Coupling of Pervaporation system with Fermentation Process

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Abstract

The ethanol fermentation process using beet molasses as the feedstock has been studied. The fermentation process, which was coupled with a membrane separation unit (Pervaporation), was compared to a conventional batch process. Ethanol was produced by *Saccharomyces cerevisiae* ATCC 9763 and recovered by pervaporation system using a composite polydimethylsiloxane (PDMS) membrane with 10 µm thickness and 0.0132 m^2 surface area. Initial sugar concentration was adjusted to 60g/l and fermentation lasted for 120 hours.
Sugar consumption, ethanol production, cell growth and also Flux and Selectivity of membrane were measured by a function of time. Sugar conversion, ethanol productivity and cell yield in the coupled system were %94.25, 0.69 $\frac{gr}{lit.hr}$ and 0.107 $\frac{gr\ cell}{gr\ sugar\ utilized}$ respectively. Also average flux and selectivity of 0.204 $\frac{kg}{m^2 \times hr}$ and 7.993 respectively were achieved.

Keywords: Ethanol fermentation, Pervaporation, PDMS, *Saccharomyces Cerevisiae*

1. Introduction

Alcohol fermentation has been extensively researched. Ethanol is its main product and is becoming increasingly important due to its possible application in liquid fuels. Production of ethanol by fermentation in simple batch or continuous fermentors is limited by toxicity of the product. Because the fermenting microorganism, usually *Saccharomyces cerevisiae*, cannot tolerate more than about 10-12% by volume of ethanol, it is necessary to start with a relatively dilute sugar solution, in order to achieve complete conversion. The large amount of water carried through the process results in high costs for large process equipment for fermentation and subsequent separation of ethanol by distillation, which needs a high amount of

energy [5]. It has been recognized that if ethanol separation is combined with fermentation there will be a reduction in the cost of process. When ethanol is removed directly from the fermentor, or by recycling the contents of a continuous fermentor through a separation device, which retains cell viability, it is possible to completely convert a much more concentrated feed [6].
Pervaporation is well known as an efficient separation method for azeotropic mixtures or similar boiling point mixtures, compared to distillation. From the point of saving both energy and cost, for most organic liquid mixtures that can be separated by distillation pervaporation is a better choice. Therefore, pervaporation has attracted a lot of attention and many studies have been reported [4].
In this article the results of fermentation process coupled with a pervaporation system are presented and are compared with conventional batch fermentation.

2. Materials and Methods

Microorganism Ethanol producing yeast *Saccharomyces cerevisiae* ATTC 9763 was obtained from IROST (Iranian Research Organization of Science and Technology), which were kept on YM agar slants at 4 $^{\circ}C$ and subcultured every month. The composition of YM agar medium was as follows (*g/l*): peptone 5; yeast extract 3; malt extract 3; glucose 10, and agar 15.

Medium starter culture was prepared by transferring a full loop of yeast from the YM agar slant to 100 ml of broth containing (*g/l*): sucrose 100; yeast extract 4; peptone 4; KH_2PO_4 1; $MgSO_4$ 0.1; $CaCl_2$ 0.1 and $(NH_4)_2SO_4$ 1.5 which was sterilized at 121 $^{\circ}C$ and 15 psi for 15 minutes. The starter culture was incubated at 30 $^{\circ}C$ and 250 *rpm* for 24 h.
Beet molasses obtained from Karaj sugar Industry (Karaj-Iran) with Brix 73.16 and pH 6.4 was used as the feedstock for ethanol fermentation which was diluted to 6% (*w/v*) sugar medium. pH was adjusted between 6.4-6.6 and was sterilized at 121 $^{\circ}C$ and 15 psi for 15 minutes.

Apparatus The fermentor was a 5*l* Discovery100 manufactured by *New Brunswick Co. Ltd.* coupled with a pervaporation module including the composite polydimethylsiloxane (PDMS) membrane with 10 µm thickness and 0.0132 m^2 surface area.
Fermentor was autoclaved at 121 $^{\circ}C$ and 15 psi for 15 minutes. And pervaporation module was sterilized by circulation of 70% (*v/v*) ethanol solution through the module.

Batch fermentation In order to investigate the inhibition, by ethanol, of fermentation, a conventional batch process was conducted with initial sugar concentration of 60 (*g/l*) and lasted for 120 h.

Batch fermentation with Pervaporation fermentation with simultaneous ethanol recovery by PDMS membrane was carried out with initial concentration of 60 (*g/l*). Ethanol recovery started after 24 h by circulating the fermentation broth through

membrane module with a perstaltic pump with flow rate of 100 (*l/h*). The downstream pressure was kept at 1 mmHg. Permeate was collected in a glass trap and condensed in a liquid nitrogen flask, which was weighted every 4 h. All fermentations were carried out at 30 $^{\circ}C$ and 150 *rpm* for 120 h. under anaerobic conditions.

Analytical methods The sugar concentration was determined by the phenol-sulfuric acid method. Ethanol concentration was measured by FID gas chromatography using a capillary column (Acme 6000 GC manufactured by *YOUNGLIN Co. Ltd.*). Yeast concentration was measured by cell dry weight method.

3. Results

Ethanol concentration in Batch and batch with PV fermentations were illustrated in Fig. 1. In comparison of batch fermentation with batch process with PV, ethanol concentration in the process with continuous ethanol recovery was kept rather constant under the inhibition level.

