Separation and Purification Technology 170 (2016) 353–359

Contents lists available at ScienceDirect

Separation and Purification Technology

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

Recovery of gamma-aminobutyric acid (GABA) from reaction mixtures containing salt by electrodialysis

Yaoming Wang, Zenghui Zhang, Chenxiao Jiang, Tongwen Xu *

CAS Key Laboratory of Soft Matter Chemistry, Laboratory of Functional Membranes, School of Chemistry and Materials Science, University of Science and Technology of China, Hefei, Anhui 230026, People's Republic of China

ARTICLE INFO

Article history:
Received 15 March 2016
Received in revised form 1 July 2016
Accepted 2 July 2016
Available online 2 July 2016

Keywords:
Ion exchange membranes
Electrodialysis
Separation
Gamma-aminobutyric acid

ABSTRACT

During the chemical synthesis of gamma-aminobutyric acid (GABA), a large amount of ammonium chloride is generated and coexisted with the product. In this study, electrodialysis (ED) was employed to separate and recover GABA from reaction mixtures containing salts. The selection of membranes and electrolytes were investigated. Results indicated that the CJ-MA-3/CJ-MC-3 membrane was more suitable for ED operation. The highest desalination rate was observed at 99.29% with GABA loss rate less than 3%. To increase the GABA recovery rate, the lost GABA was mixed with fresh raw material and recycled for the next production loop. Results showed that this recycling strategy can be effectively carried out for only one time. The total energy consumption for GABA dry product was less than 500 kW h/t, which was much less than the conventional separation technologies. Naturally, industrial production of high purity gamma-aminobutyric acid by ED was not only energy efficient but also environmentally friendly.

1. Introduction

Gamma-aminobutyric acid (GABA, CAS 56-12-2) is an important non-protein amino acid. It is the major inhibitory neurotransmitter and the cornerstone of the inhibitory system in the body [1]. GABA has several important physiological functions, such as neurotransmission, induction of hypotension, diuretic effects, enhancement of reproductive performance, enhancement of long-term memory, improvement the quality of sleep, resisting pathogen attack of plants, and tranquilizer effects [2,3]. Due to the special physiological functions of GABA, it is widely used in pharmaceutical, food, chemical engineering, and agricultural industries. The demand for GABA is increasing due to the fast development of GABA as a dietary supplement and as an active drug for some neurological diseases. Nowadays, GABA is produced by both chemical synthesis and biological transformations. The biological method includes plant accumulation and microbial fermentation. Plant accumulation of GABA is achieved by induce stress in plants including lower temperature and oxygen, darkness, drought, damage by pest, or mechanical manipulation [4]. However, accumulation of GABA by plants has low efficiency and high cost; it is not suitable for industrial production. Microbial fermentation is the prevalent approach for GABA production by transforming L-glutamic acid (or sodium) with GAD (glutamate decarboxylase) as catalyst. Microbial fermentation of GABA is a cost-effective and high-efficient process with cheap raw sources and relatively short preparation period [5–7]. But the downstream separation of GABA from fermentation broths and the screening of GABA high-production strains are the most important and difficult issues of this technology. Preparation of GABA by chemical synthesis is a simple and cost-effective process, which takes the second place in industrial production. Among the various chemical synthesis methods, the Hell-Volhard-Zelinsky is a simple and robust method [8,9]. A schematic preparation route of GABA by this method is indicated in Fig. 1. However, the separation of GABA from the byproduct is a challenging problem for this method, since the product GABA and byproduct NH_4Cl have a similar molecular weight and a similar solubility to most organic solvents. The conventional separation technology is called "ethanol elution", which takes advantage of the tiny solubility difference between GABA and NH_4Cl in ethanol-water solvent. This separation technology not only has high consumption of chemicals and energy but also environmental pollution problem. For example, ethanol consumption is as high as 50 tons for one ton dry product with 5% loss in the subsequent evaporation and crystallization process. Therefore, it is necessary to explore an environmentally friendly, cost-effective and high efficient separation technology to simplify the purification steps.

* Corresponding author.
E-mail address: twxu@ustc.edu.cn (T. Xu).

