UNIVERSITI PUTRA MALAYSIA

RECOVERY OF LOW LACTOSE GOAT'S MILK USING CROSS-FLOW ULTRAFILTRATION MEMBRANE

NUR SOFUWANI BINTI ZAINUL ABIDIN

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By

NUR SOFUWANI BINTI ZAINUL ABIDIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

June 2016

Dedicate to my husband, Faiz, and my parents who have always encouraged me to follow my passion. Thank you for your loving support.

2016, Serdang, Malaysia

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chair: Assoc. Prof. Datin Siti Aslina Binti Hussain, PhD
Faculty: Engineering

An extensive amount of research has reported on the use of ultrafiltration (UF) membrane, particularly in the improvement of membrane performance efficiency on cow's milk. However, a very limited number of researches reported on using UF for producing low-lactose goat's milk due to inherently low lactose. Nonetheless, goat's milk is still not suitable to be consumed in a large amount by people who are lactose intolerant, especially among Asians, where over 90% of the populations are suffering from lactose intolerance.

Until today, fouling and concentration polarization (CP) on membrane surface in cross-flow hollow fiber UF unit are the major problems in the dairy industry. Discovery on how to overcome the problem is still in a hot debate due to the nature's complex composition in milk. One way to overcome this problem is by evaluating the effects of processing parameters such as trans-membrane pressure (TMP) and feed-flow rate on flux (J), lactose rejection (Ri), concentration factor (CF), and accumulation rate (AR) during the fractionation of lactose.

In terms of lactose fractionation for 5 KDa and 10 KDa UF membranes, the TMPs examined were 0.41, 0.55, and 0.69 bars, while feed flow-rates examined were 0.18, 0.34, 0.54, and 0.74 L/min. 5 KDa membrane shows that feed flow-rate and flux behave in a direct relationship, while an inverse relationship in 10 KDa membrane. Both membranes showed that TMP 0.55 bar exhibit the best flux value without reaching the limiting flux region, but with feed flow rate of 0.74 L/min in 5 KDa, while 0.18 L/min in 10 KDa membrane.

In statistical analysis software (SAS), feed flow-rate of 0.74 L/min was significantly greater ($P < 0.05$) in 5 KDa, while in 10 KDa membrane, flow-rate of 0.18 L/min gave the best condition ($P < 0.05$) that required in the lactose fractionation. Lactose rejection percentage (%Ri) is the lowest with 77.71% in 5 KDa membrane while 66.28% in 10 KDa membrane. This can be summarized

that the best parameters for 5 KDa membrane is at TMP 0.55 bar with feed flow-rate of 0.74 L/min, while for 10 KDa membrane is at TMP 0.55 bar with feed flow-rate of 0.18 L/min. Due to higher flux value and lowest lactose rejection obtained from low feed flow-rate, 10 KDa UF membrane size was chosen over 5 KDa.

The competitiveness between the concentrated milk obtained from 10 KDa UF membrane in this study and the commercial milk powder were compared in terms of nutrition facts and lactose concentration. The concentrated milk contained 5.63 g per 100 ml lactose concentration, which ranked at the second lowest concentration in the range of 2.81 to 7.91 g per 100 ml, proved that it is similar and comparable in standard as to commercial milk. As a conclusion, a high degree of lactose removal from goat's milk could be achieved by 10 KDa UF membrane in a cross-flow hollow fiber system, which proved that different outcomes between 5 KDa and 10 KDa membranes and feed flow-rate required is closely associated to UF pore size and molecular weight of feed solute particles.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMULIHAN SUSU KAMBING RENDAH LAKTOSA MENGGUNAKAN MEMBRAN ULTRATURASAN ALIRAN SILANG

Oleh

NUR SOFUWANI BINTI ZAINUL ABIDIN

Jun 2016

Pengerusi: Prof. Madya Datin Siti Aslina Binti Hussain, PhD
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Banyak kajian telah dilaporkan mengenai penggunaan membran ultraturasan (UF), terutamanya dalam peningkatan kecekapan prestasi membran pada susu lembu. Walaubagaimanapun penyelidikan yang dilaporkan terhadap pemulihan susu kambing rendah laktosa amat terhad kerana kandungan laktosa yang sememangnya lebih rendah. Walaupun susu kambing mempunyai laktosa yang lebih rendah, ia masih tidak sesuai untuk diambil dalam jumlah yang besar untuk orang-orang yang tidak toleran terhadap laktosa, terutamanya bagi orang-orang Asia di mana lebih 90% daripada populasi ini mengalami intoleransi laktosa.

Sehingga hari ini, kekotoran dan penumpuan polarisasi (CP) pada permukaan membran dalam unit aliran silang serat berongga UF adalah masalah utama dalam industri tenusu dan penemuan mengenai bagaimana untuk mengatasi masalah ini masih dalam perdebatan yang panas kerana sifat komposisi susu yang kompleks. Salah satu cara untuk mengatasi masalah ini adalah dengan menilai kesan parameter pemprosesan seperti tekanan trans-membran (TMP), dan kadar aliran suapan ke atas peratus penolakan laktosa (Ri), faktor kepekatan (CF), dan kadar akumulasi (AR) semasa fraksinasi latosa.

Dalam fraksinasi laktosa, TMP yang diperiksa adalah 0.41, 0.55, and 0.69 bar, manakala kadar aliran suapan yang diperiksa adalah 0.18, 0.34, 0.54, dan 0.74 L/min. Dalam membran 5 KDa, kadar aliran suapan dan fluks bertindak balas dalam hubungan secara langsung, manakala bertindak balas dalam hubungan bertentangan dalam membran 10 KDa Kedua-dua membran menunjukkan bahawa TMP 0.55 bar menghasilkan nilai fluks terbaik tanpa melepasi garisan had fluks, tetapi pada kadar aliran suapan 0.74 L/min untuk 5 KDa, manakala 0.18 L/min untuk 10 KDa.

Menggunakan perisian analisis statistik (SAS), kadar aliran suapan 0.74 L/min adalah jauh lebih besar ($P < 0.05$) dalam membran 5 KDa, manakala dalam membran 10 KDa, kadar aliran suapan 0.18 L/min memberikan keadaan terbaik

($P < 0.05$) yang diperlukan dalam fraksinasi laktosa. Peratus penolakan laktosa (%Ri) adalah yang paling rendah dengan 77.71% dalam membran 5 KDa manakala 66.28% dalam membran 10 KDa. Ini boleh dirumuskan bahawa parameter terbaik untuk membran 5 KDa adalah pada TMP 0.55 bar dengan kadar aliran suapan 0.74 L/min, manakala bagi membran 10 KDa adalah pada TMP 0.55 bar dengan kadar aliran suapan 0.18 L/min. Disebabkan oleh nilai fluks yang lebih tinggi dan peratus penolakan laktosa yang paling rendah diperolehi dari kadar aliran suapan yang rendah, maka membran UF bersaiz 10 KDa dipilih berbanding 5 KDa.

Daya saing di antara susu pekat yang diperoleh dari membran 10 KDa hasil dari kajian dan susu tepung komersial telah dibandingkan dari segi fakta nutrisi dan kepekatan laktosa. Susu pekat mengandungi 5.63 g per 100 ml kepekatan laktosa, yang berkedudukan kedua terendah dalam julat 2.81 ke 7.91 g per 100 ml, membuktikan bahawa susu pekat adalah setaraf dengan susu komersial. Kesimpulannya, penyingkiran laktosa yang tinggi daripada susu kambing boleh dicapai menggunakan membran UF 10 KDa dalam sistem aliran silang serat berongga, membuktikan bahawa keputusan yang berbeza di antara 5 KDa dan 10 KDa dan kadar aliran suapan yang diperlukan berkait rapat dengan saiz liang UF dan berat molekul zarah suapan bahan larut.

ACKNOWLEDGEMENTS

“In the name of Allah, the most beneficient, the most merciful”
All praise to Allah SWT the Most Gracious to give me the strength and desire to complete my study.

