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In situ combination of fermentation and electrodialysis with bipolar membranes for the production of lactic acid: Operational compatibility and uniformity

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HIGHLIGHTS

- An in situ combination of fermentation and EDBM was firstly customized.
- An EDBM stack was established according to the operating conditions of fermenter.
- The lactic acid recovery ratio was 86.05% with a complete fermentation.
- The synchronous operation of the fermentation and EDBM can be industrially used.

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ABSTRACT

An in situ combination of fermentation and electrodialysis with bipolar membranes was customized for the production of lactic acid to achieve their operational compatibility and uniformity. Primarily, fermentation experiments for lactic acid production were conducted by *Lactobacillus plantarum* with an average lactate productivity of 1.76 g/(L h) and yield coefficient of 56.77%. Subsequently, an electrodialysis with bipolar membranes (EDBMs) stack was established with the fermented lactate mixtures as a feed. Effect of operating current density on the production of lactic acid and alkali liquor was investigated. Results indicated that only the current density of no less than 50 mA/cm^2 can produce enough alkali liquor to meet the need for fermentation. Ultimately, a combination of fermentation and EDBM process was carried out and the integration can achieve a lactic acid recovery ratio of 86.05% at the current density 60 mA/cm^2.

1. Introduction

Lactic acid is an important daily material with the major applications found in food and food-related industries. In addition, lactic acid has also involved in many nonfood applications, especially as a chemical feedstock due to its special chemical structure, such as the emerging use of polylactic acid (PLA) as a biodegradable material (Datta and Henry, 2006; John et al., 2009). Lactic acid can be produced in two ways: chemical synthesis and carbohydrate fermentation. The latter route has proved to be superior to the former one from both technical and economical perspectives, because a pure lactic acid product can be obtained with many extensive and cheap raw sources (Datta et al., 1995; Oh et al., 2005; Vaidya et al., 2005; Wee and Ryu, 2009).

To improve the yield efficiency of lactic acid in fermentation process, the most significant efforts underway can be summarized into two aspects. On one hand, much attention has been paid to the screening, isolation, mutation, or genetic modification of the strains that can produce the lactic acid, especially the screening of some special microorganism with the advantages of outstanding capacity to ferment, high optically purity and yield reduction of by-product (Ilmen et al., 2007; Qin et al., 2009; Ryu et al., 2003; Wang et al., 2010; Zhu et al., 2007). On the other hand, many efforts were dedicated to the downstream separation processing to enhance the separation efficiency (Chen et al., 2012; Wasewar et al., 2004). Because the fermentation broth is very complex and the produced acid coexists with other impurities such as residual sugar, impurity protein, pigment, mycelium and carbohydrates. The extraction of lactic acid from these mixtures is a cumbersome process, which accounts for the majority of the total process cost for lactic acid production (Yi et al., 2008). The extraction of lactic acid from fermentation broth mainly consists of three processes, i.e. filtration, precipitation, and acidification. During the fermentation process, the slack lime is usually supplied to the fermentation broth to

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