http://dx.doi.org/10.1016/j.seppur.2016.07.002
1383-5866/

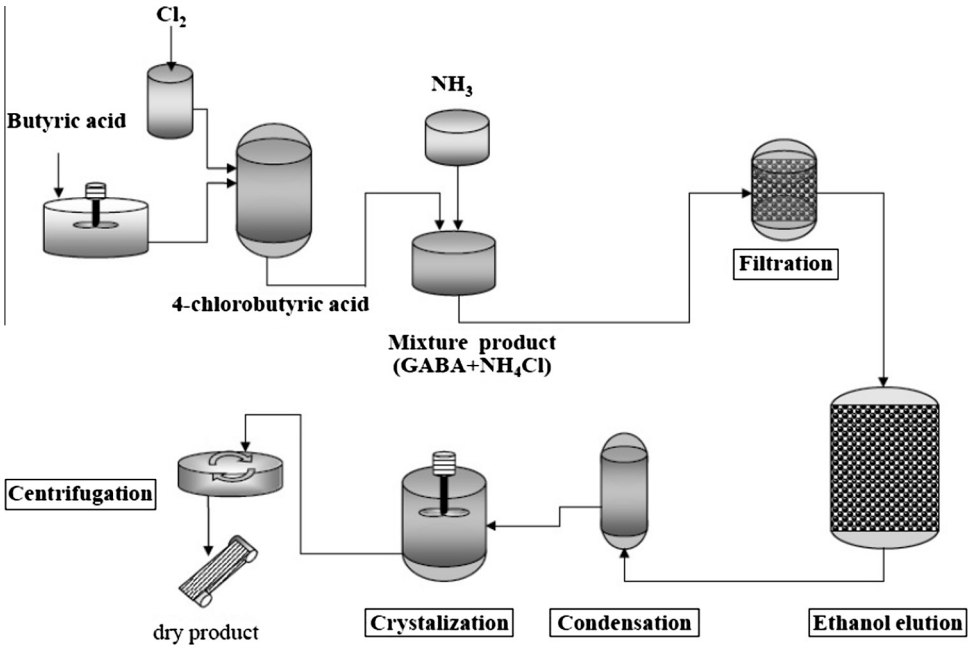

Fig. 1. Conventional preparation route of gamma-aminobutyric acid (GABA) using the Hell-Volhard-Zelinsky method.

Electrodialysis (ED) is a well proven separation technology, which has found more and more significant applications in chemical cleaner production, environmental protection and energy conversion [10–12]. As opposed to other separation techniques, electrodialysis (ED) does not suffer from major drawbacks, such as generation of large amounts of waste, use of hazardous solvents and short lifetimes of adsorbents [13,14]. ED is thus considered an environmentally friendly and sustainable technology and may be a very competitive one when it comes to separation and production of GABA. According to the characteristics of GABA and NH_4Cl mixtures, GABA can be considered as zwitterionic molecules while NH_4Cl is totally dissociated in an aqueous solution. The ionization status of GABA is very sensitive to surrounding pH whose charge is neutral at the isoelectric point of ~7.2 [15]. Based on this principle, it should be easy to separate GABA from salts mixtures by introduction an ED process. The selective separation of GABA from their solution mixtures using ED has previously been applied successfully [16,17]. But these GABA in the literature are produced by microbial or enzymatic conversion. These separations are conducted between GABA with L-glutamic acid (Glu) or aspartic acid (Asp); the separation of GABA from a chemical synthesis reaction containing inorganic salts is seldom reported. Therefore, the main objective of this study is to test the feasibility of separation of GABA from NH_4Cl, to select the optimal membranes, to identify the most suitable electrolytes, and to estimate the cost of separation process. Moreover, a small amount of GABA will be lost during the ED process due to concentration-gradient diffusion and electro-migration of GABA molecules, so it is desirable to recover this missing GABA by considering the high added value of this product. The recycling strategy of the lost GABA is another interest of this study.

2. Experimental

2.1. Material

Mixture dry product was supplied by Zhejiang Borun Chemicals Co., Ltd. This solid mixture was containing 78.64 wt% GABA and

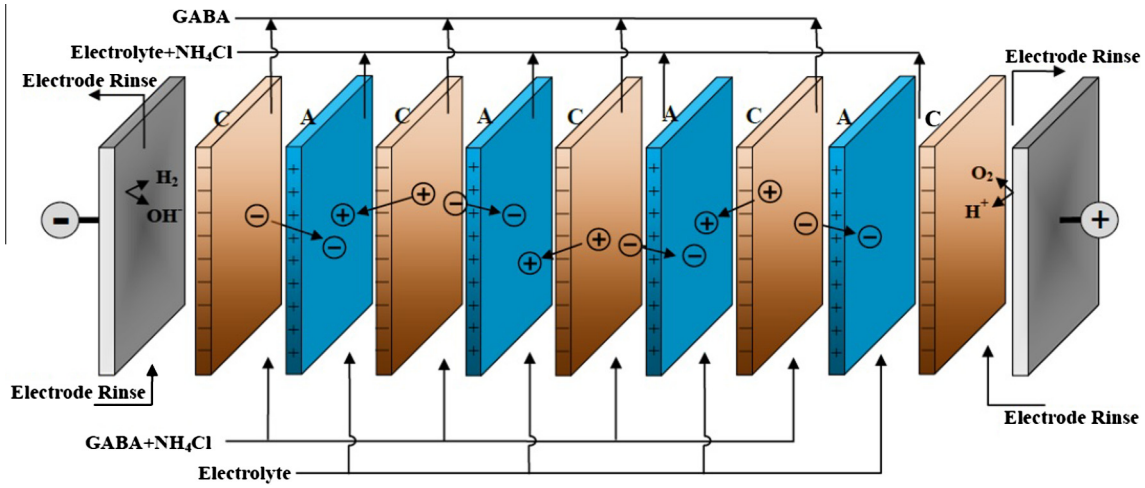

Fig. 2. A schematic ED stack for GABA separation. C, cation-exchange membrane; A, anion exchange membrane.