PRODUCTION OF VIRGIN COCONUT OIL (VCO) VIA WATER SOLUBLE MATERIALS AND CENTRIFUGATION METHOD

KHOO CHOON GEK

DEGREE OF BACHELOR OF CHEMICAL ENGINEERING (CHEMICAL) UNIVERSITI MALAYSIA PAHANG

PRODUCTION OF VIRGIN COCONUT OIL (VCO) VIA WATER SOLUBLE MATERIALS AND CENTRIFUGATION METHOD

KHOO CHOON GEK

Report submitted in partial fulfillment of the requirements for the award of the

Degree of Bachelor of Chemical Engineering (Chemical)

Faculty of Chemical and Natural Resources Engineering

UNIVERSITI MALAYSIA PAHANG

JANUARY 2012

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS

JUDUL : <u>PRODUCTION OF VIRGIN COCONUT OIL (VCO) VIA WATER</u> <u>SOLUBLE MATERIALS AND CENTRIFUGATION METHOD</u>

SESI PENGAJIAN : <u>2011/2012</u>

KHOO CHOON GEK (HURUF BESAR)

mengaku membenarkan tesis (PSM/Sarjana/Doktor Falsafah)* ini disimpan di Perpustakaan Universiti Malaysia Pahang dengan syarat-syarat kegunaan seperti berikut :

- 1. Tesis adalah hakmilik Universiti Malaysia Pahang
- 2. Perpustakaan Universiti Malaysia Pahang dibenarkan membuat salinan untuk tujuan pengajian sahaja.
- 3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.

4. **Sila tandakan ($\sqrt{}$) SULIT

Saya

(Mengandungi maklumat yang berdarjah keselamatan	atau
kepentingan Malaysia seperti yang termaktub di dalam	
AKTA RAHSIA RASMI 1972)	

TERHAD(Mengandungi maklumat TERHAD yang telah ditentukan
oleh organisasi/badan di mana penyelidikan dijalankan)

√ TIDAK TERHAD

(TANDATANGAN PENULIS)

Alamat Tetap: 42, Jalan Bestari 34/2, Taman Bestari Indah, 81800 Ulu Tiram, Johor Darul Takzim.

(TANDATANGAN PENYELIA) ASSOCIATE PROF.

Disahkan oleh

DR. ABDURAHMAN H. NOUR

Nama Penyelia

Tarikh: January 2012

Tarikh: January 2012

CATATAN: * Potong yang tidak berkenaan.

Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasiberkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Lapuran Projek Sarjana Muda (PSM).

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering (Chemical).

Signature	:	
Name of Supervisor	:	ASSOC. PROF. DR. ABDURAHMAN H. NOUR
Position	•	SENIOR LECTURER
Date	:	JANUARY 2012

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature : Name : KHOO CHOON GEK ID Number : KA 08058 Date : JANUARY 2012 DEDICATION

Special Dedication to my supervisor, my family members, my friends, my fellow colleague and all faculty members for all your care, support and believe in me.

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Assoc. Prof. Dr. Abdurahman H. Nour for his germinal ideas, invaluable guidance, continuous encouragement and constant support in making this research possible. He has always impressed me with his outstanding professional conduct, his strong conviction for science, and his belief that a degree program is only a start of a life-long learning experience. I appreciate his consistent support from the first day I applied to Undergraduate Research Program (URP) to these concluding moments. I am truly grateful for his progressive vision about my training in science, his tolerance of my naïve mistakes, and his commitment to my future career.

My sincere thanks go to all my lab mates and members of staff of the Faculty of Chemical and Natural Resources Engineering, who helped me in many ways and made my stay at UMP pleasant and unforgettable. I am very thankful for the facilities provided in the lab from University Malaysia Pahang (UMP) and to all the staff that ever helped me during my experimental works.

I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. I acknowledge the sincerity of my parents, who consistently encouraged me to carry on my higher studies in Malaysia. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. Special thanks should be given to my beloved fellow friends and course mates. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this research of study.

ABSTRACT

The traditional ways of breaking Virgin Coconut Oil (VCO) using fermentation and heating are disadvantageous from both economic and environmental perspectives. In this study, the potentials of the water soluble, oil soluble materials that are environmentally friendly materials and centrifugation methods in demulsification of Virgin Coconut Oil (VCO). The effect of alcohols (methanol and ethanol) added to demulsification via water soluble material and centrifugation methods were also investigated. The study began with some characterization studies to provide understandings of fundamental issues such as formation, formulation and breaking of emulsions. The aim was to obtain optimized operating conditions as well as fundamental understanding of oil-in-water emulsion stability upon which further developing on demulsification process that could be developed. It was found that emulsion demulsification was related to some parameters such as water soluble concentration (0.5 v/v %), centrifugation speed (2,000 - 8,000 rpm) and processing time (30 - 90 minutes). Experimental results found that centrifugation method can enhance the demulsification in a very short time compared to the conventional fermentation method. The results obtained in this study have exposed the capability of centrifugation method in demulsification of Virgin Coconut Oil (VCO) emulsion. Further works are nevertheless required to provide deeper understanding of the mechanisms involved to facilitate the development of an optimum emulsion breaking system applicable to the industry.

Key words: Demulsification; O/W emulsion; Centrifuge; Virgin Coconut Oil (VCO); Separation

ABSTRAK

Cara-cara tradisional yang digunakan untuk menghasilkan Minyak Kelapa Dara (VCO) termasuk penapaian dan pemanasan merupakan satu kerugian dari perspektif ekonomi dan alam sekitar. Dalam kajian ini, potensi minyak bahan larut air, bahan larut minyak yang bersifat mesra alam sekitar dan kaedah centifukasi telah digunakan dalam demulsifikasi Minyak Kelapa Dara (VCO). Kesan penggunaan alcohol (metanol dan etanol) dalam proses demulsifikasi dengan bahan larut air dan centifukasi juga disiasat. Kajian ini bermula dengan beberapa kajian pencirian untuk memberi pendedahan dalam pemahaman isu-isu asas seperti pembentukan, penggubalan dan pemisahan emulsi. Tujuannya adalah untuk mendapatkan keadaan operasi optimum serta sebagai pemahaman asas terhadap kestabilan emulsi minyak dalam air untuk membangunkan lagi proses demulsifikasi. Ia mendapati bahawa beberapa parameter mamainkan peranan penting dalam demulsifikasi emulsi seperti kepekatan larut air (0.5 v/v %), kelajuan centifukasi (2000 – 8000 rpm) serta masa pemprosesan centifukasi (30 - 90 minit). Keputusan uji kajian mendapati bahawa kaedah centifukasi boleh meningkatkan kecekapan demulsifikasi dalam masa yang singkat berbanding dengan kaedah penapaian konvensional. Keputusan yang deperolehi dalam kajian ini telah mendedahkan keupayaan kaedah centifukasi dalam demulsifikasi emulsi Minyak Kelapa Dara (VCO). Kerja-kerja selanjutnya dekehendaki untul memberi kefahaman yang lebih mendalam mengenai mekanisme yang terlibat untuk memudahkan pembangunan dalam pemisahan system emulsi pada keadaan yang optimum untuk kegunaan industri.

Kata Kunci: Demulsifikasi; O/W emulsi; centifukasi; Minyak Kelapa Dara (VCO); Pengasingan

TABLE OF CONTENTS

BORANO	G PENGESAHAN STATUS TESIS	iii
SUPERV	ISOR'S DECLARATION	iv
STUDEN	T'S DECLARATION	V
DEDICA	TION	vi
ACKNO	WLEDGEMENTS	vii
ABSTRA	CT	viii
ABSTRA	К	ix
TABLE (OF CONTENTS	X
LIST OF	TABLES	XV
LIST OF	FIGURES	xviii
LIST OF	APPENDICES	xxii
LIST OF	SYMBOLS	xxiv
LIST OF	ABBREVIATIONS	XXV
СНАРТЕ	ER 1 INTRODUCTION	1
1.1	Background of Study	1
1.2	Problem Statement	4
1.3	Research Objectives	
1.4	Scopes of Study	
1.5	Research Questions	6
1.6	Rationale and Significance of Study	6
1.7	Summary	7
СНАРТЕ	ER 2 LITERATURE REVIEW	
2.1	Introduction	
2.2	Definition of Virgin Coconut Oil (VCO)	9
2.3	Coconut Milk Emulsion	

