Integrated process for bioethanol production using immobilized yeast cells in calcium-alginate films and hybrid composite pervaporation membrane.

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Highlights

- Yeast cells were immobilized in calcium alginate film casted on a microchannel.
- Immobilized cells produced a higher bioethanol yield than free yeast cells.
- Silicalite-1 / PDMS pervaporation membrane was synthesized for ethanol separation.
- An integrated reaction-separation device is being tested for bioethanol production.

1. Introduction

One of the most popular and promising renewable fuel alternatives is bioethanol [1]. Techniques for immobilization of microorganisms could help to improve fermentation processes. Calcium-alginate gel has showed promising results [2,3]. Productivity of the fermentation process can be markedly improved by continuous selective removal of ethanol [4]. This separation of ethanol can be achieved using pervaporation membranes [5,6]. In this work, fermentation of sugar for production of bioethanol was carried out by Saccharomyces cerevisiae cells immobilized in a non-conventional calcium alginate thin film on a microchannel surface. Furthermore, a silicalite-1/poly dimethyl siloxane composite pervaporation membrane was synthesized for ethanol separation. The alginate film, and SiO2/PDMS membrane is currently being tested in an integrated microreactor device for the continuous production and separation of bioethanol.

2. Methods

Mixtures of sodium alginate with Saccharomyces cerevisiae were dropped into calcium chloride solutions, and casted in an acrylic plate with carved microchannels (1 mm deep) to form calcium alginate films. Free yeast cells (non-immobilized) were prepared to be used as control. The amount of ethanol produced by fermentation was determined at time intervals. Ethanol concentration was measured by gas chromatography. Pervaporation membranes were prepared with Sylgard 184 polydimethylsiloxane (PDMS), isooctane, and silicalite-1. The membranes were casted in an acrylic mold (7 cm radius x 1 mm depth) created with Computer Numerical Control machine. A pervaporation process was installed as shown in Figure 1. The content of ethanol in the retentate side was determined using gas chromatography and used to calculate the flux and separation factor of the membrane.

3. Results and discussion

The performance of the batch fermentation process with free cells and yeast cells immobilized on different calcium alginate films was studied. The results showed that after 3 hours of fermentation, the yeast immobilized in alginate films provided overall better performance compared with free cells. The mean ethanol concentration was 0.046%, 0.042%, 0.048%, and 0.047% for fermentation with calcium alginate films prepared with sodium alginate and calcium chloride concentrations of 3%-3.5%, 3%-4%, 4%-3.5%, and 4%-4% respectively. Whereas the mean ethanol concentration was 0.032% for fermentation with non-immobilized cells. Silicalite-1/poly dimethyl siloxane composite pervaporation membranes were synthesized and used for ethanol separation. Figure 2 shows the experimental results of flux and separation factor as a function of silicalite-1/PDMS ratio. Flux decreases with increasing silicalite-1 content implying a facilitated transport of ethanol molecules in a membrane with less silicalite-1, while on the opposite, separation factor increases with the amount of silicalite-1. From our results, the membrane with silicalite-1/PDMS ratio of 3:1 could be considered the best candidate for practical applications.

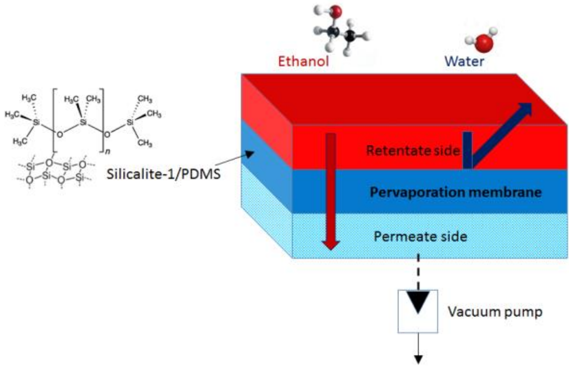
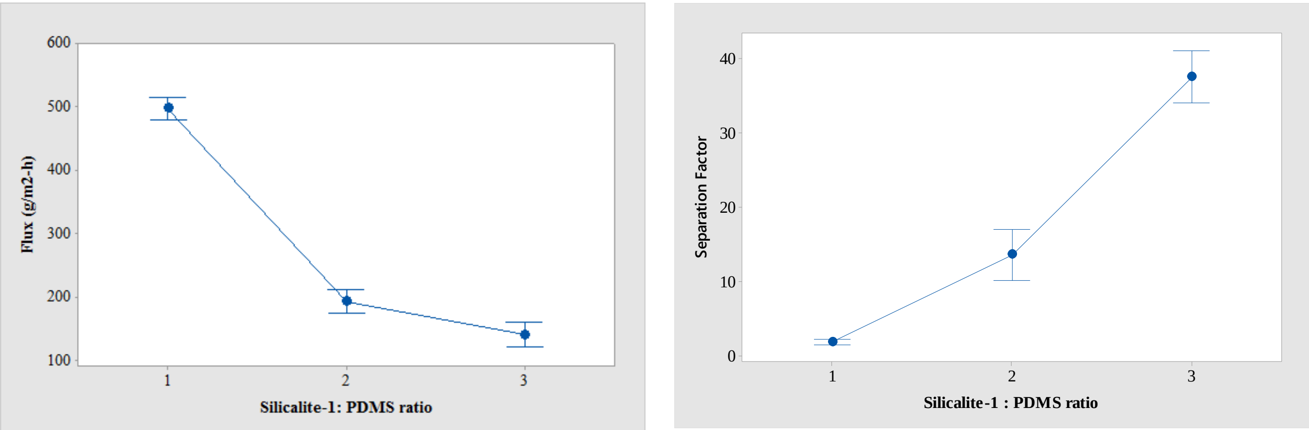


Figure 1. Schematic diagram of the pervaporation process.



(a) **(b)**

Figure 2. (a) Comparison for the membrane flux as a function of the Silicalite 1:PDMS ratio. (b) Comparison for the membranes separation factor as a function of Silicalite-1:PDMS ratio. Bars represents 95% confidence intervals for the mean.

4. Conclusions

Yeast was immobilized in thin films of calcium alginate on a microchannel surface, instead of the typical spherical bead configuration. Immobilized yeast in the films exhibited a higher ethanol productivity than free-yeast cells. Also, hybrid composite pervaporation membrane synthesized with a 3 to 1 ratio of silicalite-1 to poly dimethyl siloxane showed promising results, with a flux of 140.6 g/m^2 h ± 19.3 and a separation factor of 37.52 ±3.55. The performance of both the alginate film with immobilized cells and the customized hybrid membrane suggests interesting potential application in an integrated reaction-separation device for the production and purification of bioethanol, which is currently under current progress. The results will be presented in the full manuscript.

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Keywords
Immobilized yeast; bioethanol production; calcium alginate films; silicalite-1; polydimethyl siloxane pervaporation membrane.