CONTINUOUS MEMBRANE FERMENTOR SEPARATOR FOR ETHANOL FERMENTATION

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Continuous membrane fermentor separator for ethanol fermentation

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CONTINUOUS MEMBRANE FERMENTOR SEPARATOR

FOR

ETHANOL FERMENTATION

A Dissertation submitted to the

Department of Chemical and Nuclear Engineering
College of Engineering
Division of Graduate Education and Research
UNIVERSITY OF CINCINNATI

in partial fulfillment of the
requirement for the degree of

DOCTOR OF PHILOSOPHY

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I hereby recommend that the thesis prepared under my supervision by CHUNG-WON CHO

entitled CONTINUOUS MEMBRANE FERMENTOR SEPARATOR FOR ETHANOL FERMENTATION

be accepted as fulfilling this part of the requirements for the degree of DOCTOR OF PHILOSOPHY

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ABSTRACT

Ethanol fermentation by yeast has received renewed interest because of the petroleum shortage and the need for renewable resources. However, there are limitations in conventional ethanol fermentation technologies, such as product ethanol inhibition, low yeast concentration, high energy cost for ethanol recovery, etc.

The inhibiting effect of ethanol on yeast growth and ethanol production has been studied using the strain Saccharomyces cerevisiae NRRL-Y-2034 under anaerobic conditions. Batch and continuous fermentation data were fitted to a kinetic model incorporating a generalized nonlinear relationship of ethanol inhibition and Monod dependence of glucose.

The integration of continuous fermentation and separation of ethanol in the same unit to enhance the performance of bioreactor has been proposed. Pervaporation with ethanol selective silicone rubber hollow fiber membranes was considered for separation. This is called the "CONTINUOUS MEMBRANE FERMENTOR SEPARATOR."

A laboratory scale Continuous Membrane Fermentor Separator unit utilizing a shell and tube configuration was designed and fabricated to be easily assembled and disassembled. Two types of continuous fermentation experiments were carried out: fermentation with dead membranes (membranes were in place but they were inactive) as the reference, which was the conventional continuous fermentation and; the other was fermentation with live membranes through which ethanol was continuously removed by pervaporation from the fermentor, which was the Continuous Membrane Fermentor Separator.

Relative to conventional continuous fermentation, performance of the Continuous Membrane Fermentor Separator results in higher yeast cell densities, reduction of ethanol inhibition, longer residence time of substrate, more glucose consumption, and recovery of clean and concentrated ethanol; these are called "Membrane Effects." Comparing both processes, a 20% increase in ethanol productivity over conventional fermentation was achieved and pervaporated ethanol concentration was 7 times higher than that in the residue.

A mathematical model was developed and used to determine the effects of design and operation parameters of

the Continuous Membrane Fermentor Separator, including dilution rate, dimensionless membrane volume, substrate concentration, membrane properties, etc. Computer simulation results indicated that the Continuous Membrane Fermentor Separator could provide significant improvements not only in ethanol productivity but also in glucose consumption for highly concentrated substrate when the dimensionless membrane volume and/or permeability of ethanol was increased. In addition, the analysis also predicts a dimensionless membrane volume minimal enough to obtain maximum ethanol productivity.

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DEDICATION

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