JRIFST

www.journals.rifst.ac.ir
Journal of Research and Innovation
in Food Science and Technology

Research Institute of Food Science and Technology

Volume 7, Issue 2, Summer 2018, Pages 225-240
Document Type: Extended Abstract
DOI: 10.22101/JRIFST.2018.07.17.728

Extended Abstract

Synthesis and Performance Evaluation of ELVALOY®4170 Polymeric Membrane for Separation and Concentration of Omega-3 Fatty Acids

Samaneh Ghasemian[1], Reza Abedini[2*]

1- Ph.D. of Food Technology, Department of Food Science and Technology, Tarbiat Modares University, Tehran, Iran
2- Assistant Professor, Faculty of Chemical Engineering, Babol Noshirvani University of Technology, Babol, Iran
* Corresponding author (abedini@nit.ac.ir)

Received: 2017.10.06; **Accepted**: 2018.03.13

Abstract

Omega-3 is an acid that exists in the structure of some fats and has a vital role in the human health. Thus, the widespread research has been done to concentrate and purify the omega-3 from fish oil. In this research, the performance of membrane process in long chain omega-3 fatty acid concentration of Lantern fish oil which contains 25.23 wt.% omega-3, was investigated. To synthesize the membrane, the ELVALOY®4170 was used and the membrane was prepared through phase inversion method. The morphology of prepared membrane was analyzed using scanning electron microscopy. In concentration process, the effects of three parameters including temperature, pressure and mixing rate were studied through Box-Behnken statistical method. Scanning electron microscopy images showed that the prepared membrane consists of porous structure with thin dense toplayer. The obtained results from concentration process studied through ANOVA method and indicated that between evaluated parameters, temperature had the highest impact on concentration process. Moreover, the fouling behavior of membranes at different mixing rate was studied and outcomes revealed that the lowest fouling occurred at 100 rpm. Among various concentration process parameters, the highest value omega-3 concentration of 37.32% was obtained at temperature of 40 °C, pressure of 5 bar and mixing rate of zero.

Keywords: Fouling, Membrane, Omega-3, Pressure, Temperature

Introductıon

ω3-fatty acid concentration is increasing interest for both the pharmaceutical and health food industries (Rodriguez *et al*., 2010; Monroy *et a*l., 2003). As fish oils are a major source of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), an adequate intake of sea foods provides levels of ω3-PUFA required for good health. Therefore, research has been focused on concentrating ω3-PUFA to an edible oil form containing the lowest levels of saturated and monounsaturated fatty acids (Ruxton *et al*., 2005). Thus, a suitable commercial method to concentrate ω3-PUFA as efficiently as possible is desired by the edible oil industry. Vacuum distillation, hexane extraction, urea crystallization, and conventional crystallization

are currently the most common and widely used methods employed for extraction, fractionation and purification of ω3-PUFA (Chen *et al.*, 2007). The use of these conventional methods is limited due to disadvantages such as the use of toxic solvents, high energy consumption and thermal decomposition of labile compounds (Letisse *et al.*, 2006). Consequently, a new method for ω3-PUFA concentration which provides the same or higher level of efficiency but with fewer disadvantages is desirable. Membrane separation has been widely used in different applications including gas separation, desalination, pharmaceuticals and food manufacturing due to its beneficial aspects such as relatively low operating temperatures, requiring less energy and lower investment costs (James *et al.*, 2003; Abedini *et al.*, 2012; Mehrparvar & Rahimpour, 2015). Membrane separation processes are broadly used in the oil and fat industries. Performance of membranes was evaluated in numerous studies including oil deacidification and degumming, color reduction and solvent recovery (Azmi *et al.*, 2015; Stoft *et al.*, 2015). Polymeric membranes are used widely in various membrane separation applications due to ease of fabrication and economic issues (Abedini *et al.*, 2011).

The purpose of this study is to prepare the ELVALOY membranes to concentrate ω3-PUFA of lantern fish oil. The phase inversion method was employed to prepare ELVALOY membranes using a new dry/wet technique. The membrane was analyzed by SEM to evaluate its separation capability under different pressures and temperatures. The performance of prepared in ω3-PUFA rejection was investigated and finally, mechanisms of membrane fouling due to oil filtration were evaluated and discussed.

