Enhanced Knowledge in Sciences and Technology Vol. 1 No. 1 (2021) 21-26
© Universiti Tun Hussein Onn Malaysia Publisher's Office

EKST

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/ekst
e-ISSN : 2773-6385

Preparation and Characterization of Psf-Based Ultrafiltration Membrane for Possible Filtration of Coconut Milk

Nur Fatin Izzati Abdul Sukor[1], Hatijah Basri[1]*, and Atqiya Muslihati[1]

[1]Faculty of Applied Sciences and Technology,
Pagoh, Johor, Malaysia

*Corresponding Author: hatijahbasri@uthm.edu.my

DOI: https://doi.org/10.30880/ekst.2021.01.01.004
Received 22 December 2020; Accepted 03 February 2021; Available online 11 February 2021

Abstract: The membrane fabrication of polysulfone (Psf) was prepared via phase inversion method that used N-methyl-2- pyrrolidone (NMP) as a solvent and polyethylene glycol (PEG) as an additive. The added PEG to the casting solution was differed in composition in order to suit the possible pore size range for coconut milk as feed. The prepared membrane was characterized based on the mean pore size and Scanning Electron Microscopy (SEM) images. It was also subjected to the performance of flux by measuring pure water flux and PEG 20 kDA flux. All of the prepared membrane indicates it is an ultrafiltration membrane based through the average mean pore size obtained. The addition of PEG into Psf-based membrane increased membrane permeability and enhanced finger-like structure on membrane. The result also demonstrated, the PWF of pure water increased by 91% at 16 wt. % PEG content while PWF of PEG 20 kDA increased by 74% of 12 wt. % PEG content.

Keywords: Polysulfone, Polyethylene glycol, PWF

1. Introduction

Cocos nucifera L. or well-known as coconut, is a versatile crop with many advantages and uses. Coconut products and its by-products have been commercially utilized and one of its famous products is virgin coconut oil (VCO) [1]. Other than that, there is also coconut milk which is a necessary ingredient in culinary preparation of Asian households [2]. Coconut milk composed of coconut proteins such as globulins, albumins and phospholipids [3]. Traditionally, coconut milk was extracted by hand [4]. However, several technologies have been established in order to preserve its quality such as heat-treated, dried and frozen [3]. Consequently, this thermal processing degrades or destroyed edible protein available and decreased it value added quality [3]. Membrane separation is common and popular technique applied in food industry to recover and increase the value added quality of products.

*Corresponding author: hatijahbasri@uthm.edu.my

Ultrafiltration membrane is one of the membrane separations techniques that is widely used in separating materials [5] and purify the filter [6].

Membrane is a selective barrier between two phases [7] and separation occurs due to one permeant is filtered while the other permeants moved accordingly [5]. Membrane can be classified into reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF) [6,8]. Ultrafiltration process is widely employed in food processing over two decades due to its advantages over conventional method. In dairy industry, it is one of the major membranes use in the production of cheese where it can be processed by increasing milk protein fractionation. Besides that, ultrafiltration separates juices into concentrates pulp and clarified the liquid [9]. This process recovered bioactive component in fruit juice [9]. Polysulfone is a versatile polymer in membrane fabrication due to its excellent transport properties, good mechanical strength, chemical and thermal resistance [10]. Despite all of its advantages, the major drawback of polysulfone is hydrophobic in nature which can lead to fouling and reduce flux performances [11, 12]. Polyethylene glycol (PEG) recognized as a polymer additive or non-solvent additive in membrane fabrication of polysulfone [11]. Research stated the properties of PEG as pore forming agent due to improvement of membrane permeability [10]. Hence, in this study, the objectives are to prepare and characterize the properties and performance of prepare membrane for possible filtration of coconut milk.

2. Materials and Methods

2.1 Materials

Polysulfone (Psf) and N-methyl-2-pyrrolidone (NMP) were used to prepare a polymer solution. Polyethylene glycol (PEG) 400 was used as an additive. For phase inversion purposes, distilled water was used as non-solvent.

2.2 Membrane preparation

In this study, Psf/PEG flat sheet membranes were prepared using the composition of (15% wt. Psf) and (85% wt. NMP). The different PEG 400 content used was presented in Table 1. Polymer solution was casted on the glass plate with appropriate knife gap. Then, the cast solution was immersed in water bath until the membrane peeled off naturally and dried for 24 hours in room temperature.

