JFBE 1(2): 133-136, 2018

Journal of Food and Bioprocess Engineering

Journal homepage: https://jfabe.ut.ac.ir

Original research

Difference between efficiency of ultrasound treatments above and below the membrane surface in membrane clarification of pomegranate juice

Morteza Aliasghari Aghdam, Hossein Mirsaeedghazi*, Mohammad Aboonajmi, Mohammad Hossein Kianmehr

Department of Food Technology Engineering, College of Abouraihan, University of Tehran, Pakdasht, Iran

A B S T R A C T

Microfiltration can clarify pomegranate juice; however, fouling is a limiting phenomenon in the process. In current work ultrasound was applied above and below the membrane surface to reduce fouling after removing temperature effect. A hydrophilic mixed cellulose ester membrane with pore size of 0.45 µm was used in lab scale flat sheet module. Membrane module was placed above and below the ultrasonic probe with frequency of 30 kHz and power of 1000 W, separately. The feed temperature in ultrasonic-membrane process was recorded and the experiment was repeated without ultrasonic treatment in similar feed temperature. Results showed that ultrasonic treatment above the membrane surface can increase the permeate flux; however, difference between the permeate fluxes was only before the steady state condition. On the other hand, the ultrasonic treatment below the membrane surface compared with the process which was performed without ultrasonic treatment cannot change the permeate. Also standard blocking was the main fouling mechanism in the membrane process which was equipped with the ultrasound probe above and below the membrane surface. Evaluation of blocking index showed that the cake formation is the main fouling mechanism all over the time in the process where ultrasound probe was inserted above the membrane surface. However, inserting the ultrasound probe below the membrane surface changed the value of blocking index. In this configuration cake formation was followed by intermediate blocking, standard blocking and complete blocking.

Keywords: Juice, Membrane, Microfiltration, Pomegranate, Ultrasound

Received 10 September 2017; Received 3 December 2017; Accepted 24 December 2017

1. Introduction

Fruit juices should be clarified before its concentration due to prevent production of off flavor which caused with burning the large particles on the walls of evaporators (Sharifanfar et al., 2015). Traditional methods to clarify fruit juices need high energy and cause environmental problems due to use gelatin, bentonite and silica as a filter aid (Vaillant et al., 1999). Nowadays, novel food processing such as membrane technology is used to save energy and time (Girard & Fukumoto, 2000). Some membrane processes such as microfiltration and ultrafiltration can be used to clarify fruit juices (Mirsaeedghazi et al., 2010). Microfiltration is a pressure driven process which can remove large particles and reduce juice turbidity (Cassano et al., 2007; Rai et al., 2005). Fouling is a limiting phenomenon which acts against industrialization of membrane clarification of fruit juices. It is dependent on the nature of membrane, feed and processing parameters (Cassano et al., 2007). Fouling decreases economic efficiency of the membrane processing and reduces membrane shelf life; since, evaluation of fouling phenomenon has an important role in increase the effectiveness of the membrane clarification of fruit juices (Aydiner et al., 2005). Nowadays, ultrasonic waves are used as a potential tool to reduce fouling in the membrane processing. Kobayashi et al. used polyacrylonitrile in ultrafiltration unit and increased permeate flux in the membrane processing using ultrasound waves at 45 kHz (Kobayashi et al., 1999). Matral et al. (2000) used ultrasound to monitor fouling rate in the reverse osmosis process. Muthukumaran et al. (2004) used ultrasonic treatment to reduce fouling resistance in the membrane which had been fouled with whey. Results showed that ultrasonic treatment has an important role to remove fouling which was caused with protein. Also, simultaneous use of surfactant and ultrasound had synergic effect on reduction of fouling. Chen et al. (2006) evaluated the effect of ultrasonic treatment on the fouling control in ceramic membranes. They used ultrasound wave at frequency of 20 kHz in cross flow ultrafiltration. They concluded that the most effectiveness of membrane cleaning was out of the cavitation region; however it

*Corresponding author.
E-mail address: mirsaaed@ut.ac.ir (H. Mirsaeedghazi).

should be near this region. Increasing the pressure destroyed the cavitation region and decreased the recovery of permeate flux.

Ultrasonic treatment increases the feed temperature; hence, a part of increase the permeate flux should be attributed to high temperature of feed (Nourbakhsh et al., 2014). In other words, a part of increase of permeate flux in previous works can be achieved with increase the feed temperature and did not require the ultrasonic treatment. However, in current work the effect of feed temperature was removed from the effect of ultrasonic treatment and the membrane unit was undergone ultrasound waves during the membrane clarification of pomegranate juice. Ultrasound was applied above and below the membrane surface and its effects on performance of membrane clarification and fouling phenomenon were studied.