Material and methods

Lantern fish oil was purchased from Qeshm Fish Process Company of South Iran. To prepare fatty acid methyl esters, a Metcalfe method was used. The ELVALOY with density of 0.94 g/cm^3 was purchased from DuPoint company. Asymmetric ELVALOY membranes were prepared via the dry/wet technique along with the phase inversion method. First, a specific amount of ELVALOY was dissolved in toluene. The prepared homogenous solution was cast to a thickness of 300 μm on a glass plate substrate. The casted film was placed in a 60 °C vacuum oven for 2 min to allow solvent evaporation. In the next step, for phase inversion, the casted film was moved to a de-ionized water coagulation bath. Finally, the formatted membrane was placed in a vacuum oven to dry the membrane.

Results and discussion

Figure (1a) shows the effect of temperature on the concentration of ω3-PUFA. From 30 to 40 °C the concentration of ω3-PUFA increased with increasing temperature. However, increasing the temperature beyond 40 °C led a reduction of ω3-PUFA concentration. At 30 °C, which is closer to the melting point of the oil, there were some solid particles suspended in the oil phase. Triglycerides containing higher levels of SFAs in their structure have higher melting points than those with only ω3-PUFA and because of the saturates in their structure, the obtained retentate phase at 30 °C is lower in ω3-PUFA concentration (Hibino *et al.*, 1995). At elevated temperatures, I) the oil is homogeneous liquid with no suspended solids; and II) the mobility of the oil increases leading to improved transport of the linear SFAs through the membrane. Thus more concentrated ω3-PUFA can be attained in the retentate phase.

Figure (1b) illustrates the variation of ω3-PUFA concentration versus the feed pressure. It was observed that increasing pressure from 3 to 4 bar leads to a rise in ω3-PUFA. Increasing the pressure to 5 bar resulted in trade-off variation in ω3-PUFA concentration. At pressures ranging from 4 to 5 bar, the ω3-PUFA concentration initially increased and then decreased. The variation in ω3-PUFA concentration can be attributed primarily to the unique geometry of each fatty acid structure. ω3-PUFA consists of EPA and DHA, with 5 and 6 cis-double

carbon bonds (C=C) in, respectively (Shahidi, 2005). The presence of these cis-double C=C bonds causes kinks in the arrangement of carbon atoms of EPA and DHA and consequently leads to a 30-40 °C kink. The acyl chains cannot align completely along their length, resulting in and steric hindrance. This kinking increases as the numbers of double bonds increase (Juang *et al*., 2008). Therefore, triglycerides containing higher level of EPA and DHA in their structure can be rejected at higher pressure due to space prohibition. Increasing pressure enables SFAs to be transported through the ELVALOY membranes with superior permeation. Thus, the concentration of ω3-PUFA increases in retentate phase with the pressures up to 4 bar. Higher trans-membrane pressure results in increasing permeation of both ω3-PUFA and SFA. Figure (1c) illustrates the effect of stirring rate on ω3-PUFAconcentration. The concentration of ω3-PUFA at no stirring was 36.41 wt. % and increased to 36.64 wt. % at stirring of 100 rpm. Increasing the stirring rate up to 200 rpm leads to the concentration decline of ω3-PUFA to 35.74 wt.%. The variation in ω3-PUFA concentration due to change in stirring rate can be related to the fouling factor.