2.3.1 Composition of Coconut Milk Emulsion	11
2.3.1.1 Dispersed Phase	
2.3.1.1.1 Fatty Acid Composition	
2.3.1.1.2 Triacylglycerol (TAG) Composition	
2.3.1.2 Continuous Phase	14
2.3.1.3 Chemical Composition Analysis	14
2.3.2 Microstructure of Coconut Milk Emulsion	16
2.3.3 Physicochemical Properties of Coconut Milk Emulsion	17
2.3.3.1 Density of Coconut Milk Emulsion	17
2.3.3.2 Viscosity of Coconut Milk Emulsion	
2.3.3.3 Surface Properties of Coconut Milk Emulsion	19
2.3.3.4 Interfacial Properties of Coconut Milk Emulsion	19
2.3.3.5 Effect of Temperature to Coconut Milk Emulsion	
2.4 Sensory Analysis of Virgin Coconut Oil (VCO)	
2.5 Emulsion Destabilization Mechanism	
2.5.1 Gravitational Separation	
2.5.2 Stokes' Law	
2.5.3 Flocculation	
2.5.4 Coalescence	
2.5.5 Aggregation	
2.6 Hydrophile – Lipophile Balance (HLB)	29
2.7 Methods Employed in Demulsification Process	
2.7.1 Demulsifiers - Water Soluble Materials	
2.7.2 Centrifugation Method	
2.7.3 Demulsifiers Assisted with Centrifugation Method	
2.8 Advantages and Applications of Virgin Coconut Oil (VCO)	
2.8.1 Food Uses	
2.8.2 Pharmaceuticals	
2.8.2.1 Anti-microbial	
2.8.3 Cosmetics and Body Care	
2.9 Summary	

CHAPTER	R 3 MATERIALS AND METHOD	41
3.1	Introduction	41
3.2	Experimental Design	41
3.3	Preparation of Raw Materials	
3.4	Equipments	
3.5	Experimental and Analytical Procedures	47
3.5.	Phase I: Analysis on Stability of Coconut Milk Emulsion	47
3.5.2	2 Phase II: Demulsification of Coconut Milk Emulsion	
3.5.	3 Phase III: Analysis of Virgin Coconut Oil (VCO) Extracted	51
3.7	Summary	
CHAPTER	R 4 RESULTS AND DISCUSSION	
4.1	Introduction	54
4.2	Phase I: Analysis of the Stability of Coconut Milk Emulsion	55
4.2.	1 Microstructure of Emulsion	55
4.	2.1.1 Microscopy	55
4.	2.1.2 Size Distribution	
4.2.2	2 Density of Coconut Milk Emulsion	59
4.2.	3 Rheology Properties Analysis	59
4	2.3.1 Viscosity versus Temperature	60
4	2.3.2 Viscosity versus Agitation Speed	
4	2.3.3 Shear Stress versus Shear Rate	
4	2.3.4 Viscosity versus Shear Rate	71
4.2.4	4 Surface and Interfacial Tensions	74
4.3	Phase II: Demulsification of Coconut Milk Emulsion	75
4.3.	1 Observation of Demulsification Process	75
4.3.2	2 Phase Separation of Demulsification Process	
4.3.	 Effect of Centrifugation Speed on on Virgin Coconut Oil (VCO 92) Recovery
4.3.4 Rec	4 Effect of Centrifugal Processing Time on Virgin Coconut Oil (Vovery	/CO) 98
4.4	Quality Characterization of Coconut Oil Extracted	100

	4.4.1 Analys	Critical Results from Gas Chromatography – Mass Spectromesis	ter (GC-MS) 101
	4.4.2	Data Analysis	
4.	5 S	ummary	108
СЦ	Артеі	5 CONCLUSIONS AND DECOMMENDATIONS	100
5	АГГЦ 1 Б	atroduction	109
5.	1 II 2 C	anduction	
5.	2 C	Emulsion Stability Analysis	
	522	Demulsification of Coconut Milk Emulsion	
	523	Quality Characterization	
5	3.2.5 3 R	ecommendations for Euture Experimental Works	
0.	531	Recommendations on Emulsion Stability Analysis	115
	532	Recommendation on Demulsification of Coconut Milk Emulsi	on 115
	533	Recommendation on Quality Characterization	116
5	4 S		117
APPEI	NDICI	rs	126
		FICAL MICDOCDAPH OF COCONUT MILK FMULSION	JS 126
A.1. A.2.	DR	OPLETS SIZE DISTRIBUTION FOR COCONUT MILK EMOLSION	MULSIONS
A 3	127 DH	FOLOCY DEODEDTIES OF COCONUT MILV FMULSIO	NI 120
А. Ј (ДА'	КП ТСП 1	EOLOGY FROFERITES OF COCONUT WILL EMULSIO	129
	RH	J	N 133
А. т (ВА)	ки тсн 2	N	133
(DA 15	DF	NSITV SURFACE TENSION AND INTERFACIAL TENSI	ON 137
R 1	RE	SULTS FOR DEMULSIFICATION OF COCONUT MILK I	EMULSION
VIA	CENT	FRIFUGATION METHOD	
B.2	RE	SULTS FOR DEMULSIFICATION OF COCONUT MILK I	EMULSION
VIA	OILS	SOLUBLE MATERIAL AND CENTRIFUGATION METHO)D 141
B.3 VIA	RE: WAT	SULTS FOR DEMULSIFICATION OF COCONUT MILK I ER SOLUBLE MATERIAL AND CENTRIFUGATION ME	EMULSION THOD143

B.4	RESULTS FOR DEMULSIFICATION OF COCONUT MII	LK EMULSION
VIA	METHANOL AND CENTRIFUGATION METHOD	145
B.5	RESULTS FOR DEMULSIFICATION OF COCONUT MII	LK EMULSION
VIA	ETHANOL AND CENTRIFUGATION METHOD	147
B.6	RESULTS FOR DEMULSIFICATION OF COCONUT MII	LK EMULSION
VIA	WATER SOLUBLE MATERIAL AND METHANOL WITH	
CE	NTRIFUGATION METHOD	149
С	GAS CHROMATOGRAPHY – MASS SPECTROMETER AN	ALYSIS
RE	SULTS	

LIST OF TABLES

Table No.	Title	Page
2.1	Standard quality of virgin coconut oil (VCO) according Asian and Pacific Coconut Community (APCC) standard (Adapted from Bioasli Inc.)	28
2.2	Average Composition in Coconut Milk Emulsion (Adopted from Tansakul & Chaisawang, 2006)	30
2.3	Fatty Acid Composition (Adopted from Alinorm 01/07 Codex Alimentaruis)	31
2.4	Triaclyglycerol (TAG) Composition (Adopted from Alinorm 01/07 Codex Alimentaruis)	32
2.5	Chemical composition of virgin coconut oil (VCO) (Adopted from Table 3, Marina et al., 2009b)	33
2.6	Selected HLB Group Numbers (Adopted from Bergenstahl, 1997; Friberg, 1997; & Stauffer, 1999; as cited in McClements, 2005)	48
2.7	Contents of Virgin Coconut Oil (VCO) (Adapted from Rethinam, 2004)	55
2.8	Advantages of monoglyceride monolaurin in Virgin Coconut Oil (VCO) (Adapted from Bioasli Inc.)	57
3.1	Summary Table for Raw Materials Used	62
3.2	Summary Table for Equipments Used	64
3.3	Methodology for Phase II: Demulsification of Coconut Milk Emulsion	67
3.4	Fatty Acid Compositions of Virgin Coconut Oil (VCO)	70
3.5	Summary Table for Calculation of Total Samples Needed	71
4.1	Statistical Values for Size Distribution of Coconut Milk Emulsions	76

4.2	Viscosity versus Temperature for Coconut Milk Emulsion (Batch 1)	78
4.3	Viscosity versus Temperature for Coconut Milk Emulsion (Batch 2)	79
4.4	Viscosity versus Agitation Speed for Coconut Milk Emulsion (Batch 1)	81
4.5	Viscosity versus Agitation Speed for Coconut Milk Emulsion (Batch 2)	82
4.6	Shear Stress versus Shear Rate for Coconut Milk Emulsion (Batch 1)	84
4.7	Shear Stress versus Shear Rate for Coconut Milk Emulsion (Batch 2)	85
4.8	Viscosity versus Shear Rate for Coconut Milk Emulsion (Batch 1)	89
4.9	Viscosity versus Shear Rate for Coconut Milk Emulsion (Batch 2)	90
4.10	Observations for Demulsification of Coconut Milk Emulsion via Centrifugation Method after 24hours	93
4.11	Observations for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v\% Oil Soluble Material and Centrifugation Method after 24hours	95
4.12	Observations for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v% Water Soluble Material and Centrifugation Method after 24hours	97
4.13	Observations for Demulsification of Coconut Milk Emulsion via a Concentration of $0.5 \text{ v/v}\%$ Methanol and Centrifugation Method after 24hours	99
4.14	Observations for Demulsification of Coconut Milk Emulsion via a Concentration of $0.5 \text{ v/v}\%$ Ethanol and Centrifugation Method after 24hours	102
4.15	Observations for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v% Water Soluble Material and Methanol with Centrifugation Method after 24hours	103
4.16	Settling Velocity of Oil Droplets of Two Batches of Coconut	113

