Process Improvement of Crude Palm Oil Refining by Membrane Technology

Badlishah Sham Baharin

Food Science and Biotechnology
Universiti Putra Malaysia
43400 UPM, Serdang, Selangor
Malaysia

E-mail of Corresponding Author: badli@fsb.upm.edu.my

Key words: membrane technology, crude palm oil, palm oil refining, process improvement, separation technology.

Introduction

Production of palm oil is expected to increase to 20 million tons in 2005. Although the demand for palm oil is increasing, it faces competition from other oils. In order to remain competitive, palm oil must be further improved in quality. The recovery scheme for palm oil has not improved much for the past few decades. Although much improvement has been done to optimize the processes, the basic recovery system is still very much the same. Membrane technology has already been developed and applied in areas such as ultrafiltration processing of dairy products, fruit juice processing and waste treatment with much success. However, the development of hexane resistant membranes has allowed the application of membrane technology to be more viable in the oil refining industry. Based on studies involving cottonseed oil and soybean oil, ultrafiltration processes have been successfully utilized for degumming and deacidification. The implication that ultrafiltration can replace conventional methods open new options that may enable reduction in cost and energy requirement. Cost reduction comes in the form of elimination of degumming agents such as phosphoric acid and thereby reduces the need for waste treatment of such agents. In addition to this, since the oil need not undergo energy-intensive stripping operations to remove free fatty acids, the savings in energy costs are obvious.

Materials and Methods

Crude palm oil samples (CPO) were obtained from Jomalina Sdn. Bhd., Selangor, Malaysia. The sample was stored in a cold room at 7 C for one week before use. The membrane system is equipped with a feed tank of 50 liters capacity, a feed pump, a heat exchanger for controlling liquid temperature, pressure gauges, valves and a membrane module. The membrane modules used were Ceraflo tubular types supplied by U.S. Filter, Warrendale, U.S.A. with pore sizes of 0.45 μm, 0.2 μm (microfiltration size), 50 nm and 20 nm (ultrafiltration size). The system, including the membrane module had to be dried prior to testing with CPO. This is to prevent the oil sample from becoming soapstock in the presence of water. About 25 liters of CPO was melted to about 50 C before adding to the feed tank. The sample was stirred well to obtain a homogeneous feed solution. Recycling both permeate started the experiments and retentate back to the feed tank. Data were taken once the system had stabilized. Samples of crude oil, permeate and retentate were collected for quality analysis. Effects of transmembrane pressure, feed flowrate, temperature and processing time on the permeation flux were investigated. Samples were analysed for free fatty acid (FFA), carotene, fatty acid composition and phosphorous content according to PORIM Test Methods. Iron content was determined according to AOCS Method. Permeate flux was calculated by measuring the flow rate of permeate and is expressed in liters/m^2 hr.

Results and Discussion

In the studies conducted using microfiltration membranes, no differences in FFA content were observed in the CPO, permeate and retentate samples. This indicated that there was no separation of FFA by the membrane. The removal of this acid is difficult probably due to the small differences in molecular weight between fatty acids and triglycerides for separation and the membrane pore sizes were also too big. However, it was reported that removal of FFA is possible when treating crude soybean oil with miscella-forming agents that selectively bind FFA in crude oil before introducing it to nanofiltration. Thus, modification of feed and membrane with smaller pore size are required to obtain good removal of FFA.

Reduction of β-carotene in CPO by membrane process was very small. Again, this could be due to small differences in molecular weight between carotene and CPO, which resulted in ineffective separation. Microfiltration membranes seem to be too large to separate this component from the oil. Analysis on fatty acid compositions also showed insignificant differences on the major acid compositions (C16:0 and C18:1) between permeate and retentate samples. These results indicate that fractionation did not occur for this membrane. Membrane with pore size of 0.45 μm rejected about 14% of phosphorous from CPO. Separation of phosphorous from CPO is quite difficult since the molecular weight of phospholipids is around 800. It was reported by Goh et al that phospholipids cause reverse micelle, vesicle or emulsion droplet formation. Thus, the low rejection of phosphorous of this membrane indicates that most of the formation of reverse micelle in the sample was smaller than 0.45 μm. Membrane with pore diameter of 0.2 μm showed better rejection, which is about 56.8%. This higher rejection can only indicate that there are some reverse micelle formation within the range of 0.45 μm and 0.2 μm.

About 84.7% of iron was removed when CPO was microfiltered with 0.2 μm membrane. Gapor et al. reported that metals in particulate form can be removed by filtration or magnetic trap. Goh et al also reported that phosphoric acid treatment for the removal of phospholipid gums led to the removal of substantial quantities of iron and copper. Thus, membrane processing seems to remove iron particulate and the soluble irons as well.

The average transmembrane pressures were calculated as an average of the inlet and outlet pressures since the permeate line was exposed to atmosphere (zero gauge pressure). The flux for the 0.45 μm membrane gradually increased with pressure up to 1.65 bar. However, further observations for increase in pressure could not be made due to the equipment limitation. Whereas for the 0.2 μm membrane, it was observed that there was a sharp increase in flux at the initial stage until the average transmembrane pressure reached 1.25 bar. Further increase in pressure seemed to have no effect on the membrane flux. A typical flux-pressure relationship in which the flux increased initially with pressure and then stabilized to a constant value was also observed for milk and soybean oil applications. (Bennaser et al).