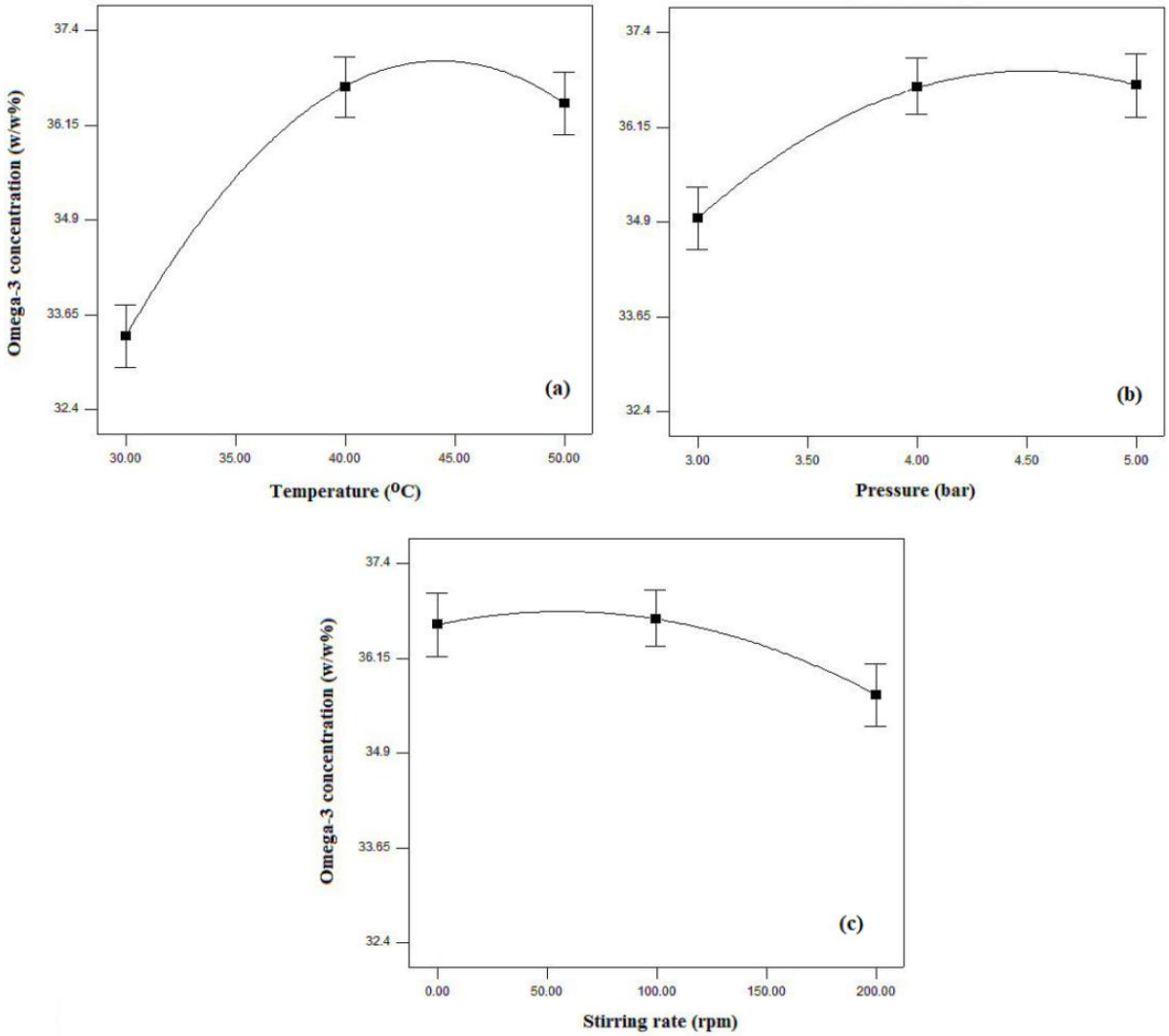

Figure 1. The effect of (a) temperature, (b) pressure and (c) stirring rate on ω3-PUFA concentration at constant pressure and stirring

As shown in Table (1), the fouling resistance and fouling factor for tests conducted at rate of 100 rpm were lower than that for the cases of no stirring and 200 rpm. Therefore, the ω3-PUFA concentration at 100 rpm was superior to the two another cases. Stirring at 100 rpm

compared to no stirring can eliminate or decrease the agglomeration of oil components at the membrane surface which debilitate the separation process. Thus the R_f and %F decreased to and ω3-PUFA concentration increased at stirring rate of 100 rpm. Although, stirring enhances the ω3-PUFA concentration, but increasing the stirring rate to 200 rpm resulted in obvious decline of ω3-PUFA concentration compared to stirring rate of 100 rpm and no stirring conditions.

Table 1. The fouling resistance and fouling factor under each stirring rate

Stirring rate	R_f	%F
No stirring	1.6×10^7	27.2
100 rpm	1.1×10^7	15.3
200 rpm	1.9×10^7	35.1

The different R_f values of each membrane are a result of the different fouling mechanisms. Table (2) lists the values of the root-mean-square deviations (RMSD) between calculated and experimental data for each proposed fouling mechanism. Table (2) shows the differences in the predominant fouling mechanisms occurring in each membrane. Except for cake formation, which has the lowest contribution to membrane fouling, the RMSD values given in Table (2) indicate that other fouling mechanisms may have accrued during ω3-PUFA concentration.

