Recovery of valuable compounds from dairy wastewaters using membrane technology

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Introduction

Efforts worldwide, for transition to a circular economy, aim at minimizing waste and maximizing utilization of resources. Therefore, this work is focused on the recovery of valuable marketable products from particular dairy industry effluents by employing the cost effective membrane separation technology. A particular type of "flushing stream" is dealt with, resulting from washing of dairy product processing equipment (i.e. pipes, tanks, etc.) with fresh water that takes place immediately after each processing run. Such streams loaded with organic matter (mainly proteins and polysaccharides, in proportion depending on dairy product processed) are commonly directed to the plant WW treatment facility. This study, in the context of an EC-funded project, aims at recovering/recycling valuable compounds, thus reducing the organic load of the wastewater treatment plant and recycling/conserving water.

Material and Methods

The experimental set-up used for the experiments under constant pressure includes a SEPA-ST model cylindrical test cell (Osmonics Inc., Minnetonka, MN) accommodating a membrane disk. All tests were performed with fluid agitation (250 rpm). The imposed filtration pressure was held constant via a nitrogen line, connected to the SEPA-ST cylindrical cell. The prevailing trans-membrane pressure (TMP) was monitored by a pressure transducer (Cole-Palmer Instr. Co., USA) connected at the cell inlet. The permeate flux was determined by measuring the permeate volume with an electronic balance (Mettler Toledo PB3001), which was interfaced with a computer for continuous data acquisition. The main characteristics of the various membranes employed in this study are summarized in Table 1. It is mentioned that the so-called "flushing" stream from milk processing was used as feed in all separation tests.

Table 1. Membrane characteristics.

Model (Manufacturer)	Type	Material	MWCO (Rejection)
ME 24/21 ST (Whatman®)	Microfiltration	Mixed cellulose ester	0.2 μm
M-U2540 (AMI® Membranes)	Ultrafiltration	Polyacrylonitrile	20 kDa
GR61PP (Alfa Laval)	Ultrafiltration	Polysulfone	20 kDa
NF270 (Dow Filmtec)	Nanofiltration	Polypiperazine	97.0 % $MgSO_4$

Results and Discussion

Dead-end filtration tests were carried out, in constant pressure mode, using 3 types of membranes; one MF membrane, two UF (i.e PAN 20 kDa and PS 20 kDa) and one NF. MF tests were performed at 10 psi, whereas UF and NF runs at 30 psi. The rejection characteristics for all filtration tests are shown in Figure 1. Concerning polysaccharides, that are predominantly lactose with trace amounts of mono-saccharides and oligosaccharides, MF exhibits notable (18.5%) rejection despite its large pore size. These results suggest that lactose (360 Da), in the presence of ions (mainly divalent) may form larger polysaccharide agglomerates that are partially retained by the membrane. As expected, UF membranes have slightly better rejection characteristics, with the PS UF membrane exhibiting approx. 30% rejection of the lactose. Finally, the NF 270 membrane, due to its substantially smaller pore sizes (in the range of 250-300 Da) is capable of almost complete lactose rejection. The same trend holds for the rejection of the proteins of the flushing stream; i.e. the rejection increases with the decreasing membrane pore size (i.e MF→UF PAN → UF PS → NF). However, it should be noted that the rejection of milk proteins is substantially greater compared to lactose (i.e. between 83% to 100%). Finally, it is observed that TOC and BOD rejection measurements are within the aforementioned rejection coefficients of lactose and proteins. In particular, the TOC rejection profile is quite similar to that of lactose due to the fact that the latter is the main organic carbon contributor of the flushing stream used. Since the main objective of this study is to achieve recovery of both lactose and proteins in an efficient way, it is obvious that NF-270 is preferable exhibiting the highest (almost 100%) percentage of valuable compounds rejection; nonetheless, energy consumption should be taken into consideration to select the most appropriate membrane process for the separation of the specific waste stream. Thus, the needed permeability values for all membrane filtration processes are as follows: 12.5 LMH/bar for the MF, 4.2 and 4.7 for the UF PAN and UF PS respectively, and finally 4.0 LMH /bar for the nanofiltration.

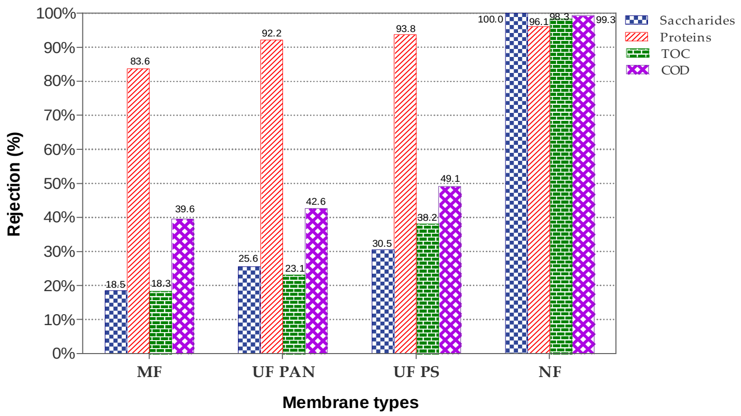

Figure 1. Membrane rejection of various parameters during lab-scale dead-end tests.

Conclusions

A particular dairy wastewater stream was effectively treated by membranes at lab-scale for recovery of saccharides and proteins. Nanofiltration membranes appear to be promising as they can achieve efficient separation under modest filtration pressure. The study is in progress to evaluate the fouling characteristics of membranes and to assess membrane process implementation at large scale, including cost estimation. Ongoing fouling and long-term tests suggest that submerged UF membranes may be preferable compared to NF membranes.

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