Deepest appreciation to my beloved husband, parents, and other family members for their unending moral support, great sacrifices, and continuous prayers to my achievement in life and studies. Special thanks are due to all those, whom I could not mention here, and contribute to the completion of this study through their physical, moral, or spiritual support.

I wish deepest acknowledgement to my supervisor, Assoc. Prof. Datin Siti Aslina binti Hussain for her valuable guides, patience, encouragement and strong support throughout this study. My gratitutde also extended to my supervisory committee member, Assoc. Prof, Dr. Siti Mazlina binti Mustapa Kamal for her advice, comments, and contributions during this study.

My special thanks are also extended to the staffs and friends in the Department of Process and Food Engineering, Department of Chemical and Environmental Engineering, and Department of Food Science and Technology, UPM particularly Mr. Jumardi Roslan, and technicians Mr. Zahir, Madam Masliza, Mr. Amran, and those have contributed in this research. Thanks are also dedicated to Madam Rosnaini Ali and Mr. Saiful from Department of Veterinary Services, Alor Gajah, Melaka for their assistance in quality analysis. I also acknowledge with great gratitude to Mr. Tan from Sungai Cheroh, Raub, Pahang, Malaysia for raw milk supply used in this research.

Acknowledgement is due to Department of Process and Food Enginering, University Putra Malaysia and Minister of Higher Education, Malaysia for granting the financial support for my Masters studies in UPM.

I certify that a Thesis Examination Committee has met 17th June 2016 to conduct the final examination of Nur Sofuwani Binti Zainul Abidin on her thesis entitled “Recovery of Low Lactose Goat’s Milk using Cross-Flow Ultrafiltration Membrane” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CF	Concentration Factor
CFF	Cross-flow filtration
CP	Concentration polarization
HPLC	High Performance Liquid Chromatography
MF	Microfiltration
NaOH	Sodium Hydroxide
NF	Nanofiltration
NFF	Normal Flow Filtration
P	Level of significance
RO	Reverse Osmosis
SAS	Statistical analysis system
TMP	Transmembrane Pressure
UF	Ultrafiltration

LIST OF GLOSSARY

Allergy	A hypersensitivity reaction initiated by specific immunologic mechanisms.
Concentration Factor	The volume reduction achieved by concentration, i.e. the ratio of initial volume of feed to the final volume of concentrate/retentate
Concentration Polarization	The accumulation of retained molecules (gel layer) on the upstream surface of the membrane.
Cow's milk protein allergen	A hypersensitivity reaction to cow's milk protein initiated by specific immunologic mechanisms allergy
Cow's milk protein	A non-allergic hypersensitivity to cow's milk protein
Cross-flow filtration	A process where the feed stream flows parallel to the membrane face. Applied pressure causes one portion of the flow stream to pass through the membrane (filtrate) while the remainder (retentate) is recirculated back to the feed reservoir
Cross-flow Rate	The recirculating volumetric flow rate of the feed solution through the cassette assembly. Flow rate is measured at the retentate, and is typically recorded as liters/minute
Feed	The solution to be concentrated or fractionated
Flux	The rate of extraction of permeate measured in litres per square meter of membrane surface area per hour (l/m2/h)
Food allergy	An adverse health effect arising from a specific immune response that occurs reproducibly on exposure to a given food. Also known as food hypersensitivity
Food intolerance	A non-allergic food hypersensitivity
Gastrointestinal allergy	Food allergy in which upper gastrointestinal symptoms may occur within minutes and lower gastrointestinal symptoms may occur either immediately or with a delay of up to several hours
Gel Layer	The microscopically thin layer of molecules that forms on the upstream side of the membrane. It causes a

	reduction in the filtrate flow rate and may increase the retention of molecules that would normally cross into the filtrate
Membrane fouling	Deposition and accumulation of feed components on the membrane surface and/or within the pores of the membrane. Causes an irreversible flux decline during processing
Permeate	The filtrate, the liquid passing through the membrane
Product Recovery	The amount of product (mass or activity) recovered after processing compared to the amount in the starting sample. Usually expressed as a percentage of starting material.
Retentate	The concentrate, the retained liquid
Skim milk (plasma)	Milk - Fat
Solid Non-fat	Protein, lactose, minerals, vitamins, and enzymes.
Total solids	Fat + Solids Non –fat
Trans-membrane Pressure	It is the driving force for liquid transport through the ultrafiltration membrane. Calculated as the average pressure applied to the membrane minus any filtrate pressure. In most cases, pressure at filtrate port equals zero
Water Permeability	The water filtrate flux rate over the TMP for a given membrane
Whey (serum)	Skim milk - Casein micelles

LIST OF NOTATIONS

A	Membrane effective area (m^2)
Cf	Concentration of solute in the feed stream (mg/mL)
Cp	Concentration of solute in the permeate (mg/mL)
Cr	Concentration of solute in the retentate stream (mg/mL)
J	Permeating Flux ($L/m^2.hr$)
L	Liter
M	Meter
R	Lactose recovery or transmission of lactose in permeate
Ri	Rejection of Lactose or lactose left in the retentate
t	Time (minute)
Vp	Permeate volume (L)

CHAPTER 1

INTRODUCTION

1.1 Background

In Malaysia, the government has begun its focus on increasing local milk production within the dairy sector due to economic changes among consumers (Wouters, 2011). In fact, researchers reported that more goats are being reared at present in Malaysia compared to cow in year 2003, as to meet the requirements of consumers for high quality, healthy, and a variety of food at reasonable price (Rezai et al., 2011; Liana et al., 2010; Omar, 2010; Arshad et al., 2006). Additionally, many factors, such as education and modernization, have increased consciousness among consumers towards their routine diet (Quah & Tan, 2010; Ishida et al., 2003). These statements, moreover, are supported by the data gathered by FAO 2015, which claimed a significant increase in the total milk production in Malaysia that rose from 0.03 million tons (MT) in 1990 to 0.08 MT in 2013. The increment in the production value of milk in Malaysia was approximately threefold and had been expected to rise throughout the next decade.

Goat's milk is a complex biological fluid that contains proteins, lipids, lactose (carbohydrate), minerals, bacteria, and various micronutrients. The two types of proteins in the milk are the predominant 80% caseins (αS1, αS2, β, κ) and 20% whey (α -lactalbumin and β –lactoglobulin). Besides, Mahmood and Usman (2010) reported that goat's milk contained slightly lower lactose, which was 4.39 ± 0.34%, compared to 4.51 ± 0.38% of lactose in cow's milk. This is supported by most previous studies, provided that goat's milk was found to have 4.08% of lactose, which is lower in comparison to 4.78% of lactose content in cow's milk (Saini & Gill, 1991; International Dairy Federation, 1986; Posati & Orr, 1976). Basically, lactose (β-D-galactopyranosyl-(1$\rightarrow$4)-D-glucose) is a natural sugar and the main carbohydrate in all mammalian milks.

Nevertheless, Lehr and Chang (2010) reported that the average daily intake of milk in Malaysia was far less than in Scandinavia as a majority of Malaysians were found sensitive to lactose and this sensitivity is called 'lactose intolerance'. Moreover, Asmawi (2006) also proved that over 80% of Malaysians suffered from lactose intolerance. In short, lactose intolerance is the lack of lactase enzyme to digest sugar lactose, which normally disappears after weaning for most humans (Leonard, 2013). In fact, it has been proved that due to the lower lactose and other biological fluid properties, goat's milk is healthier than cow's milk for humans. Thus, as reported by Pouliot (2008) and Robinson and Tamime (1991), since in the early 1970s, a huge idea to separate milk components at the molecular level via separation technique to better utilize each component have been implemented in the dairy industry.

