BAG-IN-BOX TECHNOLOGY: Membrane Filtration of Cucumber Fermentation Brine

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ABSTRACT

A major goal in producing process-ready, brined cucumbers is the reclaiming of the brine obtained from the fermentation for use in other products. This article summarizes research results obtained from the use of membrane filtration technology to remove microbial cells and other sediments from cucumber fermentation brine. The effects of process factors (filter pore size, flow rate, microbial cell concentration and pressure) on the rate of filtration are presented. In addition, a review of the applications of membrane filtration technology in food processing is given in the Appendix section of the article.

INTRODUCTION

A major benefit of producing process-ready, brined cucumbers, as proposed by Fleming et al. (2002), is the use of the entire container contents in finished products. The cucumbers are washed and blanched before they are conveyed into the bag. The brine components, including salt, are food-grade. The cucumbers are fermented by an added food-grade culture of lactic acid bacteria in a closed container, sealed from the environment. The low concentration of salt used does not require that it be leached from the fermented cucumbers before they are manufactured into finished products. Although the lactic acid content in the fermented cucumbers may be too high for certain products, strategies have been proposed for using the fermented cucumbers, as well as brine, in finished products (Johanningsmeier et al., 2002). Thus, the fermented brine is viewed as a valuable food component, rather than waste that must be treated before discharge into freshwater bodies, as in current technology.

For use of the fermentation brine in finished products, however, it must be clarified. This is because of cloudiness caused by cells of lactic acid bacteria used for fermentation. During fermentation, the bacterial cell population may reach over 1 billion cells per milliliter. It takes only about 10 million cells per milliliter to make the brine visually cloudy.

Various membrane separation processes have been used to separate components from liquids in the food industry, as is briefly reviewed in the Appendix of this paper. We chose to explore the potential of microfiltration/ultrafiltration for clarifying spent cucumber fermentation brines. We studied factors affecting the filtration of brine from one of our bag-in-box experiments. A mathematical model of the process was developed by Fasina et al. (2001).

MATERIALS AND METHODS

Brine

The brine of fermented cucumbers was obtained from experimental run no. 2 of the bag-in-box procedure (Fleming et al., 2002). Size 2B cucumbers (33-38 mm diameter) were washed, blanched, cooled, and transferred into a 300-gal bag (in box). The cover brine consisted of 4.4% NaCl (w/v), 118 mM acetic acid (as vinegar), 40 mM $Ca(OH)_2$, and 26.7 mM $CaCl_2$. Cucumbers occupied about 55% and brine 45% (w/v) of the contents of the bag. The brine-cucumber mass was inoculated with *Lactobacillus plantarum* MOP3 M6 (a culture that does not produce CO_2 from malic acid). After adding all components to the bag, the bag was heat-sealed and allowed to ferment/store at ambient temperature for 2 months. The cucumbers and brine were then removed from the bag. The cucumbers were processed into finished products by a commercial pickle company, and the brine was used for the current study.

Filtration System

A schematic diagram of the laboratory-scale, crossflow filtration system (model DC-10L, Amicon Co., Lexington, MA) used for the experiments is shown in Figure 1. The unit consisted of a 20-L reservoir and a variable speed, positive-displacement pump to pressurize and re-circulate the feed solution. Pressure and flow rates were controlled by means of a pump, a ball-type, back pressure valve and two pressure gauges attached to the inlet and outlet of the membrane filter. Flow rates were measured with a direct reading, block-type flowmeter (model P-32462-00, Cole Parmer Instrument Co., Vernon Hills, IL) for the retentate and a turbine-type flometer (model S-111, McMillan Co., Georgetown, TX) for the permeate. The readings from the permeate flowmeter were automatically sent to and stored in a computer via a DaqBook Data Acquisition System

