Conversion of Sodium Lactate to Lactic Acid with Water-Splitting Electrodialysis

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Abstract

The conversion of sodium lactate to lactic acid with water-splitting electrodialysis was investigated. One way of reducing the power consumption is to add a conductive layer to the acid compartment. Doing this reduced the power consumption by almost 50% in a two-compartment cell, whereas the electric current efficiency was not affected at all. Three different solutions were treated in the electrodialysis unit: a model solution with 70 g/L of sodium lactate and a fermentation broth that had been prefiltered two different ways. The fermentation broth was either filtered in an open ultrafiltration membrane (cut-off of 100,000 Dalton) in order to remove the microorganisms or first filtered in the open ultrafiltration membrane and then in an ultrafiltration membrane with a cut-off of 2000 Dalton to remove most of the proteins. The concentration of sodium lactate in the fermentation broth was 70 g/L, as well. Organic molecules present in the broth (peptides and similar organic material) fouled the membranes and, therefore, increased power consumption. Power consumption increased more when permeate from the more open ultrafiltration membrane was treated in the electrodialysis unit than when permeate from the membrane with the lower cut-off was treated, since there was a higher amount of foulants in the former permeate. However, the electrodialysis membranes could be cleaned efficiently with a 0.1 M sodium hydroxide solution.

Index Entries: Lactic acid; electrodialysis; bipolar membranes; fermentation broth; wheat.
Introduction

Lactic acid is a well-known organic acid that can be polymerized to polylactic acid, which is biodegradable and therefore used in the pharmaceutical industry for the production of sutures and matrices for slow-release drugs (1). Lactic acid can be produced by both organic synthesis and fermentation (2). Organic synthesis is most widely used for the production of lactic acid in the pharmaceutical industry, but as the cost of petroleum has increased, fermentation has become more interesting (3). Fermentative production of lactic acid is inexpensive, especially when waste products such as whey are used as substrate. On the other hand, the subsequent downstream processing is difficult owing to the complexity of the media and the byproducts, such as proteins and organic acids, formed during fermentation. In addition, lactic acid has a high boiling point and polymerizes at elevated temperatures, and, thus, traditional processes, such as distillation and conventional evaporation, cannot be used for the recovery (4). Because lactic acid–producing bacteria often exhibit the highest production rate at pH values over the pK_a of lactic acid, the acid is present as a salt (e.g., sodium lactate) in the fermentor. Many different processes have been suggested for the downstream processing of lactic acid/lactate, including extraction and ion-exchange chromatography (5,6). Another method of recovery is to precipitate the lactic acid with calcium hydroxide, refine the calcium lactate, and convert it to lactic acid by acidification with sulfuric acid (7). These processes all have disadvantages in that they are unspecific and expensive, produce waste streams, and are difficult to scale up (4,7–9). Water-splitting electrodialysis is a membrane process that has been suggested as a competitive alternative for the conversion of lactate to lactic acid because the process does not produce waste streams.

Research has been conducted on electrodialysis for the desalination of seawater. However, electrodialysis has been found to be a more realistic alternative when used for desalination of brackish water (10–12). It is also used to remove salts from process water in power plants and to remove radioactive substances from water in nuclear power plants (13). Recently, electrodialysis has attracted interest in other areas for the recovery or removal of chemicals in process streams such as those in the pulp and paper and the iron and steel industries (14,15). In the food industry, electrodialysis has been suggested for various processes such as desalination of whey, prevention of precipitation of tartrates in wine, and for purification of proteins (16). In the biotechnologic industry, electrodialysis can be used for the refinement of organic acids from fermentation broths (17,18). Much interest has been focused on recovery of the organic acid lactic acid from fermentation broth using electrodialysis to use the acid for the production of the biodegradable and environmentally friendly polymer polylactic acid (19–22). Several mathematical models for the conversion of sodium lactate to lactic acid have also been presented (23–25).