Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2014.981924

56 (2015) 3273–3277
December

Taylor & Francis
Taylor & Francis Group

Using foil membranes for demineralization of whey by electrodialysis

Jiří Ečer[a,*], Jan Kinčl[a], Ladislav Čurda[b]

[a]*MemBrain s.r.o., Pod Vinicí 87, 471 27 Stráž pod Ralskem, Czech Republic, Tel. +420 601555373; email: jiri.ecer@membrain.cz (J. Ečer), Tel. +420 725079270; email: jan.kincl@membrain.cz (J. Kinčl)*
[b]*Department of Dairy, Fat and Cosmetics, Institute of Chemical Technology Prague, Technická 5, 166 28 Prague 6, Czech Republic, Tel. +420 608571710; email: ladislav.curda@vscht.cz*

Received 28 July 2014; Accepted 7 October 2014

ABSTRACT

The aim of the experiments was to verify the possibility of using film ion-exchange membranes for demineralization of whey by electrodialysis (ED). Foil and standard ion-exchange membranes behaved similarly in process of ED of whey, capacity of ED with foil membranes was only slightly higher by 3–5%. Advantage of foil membrane usage lies mainly in their lower production costs.

Keywords: Foil ion-exchange membrane; Electrodialysis; Whey

1. Introduction

Electrodialysis (ED) is used in many food treatment technologies. Largest application of ED in food industry is demineralization of sweet or acid milk whey [1]. Optimization of this process should lead to significant investment and operating costs. Development and usage of new ion-exchange membranes with lower price or higher productivity is one of the possible ways of process improvement.

The principle of ED is based on selectivity of ion-exchange membranes rejecting cations or anions in conductive aqueous solution in direct-current electrical field [2]. There are two basic categories of ED membranes—anion exchange membranes and cation exchange membranes, which differs by type of ionic groups attached to the membrane matrix. Anion exchange membrane contains positively charged groups, passage of anions is allowed though this membrane but cations are rejected. Cation exchange membrane with negatively charged groups passes cations and rejects anions. Charged groups can be incorporated in membrane structure by two ways—chemically in so-called homogenous membranes or physically in heterogeneous type of membranes. The matrix of ED membranes is mostly polymeric, inorganic membranes or combination of both materials is under development [3].

Ion-exchange membranes are key components in ED process. Membranes are arranged in ED stack, alternately cation exchange and anion exchange membranes. Arrangement of ED apparatus is schematically presented in Fig. 1. During ED, ions are removed from the feed solution. There is a desalted solution, called diluate, and solution containing the converted ions, called concentrate.

*Corresponding author.

Presented at the MELPRO 2014 Conference Membrane and Electromembrane Processes, 18–21 May 2014, Prague, Czech Republic

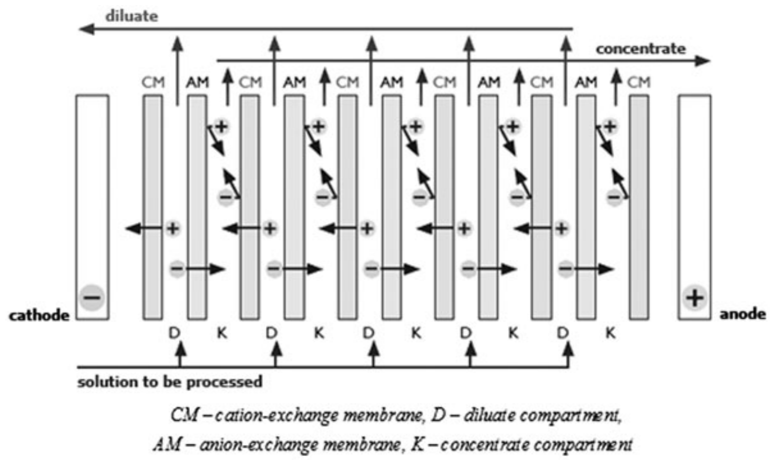

Fig. 1. Diagram of the process of electrodialysis [5].