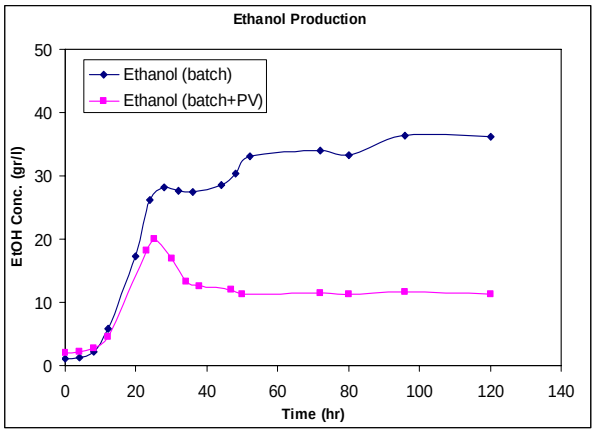

Fig.1 Ethanol production curve

As it is shown in Fig.2. rate of sugar consumption in the fermentation system coupled with PV is higher than the batch process without PV. Therefore by continuous ethanol removing from fermentation broth, the fermentation time decreases rather than process without ethanol recovery.

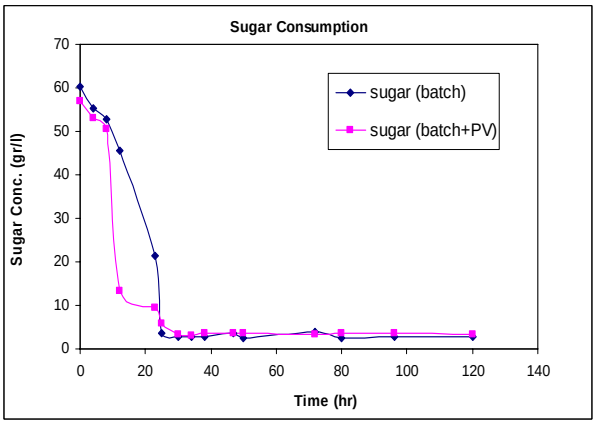

Fig.2. Sugar consumption curve

Fig.3. Illustrated that cell density in the process with PV is higher than conventional batch fermentation. So continuous removal of ethanol from fermentation broth reduces the toxic effect of ethanol on yeasts and cell growth rate increased.

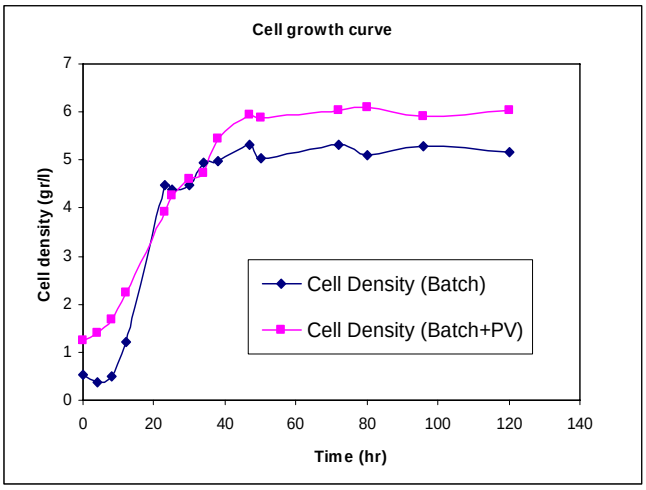

Fig.3 Cell growth Curve

A comparison between yields of batch fermentation and batch process with PV is presented in Fig.4. As it is shown in this figure ethanol productivity in the process with continuous ethanol removal is much higher than productivity in Conventional batch fermentation. Also sugar conversion in the process with PV is more than process without PV.

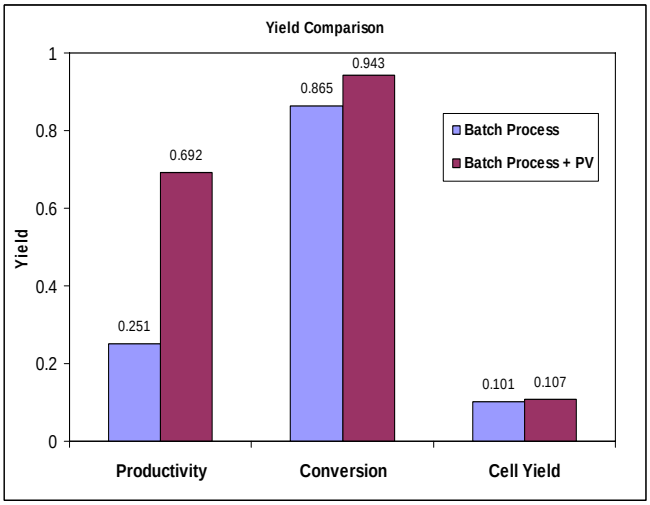

Fig.4 Yields Comparison

4. Conclusion

In this study, a more highly concentrated ethanol solution could be produced by using PDMS membrane in the coupled fermentation/pervaporation process comparing with the process with continuous product removal. Therefore it is possible to produce a clear concentrated ethanol solution which is better and easier to be purified in distillation process.

When ethanol is removed directly from the fermentor, by recycling the contents of fermentation broth through the membrane module, which retains cell viability, it is possible to completely convert sugar in a shorter fermentation time, which reduces the costs of process from a process point of view based on membrane separation techniques.

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