	Milk Emulsion with Different Centrifugal Processing Speed	
4.17	Chosen Samples for Gas Chromatography – Mass Spectrometer (GC-MS) Analysis	120
4.18	Quality Characteristics of Coconut Oil Recovery Samples	121
4.19	Age of Coconut Milk Emulsion with the Content Percentage of Acid Lactone (6,6-dimethyltetrahydro-2H-pyran-2-one) Existed	125

xviii

LIST OF FIGURES

Figure No.	Title	Page
2.1	Schematic Diagram of Oil-in-Water Emulsion	30
2.2	Coconut milk emulsion consisting of oil droplets dispersed in an aqueous (water) medium. (Adopted from McClements, 2005)	35
2.3	Figure of variation of shear stress with the rate of deformation for Newtonian and non-Newtonian fluids. (Adapted from Figure $2 - 14$, Cengel and Cimbala, 2006)	37
2.4	Interfaces are often assumed to be planar surfaces of infinitesimally small thickness. (Adopted from McClements, 2005)	39
2.5	The molecular origin of interfacial tension at a liquid-liquid interface is the imbalance of the attractive forces acting on the molecules in the interface. The length of the arrows is related to the strength of the attraction between molecules. Hence, water-water interactions are considerably stronger than oil-oil or oil-water interactions.	39
2.6	Visual appearance after thermal treatments of coconut milk emulsions prepared with no additive (a). Open bars represent serum layer, filled bars represent cream layer, and diagonal crisscrossed bars represent coagulated layer. (Adopted from Figure 1, Tangsuphoom & Coupland, 2009b)	40
2.7	Emulsion may become unstable through a variety of physical mechanisms, including creaming, sedimentation, flocculation, coalescence, and phase inversion. (Adopted from McClements, 2005)	42
2.8	Emulsions are prone to creaming because of the density difference between the oil and water phases. (Adopted from McClements, 2005)	43
2.9	Schematic representation of the time dependence of droplet creaming in oil-in-water emulsions. Droplets move upward until they cannot move any further and then form a "creamed" layer. Layer droplets tend to move upward faster than smaller	44

2.10	ones. (Adopted from McClements, 2005) Droplet aggregation involves a number of physiochemical processes, including droplet approach, film thinning, thin film formation, and thin film rupture. Those processes are strongly dependent on the colloidal and hydrodynamic interactions between the droplets. The overall aggregation rate and the type of aggregation that occurs depend on which of these processes are rate limiting. (Adopted from McClements, 2005)	45
2.11	Droplet coalescence leads to a growth in the mean droplet diameter and may eventually lead to complete separation of the oil and aqueous phases. (Adopted from McClements, 2005)	45
2.12	Scheme of Action of Destabilization Mechanism Responsible for Emulsion Breakdown. (Adopted from Chiralt, 2005)	46
2.13	Types of Emulsion (Adopted from EAC Industrial Ingredients.)	48
2.14	HLB Characteristic of Emulsions (Adopted from EAC Industrial Ingredients.)	48
2.15	Schematic representation of possible processes during emulsion breakdown. (Adopted from EAC Industrial Ingredients.)	49
3.1	Experimental Design	60
3.2	Different layers are often observed in an emulsion undergoing creaming: (i) an upper "cream" layer; (ii) a middle layer; (iii) a lower "serum" layer	68
4.1	Optical micrograph using reflected fluorescent light showing Oil-in-water (O/W) emulsion. The continuous water phase (darker phase) shows dispersed oil droplets (bright droplets) for Batch 1 emulsion.	73
4.2	Optical micrograph using reflected fluorescent light showing Oil-in-water (O/W) emulsion. The continuous water phase (darker phase) shows dispersed oil droplets (bright droplets) for Batch 2 emulsion.	74
4.3	Histogram of size distribution for coconut milk emulsion (Batch 1).	75
4.4	Histogram of size distribution for coconut milk emulsion (Batch 2).	75

4.5	Effect of Temperature to Viscosity of Coconut Milk Emulsion for Different Agitation Speed (Batch 1)	79
4.6	Effect of Temperature to Viscosity of Coconut Milk Emulsion for Different Agitation Speed (Batch 2)	80
4.7	Effect of Agitation Speed to Viscosity of Coconut Milk Emulsion at Different Temperature (Batch 1)	82
4.8	Effect of Agitation Speed to Viscosity of Coconut Milk Emulsion at Different Temperature (Batch 2)	83
4.9	Shear Stress versus Shear Rate at Different Temperature for	84
4.10	Shear Stress versus Shear Rate at Different Temperature for Coconut Milk Emulsion (Batch 2)	86
4.11	Typical flow curves of shear stress versus shear rate (Schramm, 1996).	86
4.12	Viscosity versus Shear Rate at Different Temperature for Coconut Milk Emulsion Batch 1	89
4.13	Viscosity versus Shear Rate at Different Temperatures for Coconut Milk Emulsion Batch 2	90
4.14	Typical flow curves of viscosity versus shear rate (Schramm, 1996).	91
4.15	Separation of creaming part itself for samples runs at 2,000rpm for 30, 60 and 90 minutes.	101
4.16	Phase Separation of Demulsification of Coconut Milk Emulsion via Centrifugation Method	106
4.17	Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v\% Oil Soluble Material and Centrifugation Method	106
4.18	Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v % Water Soluble	107
4.19	Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v% Methanol and Centrifugation Method	107
4.20	Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of $0.5 \text{ v/v}\%$ Ethanol and	108

Centrifugation Method

4.21	Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v% Water Soluble Material and Methanol with Centrifugation Method	108
4.22	Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Time of 30 minutes.	111
4.23	Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 60minutes.	112
4.24	Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 90minutes.	112
4.25	Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 2,000rpm	117
4.26	Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 5,000rpm	117
4.27	Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 8,000rpm	118
4.28	Comparison of Fatty Acid Composition of VCO Yield under Different Centrifugation Conditions	122
4.29	Comparison of Lauric Acid, C12 Content in VCO Yield under Different Conditions	124
4.30	Comparison of Myristic Acid, C14 Content in VCO Yield under Different Conditions	124
4.31	Relationships between Age of Batch 1 Coconut Milk Emulsion with Amount of Acid Lactone Content	126
4.32	Relationships between Age of Batch 2 Coconut Milk Emulsion with Amount of Acid Lactone Content	126
5.1	Effect of viscosity to temperature at 100RPM	150

LIST OF APPENDICES

Appendix No.	Title	Page
A.1	OPTICAL MICROGRAPH OF COCONUT MILK EMULSIONS	145
A.2	DROPLETS SIZE DISTRIBUTION FOR COCONUT MILK EMULSIONS	146
A.3	RHEOLOGY PROPERTIES OF COCONUT MILK EMULSION (BATCH 1)	148
A.4	RHEOLOGY PROPERTIES OF COCONUT MILK EMULSION (BATCH 2)	152
A.5	DENSITY, SURFACE TENSION AND INTERFACIAL TENSION	156
B.1	RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA CENTRIFUGATION METHOD	157
B.2	RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA OIL SOLUBLE MATERIAL AND CENTRIFUGATION METHOD	159
B.3	RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA WATER SOLUBLE MATERIAL AND CENTRIFUGATION METHOD	161
B.4	RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA METHANOL AND CENTRIFUGATION METHOD	163
B.5	RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA ETHANOL AND CENTRIFUGATION METHOD	165
B.6	RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA WATER SOLUBLE MATERIAL AND METHANOL WITH CENTRIFUGATION METHOD	167

- C GAS CHROMATOGRAPHY MASS SPECTROMETER 169 ANALYSIS RESULTS
- D SCHEDULE FOR UNDERGRADUATE RESEARCH PROJECT

LIST OF SYMBOLS

\mathbf{v}_0	-	Settling Velocity	
$ ho_{w}$	-	Water Density	

- ρ_o Oil Density
- r Radius of Rotation
- ω Angular Velocity of Centrifugation
- d Diameter of Droplets
- μ_w Viscosity of Water Phase