Additionally, previous studies reported that several technologies could actually remove lactose from milk (Baker, 2005; Khider et al., 2004; Barba et al., 2001; Barba & Beolchini, 2000; Pouliot et al., 1999; Hall, 1995). First, lactose is hydrolyzed into glucose and galactose, but this method is not preferred due to the disadvantage in terms of sweetness. Besides, Novalin et al., (2005) and Mahoney (1992) reported that the sweetness increased up to 70% for sucrose and this high level of sweetness can be an advantage or disadvantage; depending on the purpose of the products. Second is through enzymatic hydrolysis, but it involves high enzyme cost (Bylund, 1995). The third alternative is to separate lactose via crystallization, however, it is limited to only by-products from whey or whey permeated (Vyas, 2003). Lastly, the fourth approach is chromatographic separation, proposed by Barillas and Solomons (1987), where milk is fractionated where lactose fraction is separated and the salts remain in the protein fraction or the protein/fat fraction. The advantage of the process is that instead of permeate, a pure lactose solution is obtained and all substances significant to the taste, including salts, remain in the milk. However, it is a time-consuming and complex process, and besides, expensive equipment is required.

At present, the membrane technology has become widely used because it does not require phase change in dewatering, unlike condensation and evaporation, hence an energy saving process, a non-thermal technique, higher separation efficiency, and organoleptic characteristics of the milk product may be retained (Humphrey & Siebert, 1992). It also replaced some conventional concentration techniques (Jelen & Tossavainen, 2003; Humphrey & Siebert, 1992; International Dairy Federation, 1991). In dairy industry today, there are four types of pressure-driven membrane filtration processes used, which are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) (Pouliot, 2008).

Ultrafiltration (UF) is a medium pressure-driven membrane filtration process that emerged in the 1970s, which can separate components on a molecular basis. UF has molecular weight cut-off (MWCO) in the range of 1-500 KDa and corresponds to a nominal pore diameter of 1 to 100 nm (Kulkarni et al., 2001; Zall, 1987). The cut-off means molecular weight of the smallest molecule that cannot pass through the membrane. The pore size of the UF membrane is selected based on the size of the molecules being separated.

In UF, water, minerals, sugars (lactose), urea, amino acids, organic acids, and vitamins pass through the membrane (Shakeel-Ur-Rehman, 2009; Nielsen, 2000), while retaining 20-40% of non-protein nitrogen compounds, up to 10% lactose and minerals, and other ions attached to proteins (calcium, magnesium, phosphate, and citrate). In other words, larger molecules, such as proteins, fat, and carbohydrates, are fully or partially retained; depending on the pore size of the membrane used (Mulder, 1991). UF was mainly used for producing low lactose dairy products from cow's milk (Patel et al., 1991; Edelsten et al., 1983; Kosikowski, 1979). Hence, applying UF membrane with MWCO greater than 10 KDa would lead to increased transmission or loss of essential milk proteins, while using UF membrane with pore size smaller than 5 KDa may cause inefficiency in the UF process due to a significant reduction in lactose transmission. That is why the most common cut-off in dairy standard is 10 KDa.

Generally, the membrane technique method possesses two possible phenomena that can affect the accuracy or the operation effectiveness, which are concentration polarization (CP) and fouling at the membrane surface (Ochando-Pulido et al., 2015; Norafifah et al., 2015; Castro & Gerla, 2005). Membrane fouling is the accumulation of soil, or foulant, on the surface or within the pores of a membrane. Fouling prolongs processing times, increases energy and cleaning costs, decreases separation efficiency, and may lead to irreversible clogging of the membrane (Brans et al., 2004; Choi, 2003). The severity of fouling may be controlled and reduced, but it is impossible to be completely vanished (Howell & Finnigan, 1991). Meanwhile, CP is the accumulation of excess particles in a thin layer adjacent to the membrane surface and is inherent of all membrane filtration processes. It may increase resistance to solvent flow, and thus, reduce the permeate flux (Song & Elimelech, 1995).

1.2 Problem Statement

An extensive amount of researches has been conducted and reported on the use of UF in dairy industry, particularly in the lactose separation process, and most researchers investigated the improvement of membrane performance efficiency only on cow's milk, while very limited research reported using UF on producing low-lactose goat's milk. This is due to the inherently lower lactose in goat's milk, ~4.39% as compared to cow's milk, 4.51% (Mahmood & Usman, 2010).

Even though goat's milk naturally has lower lactose than cow's milk (~4.39% compared to 4.51%), however, when consumed in a large amount, those intolerant to lactose may suffer several inconvenient symptoms, such as bloating, nausea, and diarrhea (Hogenauer & Hammer, 2010; Swagerty et al., 2002). This is due to the different collection of protein composition in goat's milk that form a weaker and softer bolus curd which coagulates faster during digestion (Cooke, 2010; Haenlein, 2004; López-Aliaga, 2003; Park, 1994), and smaller size of fat globules that is one fifth the size of fat globules in cow's milk which offer naturally homogenized mixture of fat in milk (Park et al., 2007; Alférez, 2001). Hence, goat's milk is originally not suitable as an alternative to cow's milk when a particular amount is consumed.

Therefore, goat's milk had been used throughout this research as it may contribute to the Malaysian dairy industry and a variety of products for Asians where over 90% of the population suffers from lactose intolerance (Sloan, 1999). Hence, the novelty of this research is the removal of lactose using goat's milk as a raw material. Moreover, goat's milk contains many benefits compared to other mammal milk because it is very close to human's breast milk, naturally homogenized, less likely to trigger lactose intolerance and irritability, easily digested, has better buffering quality which is good for ulcer treatment, and matches up to the human body.

In fact, recently people had realized the benefits of goat's milk as compared to cow's milk, where reported that more goats are being reared at present in Malaysia compared to cow in year 2003, as to meet the requirements of consumers for high quality, healthy, and a variety of food at reasonable price (Rezai et al., 2011; Liana et al., 2010; Omar, 2010; Arshad et al., 2006). Goat farming in Malaysia specifically has increased substantially during the last two decades, which is over 45% from 331 thousands (K) in 1990 to 482 K number of heads in 2013 (FAO, 2015). This leads to a good opportunity for Malaysia's dairy industry to utilize goat's milk for a low-lactose product.

Fouling and concentration polarization on membrane surface during goat's milk processing which deteriorating the flux and gave negative impact on product yield are the major problems in the dairy industry. Until today, the issue concerning how to overcome fouling in cross-flow hollow fiber ultrafiltration unit is still debated due to the complex composition characteristic of milk that consists of proteins, minerals, lactose, and fat which contributes to the major foulants during the dairy UF process (Cheryan, 1998; Zeman & Zydney, 1996). Hence, this study focuses on determining the best condition of processing parameters and evaluating the effects of the selected parameters on flux (J),

lactose rejection (Ri), concentration factor (CF), and accumulation rate (AR) as Yeh et al., (2003) and Cheryan (19980) reported that the most significant operating conditions in UF are trans-membrane pressure, cross flow velocity, feed concentration, and temperature.
Particularly, in aspects of lactose removal with sizes of 342 Da from goat's milk, fractionation via reverse osmosis (RO) and nanofiltration (NF) membrane are more efficient, but they need higher operating pressure and higher cost consumption compared to the UF process (Namvar-Mahboub & Pakizeh, 2012). Thus, UF was used in this study since it has been mainly used for producing low lactose dairy products from cow's milk (Patel et al, 1991; Edelsten et al, 1983; Kosikowski, 1979).

1.3 Objectives

1. To evaluate the effects of processing parameters on flux (J), lactose rejection (Ri), concentration factor (CF), and accumulation rate (AR) in the fractionation of lactose using cross-flow ultrafiltration membrane.
2. To evaluate and compare the quality of concentrated goat's milk powder with commercialized milk products in terms of milk composition and lactose concentration.

1.4 Scopes of Work

The scopes of work in this research had been limited to determine the performances of two sizes of MWCO 5 KDa and 10 KDa UF membranes in a cross-flow filtration unit by means of lactose concentration, permeate flux (J), and lactose rejection percentage (%Ri), and accordingly, to select the best processing parameters examined, which were TMP and feed flow-rate. Hence, in order to ensure the comparability of low lactose goat's milk produced with other commercialized milk, all the milk samples were compared after atomization by spray-drying in terms of lactose percentage range and nutritional composition. Nonetheless, this research was not extended to determine the amount of protein content in concentrated milk.

