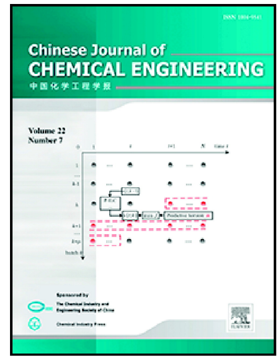
Accepted Manuscript



Modelling of heat transfer for progressive freeze concentration process by spiral finned crystallizer

Shafirah Samsuri, Nurul Aini Amran, Mazura Jusoh

PII: S1004-9541(17)30987-4
DOI: doi:10.1016/j.cjche.2017.09.025
Reference: CJCHE 942

To appear in:

Received date: 2 August 2017
Revised date: 12 September 2017
Accepted date: 13 September 2017

Separation Science and Engineering

Modelling of heat transfer for progressive freeze concentration process by spiral finned crystallizer

Shafirah Samsuri[1], Nurul Aini Amran[1] and Mazura Jusoh[2,*]
[1]Department of Chemical Engineering, Universiti Teknologi PETRONAS, 32610 Seri Iskandar, Perak, Malaysia.
[2]Department of Chemical Engineering, Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.
*Corresponding author: Tel: +6075535535; Fax: +6075588166; Email: mazura@cheme.utm.my

ABSTRACT
This study presents a novel design for a spiral finned crystallizer which is the primary element of progressive freeze concentration (PFC) system, which simplifies the setup of the conventional system. After the crystallizer has been designed, the research experiments have been conducted and evaluated through a thorough analysis of its performance by developing a mathematical model that can be used to predict the productivity of ice crystal at a range of coolant temperature. The model is developed based on the basic heat transfer equation, and by considering the solution's and the coolant's convective heat transfer coefficient (h) under the forced flow condition. The model's accuracy is verified by making comparison between the ice crystal mass' experimental value and the values predicted by the model. Consequently, the study found that the model helps in enhancing the PFC system.

Keywords: Heat transfer model; progressive freeze concentration; ice crystal; spiral finned crystallizer; ice production.

1. Introduction

The Freeze concentration (FC) technology is grounded on the principle which states that water could be separated from a solution by freezing or cooling, and this process would form ice crystals and leave behind a concentrated liquid [1]. FC aims to produce very pure ice crystal, containing only water and no solutes are retained in the ice crystal [2]. Subsequently, the solid and liquid phases produced will be separated into ice and concentrated solution. This technique is known as a concentration method which can be used to prevent the loss of quality in liquid foods, including fruit juices and dairy products [3, 4].

There are three categories of FC: progressive freeze concentration (PFC), block freeze concentration (BFC) and suspension freeze concentration (SFC) [5-8]. SFC is deemed as the most traditional approach of FC where ice is formed in a chilled solution and it comprises of nucleation and crystal growth by using recrystallizer and a scraped-surface heat exchanger (SSHE) [9]. In this light, the application of SSHE takes up to 30% of the investment costs for an FC plant, making it the costliest processing unit in the FC plant [10]. The SSHE produces small ice crystal from the solution which is pumped from a feed tank. Then, the outflow of the SSHE, which contains small ice crystal will be fed to the recrystallizer and mixed with larger crystals. In this process, the Gibbs-Thomson effect (Ostwald ripening) leads to the growth of crystal in the recrystallizer [11]. The resultant slurry flow will be transported to a separation device which will separate the concentrated liquid from the ice crystals [12]. These phases of ice crystals separation and washing are crucial in SFC as the solute in the solution will adhere to the ice crystals and contaminate them. In this light, even though there is an