LIST OF ABBREVIATIONS

APCC	-	Asia and Pacific Coconut Community
GC – MS	-	Gas Chromatography-Mass Spectrometer
HLB	-	Hydrophile – Lipophile Balance
МСТ	-	Medium Chain Triglycerides
O/W	-	Oil-in-Water
TAG	-	Triacylgycerol
VCO	-	Virgin Coconut Oil
v/v	-	Volume / Volume Ratio
W/O	-	Water-in-Oil

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The production of Virgin Coconut Oil (VCO) or it is also known as the demulsification (emulsion breaking) of coconut milk is through the extraction of oil from an emulsion of coconut milk. A coconut milk emulsion consists of two immiscible liquids, which is coconut oil and water, with the coconut oil layers dispersed as small spherical droplets in the water layers in a continuous phase that cannot be separated easily (Friberg, 1997; as cited in Tangsuphoom and Coupland, 2009a). It means that coconut milk exist as a natural oil-in-water emulsions that is being extracted from the endosperm of mature coconut oil *(Cocos nucifera L.)*, either with or without the addition of water (Seow and Gwee, 1997; as cited in Marina et al., 2009a). The main components of coconut milk are water and fats, with carbohydrates, proteins and ash as minor components (Tansakul and Chaisawang, 2005).

On the other hand, one of the chemical property of coconut milk emulsions is the unfavourable contact between coconut oil droplets and water molecules and it causes the emulsion exists thermodynamically unstable and readily separates into two distinct phases – a heavy aqueous phase and a lighter cream phase (Cancel, 1979; Gonzales, 1990; as cited in Nour et al., 2009). The reason behind this phenomenon is the protein contents and quality in coconut milk is not sufficient to stabilize the fat globules (Monera and del Rosario, 1982; as cited in Tangsuphoom and Coupland, 2009). However, the coconut milk emulsion is known to be naturally stabilized by coconut proteins – globulins, albumins and phospholipids (Birosel et al., 1963; as cited in Tangsuphoom and Coupland, 2008). Therefore, this concept can be apply in production of VCO, which is the coconut oil extracted from well matured and fresh coconut through specialized process without changing its natural nutrition as they were present in their original state in coconut milk emulsions.

In past, the conventional method used to produce VCO is via fermentation method. "Fermentation" is a natural separation of coconut oil from water by gravity separation. This involves splitting the nut, grating the meat to fine particle, squeezing the milk either manually or by mechanical means with or without water, and allowing the coconut milk to ferment for 36 to 48 hours. During this time, the heavier water will separates from coconut oil by sinking to the bottoms and discharged out, while the lighter coconut solids float to the top (curds). In between the coconut solids and water is a crystal clear coconut oil (cream) that is completely unrefined. The oil is then slightly heated (less than boiling temperatures) for a short time (5 to 15 minutes depending on the air temperatures) to remove any remaining moisture, and then filtered to further recovered some coconut oil. The result is a clear coconut oil that retains the distinct scent and taste of coconuts (Tropical Traditions Inc.).

As an engineer, we need to think based on 3Es – Environment, Economic and Engineering. As a result, the water soluble materials and centrifugation methods had been introduced in order to increase the yield of VCO and at the same time to reduce the production costs and time consuming in the production process.

Despite of this, the using of water soluble materials or hydrophilic chemicals is another method that has been applied in the demulsification of coconut milk to produce VCO in a shorter duration. By using a hydrophilic chemical, we can carry out the demulsification of coconut milk by damaging the bond of lipoprotein in emulsion (Nik Norulaini et al., 2009). Thus, it is very important to be precise and careful in choosing the type of chemicals that use in the separation process, make sure that the chemicals use is hydrophilic (attract to water phase) rather than lipophilic (attract to oil phase). This is due to the lipophilic chemicals will create environmental problems as well as various side effects on consumers health since VCO that is being extracted had been polluted by chemicals.

On the other hand, gravity separation is mainly associated with the slow creaming process of an oil-in-water immiscible mixture. A common way to accelerate this creaming process is by the use of centrifugation, where the high achievable rotation frequencies allowed an effective acceleration; highly superior to the simple gravitation case (Starobinets et al., 1979; Nour et al., 2009). Sometimes, gravity separation may be too slow because of closeness of the densities of the particles and the fluid, or because of association forces holding the components together (Nour et al., 2009). Gravity separation is time consuming, while centrifugal separation is accomplished in minutes (Geankoplis, 2003). The centrifuge works according to the sedimentation principle, where the centripetal acceleration is used to separate substance of greater and lesser density. By using centrifuge, it is possible to break down emulsions and to separate dispersions of fine liquid droplets; through in this case the suspended phase is in the form of liquid droplets, which will coalesce following separation of VCO from the water phase (Coulson and Richardson, 1991; as cited in Nour et al., 2009).

1.2 Problem Statement

One of the main reason that caused the highly demand of Virgin Coconut Oil (VCO) in market is due to its benefits to human being health. The facts are quoted below according to Tropical Traditions:

"VCO is the highest source of saturated medium chain triglycerides, MCT (62%). Furthermore around 50% of these MCT's are made up of lauric acid (C_{12}), the most important essential fatty acid in building and maintaining the body's immune system."

Therefore, this research topic is purposed in order to find out a solution that are environmental friendly and can yield more production of VCO in a shorter time by using the water soluble materials and centrifugation method. At the same time, there is still room for improvement on the quality of VCO produced by using these two methods.

1.3 Research Objectives

As research was carrying out the on the production of Virgin Coconut Oil (VCO), there are a few objectives that need to be achieved throughout the experiment. The research objectives that are formulated and shown in below:

i. To investigate the separation and filtration of Virgin Coconut Oil (VCO) using water soluble materials and centrifugation method.

ii. To study the potentials of water soluble demulsifiers in demulsification (emulsion breaking) of Virgin Coconut Oil (VCO) emulsion.

With the help of the research objectives which act as a guideline throughout the research, a clearer target was set in order to achieve in the end of the research.

1.4 Scopes of Study

In this research, a new combination method in the production of Virgin Coconut Oil (VCO) was proposed, which is by water soluble material and centrifugation method. However, there are some limitations made in order to narrow down the area of field of study. The limitations of this research are as list down in below:

- i. Characterization of oil and aqueous phase of Virgin Coconut Oil (VCO).
- ii. Analyse the composition of Virgin Coconut Oil (VCO) using Gas Chromatography – Mass Spectrometer (GC-MS).
- iii. Comparing the extraction yield that will be achieved when using water soluble materials and centrifugation method.
- iv. Study the effect of extraction time for oil recovery.
- v. Study the performance of water soluble materials and centrifugation method in extraction of virgin coconut oil (VCO) from coconut milk emulsion.
- vi. Study the effect of alcohol on the performance of water soluble materials and centrifugation method in extraction of virgin coconut oil (VCO) from coconut milk emulsion.

1.5 Research Questions

In conducting this research, there are a few research questions aroused in this study and needed to be answer at the end of the research. These research questions are as shown below:

- What is the separation and filtration efficiency of Virgin Coconut Oil (VCO) via water soluble materials and centrifugation method?
- ii. What is the potentials water soluble demulsifiers in demulsification (emulsion breaking) of Virgin Coconut Oil (VCO)?

1.6 Rationale and Significance of Study

Virgin Coconut Oil (VCO) is growing in popularity as functional food oil and the public awareness of it is increasing. It is expected that the VCO will experience a dramatic growth in the market due to the finding from Arancon (2008); as cited in Henderson et al. (2010), the exports of VCO rose from nil in 2000 to almost 1131 metric tonnes in 2005 in Philipines. However, the conventional method – fermentation method used in production of VCO, is a time consuming process and will produce a lot of waste during the fermentation process. This will cause environmental problems like pollutions. Therefore, it is important to carry out a research in order to resolve this problem. In addition, a solution that can produce VCO in a more convenient and easy way should be formulated. Besides that, this research also aims to improve the quality of VCO extracted from coconut milk emulsions. VCO is marketed lately as functional oil and had captured the attention of vast majority of publics since it's first introduced. The beneficial properties of VCO especially in human health are fast spreading. The availability of VCO is increasing in the market especially in South East Asia involving countries like the Philippine, Thailand, Indonesia and Malaysia. Since the demand of commercial VCO continues to increase in the market, thus a few current status and research trends of on going research in VCO are focused on physicochemical properties, antioxidant activity and phenolic contents and lastly, the clinical studies.

