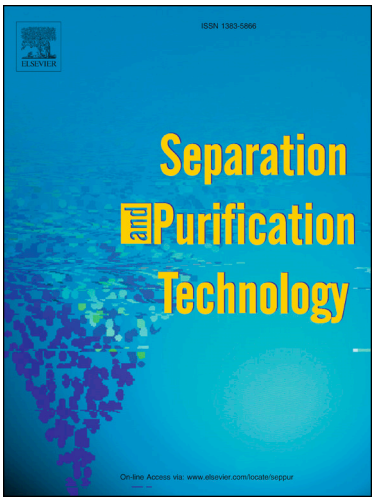

Heat-Pump Assisted Distillation versus Double-Effect Distillation for Bioethanol Recovery followed by Pressure Swing Adsorption for Bioethanol Dehydration

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Heat-Pump Assisted Distillation versus Double-Effect Distillation for Bioethanol Recovery followed by Pressure Swing Adsorption for Bioethanol Dehydration

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Abstract

Bioethanol recovery (i.e., pre-concentration from 5-10 wt.% ethanol to near azeotrope composition) from the fermentation broth requires significantly more energy compared to bioethanol dehydration from near azeotrope composition to > 99.5 wt.% ethanol. The present article proposes and evaluates two different alternatives, namely, double-effect distillation (DED) and heat-pump assisted distillation (HPAD) as opposed to simple distillation for bioethanol recovery followed by dehydration using pressure-swing adsorption (PSA). Preliminary design reveals that HPAD-PSA process outperforms DED-PSA process resulting in 19% savings in total annual cost. Multi-objective optimization is hence performed for HPAD-PSA process, and the obtained Pareto-optimal solutions for minimizing fixed capital investment and annual operating cost are presented and discussed. Compared to the simple distillation followed by PSA process, HPAD-PSA process reduces specific energy consumption (SEC) by 38% to 3.2 MJ-fuel/kg of bioethanol. Further, compared with other, recent bioethanol separation processes, HPAD-PSA process results in 35-64% lesser SEC.

Keywords: Bioethanol Separation; Double-effect Distillation; Heat-Pump Assisted Distillation; Pressure-Swing Adsorption; Multi-Objective Optimization

1. Introduction

The past decade has witnessed a flurry of interest over bioethanol as a renewable energy source for mitigation of greenhouse gas emissions especially from the transport sector. Today, several technologies exist for bioethanol recovery and dehydration to produce > 99.5 wt.% bioethanol from a dilute range of 5-20 wt.% ethanol and remaining water [1]. Notable among them include vapor compression distillation followed by salt-based extractive distillation [2], heat-pump (HP) assisted single extractive dividing wall column (E-DWC) [3], E-DWC [4,5], double effect distillation (DED) followed by EDWC [6], EDWC with three