Table 2. Root-mean-square deviation (RMSD) between calculated and experimental flux data for each fouling model

Stirring rate (rpm)	Fouling model			
	Cake formation (n=0)	Intermediate pore blocking (n=1)	Internal pore blocking (n=1.5)	Complete pore blocking (n=2)
0	1.87	0.78	0.89	0.21
100	2.38	0.43	0.74	0.56
200	1.26	0.68	0.85	0.14

Conclusion

An asymmetric ELVALOY membrane with dense thin selective layers were prepared using phase inversion The ω3-PUFA concentration performance of membrane was evaluated by filtering lantern fish oil under different temperature and pressure conditions. Increasing the temperature from 30 ºC to 50 ºC led to enhancement of ω3-PUFA concentration. Increasing pressure from 3 to 5 bar had the same effect on ω3-PUFA concentration. Fouling analysis of the membranes revealed that different mechanisms effect the oil flux variation.

References

Abedini, R., Mousavi, S.M., & Aminzadeh, R. (2012). Effect of sonochemical synthesized TiO2 nanoparticles and coagulation bath temperature on morphology, thermal stability and pure water flux of asymmetric cellulose acetate nanocomposite membranes prepared via phase inversion method. *Chemical Industry & Chemical Engineering Quarterly, 18*(3), 385-398.

Abedini, R., Mousavi, S.M., & Aminzadeh, R. (2011). A novel cellulose acetate (CA) membrane using TiO_2 nanoparticles: Preparation, characterization and permeation study

Azmi, R.A., Goh, P.S., Ismail, A.F., Lau, W.J., Ng, B.C., Othman, N.H., Noor, A.M., & Yusoff, M.S.A. (2015). Deacidification of crude palm oil using PVA-crosslinked PVDF Membrane. *Journal of Food Enginnering, 166*, 165-173. doi:https://doi.org/10.1016/j.jfoodeng.2015.06.001

Rodriguez, N.R., Beltran, S., Jaime, I., de Diego, S.M., Sanz, M.T., & Carballido, J.R. (2010). Production of omega-3 polyunsaturated fatty acid concentrates: a review. *Innovative Food Science & Emerging Technologies, 11*(1), 1-12. doi:https://doi.org/10.1016/j.ifset.2009.10.006

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Ruxton, C.H.S., Calder, P.C., Reed, S.C., & Simpson, M.J.A. (2005). The impact of longchain n-3 polyunsaturated fatty acids on human health. *Nutrition Research Reviews, 18*(1), 113-129. doi:https://doi.org/10.1079/NRR200497

Chen, Y.Q., Edwards, I.J., Kridel, S.J., Thornburg, T., & Berquin, I.M. (2007). Dietary fat'gene interaction in cancer. *Cancer Metastasis Reviews, 26*(3-4), 535-551. doi:https://doi.org/10.1007/s10555-007-9075-x

Letisse, M., Rozieres, M., Hiol, A., Sergent, M., & Comeau, L. (2006). Enrichment of EPA and DHA from sardine by supercritical fluid extraction without organic modifier: I. optimization of extraction conditions. *The Journal of Supercritical Fluids, 38*(1), 27-36. doi:https://doi.org/10.1016/j.supflu.2005.11.013

James, B.J., Jing, Y., & Chen, X.D. (2003). Membrane fouling during filtration of milk-a microstructural study. *Journal of Food Engineering, 60*(4), 431-437. doi:https://doi.org/10.1016/S0260-8774(03)00066-9

Mehrparvar, A., & Rahimpour, A. (2015). Surface modification of novel polyether sulfone amide (PESA) ultrafiltration membranes by grafting hydrophilic monomers. *Journal of Industrial and Engineering Chemistry, 28*, 359-368. doi:https://doi.org/10.1016/j.jiec.2015.03.016

Sotoft, L.F., Lizarazu, J.M., Parjikolaei, B.R., Karring, H., & Christensen, K.V. (2015). Membrane fractionation of herring marinade for separation and recovery of fats, proteins, amino acids, salt, acetic acid and water. *Journal of Food Enginnering, 158*, 39-47. doi:https://doi.org/10.1016/j.jfoodeng.2015.02.020

Hibino, M., Sumi, A., & Hatta, I. (1995). Atomic images of saturated and unsaturated fatty acids at liquid/graphite interface and difference of tunneling currents between them observed by scanning tunneling microscopy. *Japanese Journal of Applied physics, 34*(1), 610-619.

Shahidi, F. (2005). *Bailey' Industrial Oil and Fat Products*. Wiley and Sons, New York.

Juang, R.S., Chen, H.L., & Chen, Y.S. (2008). Membrane fouling and resistance analysis in dead-end ultrafiltration of bacillus subtilis fermentation broths. *Separation and Purification Technology, 63*(3), 531-538. doi:https://doi.org/10.1016/j.seppur.2008.06.011

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