REFERENCES

Adams, M.C. (2012). *Examination of Methods To Reduce Membrane Fouling During Dairy Microfiltration and Ultrafiltration.* Pages: 122. Master dissertation, Cornell University.

Aimar P., Tadd, E.C., Lafaille, P., Sanchez, V. (1988). *Journal of Membrane Science*. 38: 203-221.

Aimar, P. (1987) Ultrafiltration of pseudoplastic fluids. In Separations for Biotechnology. Verrall, M.S. and Hudson. M.J. (eds.), Ellis Horwood, Chichester, pp. 360-372.

Aimar, P. and Howell, J.A. (1989). Effects of concentration boundary layer development on the flux limitations in ultrafiltration, Chemical Engineering Research and Design. 67: 255-261.

Alférez, M.J.M., Barrionuevo, M., Lopez Aliaga, I., Sanz Sampelayo, M.R., Lisbona, F., Robles, J.C., Campos, M.S. (2001). Digestive utilization of goat and cow milk fat in malabsorption syndrome. *Journal of Dairy Research*. 68: 451–461. doi:10.1017/S0022029901004903

Almaas, H., Cases, A.L., Devold, T.G., Holm, H., Langsrud, T., Aabakken, L., Aadnoey, T., Vegarud, G.E. (2006). In vitro digestion of bovine and caprine milk by human gastric and duodenal enzymes. *International Dairy Journal*. 16: 961-968.

Alvarez, F., Arguello, M., Cabero, M., Riera, F. A., Alvarez, R., Iglesias, J.R. and Granda J. (1998). Fermentation of concentrated skim-milk. Effects of different protein/lactose ratios obtained by ultrafiltration-diafiltration. *Journal of the Science of Food and Agriculture*. 76: 10-16.

Ambrosoli, R., Stasio, L. and Mazzocco, P. (1988). Content of alpha-s-1-casein and coagulation properties in goat milk. *Journal of Dairy Science*. 71: 24-28.

Amigo, L. and Fontecha, J. (2011). Goat milk. Encyclopedia of Dairy Science(Second Edition): 484–493.

Anonymous. (2005). ChE 382: Unit Operations Laboratory: Ultrafiltration. Issue: 1. Pages: 1-6.

Anonymous. (2015). Membrane Operations. Retrieved on 28th May 2015. Available from http://www.separationprocesses.com/Membrane/MT_Chp05i.htm#TopPage

AOAC, 1990. Official Methods of Analysis Chemists, 15th ed. Association of Official Analytical Chemists AOAC, USA, Virginia, Arlington.

AOAC. 2000. Official Methods of Analysis. Association of Official Analytical Chemists. 17th Ed Washington, DC.

AOAC, 2003. Official methods of analysis of the association of official's analytical chemists, 17th edn. Association of official analytical chemists, Arlington, Virginia.

Arshad, F. M., Mohamed, Z., & Latiff, I. A. (2006). Changes in Agri-Food Supply Change in Malaysia : Implications on Marketing Training Needs. In, FAO/AFMA/FAMA Regional Workshop on Agricultural Marketing Training, Kuala Lumpur, Malaysia.

Asmawi, M.Z., Seppo, L., Vapaatalo, H. and Korpela, R. (2006). Hypolactasia and lactose intolerance among three ethnic groups in Malaysia. *Indian*

Journal of Medical Research. 124: 697-704.
Aspelund, M. T. (2010). Membrane-based separations for solid/liquid clarification and protein purification. Iowa State University.
Atkinson, S. (2005). Isoflux membrane technology is efficient and economical. Membrane Technology. Volume 2005, Issue 8, pp. 9- 10, August 2005, from http://www.sciencedirect.com/science/article/pii/S095821180570481X
Atra, R., Vatai, G., Bekassy-Molnar, E. and Balint, A. (2004). Investigation of ultra and nanofiltration for utilization of whey protein and lactose. *Journal of Food Engineering*. 67: 325-332.
Attaie, R., Richter, R.L. (2000). Size distribution of fat globules in goat milk. *Journal of Dairy Science*. 83: 940-944.
Attia, H., Bennasar, M., de la Fuente, B.T. (1991). *Journal of Dairy Research*. 58: 51-65.
Babayan, V.K. (1981). Medium chain length fatty acid esters and their medical and nutritional applications. *Journal of the American Oil Chemists' Society*. 59: 49A-51A.
Babu, J., Kumar, S., Babu, P., Prasad, J.H. and Ghoshal, U.C. (2010). Frequency of lactose malabsorption among healthy southern and northern Indian populations by genetic analysis and lactose hydrogen breath and tolerance tests. *The American Journal of Clinical Nutrition*. 91: 140-146.
Baker, R.J., Fane, A.G., Fell, C.J.D. and Yoo, B.H. (1985). Factors affecting flux in cross-flow filtration, *Desalination Journal*. 53: 81-93.
Baker, R.W. (2005). Membrane Technology and Application. 2nd Ed. Kirk-Othmer Encyclopedia of Chemical Technology. John Wiley & Sons, Inc, New Jersey. pp 1-66.
Barba, D., Beolchini, F. (2000). Minimizing water use in diafiltration of whey protein concentrates. Separation Science and Technology. 35, No. 7, p. 951-965.
Barba, F., Beolchini, D., Cifoni, F., Veglió. (2001). Whey protein concentrate production in a pilot scale two-stage diafiltration process. Separation Science and Technology. 36, No. 4, p. 587-603.
Barillas, C. and Solomons, N. (1987). Effective reduction of lactose maldigestion in preschool children by direct addition of beta-galactosidases to milk at mealtime. *Journal of Pediatrics.* 79: 766- 772.
Barling, P.M. (2012). Lactose tolerance and intolerance in Malaysians. International e-*Journal of Science*, Medicine and Education. 6 (Suppl 1): S12-S23.
Belfort, G., Davis, R.H. and Zydney, A.L. (1994). The behavior of suspensions and macromolecular solutions in cross-flow microfiltration. *Journal of Membrane Science. 96: 1-58.*
Benkahla, Y.K., Ould-Dris, A., Jaffrin, M.Y. (1993). Hydrodynamic anti-fouling mechanism in cross-flow microfiltration, Poster Presentation at ICOM '93, Aug. 30-Sept. 3, 1993, Heidelberg.
Blanpain, P., Hermia, J., and Lenoel, M. (1993). Mechanisms governing permeate flux and protein rejection in the microfiltration of beer with a cyclopore Membrane. *Journal of Membrane Science*. 84: 37-51.
Bowen, W.R. and Sabuni, H.A.M. (1992). Pulsed Electrophoritic Membrane Cleaning, Ind. Chem. Eng. Res. Event. 92- 94.
Bowen, W.R., Doneva, T.A. and Stoton, J.A.G. (2003). Protein deposition