Table 1: The dope formulation with different PEG content in membrane fabrication.

Sample	Psf (wt. %)	NMP (wt. %)	PEG 400 (wt. %)
1			0
2			4
3	15	85	8
5			12
6			16

2.3 Membrane mean pore radius

Mean pore size of the membrane was determined by using the filtration velocity method as stated in the Guerout-Elford-Ferry equation [11, 13, 14]:

$$\text{Mean pore radius, Rm: } \frac{\sqrt{2.9-1.75} \times 8\eta l Q}{\sqrt{\varepsilon} \times A \times \Delta P} \qquad \text{Eq. 1}$$

Where, η is the water viscosity, l is the membrane thickness and Q is the volume of permeate water per-unit time. ε is the porosity of the membrane, A is the membrane area and ΔP is the operational membrane pressure.

Before that, the membrane porosity was obtained with measured density (ρ_w), volume of membrane in wet state (v), membrane weight in the wet state (g) and membrane weight in the dry state (g). The membrane was immersed in distilled water for 24 hours at 25 °C. The membrane surface was wiped with tissue paper prior to weighing. The initial weight was subjected as W_w (weight in wet state). Then, the membrane was placed in the oven at 60 °C for 24 hours. It was weighed again and denoted as W_d (weight in dry state). Membrane porosity was calculated using the following equation.

$$\varepsilon = \frac{(Ww - Wd)}{(\rho\omega \times v)} \quad \text{Eq. 2}$$

2.4 Scanning electron microscopy (SEM)

SEM was used to examine the morphology of the membrane. The membrane was immersed in liquid nitrogen and fractured carefully. The fractured sample then subjected to gold coating prior to scanning.

2.5 Permeation of flux

The flux permeation was determined for both pure water and PEG 20 kDA as feed stream. This study was conducted at pressure of 2 bar. Both of the flux was calculated using the following equation:

$$\text{PWF} = \frac{Q}{(A \times \Delta t)} \quad \text{Eq. 3}$$

where, PWF is the pure water flux (L/m^2 h), Q is the permeate volume with fixed pressure. A is the membrane area (m^2), and Δt is the permeate time (h) [11, 13, 14].

3. Results and Discussion

3.1 Membrane mean pore size

Table 2: The average mean pore size of membranes

Membrane	Mean Pore Radius (µm)
Psf only	3.255×10^{-7}
Psf/PEG (4 wt. %)	4.182×10^{-7}
Psf/PEG (8 wt. %)	1.856×10^{-7}
Psf/PEG (12 wt. %)	7.375×10^{-7}
Psf/PEG (16 wt. %)	1.013×10^{-6}

As demonstrated in the Table 2, the addition of PEG as an additive to Psf based membrane has decreased the average mean pore size exclude for high percentage. As can be seen, the average pore size of the membrane was increased from 3.255×10^{-7} µm to 7.375×10^{-7} µm as PEG content increased from 0 wt. % to 12 wt. %. This result should lead to the increase of mean pore size due to formation of finger-like and macrovid structure [13]. This trend can be observed by comparing between Psf pristine membranes to Psf/PEG with 16 wt. % where the mean pore radius was increased.

3.2 Scanning electron microscopy (SEM)

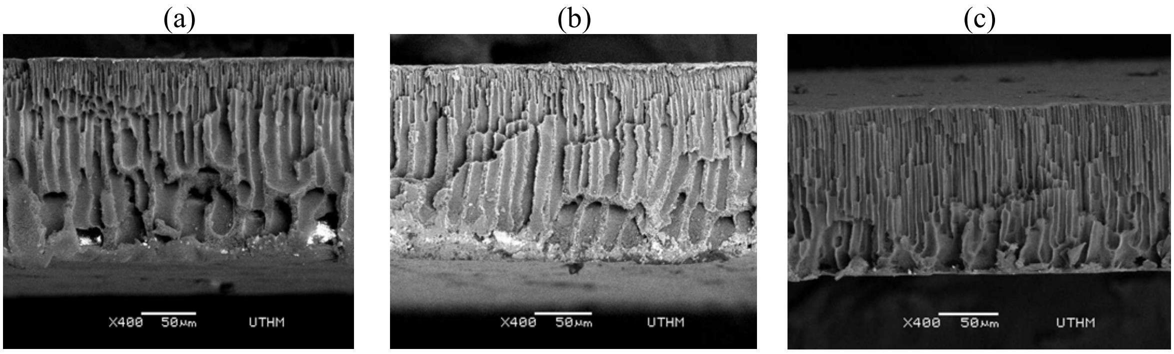

Figure 1: The image of cross-sectional morphology of different Psf/PEG membranes: (a) Psf only, (b) Psf with PEG (4 wt.%), and (c) Psf with PEG (16 wt. %)

Figure. 1 showed that the sub layer of membranes that seems to have finger-like structure below the top surface layer as well as macrovoids structure. The addition of PEG as an additive has contributed to the formation of finger-like structures on the top of the membrane [10]. This is due to the reason that the dope solution has become thermodynamically less stable with the presence of PEG [13].

