Microfiltration with chemistry treating of commercial membranes and microporous tubes for retention of bacteria \textit{E. coli} on processing of wastewater of dairy products

Renata N. Haneda\textsuperscript{a}\textsuperscript{*}, Rogério Ikegami\textsuperscript{a}, Carlos A. Fortulan\textsuperscript{a}, Benedito M. Purquerio\textsuperscript{a}, Elson Longo\textsuperscript{b}, Sérgio R. Fontes\textsuperscript{a}

\textsuperscript{a}Department of Mechanical Engineering, São Carlos School of Engineering, University of São Paulo — USP, Av. Trabalhador São-Carlense, 400, C.P. 359, 13566-590 São Carlos, São Paulo, Brazil

\textsuperscript{b}Department of Chemistry, University of São Carlos — LIEC/UFSCar/Unesp, São Carlos, São Paulo, Brazil

Received 22 October 2005; accepted 4 March 2006

1. Introduction

Microfiltration is the oldest membrane filtration process and shows up to now the largest market for technical membranes and membrane modules. Microfiltration (MF) is a pressure-driven membrane process for the separation of fine particles, microorganisms and emulsion droplets [3]. In technical applications crossflow microfiltration has become an established process for the separation of microparticles, bacteria and emulsion droplets in a variety of industrial applications [5]. The microfiltration process is also utilized in the dairy products, due to its capacity to retention of bacteria, fats and whey proteins [1], but the retention of the bacteria is not 100% effective without a material bactericide.

Silver has been used for centuries as bactericide. One of the most fascinating properties of silver is its bactericidal quality [2]. Small concentrations of silver or silver salts kill bacteria by chemically affecting the cell membranes, causing them to break down. Bacteria do not develop resistance to silver, as they do to many antibiotics. Literature [4] confirmed that the \textit{E. coli} cells were damaged, showing formation of “pits” in the bacteria cell wall, while the silver nanoparticles were found to accumulate in the bacterial membrane.

In this work membranes were chemically prepared for the impregnation with silver citrate solution by adsorption for a better bacteria retention in the microporous structures. From the image analysis of the scanning electronic microscopy (MEV), it was found that the impregnation of nanoparticles of silver in the membrane was successful. Experiments were carried out using a laboratory unit of microfiltration with transmembrane pressure of 100, 200, 300 and 400 kPa, and with tangential flow rates corresponding to the turbulent flow. The transmembrane flow was analyzed with membranes without and with adsorption of silver, taking into account the fecal and total coliform by 20th Edition of the
Standard Methods for Examination of Water and Wastewater.

2. Materials and methods

An experimental study was made on microfiltration process of suspensions of bacteria from wastewater of dairy industry applied in the retention of group coliforme (Escherichia coli). In this study was used a microporous tube of alumina and commercial ceramic membranes of nominal porous size of 0.4 and 1.2 µm, respectively. The microporous tube was burnt at temperature of 1400°C and characterized by the introduction of mercury technique. The microporous tube and tubular membrane were subjected to impregnation of metallic silver bactericide obtained from silver citrate. The characterization of morphology and composition were accomplished using of technique of electronic microscopy (MEV).

Experiments of wastewater of dairy industry processing were accomplished during 30–60 min, with the objective of analyzing of the bacteria E. coli retention. The permeate was analyzed following the standards of the 20th Edition of Standard Methods for the Water and Wastewater and all the experiments followed the sterilization patterns to minimize the possibility of contamination of the tubular filter. The physiology of bacteria in solution was controlled with the pH of 6–7 and temperature between 25 and 30°C.

A chemistry impregnation was done in tubes with the prepared solution of silver nitrate in the proportion of 3 mol of citric acid for 1 mol of silver nitrate. After the impregnation through capillarity the ceramic tubes were burnt in nitrogen atmosphere for the formation of metallic silver.

All process was studied in a experimental setup with capacity for the variation of transmembrane pressure from 1 to 10 bar and flow from 0 to 500 L/h. In the experimental setup the procedure for washing and sterilization were made in a housed hydraulic circuit before and after of filtration, with washing flow of neutral detergent, flow of formaldehyde (40%) solution and baths of heat water in the housing. After the using of the ceramic structures, the tubes were immersed in enzymatic detergent during 8 h and heated for the elimination of organic matter.

3. Results and discussion

Fig. 1 presents the results of the transmembrane flow in function of Reynolds number. The results

![Graph](image1.png)

![Graph](image2.png)

Fig. 1. Transmembrane flow (L/h m²) in function of Reynolds number: (a) process with commercial membrane (1.2 µm) — with impregnation of Ag; (b) process with microporous tube (0.4 µm) — without impregnation of Ag.
are obtained from the process with commercial membrane of German origin (1.2 µm, Fig. 1a) and with microporous tube (0.4 µm, Fig. 1b), respectively. The microporous tube was manufactured in Department of Mechanical Engineering of University of São Paulo, Brazil, using the extrusion method and porosity control. In Fig. 1 the transmembrane flow increased in function the transmembrane pressure and Reynolds number. Besides the presence of silver in the commercial membrane (Fig. 1a), any alterations in the mechanism of mass transfer and variations in Sherwood number was observed. The filtration results from microporous tube of nominal porous size of 0.4 µm presented values of transmembrane flow in agreement with the commercial membrane of 1.2 µm. The microporous tube presented satisfactory retention of bacteria (E. coli) in all the conditions of transmembrane pressure and turbulent flow without the impregnation with silver. The commercial membrane of 1.2 µm presented the bacteria retention only in the condition of laminar flow and with impregnation with silver; in this case the influence of silver as bactericide was evident.

Table 1 presents for different transmembrane pressures and Reynolds numbers, the number of units of bacteria colonies in grams (UCB/g) in samples of permeate process with commercial membrane. It was observed in the condition of \( Re = 2800 \) and transmembrane pressure \( \Delta P_t \) between 1 and 3 bar, the absence of UCB/g in the process. Table 1 also presents results of “UCB/g” for the samples of permeate process with microporous tube of 0.4 µm; in the condition of \( Re = 18,000 \) and \( Re = 25,000 \) and the total retention of bacteria observed.

4. Conclusions

The filtration results from microporous tube of nominal porous size of 0.4 µm presented

Table 1
Units of colonies of bacteria by gram (UCB/g) of fecal coliform (E. coli) group in samples of permeate in the end of process

<table>
<thead>
<tr>
<th>Reynolds no.</th>
<th>( \Delta P_t = 1 ) bar</th>
<th>( \Delta P_t = 2 ) bar</th>
<th>( \Delta P_t = 3 ) bar</th>
<th>( \Delta P_t = 4 ) bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial membrane of 1.2 µm — UCF/g vs. Re</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2800</td>
<td>Saturation</td>
<td>Saturation</td>
<td>Saturation</td>
<td>Without impregnation</td>
</tr>
<tr>
<td>2800</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>One impregnation</td>
</tr>
<tr>
<td>2800</td>
<td>Smaller of 1</td>
<td>0</td>
<td>0</td>
<td>Twice impregnation</td>
</tr>
<tr>
<td>Reynolds no.</td>
<td>( \Delta P_t = 1 ) bar</td>
<td>( \Delta P_t = 2 ) bar</td>
<td>( \Delta P_t = 3 ) bar</td>
<td>( \Delta P_t = 4 ) bar</td>
</tr>
<tr>
<td>Microporous tube of 0.4 µm — UCF/g vs. Re</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>21,000</td>
<td>0</td>
<td>Smaller of 1</td>
<td>0</td>
<td>Smaller of 1</td>
</tr>
<tr>
<td>18,000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

References


