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On controllability of an integrated bioreactor and periodically operated membrane separation process

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Abstract:

Investigation of integrated processes involves challenges at both design and control levels, these can mainly be associated with different dynamic behaviors of the individual units plus their interaction. Therefore, the design and operation of the integrated system constitutes a key issue. In order to understand the controlled operation of the integrated process, it is convenient to use a model based approach supported by experimental evidence.

Recently, an integrated bioreactor and electrically driven membrane separation process (Reverse Electro-Enhanced Dialysis - REED) has been proposed as a method for intensification of lactic acid fermentation (Rype, 2003). This fermentation has been studied extensively driven by an increasing number of applications of the potential fermentation products. The main limitation of lactic acid bioproduction is that lactic acid bacteria normally are impaired by product inhibition at a certain lactate concentration level. Hence, productivity can be enhanced by the *in situ* lactate removal from the cultivation broth during pH controlled fermentation. This can be done by means of ion exchange membranes and electrical potential gradients. The novelty of the integrated process lies on the innovative REED technology, where lactate ions are exchanged by hydroxide ions. This allows the lactate removal and simultaneously facilitates the pH control in the fermenter. Long operation time is achieved by reversing periodically the polarity of the imposed electrical field to significantly reduce the influence of membrane fouling.

Previously, the REED and fermentation processes have been modeled and investigated separately (Prado-Rubio *et al.*, 2011a; Boonmee, 2003). Additionally, a simple quasi-sequential strategy for integrated process design and control structure development has been proposed (Prado-Rubio *et al.*, 2011b). The main purpose of this first attempt of process integration was to predict the productivity improvements and to reveal to which extend the REED module can facilitate the pH control in the fermenter. There, the membrane and reactor unit interactions are exploited to substantially increase the lactate productivity and substrate utilization compared to a conventional fermentation with a crude control of pH. Nevertheless, the proposed pH control structure is unable to tightly control the pH in the fermenter, which may result in a loss of productivity. The purpose of this contribution is to discuss the controllability of the integrated system, focused on the role of the REED module within the process. Interestingly, there are potential solutions either from process and control structure design such as: i. Account for the productivity enhancement earlier in the integrated process design, ii. Use multiple REED units activated sequentially or iii. Try to avoid the controllers fighting by a more appropriate control structure design. Hopefully merging those ideas, an improved strategy for the integrated process design and control development can be proposed.

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