3.3 Permeation flux

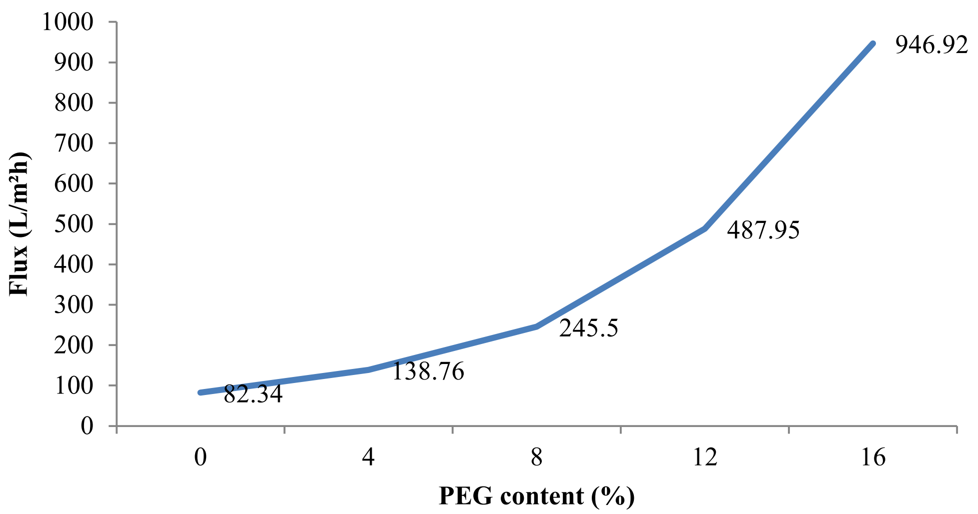

Figure 2: The effect of different PEG content on the PWF performance of Psf based membrane

Based on experimental results, the PWF of Psf/PEG was increased from 0 wt. % of PEG at 82.34 % to 946.92 % at 16 wt. % composition of PEG in Psf based membrane (Figure 2). The increase of water permeability of the membrane is due to the incorporation of PEG content to casting solution that helps in increasing membrane pore size and hydrophilicity [13]. PEG was used as a pore forming agent in order to improve the permeability of membrane that led to better flux in membrane performance [14].

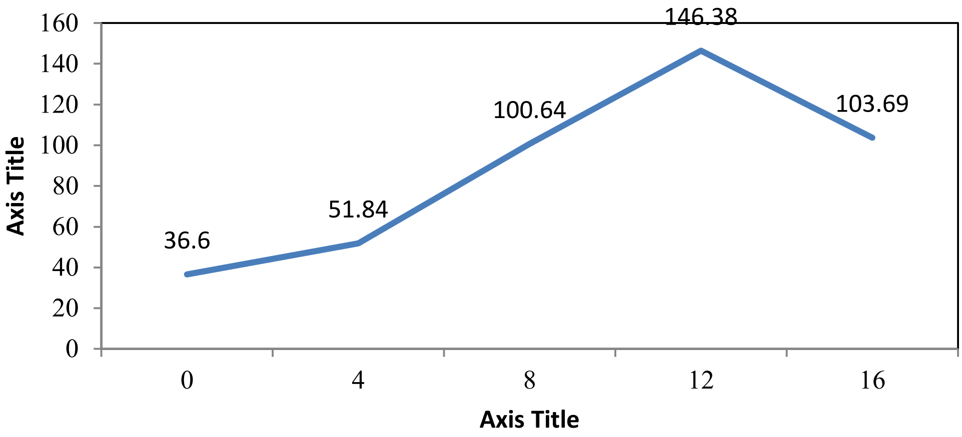

Figure 3: The effect of different content of PEG on Psf based membrane to the performance of the PEG 20 kDA flux.