1.7 Summary

As for the overall in this chapter, the combination methods – water soluble materials and centrifugation methods in production of virgin coconut oil (VCO) hadintroduced. When compared to conventional method, which is fermentation method, the using of this combination method will be more environmental friendly and saving cost in terms of time.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, all the reading regarding this study, which is Production of Virgin Coconut Oil (VCO) via Water Soluble Material and Centrifugation Method will be summarized. In the preceding chapter, the physical properties of coconut milk emulsion will be reported and the term VCO will be defines. It is followed by the discussions of the analysis of physicochemical properties of VCO, then different treatments that employed in destabilization coconut milk emulsion will be discussed, and lastly, it will presented the roles play by water soluble materials and centrifugation methods in the production of VCO.

2.2 Definition of Virgin Coconut Oil (VCO)

Virgin Coconut Oil (VCO) is extracted from fresh and well matured coconut or known as non-copra without damaging its natural structure and nutrition as in their original state in the coconut through specialized manufacturing process (Bioasli Inc.). The production of VCO did not involved further refining by using chemicals and high heating, since it is very stable and has a long shelf life of several years (Tropical Traditions Inc.; Villarino et al., 2007). Therefore, the term "Virgin" is used to indicate the manufacturing process of the coconut oil and it is not an explanation on VCO chemical properties (Carandang, 2005).

According to Asian and Pacific Coconut Community (APCC), the standard quality for VCO produced had been presented in the table below:

Table 2. 1:	Standard quality of virgin coconut oil (VCO) according Asian and
	Pacific Coconut Community (APCC) standard (Adapted from Bioasla
	Inc.).

Identity Characteristics	APCC Standard
Relative density	0.915-0.920
Refractive index at 40°C	1.4480-1.4492
Moisture content, max (%)	0.1-0.5
Insoluble impurities per cent by mass max	0.05
Saponification value	250-260 min
Iodine value	4.1-11.00
Specific gravity at 30°C	0.915-0.920
Acid value max	0.5
Polenske value min	13
GLC range of fatt	y acid composition
Caproic Acid (C 6:0) (%)	0.4-0.6
Caprylic Acid (C 8:0) (%)	5.0-10.0
Capric Acid (C 10:0) (%)	4.5-8.0
Lauric Acid (C 12:0) (%)	43.0-53.0
Myristic Acid (C 14:0) (%)	16.0-21.0
Palmitic Acid (C 16:0) (%)	7.5-10.0
Palmitoleic Acid (C 16:1) (%)	2.0-4.0

Stearic Acid (C 18:0) (%)	5.0-10.0
Oleic Acid (C 18:2) (%)	1.0-2.5
C 24:1 (C 18:3) (%)	-
Quality c	haracteristics
Colour	clear
Free fatty acid (%)	0.5
Peroxide value meg/kg oil	3
Total plate count	-
Odour and taste	Free from foreign and rancid odor and taste
Odour and taste Cont	Free from foreign and rancid odor and taste aminants
Odour and taste Cont Matter volatile at 105°C (%)	Free from foreign and rancid odor and taste aminants 0.2
Odour and taste Cont Matter volatile at 105°C (%) Iron (Fe) (mg/kg)	Free from foreign and rancid odor and taste aminants 0.2 5
Odour and taste Cont Matter volatile at 105°C (%) Iron (Fe) (mg/kg) Copper (mg/kg)	Free from foreign and rancid odor and taste aminants 0.2 5 0.4
Odour and taste Cont Matter volatile at 105°C (%) Iron (Fe) (mg/kg) Copper (mg/kg) Lead (mg/kg)	Free from foreign and rancid odor and taste aminants 0.2 5 0.4 0.1

2.3 Coconut Milk Emulsion

As reported in Seow & Gwee (1997), as cited in Marina et al. (2009a), coconut milk is the natural oil-in-water emulsion extracted from the endosperm of mature coconut *(Cocos nucifera L.)*, either with or without the addition of water. This naturally occurs coconut milk emulsion contains 54% moisture, 35% fat and 11% solid non-fat (Simuang et al., 2004; Tansakul & Chaisawang, 2006). It is naturally stabilized by coconut proteins such as globulins, albumins and phospholipids (Tangsuphoom & Coupland, 2008). However, due to interaction of fat globules aqueous phase of coconut milk that contains some proteins, this will form a thin layer that surrounding the surface and acts as emulsifier in order to form a stable emulsion (Peamprasart & Chiewchan, 2006). As a result, it will require extra energy to destabilize coconut milk emulsion (Raghavendra & Raghavarao, 2010).



Figure 2.1: Schematic Diagram of Oil-in-Water Emulsion

2.3.1 Composition of Coconut Milk Emulsion

According to Tansakul & Chaisawang (2006), the milky white oil-in-water coconut milk emulsion contains the major components, water and fats. It is a system that consists of oil droplets dispersed in an aqueous phase, which makes up the droplets in an emulsion is referred to as the dispersed phase, whereas the substance that make up the surrounding liquid is called continuous phase. However, it is physically unstable and readily to separate into two distinct phases, which is a heavy aqueous phase and a lighter cream phase (Cancel, 1979; Gonzales, 1990; as cited in Nour et al., 2009). Besides that, the solid-non-fat composition, which consists of protein, carbohydrate and ash also presented in emulsion. The average composition of coconut milk emulsion had been tabulated in the table below:

Table 2. 2:Average Composition in Coconut Milk Emulsion (Adopted from
Tansakul & Chaisawang, 2006)

Common and	Percentage (%)	
Component	Minimum	Maximum
Fat	20.00	35.00
Water	74.60	55.26
Solid-non-fat	5.40	9.74
-----------------	--------	--------
i. Protein	2.06	4.02
ii.Carbohydrate	2.70	4.70
iii. Ash	0.64	1.02
TOTAL	100.00	100.00

2.3.1.1 Dispersed Phase

The dispersed phase is typically make up of 35 wt% of the total mass of coconut milk emulsion and is comprised majority of fat that presented as droplets (Tansakul & Chaisawang, 2006). As reported by Gunstone, 2002, the overall fat fraction of coconut milk emulsion consists of about 80% short and medium fatty acid chain lengths ($C_6 - C_{14}$), 18.5% triacylglyceros (TAG), and the remains with a maximum allowable 1.5% of unsaponifiable materials such as sterols, tocols, squalene, colour compounds, carbohydrates and odour compounds like lactones. In the next subtopic, the fatty acids and triacylglycerol (TAG) will be further discussed.

2.3.1.1.1 Fatty Acid Composition

According to Gunstone (2002), the major fatty acids presented in coconut milk emulsion are lauric acid, C_{12} and myristic acid, C_{14} , at about 48% and 18%, respectively, while others fatty acids composition are as tabulated in Table 2.2. The exist of lauric acid had contributed to the sharp melting properties of coconut milk emulsion, meaning hardness at room temperature, but with a low melting point, around 24 – 29°C. At the same time, lauric acid is extremely stable to oxidation due to their low unsaturation. This outstanding characteristic determines their use in edible field and justifies their higher price compared with other major oils.

Fatty Acid	Range Limit (% mass)
C _{6:0}	ND – 0.7
$C_{8:0}$	4.6 - 10.0
$C_{10:0}$	5.0 - 8.0
C _{12:0}	45.1 - 53.2
C _{14:0}	16.8 - 21.0
C _{16:0}	7.5 - 10.2
$C_{18:0}$	2.0 - 4.0
$C_{18:1}$	5.0 - 10.0
C _{18:2}	1.0 - 2.5
C _{18:3}	ND – 0.2
C _{20:0}	ND – 0.2
C _{20:1}	ND – 0.2
Others	ND
Iodine value	6.3 - 10.6

 Table 2. 3:
 Fatty Acid Composition (Adopted from Alinorm 01/07 Codex Alimentaruis)

* ND = Not Detectable (limit 0.05%)

2.3.1.1.2 Triacylglycerol (TAG) Composition

The triacylglycerol (TAG) structure plays an important role in interpreting the physical properties of coconut oil, in term of saturation (Gunstone, 2002). In coconut oil phase, the TAG range is C_{28} to C_{52} , with shorter chain lengths (C_{34} and below) and less longer chain lengths (C_{42} and above). The TAG composition was summarized in the table below:

Table 2. 4:	Triaclyglycerol	(TAG)	Composition	(Adopted	from	Alinorm	01/07
	Codex Alimenta	ruis)					