during cross- flow membrane filtration: AFM studies and flux loss, Colloids and Surfaces B- Biointerfaces. 27: 103-113.
Bozzone, D.M. (2013). *Lactose Intolerance and the Geographic Variation of Human Traits.* Oxford University Press. Retrieved 20th December 2015. Available from http://oxfordpresents.com/bozzone/lactose-intolerance/
Brans, G., Schroen, C.G.P.H., van der Sman, R.G.M. and Boom, R.M. (2004). Membrane fractionation of milk: state of the art and challenges. *Journal of Membrane Science*. 243: 263–72.
Brenneman, J.C. (1978). Basics of food allergy. Charles C. Thomas Publisher., Springfield, Illinois.
Bylund, G. (1995). Dairy Processing Handbook- chapter15.pdf. Tetra Pak Processing Systems, 331–352. Retrieved from http://www.ales2.ualberta.ca/afns/courses/nufs403/PDFs/chapter15.pdf
Castro, B.N. and Gerla, P.E. (2005). Hollow fibre and spiral cheese whey ultrafiltration: minimizing controlling resistances. *Journal of Food Engineering*. 69: 495-502.
Cerbulis, J., Parks, O.W., Farrell, Jr. H.M. (1982). Composition and Distribution of Lipids of Goats´ Milk. *Journal of Dairy Science*.65: 2301-2307.
Chen, C.S., Hsu, C-K. and Chiang, B-H. (2002). Optimization of the enzymic process for manufacturing low-lactose milk containing oligosaccharides. Process Biochemistry. 38: 801-808.
Cheryan, M. (1998). Ultrafiltration and microfiltration handbook. Technomic Publishing Company, Inc., Lancaster, PA, USA. 527p.
Cheryan, M. Ph.D. (1986). Ultrafiltration Handbook. Technomic Publishing Co., Lancaster
Choi, Y.-J. (2003). A thesis in Environmental Engineering. Critical flux, resistance, and removal of contaminants in Ultrafiltration (UF) of Natural Organic Materials. The Pennsylvania State University.
Chollangi, A. and Hossain, M.Md. (2007). Separation of proteins and lactose from dairy wastewater. Chemical Engineering and Processing, 46: 393-404.
Clarke, T.E. and Heath, C.A. (1997). Ultrafiltration of Skim Milk in Flat-plate and Spiral- wound Modules. *Journal of Food Engineering*. 33: 373-383.
Cook, G.C. and Al-Torki, M.T. (1975). High intestinal lactase concentrations in adult Arabs in Saudi Arabia. *British Medical Journal*. 5976: 135-136.
Cooke, T. August 20, 2010. The High Road to Health, University of Mt. Capra, http://www.mtcapra.com/benefits-of-goat-milk-vs-cow-milk/ (Accessed 20 October 2013).
Cousins, R.B. (2004). Membrane Technology. Department of Chemical and Process Engineering, University of Strathclyde in Glasgow.
Cuperus, F.P. and Nijhuis, H.H. (1993). Applications of membrane technology of food processing. Trends in Food Science & Technology, 4: 277-282.
Curcio, S., Calabro, V., Iorio, G. (2006). A theoretical and experimental analysis of a membrane bioreactor performance in recycle configuration. *Journal of Membrane Science*. 273, p. 129-142.
Davis, R.H. and Birdsell, S.A. (1987). Hydrodynamic model and experiments for cross- flow microfiltration. *Journal of Chemical Engineering Communications*. 49: 217-234.
De Jong, P. (1997) Impact and control of fouling in milk processing. Trends in Food Science and Technology. 8: 401-405.
Delaney, R.A.M., Donnelly, H.K. (1977). Application of Reverse Osmosis in the

Dairy Industry. NRC, Ottawa, Canada.
Devereux N., Hoare, M. (1986). Biotechnology and Bioengineering. 28: 422-431.
Dissanyake, A.S., El-Munshid, H.A. and Al-Qurain, A. (1990). Prevalence of primary adult lactose malabsorption in the eastern province of Saudi Arabia. Annals of Saudi Medicine. 10: 598-601.
Edelsten, D., Meersohn, M., Friis, P., Nielsen, E.W., Sørensen, K.L., and Gudmand-Høyer, E. (1983). Production of skim milk powder with lactose content reduced by ultrafiltration. Milchwissenschaft. 38:261–263.
European Food Safety Authority. (2010). Scientific opinion on lactose thresholds in lactose intolerance and galactosaemia. EFSA Journal. 8: 1777.
Fane, A.G. and Fell, C.J.D. (1987). A review of fouling control of ultrafiltration. *Desalination Journal*. 62: 117-136.
Fane, A.G. and Fell, C.J.D. and Waters A.G. (1981). The relationship between membrane surface pore characteristic and flux for ultrafiltration membranes. *Journal of Membrane Science.* 9: 245-262.
FAO Statistic Division. (2015). Retrieved 4th December 2015. http://faostat3.fao.org/home/E
Farah, Z., Ruegg, M. (1991). The Creaming Properties and Size Distribution of Fat Globules in Camel Milk. *Journal of Dairy Science*. 74: 2901-2904.
Field, R. W., Wu, D., Howell, J. a., & Gupta, B. B. (1995). Critical flux concept for microfiltration fouling. *Journal of Membrane Science*, 100(3), 259–272. doi:10.1016/0376-7388(94)00265-Z
Flatz, G., Saengudom, C.H. and Sanguanbhokhai, T. (1969). Lactose intolerance in Thailand. Nature. 221: 758-759
Foley, G., Malone, D.M. and Macloughlin, F. (1995). Modeling the effects of particle polydispersity in cross-flow filtration*. Journal of Membrane Science*. 99: 77-88.
Food Act and Regulations. (1983). Laws of Malaysia. Published by MDC Publishers Sdn Bhd. 2009 Edition.
Food intolerance and food aversion; The Royal College of Physicians and The British Nutrition Foundation, Report number: 18, 1984.
Forman, S.M., DeBernardez, E.R., Feldberg, R.S., Swartz, R.W. (1990). Crossflow filtration for the separation of inclusion bodies from soluble proteins in recombinant Escherichia coli lysate, *Journal of Membrane Science,* 48, 263-279
Galaj, S., Wicker, A., Dunas, J., Grillot J.P., Garacera, D. (1984). Microfiltration tangentielle avec decolmatage sur membranes ceramiques*, Le Lait*, 64: 129.
Gésan-Guiziou, G., Daufin, G., Boyaval, E. and Le Berre, O. (1999). Wall shear stress: effective parameter for the characterization of the cross-flow transport in turbulent regime during skimmed milk microfiltration. *Le Lait.* 79: 347-354.
Ghosh, R. (2003). *Protein Bioseparation Using Ultrafiltration*: Theory, Aplications and New Developments, Imperial College Press, Lodon.
Gijsbertsen-Abrahamsea, A.J., Cornelissena, E.R. and Hofman, J.A.M.H. (2006). Fiber failure frequency and causes of hollow fibre integrity loss. *Desalination Journal*. 194: 251-258.
Gironés, M., Lammertink, R.G.H., and Wessling, M. (2006). Protein aggregate deposition and fouling reduction strategies with high-flux silicon nitride

microsieves. *Journal of Membrane Science.* 273: 68-76/
Glover, R.A., Brooker, B.E. (1980*). Journal of Dairy Research*. 41: 89.
Goulas, A.K., Grandison, A.S., Rastall, R.A. (2003). Fractionation of oligosaccharides by Nanofiltration. *Journal of the Science of Food and Agriculture*. 83, p. 675-680.
Grandison, A.S., Youravong, W. and Lewis, M.J. (2000). Hydrodynamic factors affecting flux and fouling during ultrafiltration of skimmed milk*. Lait*, 80: 165-174.
Grano, V., Diano, N., Rossi, S., Portaccio, M., Attanasio,, A., Cermola, M., Spiezie, R., Citton, C. and Mita, D.G. (2004). Production of low-lactose milk by means of nonisothermal bioreactors. Biotechnology Progress. 20: 1393-1401.
Green, G. and Belfort, G. (1980). Fouling of ultrafiltration membranes- lateral migration and the particle trajectory model. *Desalination Journal*. 35: 129-147.
Greenberger, N.J. and Skillman, T.G. (1969). Medium chain triglycerides. Physiologic considerations and clinical implications. The New England *Journal of Medicine*. 280: 1045-1058.
Guell, C. and Davis, R.H. (1996). Membrane fouling during microfiltration of protein mixtures, *Journal of Membrane Science*. 119: 269-284.
Haenlein, G.F.W. (1984). Goat milk versus cow milk. In: Extension Goat Handbook, Haenlein, G.F.W. and Ace, D.L. ed., USDA Publ., Washington, D.C., E 1-4.
Haenlein, G.F.W. (1992). Role of goat meat and milk in human nutrition. Proceedings Vth International Conference on Goats, New Delhi, India. March 1-8, ICAR Publ., New Delhi, 2 (II): 575-580.
Haenlein, G.F.W. (1993). Producing quality goat milk. *International Journal of Animal Science*. 8: 79-84
Haenlein, G.F.W. (2002). Cooperative Extension Dairy Specialist University of Delaware. Why Goat Milk. Retrieved 10th March 2014, from http://goatconnection.com/articles/publish/printer_77.shtml.
Haenlein, G.F.W. (2004). Goat milk in human nutrition. Small Ruminant Research. 51: 155- 163.
Haenlein, G.F.W. (1988). Research on goat milk-not wanted. *Dairy Goat Journal.* 66: 243-245
Hall, C.W. (1995). Milk and Milk Products. Kirk-Othmer Encyclopedia of Chemical Technology, John Wiley & Sons.
Harvey, J. (1988). A High Performance Liquid Chromatography Method for Lactose Determination in Milk*. The Australian Journal of Dairy Technology.*
Henneberg, W. and F. Stohmann. (1860). Begriindung einer rationellen Ftitterung der Wiederk~iuer. Vol. I. Schwetsehtke u. Sohn, Braunschweig, p. 4, 324.
Hijazi, S.S., Abulaban, A., Ammarin, Z. and Flatz, G. (1983). Distribution of adult lactase phenotypes in Bedouins and in urban and agricultural populations of Jordan. *Tropical and Geographical Medicine Journal*. 35: 157-161.
Hofman, P.J., Vuthapanich, S., Whiley, A.W., Klieber, A., Simons, D.H. (2002). Tree yield and fruit minerals concentrations influence “Hass” avocado fruit quality. *Sci. Hort Journal*. 92: 113–123.
Hogenauer, C., Hammer, H.F. (2010). Maldigestion and malabsorption.