Both membranes showed an increase in flux with an increase in feed flow. An increase in recirculation velocities increased the turbulence on the membrane surface and consequently resulted in an increase in flux since the removal of components on the membrane surface is more effective at higher shear rates. It was noted that the flux started to decline when the feed low was further increased. This indicated that once a certain level of turbulence has been achieved, a further increase in recirculation velocities was not effective.

In the studies conducted on variation of permeate flux with time it was found that the flux decay is rapid and the permeate flux is very low. It was noted that stable flux values were obtained after about 6 hours of operation. Flux stability is important for the assessment and economic viability of membrane-based filtration.

Ceramic ultrafiltration membranes with pore sizes of 20 and 50 nm rejected 78.1% and 60% of phosphorous, respectively. Iron content was reduced by about 60% when using the 20 nm membrane. Both membranes showed no influence on other quality parameters. The effect of temperature on flux was significant as an increase in temperature resulted in an increase of flux.

Comparison study between sample of membrane-processed palm oil (M-PO) and conventional-processed palm oil (C-PO) was also carried out. Both samples went through the same deodorization conditions. The samples were analyzed for FFA, carotene and colour. Both samples showed reduction in FFA and carotene content. However, the carotene content and colour reading for M-PO were higher as compared to C-PO.

Conclusions

Ceramic microfiltration membranes with pore size of 0.2 μm were able to remove 56.8% of phosphorous and 80% of iron from crude palm oil. Hoever, there was no effect on FFA and carotene content. The FAC also indicated that fractionation did not occur during the membrane process. Ceramic ultrafiltration membrane of 20 nm pore size was able to remove 78.1% of phosphorous and 60% of iron from crude palm oil. Again, there was no effect on FFA and carotene content. FAC study also indicated no fractionation performed by membrane. In the comparison study it was found that reduction of phosphorous by the membrane (43.4%) was comparable and in fact, higher than conventional degummed, bleached oil (34.4%). Membrane-processed palm oil gave a higher carotene content and colour reading than conventional-processed palm oil after deodorization.

Benefits from the study

Membrane separation technology is a new technology development, which has not been fully embraced by the Malaysian palm oil industry. The research showed that there is potential for adopting this technology in the palm oil refining industry as an alternative to degumming and bleaching. Phosphorous and iron removal by membranes are comparable and in fact, slightly higher than conventional methods. The membrane process is purely physical, energy-saving and environmental-friendly. This research does put a case before the palm oil industry on its potential as a viable alternative to the current pretreatment methods.

Literature cited in the text

Gapor, A. and Ong, A.S.H. 1982. Some aspects of trace metals in palm oil. *PORIM Bulletin No. 4,* Palm Oil Research Institute of Malaysia, Pp 19-26.

Goh, E.M 1991. Palm oil composition and quality. *Proc. Of 1991 PIPOC* Pp 268-278. Palm Oil Research Institute of Malaysia.

Project Publications in Refereed Journals

Abdul Majid, R., Baharin, B.S., Ahmadun, F.R. and Che Man, Y.B. 2000. Processing of crude palm oil with ceramic micro filtration membrane. *J. of Food Lipids* 7(2): 113-126 (Won best MPOB staff publication award 2000).

Abdul Majid, R., Baharin, B.S., Ahmadun, F.R. and Che Man, Y.B. 2001. Processing of crude palm oil with ceramic ultrafiltration membrane. *J. Amer. Oil Chem. Soc.* (submitted).

Bennasar, Rouleau, M., Mayer, D., R. and Tarodo de La Fueute, B. 1982. Ultrafiltration of milk on mineral membranes:improved performance. *J of Society of Dairy Technology.* 35:43-49.

Ong, K.K., Baharin, B.S., Hassan, M.A., and Fakhru'l Razi, A. 1999. Degumming of crude palm oil by membrane filtration. *J. of Artificial Cells, Blood Substitutes and Immobilized Biotechnology* 27 (5 & 6): 381-385.

R. Abdul Majid, B.S. Baharin, F.R. Ahmadun and Y.B. Che Man 2001. Comparison study on impurities removal using membrane process and conventional refining process. *J. Amer. Oil Chem. Soc.* (under review).

Project Publications in Conference Proceedings

Ong, K.K., Baharin, B.S., Hassan, M.A. and Fakhru'l Razi, A. 1999. Degumming of crude palm oil by membrane filtration. World Engineering Congress, 19-22 July, Kuala Lumpur, Malaysia.

Graduate Research

Rusnani Abdul Majid. 2001. Chemical Engineering [M.Sc]. Universiti Putra Malaysia.

Ong Kheat Khim. 1999. Chemical Engineering [M.Sc]. Universiti Putra Malaysia.

I·R·P·A INTENSIFICATION OF RESEARCH IN PRIORITY AREAS

Research funded by the Intensification of Research in Priority areas (IRPA) - Supported by IRPA RM-7 (1996-2000), Cycle 1997, Grant 03-02-04-0062.