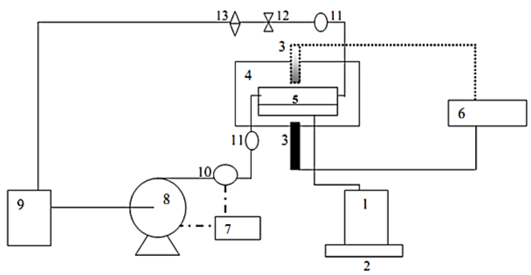

Fig. 1. Ultrasonic-membrane unit (1: permeate tank; 2: balance; 3: ultrasonic probe; 4: water bath; 5: membrane module; 6: control unit of ultrasound waves; 7: inverter; 8: pump; 9: feed tank; 10: transmitter, 11: pressure meter; 12: valve; 13: flow meter).

2. Material and Methods

2.1. Preparation of pomegranate juice

Pomegranate (variety of Malase Saveh) was prepared from local market (Saveh, Iran). It was washed, peeled and lathery skin was removed. Pomegranate juice was extracted with manually pressing and extracted juice was filled in polyethylene terephthalate bottles and they were prepared at -25°C until membrane processing.

2.2. Microfiltration unit

A hydrophilic mixed cellulose ester membrane with pore size of 0.45 µm and effective area of 78×10^{-4} m^2 (Millipore, Billerica, MA, USA) was used in lab scale flat sheet module. A rotary van pump (PROCON, Series 2, Milano, Italy) was used to pump pomegranate juice from the feed tank to the membrane unit. Permeate was collected in the permeate tank which was on a digital balance to calculate its weight and the retentate was recycled to the feed tank. A transmitter (WIKA, type ECO-1, Klingenberg, Germany) coupled with an inverter (LS, model sv015ic5-1f, Korea) were used to adjust the transmembrane pressure and feed velocity (Fig. 1).

Membrane module was placed below the ultrasonic probe with frequency of 30 kHz and power of 120 W. The experiment was repeated with an ultrasonic probe which was inserted below the membrane module. In both experiments, the distance between ultrasonic probe and membrane was adjusted on 1.7 cm. The feed temperature in ultrasonic-membrane process was recorded and the experiment was repeated without ultrasonic treatment in similar feed temperature to remove the effect of feed temperature on process efficiency from the effect of ultrasound.

2.3. Theory

Permeate flux was calculated according to Eq. 1.

$$J_p = \frac{\Delta m}{A \Delta t} \qquad (1)$$

where Δm (kg) is the weight of permeate which was collected from 1 m^2 of the membrane surface in Δt (s).

According to Hermia, dominant fouling mechanism can be determined using the curve of permeate volume (v) versus time (t). Linearity of the curves of t/v versus v, t/v versus t and Ln(t) versus v show that cake formation, standard blocking and intermediate blocking mechanisms, are the main fouling mechanism, respectively. Hermia's model can be used to study the creation time of each fouling mechanism according to Eq. 2.

$$\frac{d^2 t}{dv^2} = K \left(\frac{dt}{dv}\right)^i \qquad (2)$$

where K and i are resistant coefficient and blocking index, respectively. When amount of i is 2, 1.5, 1 and 0, complete blocking, standard blocking, intermediate blocking, and cake formation are the main fouling mechanisms, respectively (Mirsaeedghazi et al., 2009).

3. Results and Discussion

Evaluation of the permeate flux in membrane clarification of pomegranate juice showed that ultrasonic treatment above the membrane surface can increase the permeate flux; however, difference between the permeate fluxes was only before the steady state condition in membrane clarification process of pomegranate juice (before 30 min). It can be attributed to the effect of ultrasound waves on movement of large particles toward the membrane surface. It is a hypothesis which will be considered in the next section. On the other hand, the ultrasonic treatment below the membrane surface compared with the process which was performed without ultrasonic treatment cannot change the permeate flux (Fig. 2). The reason of such behavior of permeate flux was probably the upward force exerted by the ultrasound probe to the membrane surface which can prevent the penetration of permeate throughout the membrane.

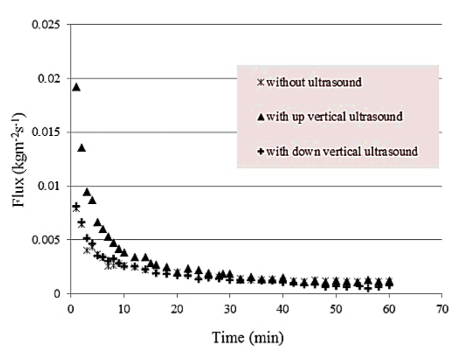

Fig. 2. Effect of ultrasound waves on the permeate flux during membrane clarification of pomegranate juice.

