Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 14 (12): 1343-1346, 2014
ISSN 1812-5654 / DOI: 10.3923/jas.2014.1343.1346

Resistance in Series Model for Ultrafiltration Betacyanin from *Hylocereus polyrhizus* Peels

S. Azimah and A.M. Mimi Sakinah
Faculty of Chemical Engineering and Natural Resources, Universiti Malaysia Pahang,
Lebuhraya Tun Razak, 26300, Kuantan Pahang, Malaysia

Abstract: This study investigates the fouling mechanism in ultrafiltration membrane during separation of betacyanin from *Hylocereus polyrhizus* extract. The Resistance-In-Series Model was used to identify the responsible hydraulic resistance. The resistance against the flux was assumed to be comprised as membrane hydraulic, adsorption, pore plugging and fouling resistance. The profile of total resistance and corresponding flux decline were calculated and compared with the experimental data. The result showed that the adsorption resistance (R_{ad}) was the main contributed the rate of flux decline. Moreover the significant organic fouling that contribute during betacyanin separation revealed that the fouling potential was R_{ad}>R_{pp}>R_F. The measured flux recovery of filtration betacyanin production was 65%.

Key words: Betacynin, ultrafiltration membrane, *Hylocereus polyrhizus*, flux recovery, resistance-in-series model

INTRODUCTION

Hylocereus polyrhizus or commonly known as pitaya or dragon fruit has gained a growing interest for cultivation in Malaysia (Hoa *et al*., 2006). This fruit has gained much interest in the society because of its exotic features, attractive colours, nutritional value and pleasant taste (Le Bellec *et al*., 2006). *Hylocereus polyrhizus* has gained a growing interest for cultivation in Malaysia. This fruit has gained much interest in the society because of its exotic features, attractive colours, nutritional value and pleasant taste. Natural colorants have a vast economic significant because the dye trade has a world market worth 2.5 billion/year (Harivaindaran *et al*., 2008). The *Hylocereus polyrhizus* flesh is used wisely in our food application industry. It can be processed into range of food products, such as juice, jam, syrup, ice cream, yogurt, jelly and candy (Wybraniec and Mizrahi, 2002). Thus the *Hylocereus polyrhizus* peels are abundance and disposed as industrial peel. Betacyanin content in *Hylocereus polyrhizus* have a great potential in colorings agents in food and textile. The composite of betacyanin in peels and pulp fruit did not differ, thus the extraction of betacyanin pigment can be indicating a similar set (Stintzing *et al*., 2002).

Ultrafiltration (UF) is widely used in clarification of various juices in processing industry. Ultrafiltration can be alternative for filtration of betacyanin from *Hylocereus polyrhizus* extract. Membrane fouling can cause many problems in industries. Fouling can cause an operational problem of membrane installations (e.g., increase of pressure drop and/or decrease of flux). Various models were proposed to analyze and predict the flux behavior during filtration of macromolecular solution. This can be classified as osmotic pressure controller, gel layer controlled and resistance-in-series models (Rai *et al*., 2006).

The reason that membrane process is not used on much large scale is the flux decline during the process (Sakinah *et al*., 2009). Flux decline cause the several phenomena in, on and near the membrane (Derradji *et al*., 2005). The flux decline during separation by UF is the cumulative effect of several mechanisms which is adsorption of solutes on the membrane surface, pore plugging (Belfort *et al*., 1993; Sakinah *et al*., 2007) and concentration polarization (Ko and Pellegrino, 1998). Adsorption of membrane surface by solute particles was determined by membrane-solute interaction (Choi *et al*., 2005; Sakinah *et al*., 2008). Moreover, pore plugging was mainly governed by relative size of the solute and membrane pore as well as the operating conditions. Concentration polarization is the accumulation of solutes particles over the membrane surface. Forming a growing gel layer or increasing the osmotic pressure at the membrane solution interface cause decreasing the effective driving force (Van Oers *et al*., 1992). By the

Corresponding Author: S. Azimah, Faculty of Chemical Engineering and Natural Resources, Universiti Malaysia Pahang (UMP), Lebuhraya Tun Razak, 26300, Kuantan Pahang, Malaysia Tel: +609-549 2825 Fax: +609-549 2889

proper membrane cleaning procedure, the type of fouling is reversible in nature and the permeability can be determined. In this study perform the separation of betacyanin from *Hylocereus polyrhizus* extract and assessed the fouling mechanism as well as the membrane resistance to the permeated pass.

MATERIALS AND METHODS

Experiment system: The membrane reactor system reactor was developed as shown in Fig. 1. The membrane reactor comprises with stirrer reactor equipped with temperature controller, membrane module unit, pump and feed pressure gauge. The ultrafiltration membrane module has a 30 cm of length and 25 cm of diameter.

Extraction and separation: The 10 L reactor was filled with *Hylocereus polyrhizus* waste and water and the ratio were 1:4. The mixture was stirred for 5 minutes at 50°C. The reaction mixture was continuously pumped to the membrane module. The operational transmembrane pressure for membrane filtration was 1.4 bar.