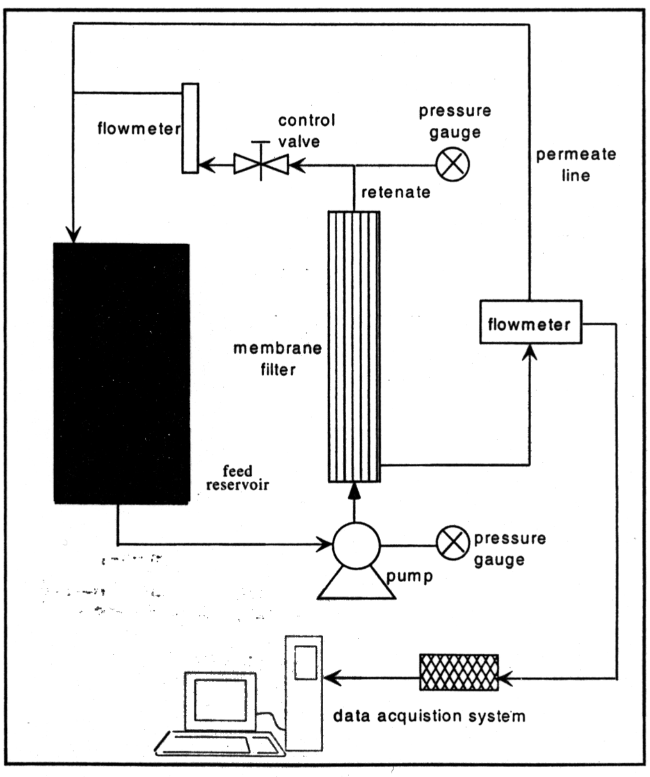

Figure 1. Schematic diagram of crossflow filtration system.

(IOtech, Inc., Cleveland, OH) every 15 sec. The flux rate was expressed in L per square m per hr (LMH) and was numerically equal to the ratio of the flow rate to the membrane filter area.

Two hollow fiber, polysulfone filtration membranes with pore sizes of 500K NMWC (500,000 nominal molecular weight cutoff) and 0.2 µm were used for the filtration experiment (models UFP-500-E-6A and CFP-2-E-6A, A/G Technology Co., Needham, MA). Each membrane was 63.5 cm in length and 3.2 cm in diameter, and had a total filtration area of 0.28 m². These membranes were chosen for our tests based on previous studies on removal of bacteria and yeasts from liquids (Merin et al., 1983; Nagata et al., 1989; Redkar and Davis, 1993).

Microbial and Chemical Analyses

General procedures for enumeration of microorganisms were carried out according to Fleming et al. (1992). High performance liquid chromatography (HPLC) analyses of organic acids and sugars were carried out by the procedures of McFeeters (1993). NaCl was determined by titration with standard $AgNO_3$ using dichloro-fluorescein as an indicator (Fleming et al., 1992).

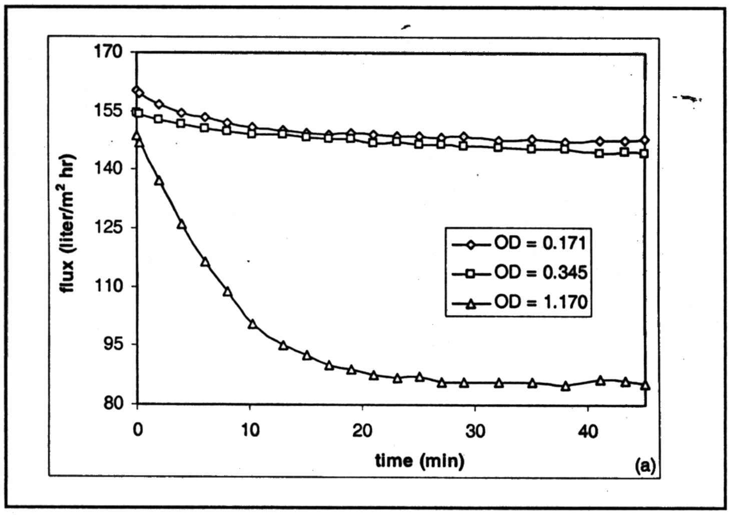

Figure 2. Flux decline curves of brine with different cell concentrations. Membrane pore size = 0.2 µm; transmembrane pressure = 103 kPa; flow rate = 11.6 L/min.