Triacylglycerol (TAG)	Composition (% mass)
C_{28}	0.5 - 10.0
C ₃₀	2.6 - 5.0
C ₃₂	10.8 - 17.5
C ₃₄	15.6 - 20.1

C ₃₆	18.3 - 20.6
C ₃₈	15.1 - 18.0
C_{40}	8.4 - 11.9
C_{42}	5.5 - 8.8
C_{44}	2.8 - 4.7
C_{46}	1.6 - 3.0
C_{48}	1.2 - 2.6
C_{50}	0.7 - 2.0
C ₅₂	ND - 2.0
C ₅₄	ND – 1.7

^{*} ND = Not Detectable (limit $0.05\overline{\%}$)

2.3.1.2 Continuous Phase

The continuous phase of coconut milk emulsion is compositionally complex, consists of a mixture water and non-solid-fat such as protein, carbohydrate, and ash. According to Birosel et al., 1963; as cited in Nour et al., 2009, the coconut proteins included globulins and albumins, and phospholipids. Since the protein content and quality of coconut milk is not sufficient to stabilize the fat globules, the emulsion will become instability (Monera and del Rosario, 1982; as cited in Tangsuphoom & Coupland, 2008). Therefore, the coconut milk emulsion is readily to separate into cream (coconut cream) and serum (coconut skim milk) layers (Seow and Gwee, 1997; as cited in Tangsuphoom and Coupland, 2009a.

2.3.1.3 Chemical Composition Analysis

According to AOCS (1996) methods, the composition of iodine (Cd 1d-92), saponification (Cd 3-25), peroxide (Cd 8-53), anisidine (Cd 18-90) and free fatty acid (Ca 5a-40) values in VCO was determined (Marina et al., 2009b).

Table 2. 5:Chemical composition of virgin coconut oil (VCO) (Adopted from Table
3, Marina et al., 2009b)

Chemical	Composition
Iodine Value	4.81
Saponification value (mg KOH / g oil)	256.29
Peroxide value (mequiv oxygen / kg)	0.21
Anisidine value	0.18
Free Fatty Acid	0.15

From the previous research carry out by Marina et al. (2009b), they found that:

- i. The degree of unsaturation of fats and oils were measured by iodine value. It was found that high degree of saturation of VCO has low content of iodine value.
- The average molecular weight of fatty acids contain in VCO was measure by saponification value. Shorter chain fatty acids will have higher saponification value on the glycerol backbone.
- iii. The concentration of peroxides and hydroperoxide forms in the initial stage of lipid concentration was measured by peroxide value. Since VCO has low content of unsaturated fatty acids, it exhibited a low rate of oxidation. This is the first phase of oxidation in VCO.
- iv. As for the second stage of oxidation, which is from the primary product of first stage oxidation, anisidine value test has been used to measure the oxidation rate. It showed the decomposition of peroxides and leads to develop of substances that responsible to the rancid smell and taste. A good quality VCO will have an anisidine value below 10 (Rossell, 1989). It is also supported by Subramaniam et al. (2000), a good quality oils having an anisidine value less than two. Since VCO anisidine value was less than one, it can be considered as a good quality oils.

v. The formation of undesirable flavour and aromas in fats are due to the existence of free fatty acids. Hence, good quality oil should indicate a low value of free fatty acids.

2.3.2 Microstructure of Coconut Milk Emulsion

A standard optical microscope was used to examine the microstructures of coconut milk emulsion. As reported by Simuang et al., 2004 (as cited in Peamprasart and Chiewchan, 2006), the size of the fat globules were varying and non-uniformly dispersed in the emulsion. According to McClements (2005), the size of droplets plays an important role in determining the coconut milk emulsion stability, appearance, texture, and taste of the extracted product - Virgin Coconut Oil (VCO). Besides that, it was also found that proteins play an important role in the stability of coconut milk emulsion. Part of the proteins was found to be dissolved in the water layer of oil-inwater (O/W) emulsion, while the remains insoluble proteins surrounding the surface of fat globules to act as emulsifier. The major factors those influents the size of droplets are properties of component phases and temperature. The different molecular structures due to different amount of fatty acids will disrupt the tension of oil-water interface and thus the droplets size. As for the temperature effect, it will affect the viscosity and interfacial tension of oil-in-water emulsion. Since viscosity is temperature dependence, so facilitating droplets disruption at high temperature. Besides that, heating an emulsion will cause slightly reduction in interfacial tension. Hence, it was expected to facilitate the production of smaller droplets.



Figure 2. 2: Coconut milk emulsion consisting of oil droplets dispersed in an aqueous (water) medium. (Adopted from McClements, 2005)

2.3.3 Physicochemical Properties of Coconut Milk Emulsion

Physicochemical properties of coconut milk refer to the physical and chemical characteristic of the coconut milk emulsions. In the following subtopic, we will define a few terms of the physicochemical properties of coconut milk.

2.3.3.1 Density of Coconut Milk Emulsion

Density is defined as mass per unit volume (Cengel and Cimbala, 2006). Since the coconut milk is an oil-in-water emulsion, which is unstable and readily separates into two distinct phases (Nour et al., 2009). Therefore, the density of each phase will be different. According to Tansakul and Chaisawang (2006), under different conditions, the density of coconut milk with 20 - 35% fat contents at different temperature (60, 70, and 80° C) was 969.00 – 983.05 kg/m³.

2.3.3.2 Viscosity of Coconut Milk Emulsion

Viscosity is a physical property that represents the internal resistance of a fluid motion (Cengel and Cimbala, 2006). As stated in the same article, viscosity is a phenomenon due to the development of internal frictional force between oil and water layers as they are force to move relative to each other.

According to the research done by Simuang et al. (2004), as cited in Peamprasart and Chiewchan (2006), it was found that viscosity decreases for increasing shear rate due to the emulsion particle interaction was deformed as the shear rate increases. It was eventually lead to particle disruption and cause reduction in flocs size and thus decrease the emulsion viscosity.

On the other hands, pseudoplastic fluid behaviour which has a flow behaviour index range from 0.713 to 0.930 was also been detected in this emulsion. It was found that in a higher fat content emulsion, pseudoplasticity of the emulsion will increased. According to Cengel and Cimbala (2006), pseudoplastic behaviour is refers to the non-Newtonian fluids, which is the relationship between shear stress and rate of deformation particles is not linear. It is also known as shear thinning fluids.



Figure 2.3: Figure of variation of shear stress with the rate of deformation for Newtonian and non-Newtonian fluids. (Adapted from Figure 2 – 14, Cengel and Cimbala, 2006)

2.3.3.3 Surface Properties of Coconut Milk Emulsion

In oil-in-water (O/W) coconut milk emulsions, oil behaves like small spherical droplets that floated on the water surface, which acts like a stretched elastic membrane under tension. The pulling force is due to the attractive forces between the oil droplets and water molecules which in turn causes this tension acts parallel to the water surface. This magnitude of forces is known as surface tension. The surface tension also will determine the size of the oil droplets formed. By kept increasing in the size of oil droplets, the addition of mass will break down when the surface tension cannot hold on anymore (Cengel and Cimbala, 2006).

2.3.3.4 Interfacial Properties of Coconut Milk Emulsion

An interface is a narrow region that separates two liquids phases (Walstra, 2003a). The two phases may consist of different kind of molecules such as oil and water. By convention, the region separating between two condensed phases is referred to as interface, while the region separating a condensed phase with gas is called a surface (Everett, 1988).

Consider the various types of molecular interactions that operate in a two-phase system consisting of oil and water in Fig. 2.4. The water molecules are capable of forming relatively strong hydrogen bonds with their neighbours in the bulk water phase, whereas the oil molecules are only capable of forming relatively weak van der Waals bonds with each other in the bulk oil phase. At oil-in-water interface, oil molecules can only form relatively weak van der Waals bonds with water molecules, because they do not have polar groups that would enable them to form hydrogen bonds. Consequently, increasing the number of interactions between oil and water molecules by increasing the interfacial area is unfavourable, because it involves replacing relatively strong waterwater bonds with relatively weak water-oil bonds.



Figure 2. 4: Interfaces are often assumed to be planar surfaces of infinitesimally small thickness. (Adopted from McClements, 2005)



Figure 2. 5: The molecular origin of interfacial tension at a liquid-liquid interface is the imbalance of the attractive forces acting on the molecules in the interface. The length of the arrows is related to the strength of the attraction between molecules. Hence, water-water interactions are considerably stronger than oil-oil or oil-water interactions. (Adopted from McClements, 2005)

2.3.3.5 Effect of Temperature to Coconut Milk Emulsion

As presented in Tangsuphoom and Coupland (2009b), stability of coconut milk emulsions was greatly affected by thermal treatments. When emulsion, which was mainly stabilized by globular protein, was being treated with temperature above its denaturation temperature of proteins, it will destabilize to some degree since coconut milk was a coarse and flocculated (i.e., effective diameter greater then primary particle size) emulsion (de Wit, 1990; Hunt & Dalgleish, 1995; Monahan et al., 1996; Demetriades et al., 1997; Kim et al., 2002; as cited in McClements, 2005).

