# REMOVAL OF FREE FATTY ACID FROM CRUDE PALM OIL USING ORGANIC SOLVENT NANOFILTRATION (OSN)

AZMIR BIN JAMALUDIN

UNIVERSITI TEKNOLOGI MALAYSIA

To my beloved family and friends

#### ACKNOWLEDGEMENT

Alhamdulillah, thanks to Allah S.W.T the Most Merciful for His blessing in giving me this opportunity to complete my thesis. First, I would like to express my gratitude and my thankfulness to my dedicative supervisor, Dr. Mohd Nazlee Faisal Md. Ghazali for his guidance, encouragement, advice, patience and support in sharing his knowledge to finish my thesis project. Besides, my sincere gratitude must surely goes to Puan Siti, senior technician who has been helping me to ensure the smoothness of my project. Last but not least, to my family and my friends those never stop in encouraging and supporting me to complete my thesis project from the beginning until the end. Special thanks also must be given to all who involved in this project whether I realized or not. Your good deeds will never be missing in my life. Thank you.

#### ABSTRACT

The high content of free fatty acid (FFA) in crude palm oil has become a challenge in refining process due to refining losses and possible bleachability problems. Nowadays, alkaline and distillation approaches are widely used in industry to remove FFA but certain factors such as high energy consumption, environmental pollution and cost had limited the usage. Organic Solvent Nanofiltration (OSN) is being studied as an alternative due to its lower energy consumption, easy scale up, lower cost and the loss of nutrients is minimal. The objective of this research is to study the feasibility of OSN to remove FFA from palm oil based on the rejection and flux of FFA and triglyceride (TG). Two parameters which are type of solvent used and the feed concentration of FFA were studied. Based on the result, acetone shows high solubility and diffusivity towards OSN membrane leading to high selectivity of FFA and high rejection of TG compared to hexane. The rejection of FFA increases with the concentration of FFA.

#### ABSTRAK

Kandungan asid lemak bebas yang tinggi dalam minyak kelapa sawit mentah telah menjadi satu cabaran di dalam proses perincian disebabkan kehilangan nutrient semasa proses perincican dan masalah kelunturan. Pada hari ini, pendekatan secara pengalkalian dan penyulingan digunakan secara meluas di industri untuk menyingkirkan asid lemak bebas tetapi beberapa faktor seperti penggunaan tenaga yang tinggi, pencemaran alam dan kos telah menyekat pengunaanya. Pelarut organik nanofiltrasi (OSN) sedang dikaji sebagai alternatif kerana penggunaan tenaga yang rendah, mudah untuk dinaikkan skala, kos yang rendah dan kehilangan nutrisi adalah sedikit. Objektif kajian ini adalah untuk mengkaji kebolehan OSN untuk menyingkirkan asid lemak bebas daripada minyak kelapa sawit mentah berdasarkan penolakan dan fluks asid lemak bebas dan trigliserida. Dua parameter iaitu jenis pelarut yang digunakan dan kepekatan suapan asid lemak bebas dikaji. Berdasarkan kepada keputusan, aseton menunjukkan keterlarutan dan keserapan yang tinggi terhadap membran OSN membawa kepada pemilihan asid lemak bebas yang tinggi dan penolakan kandungan trigliserida yang tinggi berbanding heksana. Penolakan asid lemak bebas menjadi tinggi apabila kepekatan suapan asid lemak bebas tinggi.

# TABLE OF CONTENTS

CHAPTER

## TITLE

PAGE

SUPERVISOR'S DECLARATION	ii
AUTHOR' DECLARATION	iii
DEDICATION	iv
ACKNOWLEDGEMENT	v
ABSTRACT	vi
ABSTRAK	vii
TABLE OF CONTENTS	viii
LIST OF TABLES	xii
LIST OF FIGURES	xiv
LIST OF APPENDICES	XV
LIST OF ABBREVIATIONS	xvi

## I INTRODUCTION

1.1	Research background	1
1.2	Problem Statement	3
1.3	Objective	4
1.4	Scope	4

2.1	Crude palm Oil (CPO)	5
	2.1.1 Composition and constituents of	8
	2.1.1.1 Triglyceride (TG)	9
	2.1.1.2 Mono and Diglyceride and	10
	Free fatty acid (FFA)	
	2.1.1.3 Minor Components	13
	2.1.2 The usage of treated CPO	14
	2.1.3 Quality of CPO	15
2.2	CPO refinery process	17
	2.2.1 Chemical refinery	18
	2.2.2 Physical refinery	19
2.3	CPO refinery using membrane filtration	22
	2.3.1 Type of membrane filtration	23
	2.3.2 Organic Solvent Nanofiltration (OSN)	25
	2.5.1.1 Characterization of membrane	25
	2.5.1.2 Transport mechanism by	27
	solution difussion	
	2.5.2 Flux and rejection on OSN	30
	2.5.2.1 Concentration of solute in	32
	feed	
	2.5.2.2 Type of solvent	33