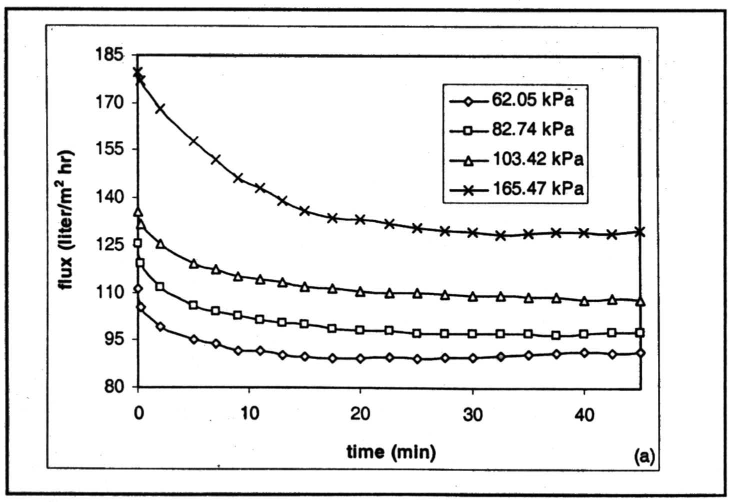

Figure 3. Flux decline curves at different transmembrane pressures for brine (OD = 0.171) filtered through 500,000 NWCO membrane; flow rate = 11.6 L/min.

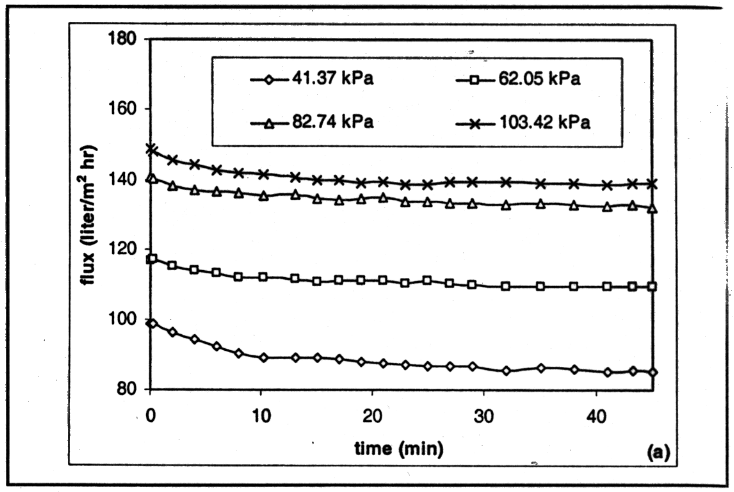

Figure 4. Flux decline curves at different transmembrane pressures for brine (OD = 0.171) filtered through 0.2 µm membrane; flow rate = 11.6 L/min.

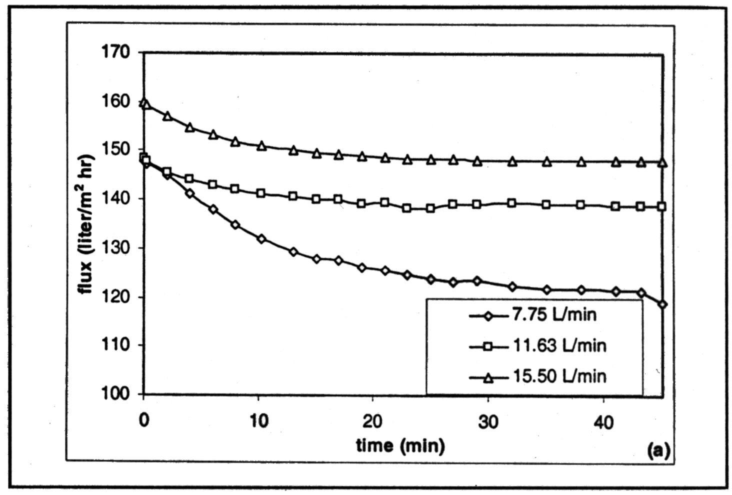

Figure 5. Flux decline curves at different flow rates for brine (OD = 0.171) filtered through 0.2 µm membrane. Transmembrane pressure was 103 kPa.

