboxylic acid separation process has been reported in the literature using microchannels [13] in which extraction is shown to be more effective. These studies however have limited their focus up to extraction. The recovery of the carboxylic acid and the solvent after extraction has not been reported in almost all the works except by Singh et al. 2020. Their work was comprised of propionic acid extraction in a microchannel and its recovery by microchannel distillation (MCD) [13].

In the process industries, the products of the extract are often recovered by distillation. The advantage of distillation is that the products are with very high purity however at the expense of a large amount of heat. Conventional distillation columns are tall and huge i.e. towers that make them inefficient. The efficiency of the distillation columns is merely about 24-40% [14]. In any typical chemical industry,

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