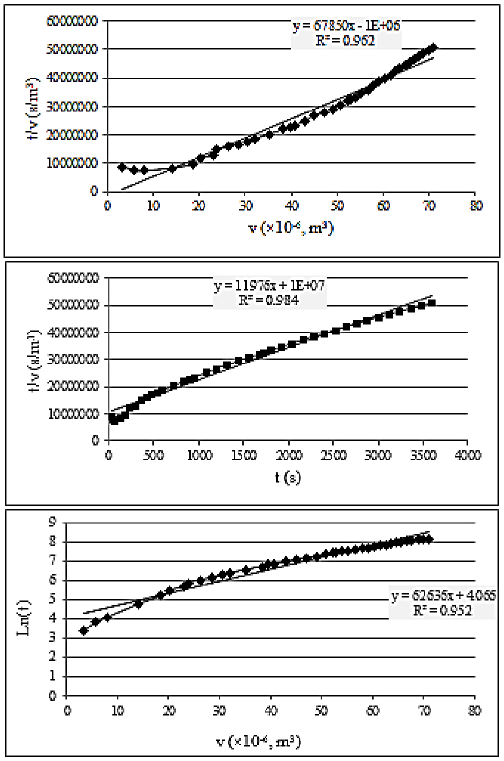

Fig. 3. The relation between permeate volume and time during the membrane clarification of pomegranate juice with ultrasonic treatment above the membrane surface.

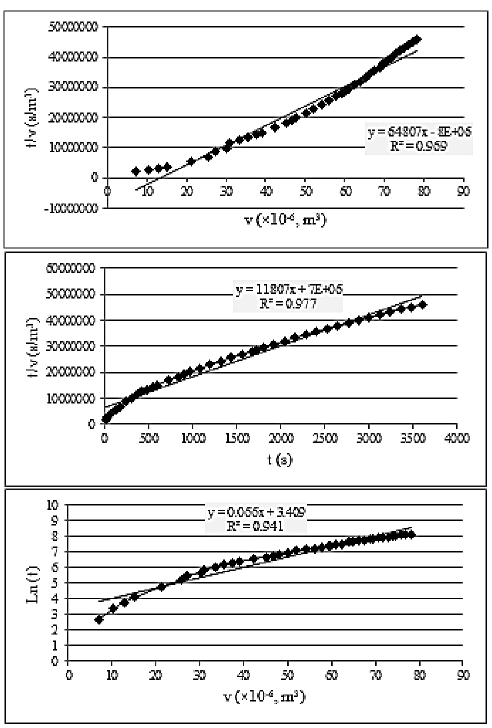

Fig. 4. The relation between permeate volume and time duringthe membrane clarification of pomegranate juice with ultrasonic treatment below the membrane surface.

The main fouling mechanism was evaluated using plot the curves of t/v versus v and t and the curve of Ln (t) versus v. Results showed that the curve of t/v versus t had the most linear behavior; hence, standard blocking was the main fouling mechanism in the membrane process which was equipped with the ultrasound probe above the membrane surface (Fig. 3). Change the location of ultrasound probe to below the membrane surface did not change the main fouling mechanism during the membrane clarification of pomegranate juice (Fig. 4).

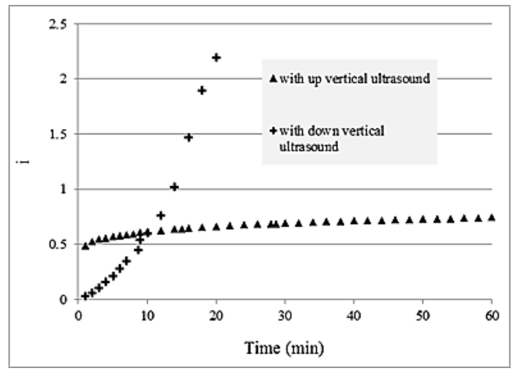

Fig. 5. Effect of ultrasonic treatment on the blocking index during the membrane clarification of pomegranate juice.

Fig. 6. Image of the membrane surface after membrane clarification of pomegranate juice with ultrasonic treatment.