# III METHODOLOGY

3.1	Calibration of Oleic acid and palmitic acid	34
	using Gas chromatography (GC)	
	3.2.1 Material and apparatus	34
	3.2.2 Methodology	34

3.2	Production of fatty acid methyl ester (FAME)	35
	from refined oil	
	3.2.1 Material and apparatus	36
	3.2.2 Methodology	36
3.3	Calibration of FAME using GC	37
	3.2.1 Material and apparatus	37
	3.2.2 Methodology	37
3.4	Preparation of fatty acid added to refined oil	38
	3.2.1 Material and apparatus	39
	3.2.2 Methodology	39
3.5	Filtration of FAME, oleic acid and fatty acid	40
	added to refined oil using OSN	
	3.2.1 Material and apparatus	40
	3.2.2 Methodology	40

# IV RESULTS AND DISCUSSION

4.1	Filtration of CPO	42
4.2	Filtration of oleic acid in acetone	45
4.3	Filtration of fatty acid added to refined oil	49
	(FAARO) in acetone by OSN	
4.4	Filtration of Triglyceride (TG) in acetone and	53
	hexane	

# V CONCLUSIONS AND RECOMMENDATION

5.1	Conclusion	57
5.2	Recommendation	58

REFERENCES
APPENDICES

# LIST OF TABLES

TABLE NO.

### TITLE

PAGE

2.1	Typical fatty acid composition in CPO (Lim,	12
	2008)	
2.2	Minor components of crude palm oil	13
2.3	Standard specification of refined palm oil	17
	(PORAM, 2006)	
3.1	Sample prepared for GC analysis	35
4.1	Flux of pure acetone and pure hexane through	43
	STARMEM 122 and STARMEM 240	
4.2	Solubility parameter for polyimide membrane,	43
	acetone and hexane (Qiau and Chung, 2005)	
4.3	Flux of CPO in acetone and CPO in hexane	44
	system through STARMEM 122 and STARMEM	
	240	
4.4	Flux as a function of oleic acid concentration	46
	through STARMEM 122	
4.5	Rejection of oleic acid in acetone through	47
	STARMEM 122	
4.6	Flux value of FAARO through STARMEM 122	50
4.7	The rejection percentage of oleic acid through	51
	STARMEM 122	

4.8	Flux for the filtration of TG in acetone and	54
	hexane through STARMEM 122	
4.9	Rejection of TG through STARMEM 122 and	55
	STARMEM 240	

## LIST OF FIGURES

FIGURE NO.

### TITLE

### PAGE

2.1	Three genotype of palm oil	6
2.2	Production of CPO in industrial scale	8
2.3	General structure of triglyceride	10
2.4	Hydrolysis of triglyceride	11
2.5	Structure of palmitic acid and oleic acid	12
2.6	Step in chemical refining process	19
2.7	Step in physical (distillation) refining process	20
2.8	Physical refining process of CPO	21
2.9	Range of filtration types	24
2.10	Molecular structure of polyimides (Hatori et al,	26
	1995)	
2.11	The flow of FFA through membrane using	30
	solution diffusion concept	
3.1	Graph of CPO-acetone peak from GC analysis	38
3.2	Filtration unit	41
4.1	Flux and rejection as a function of oleic acid	48
	concentration for STARMEM 122	
4.2	Rejection of oleic acid in FAARO by	52
	STARMEM 122	

# LIST OF APPENDICES

APPENDIX	
----------	--

### TITLE

## PAGE

А	Specification of FAME method used to analyzed	66
	the composition presented in the sample	
В	Oil sample filtered by OSN	67

# LIST OF ABBREVIATIONS

СРО	-	Crude Palm Oil
DOBI	-	Deterioration of bleachability index
FAARO	-	Fatty acid added to refined oil
FAME	-	Fatty acid methyl ester
FFA	-	Free Fatty Acid
FFB	-	Fresh fruit bunches
GC	-	Gas Chromatography
MJ	-	Mega Joule
MWCO	-	Molecular Weight Cutoff
OSN	-	Organic Solvent Nanofiltration
PFAD	-	Palm fatty acid distillate
PORAM	-	Palm Oil Refiners Association of Malaysia
RBD	-	Bleached and deodorized
RO	-	Reverse Osmosis
TG	-	Triglyceride

### **CHAPTER I**

#### **INTRODUCTION**

#### 1.1 Research background

Palm oil is an edible oil that has been used widely in food industry. It is originally produced from crude palm oil (CPO) which has gone through several treatment or refining processes. The CPO consisted of triglyceride (TG) which is the major component in palm oil, digylceride, monoglyceride, free fatty acid (FFA) and minor components such as carotenoids, tocopherols, sterols, phosphatides, triterphenic and aliphatic alcohols. The presence of FFA in CPO has become a problem in the refining process (Kaimal *et al.* 2002). The higher content of FFA will result in higher refining losses and possible bleachability problems. These factors will affected the removal process of color pigment, dirt, trace metal and various organic impurities that promote oxidation in palm oil. In order to convert CPO into an edible form, FFA must be removed or decreased to an acceptable level.