The PEG 20kDA was used as a synthetic solution to replicate coconut milk as feed. Studies showed that in the ultrafiltration stream of coconut milk, albumin and globulin have molecular weight between 17, 34, 55 and 150 kDA. PEG 20 kDA posed the same molecular weight as coconut protein. PEG 20 kDA posed the same molecular weight as coconut protein. From the flux result, Psf pristine membrane recorded the lowest flux at 36.6 %, while Psf with additive (PEG 12 wt. %) resulted in higher PEG 20kDA flux at 146.38 %. However, at Psf/PEG membrane with 16 wt. % of the additive, the flux performance was leveled off. The unexpected decline of Psf/PEG flux may be due to the formation of a thick-sponge-like structure at the top layer of membrane (Figure 3) [13].

4. Conclusion

In conclusion, the ultrafiltration membranes using Psf as a based polymer and NMP as a solvent while PEG as an additive were successfully prepared via phase inversion technique. The effect of PEG addition to Psf plain membranes were investigated and it shows enhancement in finger-like structure, mean pore size and performance of both fluxes. Overall, Psf/PEG with 12 wt.% is the best membrane for possible filtration of coconut milk due its performance in both pure water flux and PEG 20 kDA flux.

Acknowledgement

Author would like to thank Universiti Tun Hussein Onn Malaysia for the experimental facilities provided for the research.

References

[1] C. Y. Ng, A. W. Mohammad, L. Y. Ng, J. M. Jahim, “Sequential fractionation of value-added coconut products using membrane processes,” Journal of Industrial and Engineering Chemistry, vol. 6, 2014.

[2] S. Ganguly, “Health benefit of coconut in an Asian cuisine: a review,” Journal of Biological and Chemical Research, vol. 30, pp. 517-521, 2013.

[3] S. Thaiphanit and P. Anprung, “Physicochemical and emulsion properties of edible protein concentrate from coconut (Cocos nucifera L.) processing by-products and the influence of heat treatment,” Food Hydrocolloids, 2015.

[4] P. C. Sanchez, "Coconut Food Processes: Coconut Processing Technology Information Document," Cornell University: Asian and Pacific Coconut Community, 2009.

[5] R. W. Baker, Membrane Technology and Applications. 2nd ed., England : John Wiley & Sons Ltd, 2004.

[6] S. Ahmad and S. K. M. Ahmed, "Application of Membrane Technology in Food Processing," In: Food Processing: Strategies for Quality Assessment: Springer, New York, 2014.

[7] M. Mulder, "Preparation of Synthetic Membrane," In: Basic Principles of Membrane Technology, Boston, London: Kluwer Academic Publisher, 1991.

[8] A. W. Mohammad, L. Y. Ng, J. M. Jahim, "Ultrafiltration in food processing industry: review on application, membrane fouling and fouling control," Food Bioprocess Technology, 2014.

[9] A. Munir, Laboratory Feasibility Studies in Environmental Engineering. New York: Springer, 2006.

[10] N. N. Aminudin, H. Basri, Z. Harun, Z. Yunos, G. P. Sean, "Effect of pH on bovine serum albumin (BSA) solution to Polysulfone based membrane," Technology Journal, 2014.

[11] M. R. Jamalludin, "Enhancement of Antifouling Properties Using Rice Husk Silica Particles in Polysulfone Membrane and Optimization of Its Operating Condition," Master thesis, Universiti Tun Hussein Onn Malaysia, 2014.

[12] R. Kumar, A. M. Isloor, A. F. Ismail, S. A. Rashid & T. Matsuura, "Polysulfone–Chitosan blend ultrafiltration membranes: preparation, characterization, permeation and antifouling properties," RSC Advances, vol. 3, no. 21, pp. 7855-7861, 2013.

[13] M. Z. Yunos, Z. Harun, H. Basri and A. F. Ismail, "Studies on fouling by natural organic matter (NOM) on Polysulfone membranes: Effect of polyethylene glycol (PEG)," Desalination, vol. 333, pp. 36-44, 2014.

[14] A. F. Ismail and T. Matsuura, Sustainable Membrane Technology for Energy, Water and Environment, Canada: John Wiley & Sons, 2012.

[15] N. N. Aminudin, H. Basri, Z. Harun, Z. M. Yunos and G. P. Sean, "Comparative study on effect of peg and pvp as additive on polysulfone (psf) membrane structure and performance," Technology Journal, 2013