Sleisenger & Fordtran's Gastrointestinal and Liver Disease. 9th ed. Philadelphia, Pa: Saunders Elsevier: chap101.

Holsinger, V. H. (1988). Lactose. In N. P.Wong, R. Jenness, M. Keeney, & E. H. Marth (Eds.). Fundamentals of dairy chemistry, 3rd ed (pp. 279–342). New York, NY, USA: Van Nostrand Reinhold Co.

Hossain, M. B., & Dev, S. R. (2013). Physical Characteristics of Various Raw Milk Samples in a Selected Dairy Plant of Bangladesh Statistical Analysis :, *1*(3), 91–96.

Howell, J. A. and Finnigan, S. M. (1991). Hydrodynamics and Membrane Filtration, Effective Industrial Membrane Processes Benefits and Opportunities, pp. 49-60.

Howell, J.A. (1995). Sub-critical flux operation of microfiltration. *Journal of Membrane Science*. Volume 107, Issues 1–2, 15 November 1995, Pages 165–171.

Howell, J.A., Velicangil, O., Cooper, A.R. (1980). Ultrafiltration membranes and applications. New York: Plenum Press. 217-229.

Humphrey, J.L., Seibert, A.F. (1992). Chemical Engineering Progress. 3: 32-41.

Hwang, K. J. and Hwang, H. C. (2006). The purification of protein in cross-flow microfiltration of microbe/protein mixtures. *Journal of Separation and Purification Technology*. 51: 416- 423.

Hwang, K. J. and Liu, H. C. (2002). Cross-flow microfiltration of aggregated submicron particles. *Journal of Membrane Science*. 201: 137-148.

Hwang, K.J. and Cheng, Y.H. (2003). The role of dynamic membrane in cross-flow microfiltration of macromolecules. Separation Science and Technology. 38: 779-795.

International Dairy Federation. (1991). New Applications of Membrane Processes. Special Issue No. 9201. Brussels, Belgium: International Dairy Federation.

Ishida, A., Law, S.-H., &Aita, Y. (2003).Changes in food consumption expenditure in Malaysia. Agribusiness, 19(1), 61-76.

IDF. (2012). Milk and milk products- Determination of lactose content by high-performance liquid chromatography (Reference method). ISO 22662:2012 (IDF 198: 2012). Ethiopian Standards Agency.

Jelen, P., & Tossavainen, O. (2003). Low lactose and lactose-free milk and dairy products prospects , technologies and applications. Australian *Journal of Dairy Technology*, 58(2), 161–165.

Jonsson, G., Koenhen, D.M., Rasmussen, A. (1995). Process to remove turbidity-causing components from a fluid by microfiltration passes the fluid across an assymetric membrane with inlet pores larger than those of nominal size and cleans the membrane by backwashing. EP0645174.

Kalser, M.H. (1971). Medium chain triglycerides. Advance Internal Medicine. 17: 301-322.

Kanani, D. (2015) Membrane Fouling: a challenge during dairy ultrafiltration. In *Membrane Processing for Dairy Ingredient Separation*. Press Wiley Blackwell. John Wiley & Sons, Ltd. 3: 67– 83.

Kelly, S.T. and Zydney, A.L. (1995). Mechanisms for BSA fouling during microfiltration, *Journal of Membrane Science*. 107: 115-127.

Khider, K., Akretche, D.E., Larbot, A. (2004). Purification of water effluent from a milk factory by ultrafiltration using Algerian clay support. *Desalination*

Journal. 167, p. 147-151.
Kosikowski, F. (1979). Low lactose yoghurts and milk beverages by ultrafiltration. *Journal of Dairy Science*. 62: 41-46.
Kulkarni S.S., Funk, E.W. and Li, N.M. (2001). Ultrafiltration: Introduction and definitions. pp. 393-397. In W. S. Ho and K. K. Sirkar, (Eds.). Membrane Handbook. Norwell. Massachusetts.
Kuriyel, R. (2000). Ultrafiltration. Kirk-Othmer Encyclopedia of Chemical Technology. John Wiley & Sons, Inc, New Jersey. pp. 1-22.
Labbe, P., Quemerais, A., Michel, F., Daufin, G. (1990). Membrane Science. 51: 293-307.
Lee, M.F. and Krasinski, S.D. (1998). Human adult-onset lactase decline: an update. *Nutrition Reviews*. 56: 1-8.
Lee-Thorp, J. and Ackermann, B.R. (2002). Lactose intolerance is normal. Science in Africa: Africa's first on-line science magazine, Retrieved 11th October 2012, from http://www.scienceinafrica.co.za/2002/june/lactose.htm.
Lehr, H. and Chang, K.W. (2010). Bright Animal internal report. Milk production in Malaysia. Retrieved 11th October 2014. http://www.brightanimal.eu/documents/Milk Production in Malaysia.pdf
Le, M.S., Howell, A. (1984). Chemical Engineering Research and Design. 62: 373-380.
Leonard, W.R. October 7, 2013. http://anthropology.ua.edu/blogs/ant475/tag/lactose-tolerance/. Obesity, Diabetes, and Lactose-tolerance: A Summary of Human Nutritional Evolution.
Liana, M., A. Radam& M.R. Yacob. (2010). Consumer perception towards meat safety: confirmatory factor analysis. *International Journal of Economics and Management*, 4(2), 305-318.
Li, S.L., Chou, K.S., Lin, J.Y., Yen, H.W. and Chu, I.M. (1996). Study on the microfiltration of Escherichia coli-containing fermentation broth by a ceramic membrane filter. *Journal of Membrane Science*. 110: 203-210.
López-Aliaga, I., Alférez, M.J.M., Barrionuevo, M., Nestares, T., Sanz Sampelayo, M.R. (2003). Malabsorption syndrome. *Journal of Dairy Research*. 6: 451–461.
Mack, P.B (1953). A preliminary nutrition study of the value of goat milk in the diet of children. Amer. Goat Soc. Inc., Mena, Arkansas, Year Book 1952-1953, 112-132.
Mahoney, R.R. (1992). Lactose: Enzymatic modification. In Advanced Dairy Chemistry. Vol. 3. Lactose,Water, Salts, and Vitamins. P. F. Fox, (pp. 75–125), ed. Chapman & Hall, New York.
Makardij, A., Chen, X.D. and Farid, M.M. (1999). Microfiltration and ultrafiltration of milk: some aspects of fouling and cleaning. Trans IchemE. 77: 107-113.
Marshall, A.D. and Daufin, G. (1995). Physico-chemical aspects of membrane fouling by dairy fluids. Fouling and Cleaning in Pressure Driven Membrane Processes. International Dairy Federation Bulletin 9504. Brussels, Belgium.
Marshall, A.D., Munro, P.A. and Tragardh, G. (1993). The effect of protein fouling in microfiltration and ultrafiltration on permeate flux, protein retention and selectivity: a literature review. *Desalination Journal*. 91: 65-108.