Resistance-in-series model: In order to determine the hydraulic resistance of membrane separation, Resistance-in-series model was used based on Darcy's law. There are four parameters of resistance-in-series model which were used to quantify their influences on flux decline. The equations describing the cross flow filtration process are as following:

$$J_v \frac{\Delta P}{\mu\ (R_m + R_{ad} + R_{pp} + R_f)} \qquad (1)$$

where, J_v is flux through the membrane (m sec), ΔP is the transmembrane pressure (Pa), μ is the dynamic viscosity (Pa.s), R_m is the membrane hydraulic resistance, R_{ad} is the adsorption resistance, R_{pp} is the pore plugging resistance and R_f is the fouling resistance (all resistance are in m^{-1}).

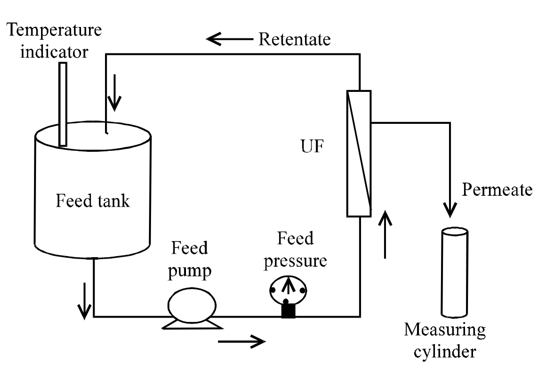

Fig. 1: Schematic diagram of membrane reactor

RESULTS AND DISCUSSION

Determine of hydraulic resistance: The amount of the hydraulic resistance can be converted into the ratio of the hydraulic resistant to the amount of the total hydraulic resistance as shown in Fig. 2 and Table 1. Based on the result, the membrane hydraulic resistance was the 51% of the total hydraulic resistance because of intrinsic property of the membrane. However, the adsorption resistance, pore plugging resistance and fouling resistance exhibited about 23, 14 and 12% of the total hydraulic resistance.

Flux decline in the UF filtration: The flux decline in membrane reactor was due to the membrane fouling. Initially, particle from the reaction mixture arrived to the membrane and blocked the smallest pore of the membrane. The inner membrane surface of bigger pore is covered. Then some particles were entered to membrane covered other arrived particles, while others directly blocked some of the pores. Finally, the cake layer begins to be developed (Bowen *et al*., 1995).

Figure 3 shows the declination of the flux in the ultrafiltration cross flow membrane. The flux of the membrane was first obtained the hydraulic resistance from the membrane due to the property of the membrane. By using the Darcy's law, the declination of flux was obtained as the increasing amount of total resistance. Moreover, once the pressure was released, the flux was increased due to the vanished of the concentration polarization. In addition, after the membrane was cleaned with clean water, the gel layer was moved out from the membrane, surface which effects an increasing of membrane's flux. The flux of the membrane was found to

Table 1: Percentage of hydraulic resistance of the UF membrane in separation of betacyanin

Type of resistances	Percentage (%)
R_m	51
R_{ad}	23
R_{pp}	14
R_f	12

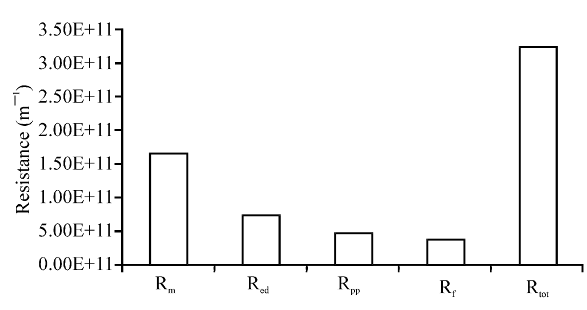

Fig. 2: Amount of hydraulic resistance of the UF membrane

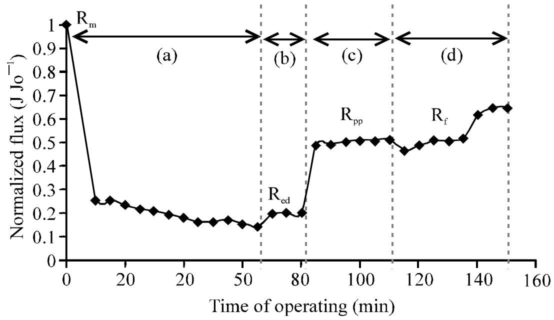

Fig. 3(a-d): Flux decline in the UF cross flow filtration (a) Flux declined during filtration, (b) Pressure released, (c) Water cleaning and (d) Chem

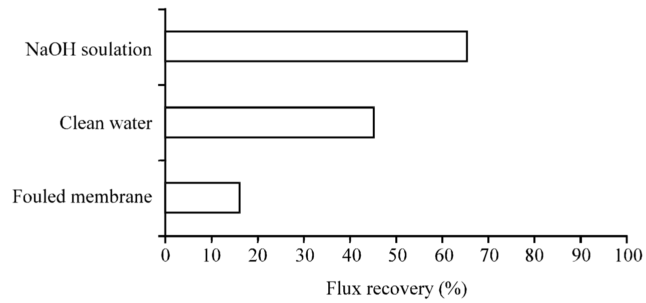

Fig. 4: Percentage of flux recovery during the separation of betacyaninical cleaning

be increase after chemical cleaning. It was presumed to be due to dynamic balance between adsorption and desorption of the soluble organic matter into the matrix of membrane.