Nowadays, there are two methods that have been used widely in refining process which are chemical approach using alkali refining and physical approach using distillation. However, these methods have been limited to several disadvantages such as high energy consumption, high cost expenditure, high neutral oil losses and also contributed to environmental pollution (Manjula *et al*, 2009). Due to these problems a new method which is Organic Solvent Nanofiltration (OSN) has been studied to remove FFA from CPO. According to Livingston, 2008, this method used only 3 MJ of energy for pump operation while in distillation method, extensive energy is required to operate the heating and cooling process leading to high energy and cost losses.

OSN is a novel method of refining palm oil. In this method, FFA will be separated from the mixture of palm oil with the presence of organic solvent using OSN membranes. These membranes have the molecular weight cutoff (MWCO) of 200 to 1000 Dalton. Solute with smaller molecular weight and high affinity to the membrane will pass to the permeate while the solute with bigger molecular weight and low affinity will be in the retentate. The flux and rejection of FFA and TG are influenced by various parameters. In this research, the concentration of FFA and type of organic solvent used are studied to determine the flux and rejection thus determining the feasibility of OSN in removing FFA from CPO.

#### **1.2 Problem statement**

FFA in CPO has given many problems in refining process. Due to this problem, various methods had been introduced purposely to remove or level down the FFA content such as alkali process (chemical method) which uses chemical to neutralize the crude oil and distillation process (physical method) that is the most common method used nowadays.

The chemical refining process also known as alkali refining is relatively simple and removes free fatty acids and residual phosphatides almost completely. During the alkali refining process however, there are always considerable losses of neutral oil, sterols, tocopherols and vitamins. Furthermore, disposal and utilization of the resulting soapstock may cause environmental pollution problems. In physical refining approach, distillation at high temperature at 260°C and pressure at 55 bar is used to evaporate the FFA from CPO, which is energy-intensive.

The usage of OSN membrane to separate FFA from palm oil has a great potential to the palm oil industry. The concept is rather simple and yet cost effective as it can be operated at ambient temperature. It also has no damage to minor compounds in palm oil. However, the separation efficiency of this method has to be studied to determine the feasibility of OSN to remove FFA from palm oil.

#### 1.3 Objective

The objective of this research is to study the feasibility of Organic Solvent Nanofiltration (OSN) by varying the concentration of FFA in feed and the type of solvent used to remove FFA from CPO.

### 1.4 Scope of Study

The scopes of the study are to investigate the removal of FFA from palm oil using OSN by varying the concentration of FFA (0.0895, 0.1790, 0.2685, 0.3580 g/ml) in the feed and type of solvent used (acetone and hexane). The results of data are the rejection and flux of FFA after filtration.

#### REFERENCES

- Barzin, J., Madaeni, S.S., Mirzadeh, H., Mehrabzadeh, M. (2004). Effect of Polyvinylpyrrolidone on morphology and performance of hemodialysis membranes prepared from polyether sulfone, J. Appl. Polym. Sci., 92, 3804.
- Beerlage, M.A.M. (1994). Polyimide ultrafiltration membranes for non-aqueous systems, PhD Thesis, University of Twente Enschede.
- Bhosle B.M., R. Subramanian, K. Ebert (2005). Deacidification of model vegetable oils using polymeric membranes, Eur. J. Lipid Sci. Technol. 107, 746-753

Bockish M. (1998). Fats and Oils Handbook. AOCS Press.

- Che Man, Y. B., Liu, Jamilah (1999). Quality changes of RBD palm olein, soybean oil and their blends during deep-fat frying. Journal of Food Lipids 6 (3): 181–193.
- Cheryan, M. (1986). Ultrafiltration Handbook, Technomic PublishingCo., Inc., Lancaster.
- Cuperus, F. P., Smolders, C. A. (1991). Characterization of UF Membranes Membrane characteristics and characterization techniques, Advances in Colloid and Interface Science, 34, 135.