Matsuura, T. (1994). Synthetic membranes and membrane separation processes. CRC Press. Boca Raton.
Mattar, R., Mazo, D.F.C., Carrilho, F.J. (2012). Lactose intolerance: Diagnosis, genetic, and clinical factors. Clinical and Experimental Gastroenterology. Volume: 5, Issue: 1, Pages: 113-121.
Matthiason, E. Sivik B. (1980). *Desalination Journal* 35: 59-103.
Maubois, J.L. (1990). Novel valorisation of dairy components. Agro- Ind. Hi-Technol.
McCarthy, A.A., Walsh, P.K. and Foley, G. (2002). Experimental techniques for quantifying the cake mass, the cake and membrane resistances and the specific cake resistance during crossflow filtration of microbial suspensions. *Journal of Membrane Science*. 201: 31-45.
Menkhaus, T. J., Bai, Y., Zhang, C. M., Nikolov Z. L. , and Glatz, C. E. (2004). Considerations for the recovery of recombinant proteins from plants, *Biotechnology Program.* 20: 1001-14.
Merin, U., Cheryan, M. (1980). *Journal of Food Processing and Preservation*. 4(3): 183-198.
Meyer, D.E., Williams, M. and Bhattacharyya, D. (1995). Reverse Osmosis, Kirk-Othmer Encyclopedia of Chemical Technology. John Wiley & Sons, Inc, New Jersey. pp. 1-54.
Minard, R. (2000). Penn State Univ. Adapted from from Introduction to Organic Laboratory Techniques: A Microscale Approach. Isolation of Casein, Lactose, and Albumin from Milk. Pavia, Lampman, Kriz & Engel, Saunders. (1990). Revised 3/20/2000.
Misselwitz, B., Pohl, D., Frühauf, H., Fried, M., Vavricka, S.R., Fox, M. (2013). Lactose malabsorption and intolerance: pathogenesis, diagnosis and treatment*. United European gastroenterology journal.* Volume: 1, Issue: 3, Pages: 151-9. Available from www.pubmedcentral.nih.gov.
Mistry, V.V. (2002). Membrane Processing in Cheese Manufacture. Elsevier Science Ltd: 300-306.
Mueller, J. and Davis, R.H. (1996). Protein fouling of surface-modified polymeric microfiltration membranes. *Journal of Membrane Science*. 116: 47-60.
Mulder, M. (1991). Basic Principles of Membrane Technology. Kluwer Academic Publishers, The Netherlands. 362p.
Mulder, M. (1996). Basic Principles of Membrane Technology. Springer Science & Business Media, vol. 384 p. 564
Nakanishi, K. and Kessler, H.G. (1985). Rinsing behavior of deposited layers formed on membranes in ultrafiltration. *Journal of Food Science.* 50: 1726- 1731.
Nielsen, W.K., editor. (2000). Membrane Filtration and related molecular separation technologies. APV Systems, Denmark. 223p.
Norafifah, H., Noordin, M. Y., Wong, K. Y., Izman, S., & Ahmad, A. A. (2015). A Study of Operational Factors for Reducing the Fouling of Hollow Fiber Membranes during Wastewater Filtration. *Procedia CIRP*, *26*, 781-785.
Novalin S., Neuhaus, W. and Kulbe, K.D. (2005). A new innovative process to produce lactose-reduced skim milk*. Journal of Biotechnology*. 119: 212-218.
Ochando-Pulido, J. M., Verardo, V., Segura-Carretero, A., & Martinez-Ferez, A. (2015). Analysis of the concentration polarization and fouling dynamic resistances under reverse osmosis membrane treatment of olive mill

wastewater. *Journal of Industrial and Engineering Chemistry*, *31*, 132-141.
Ohmori, K. and Glatz, C.E. (1999). Effects of pH and ionic strength on microfiltration of C-glutamicum. *Journal of Membrane Science*. 153: 23-32.
Omar, M. A. (March 2010). Popularising Local Goat Milk. The Star Online. Accessed on 18 May 2014, from http://goatmatters.blogspot.com/
Ould-Dris, A., Jaffrin, M.Y., Si-Hassen, D. and Neggaz, Y. (2000). Analysis of cake build- up and removal in cross-flow microfiltration of CaCO3 suspensions under varying conditions. *Journal of Membrane Science*. 175: 267-283.
Pal, D. (2003). Applications of Ultrafiltration. Membrane Techniques, 3842-3848.
Park, Y.W. (1991). Relative buffering capacity of goat milk, cow milk, soy-based infant formulae, and commercial nonprescription antacid drugs. *Journal of Dairy Science*. 74: 3326 - 3333.
Park, Y.W. (1994). Hypo-allergenic and therapeutic significance of goat milk. Small Ruminant Research. 14: 151–159. doi:10.1016/0921-4488(94) 90105-8
Park. Y.W., Juarez, M., Ramos, M., Haenlein, G.F.W. (2007). Physico-chemical characteristics of goat and sheep milk. Small Ruminant Research. 68: 88-113.
Patel, R. S., Reuter, H., Prokopek, D., and Sachdeva, S. (1991). Manufacture of low lactose powder using ultrafiltration technology. Food Science Technoogy. 24: 338–340.
Patrick, F. (2009). Fox. Lactose: Chemistry and properties. Advanced Dairy Chemistry. Volume: 3, (pp. 1-15). Publisher: Springer New York.
Pouliot, Y. (2008). Membrane processes in dairy technology- from a simple idea to worldwide panacea. *International Dairy Journal*. 18:735-740.
Pouliot, Y., Wijers, M.C., Gauthier, S.F. and Nadeau, L. (1999). Fractionation of whey protein hydrolysates using charged UF/NF membranes. *Journal of Membrane Science*. 158, p. 105-114.
Punidadas, P., Rizvi, S.S.H. (1998). Separation of milk proteins next term into fractions rich in casein or previous term whey proteins next term by cross flow filtration. *Journal of Food Research International.* 31: 265–272.
Quah, S.-H., & Tan, A. K. G. (2010). Consumer Purchase Decision of Organic Food Products: An Ethnic Analysis. *Journal of International Consumer Marketing*, 22(1), 47-58.
Renner, E. and Abd El-Salam, M. H. (1991). Application of Ultrafiltration in the Dairy Industry. Elsevier Science Publishing Company, Inc. New York, New York.
Rezai, G., Mohamed, Z., &Shamsudin, M. N. (2011).Malaysian Consumer's perceptive towards purchasing organically produce vegetable. Paper presented at the 2nd International Conference on Business and Economic Research, Holiday Villa Beach Resort and Spa, Langkawi, Kedah, Malaysia.
Rice, G., Barber, A., O'Conner., Stevens, G. and Kentish, S. (2009). Fouling of NF membranes by dairy ultrafiltration permeates. *Journal of Membrane Science*. 330: 117-126.
Riesmeier, B., Kroner, K.H.., Kula, M.R. (1987). Studies on secondary layer

