Chemical Engineering and Processing 104 (2016) 13–21

Contents lists available at ScienceDirect

Chemical Engineering and Processing: Process Intensification

journal homepage: www.elsevier.com/locate/cep

A novel process intensification approach of recovering creatine from its wastewater by batch foam fractionation

Di Huang, Zhao Liang Wu*, Wei Liu, Nan Hu, Hong Zhen Li

School of Chemical Engineering and Technology, Hebei University of Technology, No. 8 Guangrong Road, Dingzi Gu, Hongqiao District, Tianjin 300130, PR China

ARTICLE INFO

Article history:
Received 25 June 2015
Received in revised form 8 February 2016
Accepted 14 February 2016
Available online 17 February 2016

Keywords:
Foam fractionation
Creatine
Wastewater
Enrichment
Isolation

ABSTRACT

Foam fractionation is a cost-effective water treatment technology and it uses bubbles as the media for separating surfactants or non-surface materials from their aqueous solutions, where non-surface materials can be attached to the gas–liquid interface by using a surfactant as the collector. A novel two-stage batch foam fractionation was developed for recovering creatine from its wastewater. The objective of the first stage was to concentrate creatine from its wastewater and sodium dodecyl sulfate (SDS) was used as the collector. Under the suitable operating conditions, the enrichment ratio and the recovery percentage of creatine were 3.1 and 70.6%, respectively. Subsequently, the second stage was performed for isolating SDS from creatine by using the first stage foamate as the feeding solution. Under the suitable operating conditions, the recovery percentage of SDS reached 76.2% and creatine was massively remained in the residual solution because the complexation between creatine and SDS was eliminated through adjusting pH to 8.0. So, the total recovery percentage of creatine reached 59.3% and SDS in the second stage foamate could be reused for recovering creatine from its wastewater.

1. Introduction

Creatine (β-guanidinoacetic acid), an essential dietary supplement, has attracted the attention of more and more athletes and fitness enthusiasts because it can supply auxiliary energy for their muscles and neurons [1–3]. The basic chemical structure of creatine is presented in Fig. 1. Currently, the commercially available creatine is mainly synthesized by using sodium *N*-methylglycine and *S*-methylisothiourea as reactants [4]. During the production of creatine, cooling crystallization was used to separate creatine from its reaction solution through decreasing the temperature of the reaction solution to 30 °C. When the temperature was less than 30 °C, the precipitated sodium salt would seriously affect the purity of the product. Then after cooling crystallization, a large amount of the wastewater was discharged and it was usually treated by biochemical method [5]. Therefore, it is significant to develop a cost-effective technology to recover the residual creatine from its wastewater as a pretreatment technology.

Foam fractionation is such a promising separation technology and it is based on the selective adsorption of one or more solutes on the surface of gas bubbles, which rise through a solution [6,7]. Foam fractionation has been recognized as one of the most effective methods for separating a surfactant from its diluted aqueous solution [8,9]. When a gas is sparged into a solution, surfactant molecules rapidly adsorb onto the gas–liquid interface due to the favorable thermodynamics [10]. Surfactant molecules tend to lower the surface tension between the gas and liquid, thus the bubbles form a stable foam above the bulk solution [11]. There is a pronounced interest in foam fractionation to achieve industrialization owing to its outstanding engineering advantages of simple equipment, low energy consumption and environmental compatibility [12–14]. Specially in recent years, foam fractionation has also been developed to recover non-surface-active materials (e.g., isoflavones, riboflavin and folic acid) by either electrostatic or chemical interactions with a surfactant, which is called the collector [15–17]. Then, the non-surface-active material can adsorb on the gas–liquid interface in the form of complex with the collector.