The increased of effective diameter of the particle size indicated coalescence and flocculation. As for the flocculated coconut milk, less creamed were formed on emulsion due to the smaller density contrast of a floc than that of a droplet. Besides this, the extensive interconnection of large flocs that can trap the droplets in a network (Dickinson et al., 1997; as cited in Tangsuphoom and Coupland, 2009b).



Figure 2. 6: Visual appearance after thermal treatments of coconut milk emulsions prepared with no additive (a). Open bars represent serum layer, filled bars represent cream layer, and diagonal crisscrossed bars represent coagulated layer. (Adopted from Figure 1, Tangsuphoom & Coupland, 2009b)

2.4 Sensory Analysis of Virgin Coconut Oil (VCO)

VCO retains the fresh scent and tastes of coconut, since it did not undergoes any refining process. According to Villarino et al. (2007), it was found that VCO was almost a colourless solution. Besides this, it was perceived that VCO to have aroma like acid

cocojam – aroma associated with roasted coconut, latik – aroma of cooked coconut with sweet sentation, nutty and rancid (Marina et al., 2009b).

2.5 Emulsion Destabilization Mechanism

According to McClements (2005), emulsion stability is broadly used to describe the ability of an emulsion to resist changes in its properties with time. Physical mechanisms that are responsible for the instability of emulsions are creaming, sedimentation, flocculation, coalescence, and phase inversion.

Creaming and sedimentation are both gravitational separation. Creaming describes the upward movement of droplets due to the fact that they have a lower density than the surrounding liquid, whereas sedimentation describes the downward movement of droplets due to the fact that they have a higher density than the surrounding liquid.

Flocculation and coalescence are both types of droplets aggregation. Flocculation occurs when two or more droplets come together to form an aggregate in which droplets retain their individual integrity, whereas coalescence is the process whereby two or more droplets merge together to form a single large droplet. Extensive droplet coalescence can eventually lead to the formation of a separate layer of oil on top of a sample, which is known as "oiling-off".

Phase inversion is the process whereby an O/W emulsion is converted into a W/O emulsion or vice versa.



Figure 2. 7: Emulsion may become unstable through a variety of physical mechanisms, including creaming, sedimentation, flocculation, coalescence, and phase inversion. (Adopted from McClements, 2005)

2.5.1 Gravitational Separation

The droplets in an emulsion have a different density to that of the liquid that surrounds them, so a net gravitational force acts on them (Dickinson and Stainsby, 1982; Hunter, 1989; Walstra, 1996a&b; Robins and Hibberd, 1998; Robins, 2000; as cited in McClements, 2005). If droplets have a lower density than the surrounding liquid, they have a tendency to move upward, which is referred to as creaming. Therefore, it can be concluded that the droplets in an O/W emulsion tend to cream.



Figure 2. 8: Emulsions are prone to creaming because of the density difference between the oil and water phases. (Adopted from McClements, 2005)

However, gravitational separation will causes droplets to come into close contact for extended periods which can lead to enhanced flocculation or coalescence, and eventually to oiling-off – the formation of a layer of pure oil on top of emulsion.

2.5.2 Stokes' Law

The rate at which an isolated rigid spherical particle creams in an ideal liquid is determined by the balance of forces that acts on it. When a particle has a lower density than the surrounding liquid an upward gravitational force acts on it (Hunter, 1989; Hiemenz and Rajagopalan, 1997; as cited in McClements, 2005).

$$v_{\rm o} = \frac{(\rho_{\rm w} - \rho_{\rm o}) x \, r \omega^2 x \, D^2}{18 \, \mu_{\rm w}}$$
 (2.1)

In the initial stages of creaming, the droplets move upward and a dropletdepleted layer is observed at the bottom of container. When the droplets reach the top of the emulsion, they cannot move upward any further and so they pack together to form a "creamed layer". The final thickness of the creamed layer depends on the initial droplet concentration in the emulsion and the effectiveness of the droplet packing. Tightly pack droplets tend to form a relatively thin creamed layer, whereas loosely pack droplets shows the opposite result.



Figure 2. 9: Schematic representation of the time dependence of droplet creaming in oil-in-water emulsions. Droplets move upward until they cannot move any further and then form a "creamed" layer. Layer droplets tend to move upward faster than smaller ones. (Adopted from McClements, 2005)

2.5.3 Flocculation

Flocculation accelerates the rate of gravitational separation in dilute emulsions, which is usually undesirable because it reduces their shelf life (Luyten et al., 1993; Tan 2004; as cited in McClements, 2005). It will causes a pronounced increase of emulsion viscosity, and lead to the formation of gel (Demetriades et al., 1997a&b; as cited in McClements, 2005).



Figure 2. 10: Droplet aggregation involves a number of physiochemical processes, including droplet approach, film thinning, thin film formation, and thin film rupture. Those processes are strongly dependent on the colloidal and hydrodynamic interactions between the droplets. The overall aggregation rate and the type of aggregation that occurs depend on which of these processes are rate limiting. (Adopted from McClements, 2005)

2.5.4 Coalescence

It is the principal mechanism by which an emulsion moves toward it most thermodynamically stable state because it involves a decrease in the contact area between the oil and water phases. Coalescence causes emulsion droplets to cream or sediment more rapidly due to the increase in their size. In O/W emulsion, coalescence eventually leads to the formation of a layer of oil on top of the material, which is referred to as oiling-off.



Figure 2. 11: Droplet coalescence leads to a growth in the mean droplet diameter and may eventually lead to complete separation of the oil and aqueous phases. (Adopted from McClements, 2005)

2.5.5 Aggregation

As stated in Schramm (2005a), aggregation is a phenomenon when there is two or more dispersed species clump together, possibly touching at some points, and with virtually no change in total surface area. Nearly all emulsions undergo some aggregation on their own, leading to a distribution of aggregate sizes. The adding of a second, immiscible liquid to a suspension can cause flocculation if the second liquid preferentially adheres to the particles and bridges between them, and term as agglomeration. The particles can agglomerate in the form of flocs, or large rounded lumps (spherical agglomeration), or they may completely transformed into a second liquid phase, depending on the amount of bridging liquid added, and the degree of agitation present (Capes et al., 1977; Sirianni and Puddington, 1969; and Sparks et al., 1082; as cited in Schramm, 2005a).



Figure 2. 12: Scheme of Action of Destabilization Mechanism Responsible for Emulsion Breakdown. (Adopted from Chiralt, 2005).

For the case in coconut milk emulsion, it is a O/W emulsions stabilized by milk proteins. A relatively thick adsorption layer provides stability by steric stabilization or electrostatic stabilization (Campbell and Jones, 1997; as cited in Schramm, 2005d). These proteins globules stabilizers increase the continuous phase viscosity and reduce the extent of creaming. As referred to Schramm and Kwak (1982); as cited in Schramm (2005d), a kind of oil droplet aggregation termed "clustering" is used to increased viscosity and partially gel the cream, providing both spoonability and an appearance of thickness. Clustering is achieved when emulsion droplets are subdivided to the point at which the total interfacial area in the emulsion is greater than the surface-covering capability of the adsorbing proteins. This leads to proteins bridging between pairs of droplets (bridging flocculation).

2.6 Hydrophile – Lipophile Balance (HLB)

According Bergenstahl (1997); as cited in McClements (2005), Hydrophile – Lipophile Balance (HLB) concept is a semiemprical method used for classifying surfactants. HBL is described by a number that indicate the relative affinity of a surfactant molecule for the oil and aqueous phase (Becher, 1983, 1985; Davis, 1994; as cited in McClements, 2005). A molecule with a high HLB number has a high ratio of hydrophilic groups to lipophilic groups, and vice versa. The HBL number of a surfactant can be calculating by using the semiemperical method as follow (Davis, 1994; as cited in McClements, 2005):

$$HLB = 7 + \Sigma (hydrophilic group) - \Sigma (lipophilic group)$$
(2.2)



Figure 2. 13: Types of Emulsion (Adopted from EAC Industrial Ingredients.)



