NANOFILTRATION OF ACID WHEY AFTER ULTRFILTRATION PROTEIN RECOVERY PROCESS

Marjana Simonič[1]

[1]*Faculty of Chemistry and Chemical Engineering, University of Maribor, Smetanova 17, Maribor, Slovenija*
e-mail: marjana.simonic@um.si

Abstract
After the ultrafiltration of acid whey, nanofiltration of permeate was performed. The use of NFT-50 membrane for whey nanofiltration was studied. Whey flux was measured, and fouling potential was determined. Some general chemical parameters of whey were measured. The results showed that chemical parameters decreased after the treatment. Filter cake was formed, and reversible fouling prevailed at 40 bar.

Introduction
Whey has been classified into sweet, which is a by-product of cheese manufacturing, and acid whey from production of fresh and cream cheese, Greek Yogurt and caseinates (Chandrapala, 2016). There is interest in new applications of whey and its derivatives (de Souza, 2010). Lactose represent 5-6 % share in whey and can be used for production of glucose and galactose by hydrolysis.
Disposal of acid whey is complicated due to its high biological oxygen demand as well as high organic matter content (COD) that leads to the need for costly water treatment facilities prior the discharge into the environment. (Chandrapala, 2016). Several methods are available for whey concentrating, such as membrane technologies (de Souza). Most researchers focus on protein fractionation. Two nanofiltration membranes were tested for lactose separation from whey (Cuartas Uribe, 2009). The best results were achieved at 2 mPa at volume dilution factor 2.06, since lactose losses were not high. Fouling problems were not detected for the performed NF tests, however, longer experiments in larger scale plant were suggested to evaluate the economic feasibility of such nanofiltration process.
The main objective of the present research was to study the fouling properties of chosen NFT-50 membrane by separating. The aim of the research was to determine optimal conditions for lactic acid whey nanofiltration using NFT-50 membrane. The results would be used for evaluation of the feasibility of a semi-industrial scale-up. Lactic acid whey permeate would be further tested for skin moisturizing application.

Experimental
Lactic acid whey at 6,32 g/100 g of dry mass (DM) was provided by Slovene dairy factory. The product was stable, stored at 4 ºC. An Osmo Nanofiltration device was used to demineralize lactic acid whey at constant temperature. Membrane NFT-50 (Osmonics) was used with MWCO 150 g/mol, an isoelectric point close to 4.00 and water permeability 2.2 L/(h.m^2.bar). Some membrane properties are seen from Table 1.

Table 1. The NFT-membrane characteristics

Parameter	NFT-50
Producer	Alfa Laval (Sveden)
pressure	1 – 55 bar
T max	50°C
pH	2-10
MWCO	150 Da
Pore	0,43 nm
Kontaktni angle	21°
Morphology	Thin film polyamide
Support	polyesther

Transmembrane pressure (TMP) was varied between 20 and 50 bar. The water permeate flux was checked every time when transmembrane pressure was increased. The chemical analysis of water was performed according to ISO standards in three replicates. The standard methods are gathered in Table 2.

Table 2. The methods used for water analyses

Parameter	Standard method	Apparatus
T (°C)	ISO 10523	Thermometer
pH	ISO 10523	pH-meter, MA 5740
A	SIST EN ISO 7887	Spectrophotometer
Turbidity (NTU)	ISO 2027-1	Turbidity-meter

Reversible fouling Fr was determined after eq.1:

$$Fr = (Jw - Js)/Jw \qquad (1)$$

Irreversible fouling *F*ir was determined after eq.2:

$$Fir = (Jw - Jwe)/Jw \qquad (2)$$

Where

*J*w = water flux through virgin membrane
*J*we = water flux through membrane after sample filtration
*J*s = sample flux

Models were determined according to Hermia (Salahi et al, 2010). *J* and *J*o are final and initial flux, *K* is constant and *t* time.

Equation (3) regarding complete pore blocking: $\ln(J^{-1}) = \ln(Jo^{-1}) - K.t$ (3)

Equation (4) regarding standard pore blocking: $J^{-0.5} = Jo^{-0.5} - K.t$ (4)
Equation (5) regarding intermediate pore blocking: $J^{-1} = Jo^{-1} - K.t$ (5)

Equation (6) regarding cake layer formation: $J^{-2} = Jo^{-2} - K.t$ (6)

Graphs were drawn where the slope represents constant *K*.

Results and discussion

The UF permeate pH was 4.75, conductivity 7.91 mS/cm and turbidity 886 NTU were determined in untreated whey. Analyses after NFT-50 filtration showed that turbidity decreased to 0.4 NTU to and we assume that fats were mostly removed, pH remained unchanged. Absorbance at 436 nm was completely removed. Measured fluxes are presented in Figure1.