Indeed, foam fractionation can be usually applied to enrich a non-surface-active material by adding a suitable surfactant. However, the non-surface-active material still exists in the form of complex in the foamate after foam fractionation, where the foamate is the concentrated solution of deforming the foam discharging from the top of a foam fractionation column [18]. The enrichment of the non-surface-active material and the isolation of the collector from the non-surface-active material are two

* Corresponding author. Fax: +86 222656 4304.
E-mail address: zhaoliangwu@163.com (Z.L. Wu).

http://dx.doi.org/10.1016/j.cep.2016.02.005
0255-2701/

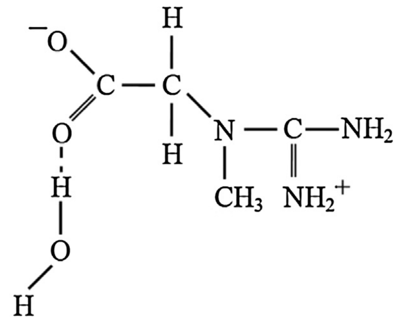

Fig. 1. The basic chemical structure of creatine.

important stages for the recovery of non-surface-active material from its aqueous solution. However, most researches only have focused their attentions on the enrichment of the non-surface-active material. Unanimously, the isolation of the surfactant is significant to the further purification of the non-surface-active material. The complexation between a non-surface-active material and a surfactant is mainly based on some weak non-covalent bonds which are extremely sensitive to the change of operating conditions, especially temperature and pH [19]. Thus, it is possible to weaken or eliminate the complexation by adjusting operating

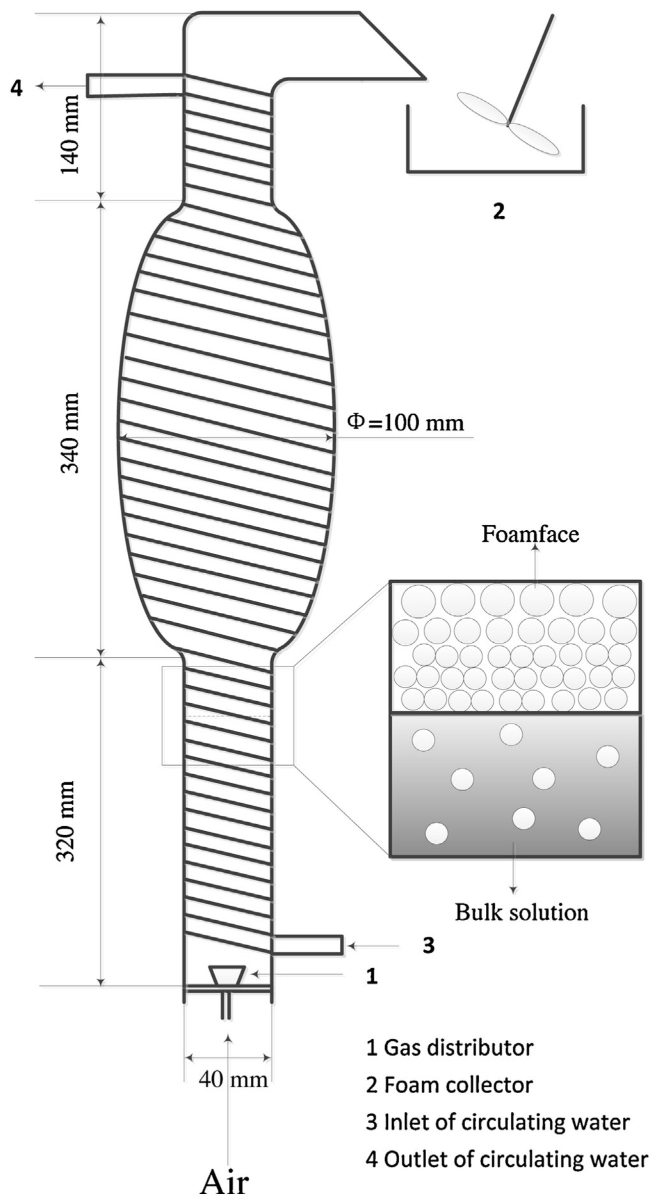

Fig. 2. The experimental apparatus of foam fractionation.