- Formo M. W., Jungermann E, Norris F. A., Sonntag N. O. (1979). Bailey's Industrial Oil and Fat Products. John Wiley & Sons Inc.
- Goh E. M. (1991). Palm Oil Composition and Quality. PORIM International Palm Oil Conference (Chemistry and Technology). 268-278
- Hashim (2004). A study of the Membrane Filtration of Whey and Palm Oil Mixtures,M. Sc., TheUniversity ofManchester, United Kingdom, 58
- Hatori H., Yamada Y., Shiraishi M. (1995). Preparation of Macroporous Carbons from Phase Inversion Membranes, J. Appl. Polym. Sci., 57, 871-876
- Hodgson, A. S. (1996). Refining and Bleaching, in Bailey's, Industrial Oil and Fat Products, Vol. 4, Edible Oil and Fat Products: Processing Technology, 5th edn., edited by Y.H. Hui, John Wiley & Sons, New York, 172–187.
- Kaimal T.N.B, Ali S.R. V., Rao B.V.S.K., Chakrabarthy P.P., Vijayalakshmi P., Kale V., Rani K.N.P., Rajamma O., Bhasakar P.S., Rao T.C, Eur. J. (2002). Lipid Sci. Technol. 104, 203-211
- Krishna Kumar N.S., Bhowmick D. N. (1996). Separation of fatty acid/triacylglycerol by membrane, 73, 3
- Leong W. L (1992). The Refining and Fractionation of Palm Oil. Palm Oil Mill Engineers-Executives Training Course 14th Semester 1. PORIM Bangi, 1-6

- Lim, Jit Kang (2008). Refinery of Plam Oil. Retrieved December 12, 2010, from http://www.andrew.cmu.edu
- Lonsdale H, Merten U., Riley R. (1965). Transport of cellulose acetate osmotic membranes, J. Appl. Polym. Sci., 9, 1341.
- Manjula S., Subramanian R. (2009). Separation and purification technology, 66, 223-228
- Noor Azian, M. (1995). The Physical Properties of Palm Oil Mixtures for Design of Process Equipment University of Leeds.Ph. D Thesis.
- Ong A. S, Goh S. H. (2002). Palm oil, A Healthful Cost-Effective Dietary Component, Food Nutr Bull. Mar; Vol.23, No.1, 11-22
- Paul D. R. (2004). Reformulation of the solution-diffusion theory of reverse osmosis, J. Membr. Sci. 241, 371–386.
- Peeva L.G, Gibbins E., Luthra S. S., White L. S., Stateva R. P., Livingston A. G. (2004). Effect of concentration polarisation and osmotic pressure on flux in organic solvent nanofiltration, J. Membr. Sci. 236, 121–136.
- Ping Tou Gee (2007). Analytical characteristics of crude and refined palm. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.
- PORAM (2006). Palm Oil Refinery Association of Malaysia. Retrieved 2006, from http://www.poram.org.my

- Qiao, Xiangyi, Tai-Shung Chung (2005). Fundamental characteristics of sorption, swelling and permeation of P84 Co-polyimide Membranes for Pervaporation Dehydration of Alcohols, Ind. Eng. Chem. Res., 44, 8938-8943
- Saravanan M. B.B. (2006). Processing hexane-oil miscella using a nonporous. Journal of food engineering, 529-535.
- Silva P., Han S., Livingston A.G. (2005). Solvent transport in organic solvent nanofiltration membranes, J. Membr. Sci. 262, 49–59.
- Silva P., Livingston A. G. (2006). Effect of solute concentration and mass transfer limitations on transport in organic solvent nanofiltration-partially rejected solute, J. Membr. Sci. 280, 889-898
- Stafie N., Stamatialis D. F., Wessling M. (2004). Insight into the transport of hexanesolute systems through tailor-made composite membranes, J. Membr.Sci.228, 103-116.
- Subramanian R., Nakajima M., Raghavarao K. S. M. S., Kimura T. (2004). Processing vegetable oils using nonporous denser polymeric composite membranes. J. Am Oil Chem Soc., 81, 313–322.
- Subramanian R., Raghavarao K.S.M.S., Nabetani H., Nakajama M., Kimura T., Maekawa T. (2001). Differential permeation of oils constituents in nonporous denser polymeric membranes, J. Membr. Sci. 187, 57–69.
- White L. S., Nitsch A. R. (2000). Solvent recovery from lube oil filtrates with a polyimide membrane, J. Membr. Sci. 179, 267–274

- White, L. S. (2001). Polyimide membranes for hyperfiltration recovery of aromatic solvents, US 6, 180, 008,
- White, L.S. (2002). Transport properties of a polyimide solvent resistant nanofiltration membrane, J. Membr. Sci., 205, 191
- Wijmans J. G., Baker R. W. (1995). The solution-diffusion model: a review, J. Membr. Sci. 107, 1–21.
- Zwijenburg H. J., Krosse A.M., Ebert K., Peinnemann K.V., Cuperus F. P. (1999). Acetone-stable nanofiltration membranes in deacidifying vegetable oil, JAOSC 76 83–87.