formation and its *characterization during cross-flow filtration of microbial-cells. Journal* of Membrane Science. 34: 245-266.
Robinson, C.W., Siegel, M.H., Condemine, A., Fee, C., Faridy, T.Z. and Glick, B.R. (1993). Pulsed-electric-field crossflow ultrafiltration of bovine serum albumin. *Journal of Membrane Science*. 80: 209-220.
Rudan, M.A. (1990). Membrane fouling during ultrafiltration of milk. Published MS Thesis, Cornell University, Ithaca, NY.
Rusynyk, R.A., Still, C.D. (2001). Lactose Intolerance. *The Journal of the American Osteopathic Association.* Volume. 101, Issue: 4 Suppl Pt 1, Pages: S10-S12. Available from www.ncbi.nlm.nih.gov
Saboya, L.V. and Maubois, J.L. (2000). Current developments of microfiltration technology in the dairy industry. *Journal of Dairy Science and Technology.* 80: 541-553.
Saini, A.L. and Gill, R.S. (1991). Goat milk: An attractive alternate. Indian Dairyman. 42: 562-564.
Sandblom, R.M. (1978). Filtering process. Alfa-Laval AB, assignee. US Pat. No. 4, 105, 547.
Sanz Sampelayo, M.R., Chilliard, Y., Schmidely, P., Boza, J. (2007). Influence of type of diet on the fat constituents of goat and sheep milk. Small Ruminant Research. 68: 42–63. doi:10.1016/j.smallrumres.2006.09.017
Savaiano DA and Levitt MD. Milk intolerance and microbe- containing dairy foods. J Dairy Sci 1987; 70: 397-406.
Schwabe, A.D., Bennett, L.R. and Bowman, L.P. (1964). Octanoic acid absorption and oxidation in humans. *Journal of Applied Physiology*. 19: 335-337.
Scott, K., Hughes, R. (2012). Industrial membrane separation technology. Springer Science & Business Media p. 305.
Scrimshaw, N.S. and Murray, E.B. (1988). Prevalence of lactose maldigestion. *The American Journal Of Clinical Nutrition.* 48: 1086-1098
Secchi, A.R., Wada, K. and Tessaro, I.C. (1999). Simulation of an ultrafiltration process of bovine serum albumin in hollow-fibre membranes. *Journal of Membrane Science*. 160: 255-265.
Singh, N. and Cheryan, M. (1997). Fouling of a ceramic microfiltration membrane by corn starch hydrolysate. *Journal of Membrane Science*. 135: 195-202.
Slacanac, V., Bozanic, R., Hardi, J., Rezessyne, J., Lucan, M., Krstanovic, V. (2010). Nutritional and therapeutic value of fermented caprine milk. International *Journal of Dairy Technology*. 63: 171-189.
Sloan, E. (1999). The new market: Foods for the not-so-healthy. Food Technology. 53(2): 54-60
Snook, C.R., Mahmoud, J.N. and Chang, W.P. (1976). Lactose tolerance in adult Jordanian Arabs. *Tropical and Geographical Medicine Journal*. 28: 333-335.
Song, L. and Elimelech, M. (1995). Theory of Concentration Polarization in Crossflow Filtration. *Journal of Chemical Society.* Faraday Transactions, 91: 3389-3398.
Strathmann, H. (1987). Membrane Separation Processes. In: Gruenwedel, W.D. and Whitaker, J.R., editors. Food Analysis: Principles and Techniques. Vol 4.
Swagerty, D.L. Jr., Walling, A.D., Klein, R.M. (2002). Lactose Intolerance. Am Fam Physician. Volume: 65, Issue: 9, Pages: 1845-1850. Available from

www.ncbi.nlm.nih.gov
Swagerty, D.L., Walling, A.D. and Klein, R.M. (1991). Lactose Intolerance. Lancet. Volume: 338, Issue: 4 Suppl Pt 1, Pages: 1280. Available from www.ncbi.nlm.nih.gov
Tanaka, T., Usui, K. and Nakanishi, K. (1998). Formation of the gel layer of polymers and its effect on the permeation flux in crossflow filtration of Corynebacterium glutamicum broth. *Journal of Separation Science and Technology*. 33: 707-722.
Tanaka, T., Yamagiwa, Y., Nagano, T., Taniguchi, M. and Nakanishi, K. (2001). Relationship between cake structure and membrane pore size in crossflow filtration of microbial cell suspension containing fine particles. *Journal of Chemical Engineering of Japan*. 34: 1524-1531.
Tantibhedhyangkul, P. and Hashim, S.A. (1975). Medium-chain triglyceride feeding in premature infants: Effects on fat and nitrogen absorption. *Journal of Pediatrics*. 55: 359-370.
Tantibhedhyangkul, P. and Hashim, S.A. (1978). Medium-chain triglyceride feeding in premature infants: Effect on calcium and magnesium absorption. *Journal of Pediatrics*. 61: 537-545.
The British Nutrition Foundation. *Adverse Reactions to Food*: Blackwell Science. 2002.
Tong, P.S., Barbano, D.M. and Rudan, M.A. (1988). Characterization of proteinaceous membrane foulants and flux decline during the early stages of whole milk ultrafiltration. *Journal of Dairy Science*. 71: 604-612.
Torniainen, S., Savilahti, E., and Järvelä, I. (2009). Congenital lactase deficiency- A more common disease than previously thought Duodecim. 125 (7): 766-770.
Tziboula-Clarke, A. (2003) Goat milk. In ‘Encyclopedia of dairy sciences, vol. 2’. (Eds H Roginnski, JW Fuquay, PF Fox) pp. 1270–1279. (Academic Press: California, USA)
U.S National Library of Medicine: Lactose Tolerance Test (2014). Retrieved 17th May 2015, from http://www.nlm.nih.gov/medlineplus/ency/article/003500.htm
Usai-Satta, P. (2012). Lactose malabsorption and intolerance: What should be the best clinical management. World *Journal of Gastrointestinal Pharmacology and Therapeutics*. Volume: 3, Issue: 3, Pages: 29.
Vyas, H.K. and Tong, P.S. (2003). Process for calcium retention during skim milk ultrafiltration. *Journal of Dairy Science*. 86: 2761-2766.
Wagner, J. (2001). Membrane Filtration Handbook Practical Tips and Hints. Osmonics Inc. 59p.
Wang, W., & Zhou, W. (2010). Effect of maltodextrins on water adsorption and glass transition of spray dried soy sauce powders, *117543*, 3–7.
Weldring, J.A.G., Van't Riet, K. (1988). Physical Properties of sodium carboxymethyl cellulose molecules adsorbed on a polyacrylonitrile UF membrane*. Journal of Membrane Science.* 38: 127-145.
Westergaard, V. (2010). Milk Powder Technology GEA Niro, Copenhagen. Retrieved 20 March 2014, from http://www.niro.com/NIRO/cmsdoc.nsf/webdoc/ndkw5y7dra
Wilt, T.J., Shaukat, A., Shamliyan, T., Taylor, B.C., MacDonald, R., Tacklind, J., Rutks, I., Schwarzenberg, S.J., Kane, R.L. and Levitt, M. (2010). Lactose intolerance and health. Evidence report/technology assessment. Issue: 192, Pages: 1-410. Available from www.ncbi.nlm.nih.gov

Winston Ho, W.S. and Sirkar, K.K. (1992). Membrane handbook. Chapman & Hall, New York. 954p.

Wouters, B. (December 2011). Sustainable Development of Dairy Chains in Malaysia (BO-10-010-105). Wageningen Livestock Research Institute.

Yeh, H.M. (2002). Decline of permeate flux for ultrafiltration along membrane tubes. *Desalination Journal*, 145: 153-157.

Yeh, H.M., Wu, H.P. and Dong, J.F. (2003). Effects of design and operating parameters on the declination of permeate flux for membrane ultrafiltration along hollow-fibre modules. *Journal of Membrane Science*. 213: 33-44.

Zall, R. (1987). Accumulation and quantification of on-farm ultrafiltered milk: The California experience. Milchwissenschaft 42: 98-100.

Zeman, F.J. (1982). Clinical nutrition and dietetics. Callamore Press, D.C. Health & Co., Lexington, Massachusetts.

Zeman, L.J. and Zydney, A.L. (1996). Microfiltration and Ultrafiltration: Principles and Applications, first ed. Marcel Dekker Inc, New York.

Zydney, A.L. and Colton, C.K.A. (1986). Concentration polarization model for the filtrate flux in cross-flow microfiltration of particulate suspensions. *Journal of Chemical* Engineering Communications. 47: 1-21.

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PUBLICATIONS

Nur Sofuwani Z. A., Siti Aslina H., Siti Mazlina M.K., (2014). Removal of Lactose from Highly Goat's Milk Concentration through Ultrafiltration Membrane. Journal of Applied Mechanics and Materials Vol. 625 (2014) pp 596-599 © (2014) Trans Tech Publications, Switzerland doi:10.4028/www.scientific.net/AMM.625.596(Citation-SCOPUS)

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