Table 1
Electrochemical properties [6]

	Resistance in 0.5 M NaCl (measured under DC current)			
Membrane RALEX® Unit	Surface R_A [Ω cm^2]	Specific R_S [Ω cm]	Transport number in 0.5/0.1 M KCl t^M	Permselectivity in 0.5/0.1 M KCl P_{STAT} [%]
AM(H)-PES	<7.5	<120	>0.95	>90
CM(H)-PES	<8	<120	>0.95	>90
AF	<6.5	<140	>0.92	>85
CF	<6.5	<140	>0.94	>88

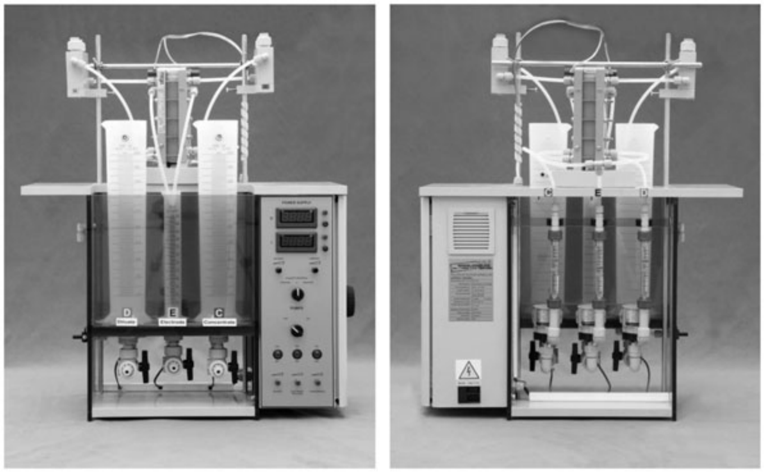

Fig. 2. Laboratory unit P EDR-Z (MemBrain s.r.o.)—front and back view.

Table 2
Properties of input raw materials

Whey	Membrane type	pH (–)	Conductivity (mS/cm)	Dry matter (g/kg)	Ash (g/kg)	Acidity ([a])
Evaporated sweet	Foil	6.21	11.72	160.7	13.63	16.0
	Standard	6.31	11.00	162.1	12.60	17.4
Nanofiltered acid	Foil	4.09	7.80	169.2	13.50	70.7
	Standard	4.35	7.51	170.5	14.23	61.8

[a]2.5 mmol H^+/l.

Table 3
Properties of final diluates

Whey	Membrane type	pH (–)	Conductivity (mS/cm)	Dry matter (g/kg)	Ash (g/kg)	Acidity [[a]]
Evaporated sweet	Foil	4.80	0.78	150.8	1.67	8.0
	Standard	5.50	0.75	153.6	1.37	5.8
Nanofiltered acid	Foil	4.50	0.86	148.6	1.99	8.5
	Standard	4.52	0.98	160.6	1.78	10.9

[a]2.5 mmol H^+/l.

Ion-exchange membranes should have some basic properties like high permselectivity, low electrical resistance, high chemical and mechanical durability, form stability, good stability at higher temperature and low production costs [4].

Foil membranes Ralex® AF and Ralex® CF are the new type of low-cost heterogeneous anionic/cationic exchange membranes designed for desalination of water solution. The membranes are produced without the reinforcement fabric. Their mechanical properties are determined by polymer matrix. The electrochemical properties of foil membranes Ralex® are very similar to common heterogeneous Ralex® AMH-PES and CMH-PES membranes.

New foil membranes were used for demineralization of whey and process parameters (capacity, product composition, energy consumption, consumption of water and chemicals) were compared for both types of membranes.

2. Materials and methods

Foil membranes Ralex® AF and Ralex® CF and heterogeneous membranes Ralex®AMH-PES and CMH-PES (MEGA a.s., Czech Republic) were tested. The electrochemical properties of both types of membranes are shown in Table 1.

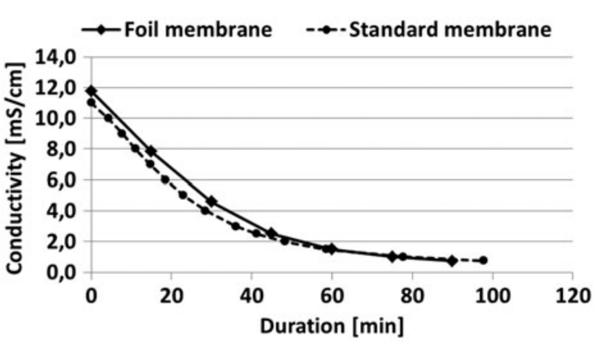

Fig. 3. Conductivity of evaporated sweet whey during demineralization.

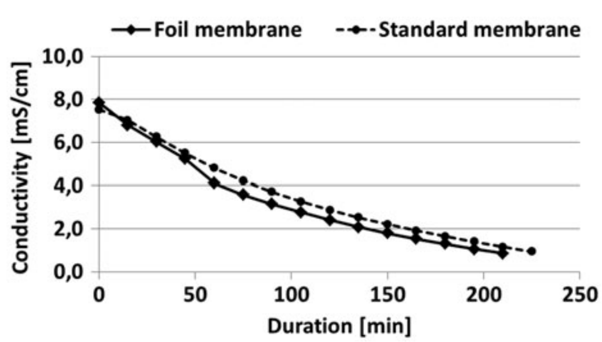

Fig. 4. Conductivity of nanofiltered acid whey during demineralization.

