Modeling Reverse Electro-Enhanced Dialysis for Integration with Lactic Acid Fermentation

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Presently, economical and sustainability issues are the driving competitive forces behind improving process design and operation. Particularly, improvements in the sustainable production of commodity chemicals, such lactic acid, by fermentation are desirable when they are used as feedstock for production of polymers, e. g. polylactic acid (PLA). PLA can substitute hydrocarbon based polymers in several applications. It is well know that lactic acid production by fermentation is impaired by product inhibition at high lactate concentration in the cultivation broth. A continuous removal of lactate from the fermentation broth will diminish the inhibitory effect, and therefore increase productivity and product yield. Integrating separation and fermentation will also enable operation at higher cell densities, thereby providing additional enhanced productivity potential. Integration also moves the degrees of freedom for control, therefore a model based study of the design, control and optimization is desirable.

In 1980's, electrodialysis was suggested as an alternative to intensify lactic acid fermentation, since lactate can be selectively removed by ion exchange membranes during electrochemically pH-controlled electrodialysis of the fermentation broth (Hongo, M. *et al.*, 1986). More recently, an improved design called Reversed Electro-Enhanced Dialysis (REED) has been proposed (Rype, J., 2003). This method has shown promising performance for continuous removal of lactic acid during fermentation. The REED module combines elements from Reverse Electro-Dialysis (RED) and Donnan Dialysis (DD) operations. Using this separation method, the fluxes obtained using Donnan Dialysis can be enhanced by imposing electrical current. In addition, the adverse influence of fouling is reduced when the current is reversed periodically.

In order to optimize the controlled operation an integrated bioreactor and membrane separation process is desirable to derive reliable models for each module; since the quality of the control strategy depends on the models. At the moment, a dynamic model for the REED module has been derived from first principles for dissociation, diffusion, convection and migration of species commonly found in the fermentation broth. This model describes the transport of multiple ions in a cell of a REED module. The model has been validated against experimental data for dialytic recovery of some monoprotic carboxylic acids. Static and dynamic investigations have been performed to provide a better understanding of competitive transport through ion selective membranes under current load conditions.

Using modelling the influence of fouling will be investigated. In particular, the current reversal will be modeled for development of an optimal operation model.

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