Evaluation of blocking index showed that the cake formation is the main fouling mechanism all over the time of membrane clarification of pomegranate juice in which ultrasound probe was inserted above the membrane surface. Hence, increase the permeate flux cannot be attributed to low value of fouling and was probably due to a force which was applied by ultrasound on the feed toward the membrane surface. However, inserting the ultrasound probe below the membrane surface changed the value of blocking index. In this configuration cake formation was followed by intermediate blocking, standard blocking and complete blocking (Fig. 5). Appearance of all fouling mechanisms after cake formation showed that cake layer is thin. So, it expected that permeate flux be high in such set up; however, different behavior was observed. As a result, low permeate flux can be attributed to the opposite force which was applied against the permeate flow path by ultrasound waves. It is a fact which was confirmed by the images of used membrane after membrane clarification of pomegranate juice. Images showed that when the ultrasound was applied above the membrane surface the membrane was fouled more than a condition in which the ultrasound probe was inserted below the membrane surface (Fig. 6). On the other hands, cake layer thickness in central regions of membrane where ultrasound probe was inserted below it (A) was more than other areas (B).

4. Conclusion

Application of ultrasound waves above the membrane surface can act as a secondary force on the membrane surface which can move more particles toward the membrane surface during membrane clarification of pomegranate juice. High transfer of large particles toward the membrane surface causes thick cake layer; however, the effect of ultrasound waves on movement of solution part of pomegranate juice toward the membrane surface neutralized the effect of cake formation.

Hence, when the ultrasound was applied above the membrane surface the permeate flux increased. Insert the ultrasound probe below the membrane surface decreased the cake formation; however it acted as an opposite force against the permeate flow path and finally decreased the membrane surface. So, application of ultrasound above the membrane surface was the most appropriate configuration to increase the efficiency of membrane clarification of pomegranate juice.

References

Aydiner, C., Demir, I., & Yildiz, E. (2005). Modeling of flux decline in cross flow microfiltration using neural networks: the case of phosphate removal. *Journal of Membrane Science*, *248*(1–2), 53–62.

Cassano, A., Marchio, M., & Drioli, E. (2007). Clarification of blood orange juice by ultrafiltration: analyses of operating parameters, membrane fouling and juice quality. *Desalination*, *212*(1–3), 15–27.

Chen, D., Weavers, L. K., & Walker, H. W. (2006). Ultrasonic control of ceramic membrane fouling by particles: effect of ultrasonic factors. *Ultrasonics Sonochemistry*, *13*(5), 379–387.

Girard, B., & Fukumoto, L. R. (2000). Membrane processing of fruit juices and beverages: a review. *Critical Reviews in Food Science Nutrition*, *40*(2), 91–157.

Kobayashi, T., Chai, X., & Fujii, N. (1999). Ultrasound enhanced cross-flow membrane filtration. *Separation and Purification Technology*, *17*(1), 31–40.

Mairal, A. P., Greenberg, A. R., & Krantz, W. B. (2000). Investigation of membrane fouling and cleaning using ultrasonic time-domain reflectometry. *Desalination*, *130*(1), 45–60.

Mirsaeedghazi, H., Emam-Djomeh, Z., Mousavi, S. M., Ahmadkhaniha, R., & Shafiee, A. (2010). Effect of membrane clarification on the physicochemical properties of pomegranate juice. *International Journal of Food Science & Technology*, *45*(7), 1457–1463.

Mirsaeedghazi, H., Emam-Djomeh, Z., Mousavi, S. M., Aroujalian, A., & Navidbakhsh, M. (2009). Changes in blocking mechanisms during membrane processing of pomegranate juice. *International Journal of Food Science & Technology*, *44*(11), 2135–2141.

Muthukumaran, S., Yang, K., Seuren, A., Kentish, S., Ashokkumar, M., Stevens, G. W., & Grieser, F. (2004). The use of ultrasonic cleaning for ultrafiltration membranes in the dairy industry. *Separation and Purification Technology*, *39*(1–2), 99–107.

Nourbakhsh, H., Emam-Djomeh, Z., Mirsaeedghazi, H., Omid, M., & Moieni, S. (2014). Study of different fouling mechanisms during membrane clarification of red plum juice. *International Journal of Food Science & Technology*, *49*(1), 58–64.

Rai, P., Majumdar, G. C., DasGupta, S., & De, S. (2005). Modeling the performance of batch ultrafiltration of synthetic fruit juice and mosambi juice using artificial neural network. *Journal of Food Engineering*, *71*(3), 273–281.

Sharifanfar, R., Mirsaeedghazi, H., Fadavi, A., & Kianmehr, M. H. (2015). Effect of feed canal height on the efficiency of membrane clarification of pomegranate juice. *Journal of Food Processing and Preservation*, *39*(6), 881–886.

Vaillant, F., Millan, P., O'Brien, G., Dornier, M., Decloux, M., & Reynes, M. (1999). Cross flow microfiltration of passion fruit juice after partial enzymatic liquefaction. *Journal of Food Engineering*, *42*(4), 215–224.