Table 4
Process capacity and consumptions

Whey	Membrane type	J_{avg} ($g\,m^{-2}\,h^{-1}$)	C_F ($kg\,m^{-2}\,h^{-1}$)	$C_{D,TS}$ ($kg\,m^{-2}\,h^{-1}$)	W_F (kg/kg_{feed})	A_F (g/kg_{feed})
Evaporated sweet	Foil	142.61	12.68	1.85	0.981	1.04
	Standard	145.87	12.06	1.47	0.922	0.99
Nanofiltered acid	Foil	56.41	4.40	0.58	0.928	0.0
	Standard	52.69	4.26	0.64	0.996	0.0

Sweet whey concentrated by evaporation and nanofiltered acid whey [7] were demineralized. Laboratory ED unit P EDR-Z (MemBrain s.r.o., Czech Republic)—see Fig. 2—was used for demineralization tests.

Test conditions	
Stack	EDR-Z/10–0.8 with foil membranes or standard membranes
Cells	10
Voltage	1.2 V/membrane pair
Diluate	1.0 kg evaporated sweet whey or nanofiltered acid whey, flow rate of 58 l/h (properties of input raw materials are listed in Table 2)
Concentrate	1.5 kg drinking water, flow rate of 58 l/h, for sweet whey with pH = 5.5 control (using a 3% solution of HNO_3)
Electrode solution	0.25 kg $NaNO_3$ (10 g/l), flow rate of 50 l/h

During the tests, conductivity and pH were measured with a calibrated multimeter WTW pH/cond340. Dry matter was determined in an oven at 105˚C for 24 h, the ash by burning in a furnace at 550˚C for 24 h. Acidity was determined by Soxhlet–Henkel method by titration with 0.25 mol/l NaOH and expressed as 2.5 mmol H^+/l (formerly ˚SH) (Table 2).

3. Results

Whey desalination was terminated when the conductivity of diluate had decreased below 1 mS/cm. Properties of final diluates are listed in Table 3.

Changes of whey conductivity during the demineralization are shown for both types of whey in Figs. 3 and 4.

Process capacity was determined for the product with conductivity of 1 mS/cm.

Capacity was calculated relative to 1 m^2 of membrane per 1 h as medium intensity flow of salt J_{avg} [$g\,m^{-2}\,h^{-1}$], as quantity of processed feed C_F [$kg_{feed}\,m^{-2}\,h^{-1}$] and as produced dry matter [$kg\,m^{-2}\,h^{-1}$]. Consumption of water W_F [kg/kg_{feed}] and consumption of nitric acid A_F [g/kg_{feed}] to regulate the pH and conductivity of the concentrate was measured too. All data are presented in Table 4.

4. Conclusion

Nanofiltered whey contains a greater proportion of multivalent ions compared to monovalent ions and has lower conductivity than whey concentrated by evaporation. Therefore, the performance of ED of nanofiltered acid whey is lower than for sweet whey concentrated by evaporation. The concentrate produced during ED acid whey has a sufficiently low pH. Therefore, it is not necessary to add acid to it.

Foil and standard membranes behave similarly in ED of both types of whey, capacity of ED with foil membranes was higher by 3–5%. Advantage of foil membrane usage lies mainly in their lower production costs.

Acknowledgements

Work supported by the Ministry of Industry and Trade of the Czech Republic within the framework of the project “Special membranes for development and intensification of electromembrane technology” program No. FR-TI4/507, using the infrastructure of the Membrane Innovation Centre (No. CZ 1.05/2.1.00/03.0084).

References

[1] I.A. Evdokimov, N.J. Dykalo, A.V. Permjakov, Elektrodialyz molochnoy syvorotki, GTI (filial) SevKav GTU, Georgievsk, 2009.
[2] M. Mulder, Basic Principles of Membrane Technology, Kluver Academic, Dordrecht, 1991.
[3] T. Xu, Ion exchange membranes: State of their development and perspective, J. Membr. Sci. 263 (2005) 1–29.

[4] H. Strathmann, Electrodialysis, a mature technology with a multitude of new applications, Desalination 264 (2010) 268–288.
[5] Processes. *MEGA*. MEGA a.s., 2012. [Cited: February 07, 2014], http://www.ralex.eu/Horni-navigace/Procesy.aspx?lang=en-US.
[6] Products. *MEGA*. MEGA a.s., 2012. [Cited: February 07, 2014], http://www.ralex.eu/Membrany/Portfolio.aspx?lang=en-US.
[7] G. Bylund, Dairy processing handbook, Whey processing, Tetra Pak Processing Systems AB, Lund, 1995.