Flux recovery during the betacyanin separation: The flux of the cleaned membrane was test through a filtration with clean water after each membrane cleaning step. The ratio of the specific flux (m^3 m^{-2} h^{-1} m^{-1}) at room temperature of cleaned membrane to the new membrane flux was used to evaluate the flux recovery of the membrane and the result as shown in Fig. 4.

Figure 4 show s that the cleaning with clean water could recover the flux of the membrane about 51%. However, the flux recovery for the cleaned membrane using 0.1M NaOH solution about 65%. Nonetheless, about 34% lost in the flux come from irreversible hydraulic resistance. This is due to the adsorption of solute within the matrix of the membrane.

CONCLUSION

A resistance in series model was proposed to quantify the flux decline during UF of betacyanin production. A systematic method was outlined to quantify the time variation of each constituent resistance, namely, the membrane resistance, adsorption, pore plugging and reversible fouling resistance. The results of these investigated that:

- The major fouling mechanism was that reversible fouling which was about 23% of the total hydraulic resistance
- The irreversible fouling mechanism could be elevated by chemical cleaning which is 16% from total hydraulic resistance
- The maximum achievable flux recovery for betacyanin separation was 65% by cleaning with alkaline solution

ACKNOWLEDGMENTS

I would like to thanks to the Universiti Malaysia Pahang and the Ministry of Higher Education, Malaysia for funding my research under grant research RDU110801.

REFERENCES

Belfor, G., J.M. Pimbley, A. Greiner and K.Y. Chung, 1993. Diagnosis of membrane fouling using a rotating annular filter. 1. Cell culture media. J. Membr. Sci., 77: 1-22.

Bowen, W.R., J.I. Calvo and A. Hernandez, 1995. Steps of membrane blocking in flux decline during protein microfiltration. J. Membr. Sci., 101: 153-165.

Choi, H., K. Zhang, D.D. Dionysiou, D.B. Oerther and G.A. Sorial, 2005. Influence of cross flow velocity on membrane performance during filtration of biological suspension. J. Membr. Sci., 248: 189-199.

Derradji, A.F., S. Taha and G. Dorange, 2005. Application of the resistance in series model in ultrafiltration. Desalination, 184: 377-384.

Harivaindaran, K.V., O.P.S. Rebecca and S. Chandran, 2008. Study of optimal temperature, Ph and stability of dragon fruit (*Hylocereus polyrhizus*) peel for use as potential natural colorant. Pak. J. Biol. Sci., 11: 2259-2263.

Hoa, T.T., C.J. Clark, B.C. Waddell and A.B. Woolf, 2006. Postharvest quality of dragon fruit (*Hylocereus undatus*) following disinfesting hot air treatments. Postharvest Biol. Technol., 41: 62-69.

Ko, M.K. and J.J. Pellegrino, 1998. Determination of osmotic pressure and fouling resistance and their effects on performance of ultrafiltration membranes. J. Membr. Sci., 74: 141-157.

Le Bellec, F., F. Vaillant and E. Imbert, 2006. Pitahaya (*Hylocereus* spp.): A new fruit crop, a market with a future. Fruits, 61: 237-250.

Rai, P., C. Rai, G.C. Majumdar, S. DasGupta and S. De, 2006. Resistance in series model for ultrafiltration of mosambi (*Citrus sinensis* (L.) Osbeck) juice in a stirred continuous mode. J. Membr. Sci., 283: 116-122.

Sakinah, A.M.M., A.F. Ismail, M.I. Rosli and H. Osman, 2007. Fouling characteristics and autopsy of a PES ultrafiltration membrane in cyclodextrins separation. Desalination, 207: 227-242.

Sakinah, A.M.M., A.F. Ismail, M.I. Rosli, H. Osman and A.W. Zularisam, 2009. Influence of starch pretreatment on yield of cyclodextrins and performance of ultrafiltration membranes. Desalination, 239: 317-333.

Sakinah, A.M.M., A.F. Ismail, R.M. Illias, A.W. Zularisam, O. Hassan and T. Matsuura, 2008. Cyclodextrins production in hollow fiber membrane reactor system: Effect of substrate preparation. Sep. Purif. Technol., 63: 163-171.

Stintzing, F.C., A. Schieber and R. Carle, 2002. Betacyanins in fruits from red-purple pitaya, *Hylocereus polyrhizus* (Weber) britton and rose. Food Chem., 77: 101-106.

Van Oers, C.W., M.A.G. Vorstman, W.G.H.M. Muijselaar and P.J.A.M. Kerkhof, 1992. Unsteady state flux decline behavior in relation to the presence of a gel layer. J. Membr. Sci., 73: 231-246.

Wybraniec, S. and Y. Mizrahi, 2002. Fruit flesh betacyanin pigments in *hylocereus cacti*. J. Agri. Food Chem., 50: 6086-6089.