RESULTS AND DISCUSSION

Many factors may influence the rate at which cucumber fermentation brine is clarified by membrane filtration. Important factors, which we studied, are pore size of the membrane, pressure on the membrane (or transmembrane pressure, TMP), microbial cell concentration, and brine flow rate. In general, the brine flux dropped most significantly within the first 15 min of filtration, and then continued to decline slowly as illustrated in Figures 2-5. The decline in flux over the course of filtration is due to fouling or clogging of the panes of the membrane during the filtration process.

Cell density was a major factor influencing brine flux (Fig. 2). At OD = 1.170 (5.4 x 10^8 CFU/mL), flux decreased greatly within the first 15 min, compared to OD = 0.171 (4.5 x 10^7 CFU/mL) or OD = 0.345 (2.35 x 10^8 CFU/mL). This demonstrates the importance of reducing cell density in the brine before filtration. Simply allowing cells in the brine to settle may greatly facilitate filtration. Also, choosing a fermentation culture that readily settles can be helpful.

Pore size of the membrane greatly influences flux, as illustrated in Figure 3 (500,000 NWCO membrane) and Figure 4 (0.2 µm membrane pore size). The 0.2 µm membrane should be adequate for

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ABOUT THE COVER:

Bulk storage in brine has been an economic means of extending the processing season of pickling cucumbers since before the 1930's (1). When larger sizes of cucumbers began to constitute a higher proportion of the crop in the 1960's, bloater formation resulted in buoyancy force sufficient to rupture tank heading timbers (2), but purging of CO_2 from the brine reduced bloater damage and buoyancy forces within the tank (3). However, use of high concentrations of salt in brine storage requires washing of the excess from the brine-stock before conversion to finished products, which requires the use of aeration ponds to biodegrade the organic matter (4), but still results in problems in the handling of salt and other non-biodegradable wastes. The use of fiberglass and polyethylene tanks (5) has reduced salt leakage that was prominent with wooden tanks (1-3), but relatively high salt concentrations are still used to serve as insurance against vagaries of nature due to tanks being open to the atmosphere. Closed tanks have been considered by the industry (6), but various factors have resulted in modernized brine yards of open-top, fiberglass and polyethylene tanks and a waste handling system (7). This issue of the journal is devoted largely to summarizing efforts to design and test a pilot system (8) for preserving "process-ready," brined cucumbers with improved quality and reduced wastes, and with intended benefits to the producer and processor of pickling cucumbers.

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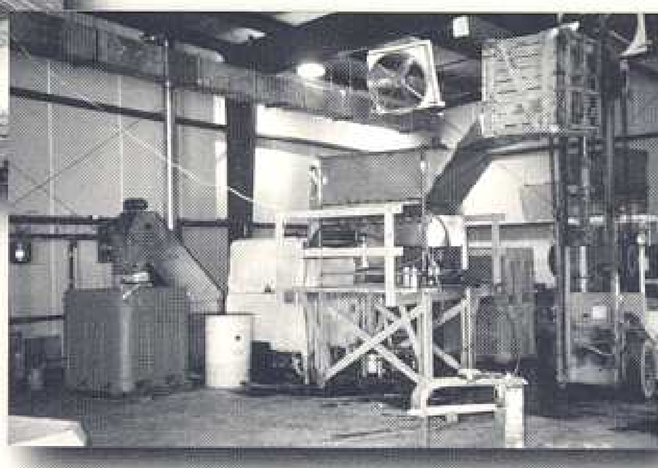
Bulk Storage in Brine Since the 1930's



A journal reporting research relating to brined, salted and pickled vegetables and fruit.