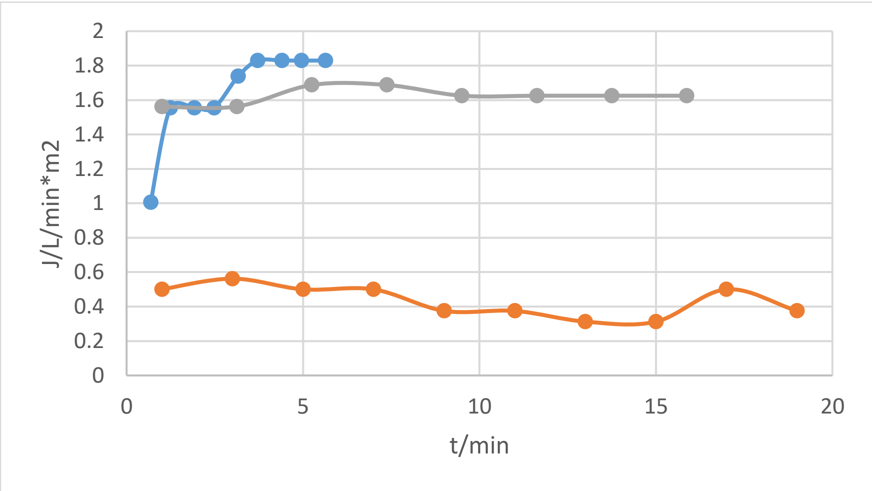

Figure 1. Flux in dependence of time: blue: millipore water, red: whey, green: millipore water after whey

Millipore water flux was determined at transmembrane pressure *TMP* from 20 bar to 50 bar using NFT-50 membrane. The reversible and irreversible fouling were determined at each TMP. The results are presented in Table 3.

Table 3: Reversible and irreversible fouling

TMP **(bar)**	***Fr***	***Fir***
20	0.61	0.4
30	0.71	0.5
40	0.79	0.11
50	0.72	0.27

It is seen that the lowest irreversible fouling was determined at 40 bar. Therefore, the experiments were continued at 40 bar in order to determine the model of clogging and physico-chemical analyses were performed at the same *TMP*.

Graph was determined according the result of eq. 3-6. Flux in dependence of time was drawn. The constant value K (the slope) while r^2 was the highest with filter cake, therefore only this kind of graph is represented (others not shown). It is seen from Figure 2 that the slope *K* was determined at 0.56 and R^2 equals 0.95.

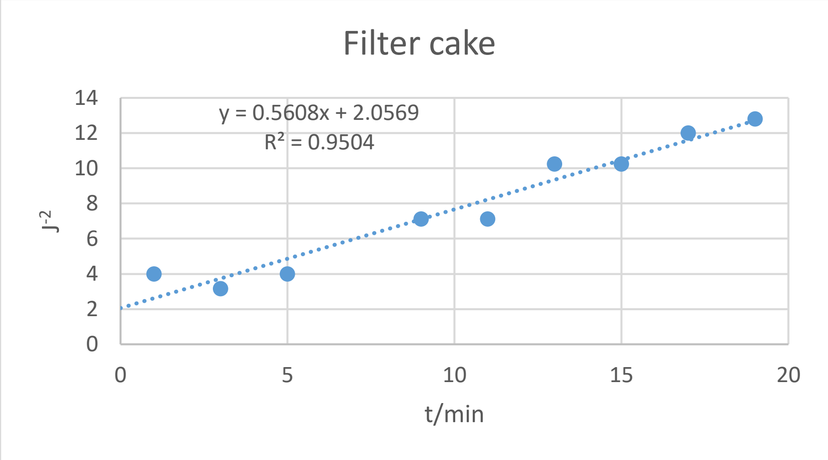

Figure 2. Flux (expressed as J^{-2}) in dependence of time representing filter cake model

The model is in accordance to cleaning: only milli pore water was used for cleaning and the flux of millipore water reached the same level as before nanofiltration started at 40 bar.

Conclusion

NFT-50 could be used in scaling up process in semi-industrial plant. Fouling was determined. The lowest irreverible fouling was observed at TMP 40 bar.

Acknowledgements

The research work was produced within the framework of the project Fractionation and processing of whey proteins and exploitation of the residue for the formation of new functional foods and food supplements (LAKTIKA).

References

[1] B. Cuartas-Uribe, M. Alcaina-Miranda, E. Soriano-Costa, A. Bes-Pia. Comparison of the behavior of Two Nanofiltration membranes for Sweet whey demineralization. Journal of Dairy Science, 90 (2007) 1094-1101.

[2] S. A. Mourouzidis-Mourouzis, A. J. Karabelas. Whey protein fouling of microfiltration ceramic membranes - Pressure effects. Journal of Membrane Science, 282 (2006) 124-132.

[3] J. Chandrapala et al., Nanofiltration and nanodiafiltration of acid whey as a function of pH and temperature, Separation and Purification Technology, 160 (2016) 18-27.

[4] M. Simonič, D. Vnučec. Coagulation and UF treatment of Pulp and paper Mill wastewater in comparison. Central European Journal of Chemistry, 10 (2012) 127–136.

[5] T. Steinhauer, M. Marx, K. Bogendörfer, U. Kulozik. Membrane fouling during ultra- and microfiltration of whey and whey proteins at different environmental conditions: The role of aggregated whey proteins as fouling initiators. Journal of Membrane Science, 489 (2015) 20-27.

[6] Salahi A., Mohsen A., Mohammadi T. Permeate flux decline during UF of oily wastewater: experimental and modeling. Desalination, 251 (2010) 153-160.

[7] Cuartas Uribe B., et al, A study of the separatioon of lactose from whey ultrafiltration permeate using nanofiltration, Desalination, 241 (2009) 244-255.