Figure 2. 14: HLB Characteristic of Emulsions (Adopted from EAC Industrial Ingredients.)

Group numbers have been assigned to different types of hydrophilic and lipophilic groups in table below:

Table 2. 6:Selected HLB Group Numbers (Adopted from Bergenstahl, 1997;
Friberg, 1997; & Stauffer, 1999; as cited in McClements, 2005)

Hydrophilic Group	Group Number	Lipophilic Group	Group Number
-SO ₄ Na ⁺	38.7	—СН —	0.475
-COO ⁻ H ⁺	21.2	$-CH_2 -$	0.475
Tertiary amini	9.4	$-CH_3 -$	0.475
Sorbitan ester	6.8	-CH =	0.475
Glycerly ester	5.25		
-соон	2.1		
-ОН	1.9		
-0 -	1.3		
$-(CH_2 - CH_2 - 0) -$	0.33		

As refer to McClements (2005), HLB is a useful indicator which shows that the solubility of emulsion in either oil and/or water phase, and further predict the type of emulsion formed. A surfactant can be either an emulsifiers or demulsifiers. Thus, a surfactant with high HLB number (10 - 18) is predominantly hydrophilic, that dissolves preferentially in water, stabilizes O/W emulsions, and forms micelles in water. Besides that, at very high or low HLB, a surfactant may have low surface activity, which does not accumulate appreciably at the droplets surface. Hence, it will not provide any protection against coalescene.



Figure 2. 15: Schematic representation of possible processes during emulsion breakdown. (Adopted from EAC Industrial Ingredients)

2.7 Methods Employed in Demulsification Process

According to Lissant (1983); Menon and Wasan (1985); Hunter (1989); as cited in McClements (2005), demulsification is the process whereby an emulsion is converted into separate oil and aqueous phases from which it was comprised, and is therefore the opposite process to homogenization. Demulsification is achieved by causing the droplets to come into close contact with each other and then to coalesce. As this process continues it eventually leads to the complete separation of oil and aqueous phases.

2.7.1 Demulsifiers - Water Soluble Materials

In demulsification (Emulsion breaking) process, the water soluble materials in this study are refer to substances that is environmental friendly, hydrophilic, non-toxic, and economic competitive. In this study, non-ionic surfactant was used. The main reason in choosing non-ionic surfactant as demulsifier it does not carry discrete charge when dissolved in aqueous media. Hydrogen bonds between hydroxyl groups from water molecules had contributed to the hydrophilicity in non-ionic surfactants. Besides this, each oxygen atom was contributed to water solubility characteristic.

As describe in the earlier subtopic, coconut milk emulsion is naturally stabilized by coconut proteins: globulins and albumins, and phospholipids (Birosel et al., 1963; as in cited in Tangsuphoom and Coupland, 2008). However, the coconut milk emulsion is unstable. It is readily to separates into a heavy aqueous phase and a light cream phase (Cancel, 1979; Gonzalez, 1990; as cited in Nour et al., 2009). This is due to the protein content and quality in coconut milk is not sufficient to stabilize the fat globules (Monera and del Rosario, 1982; as cited in Nour et al., 2009). From previous research, it shows that denature and coagulate of coconut proteins will take place on heating it to 80°C (Gonzalez, 1990; Kwon et al., 1996; as cited in Nour et al., 2009). Besides that, proteins extracted from coconut cream phase are less surface active, especially in creating small coconut oil droplets or preventing droplet aggregation, resulting in less stable emulsions (Onsaard et al., 2006). The addition of small-molecule of surface-active stabilizers to the coconut milk had completely displaced coconut proteins oil-in-water surface, and hence further stabilized the coconut milk emulsions (Tangsuphoom and Coupland, 2009).

On the other hand, in the demulsification of coconut milk emulsion, method of using water soluble (hydrophilic) materials or chemicals has been applied. By using a hydrophilic chemical, we can carry out the demulsification of coconut milk by damaging the bond of lipoprotein in emulsion (Nik Norulaini et al., 2009). Thus, it is very important to be precise and careful in choosing the type of chemicals that use in the separation process, make sure that the chemicals use is hydrophilic (attract to water phase) rather than lipophilic (attract to oil phase). This is due to the lipophilic chemicals will create environmental problems as well as various side effects on consumers health since VCO that is being extracted had been polluted by chemicals.

2.7.2 Centrifugation Method

According to Todaro (1996); as cited in Nour et al. (2009), Centrifugation is a solid – liquid separation process by magnify the forces of gravity to separate the phases. There are two general types of centrifuges:

i. Sedimentation Centrifuges

This type of centrifuge requires a density difference in the solution. For example, the oil-in-water emulsions. A heavy phase (water) settles out from a lighter phase (oil).

ii. Filtering Centrifuges

This type if separation will let the solid phase retained by a medium like a filter cloth, which will allow liquid to pass through it.

In order to enhance the demulsification of O/W coconut milk emulsion in a shorter time, centrifugation method has been introduced. The working principle of the centrifuge is by using sedimentation, where a substance with greater and lesser density is separated through an effective acceleration of centripetal that assisted with a high achievable rotation frequency. By using centrifuge, it can break down the bond of lipoprotein in emulsion and separate the coconut oil droplets from water phase, which will coalesce following separation (Coulson and Richardson, 1991; as cited in Nour et al., 2009).

As the centrifugation proceeds, the centrifugal rotation will generates heat. Since both the viscosity and density sensitive to the temperature difference, it will affect the settling velocity. However, the viscosity will decrease much faster that the density difference does, results the increase of droplets size. Therefore, centrifugal acceleration increased the velocity of oil and accelerates the separation of emulsion. While for the centrifugation time variable, it use six different times, 30,45, 60,75, 90 and 105 min, at 30°C for different centrifugation speed. The highest yield of VCO is found at 105 min. As a result, it showed that the longer the centrifugation time, the higher the yield of VCO. This is because the separation process will have longer times, results in better separation process of the oil droplets (Nour et al., 2009).

2.7.3 Demulsifiers Assisted with Centrifugation Method

According to Schramn (2005f), the first step in demulsification is to characterize the nature of emulsion, whether is oil-in-water (O/W), water-in-oil (W/O), or multiple emulsions. Then, demulsification involved two phases. Firstly, agglomeration or coagulation happened. It was followed by coalesce of agglomerated droplets. Only the completion of these two phases will lead to the separation since these two phases are rate determining of demulsification process.

Demulsification of coconut milk emulsion was carried by centrifugation and assisted with nonionic surfactant, which will self-associate and solubilize themselves to destabilize emulsion. For water soluble material or hydrophilic chemical will dissolve in water, while the oil soluble material or lipophilic chemical will dissolve in oil phase. Emulsions will undergo some aggregation by their own, leading to a distribution of aggregate (structured protein globes) sizes, and assisted by the nonionic surfactants. Hence, a low concentration, which is 0.5 v/v % is needed to promote aggregation. A large numbers of molecules from these organize aggregates will lead to the formation of casein micelles (Hartley, 1936). By homogeneous mixing, it can promote the destabilization process by breaking the stabilizing film surrounding both fat droplets and casein micelles (Dalgleish, 1990). In addition, the use of alcohols in the demulsification process, it was found that alcohols functional group, hydroxyl (- OH) played an important role in damaging the bond of lipoprotein in emulsion during demulsification process (Nik Norulaini et al., 2009).

By centrifugation, it can accelerate the creaming process in minutes. High rotation frequencies allowed an effective acceleration, which induced a faster separation compared to simple gravity separation. The centrifuge works according to the sedimentation principle, where the centripetal acceleration is used to separate substance of greater and lesser density. By using centrifuge, it is possible to break down emulsions and to separate dispersions droplets; which will coalesce following separation of coconut oil from the water phase (Coulson and Richardson, 1991). Sometimes, when the densities different for the emulsion is too low that cause the association forces holding the components together. It leads gravity separation to be time consuming (Abdurahman et al., 2009).

2.8 Advantages and Applications of Virgin Coconut Oil (VCO)

"Virgin Coconut Oil (VCO) has antivirus, anti fungus and anti natural parasites characteristics. It helps to control and overcome a variety of diseases and ailments."

(Quoted from Dr. John J. Kabara, University Michigan-USA).

The exists of high amounts of medium chain fatty acids in VCO cause them more rapidly absorb in the human body. This is due to the unique physicochemical property of medium chain fatty acids, which is with shorter chain length (Raghavendra and Raghavarao, 2010). Besides that, saturated fatty acids like Capric Acid, Caprylic Acid, Caproid Acid and Lauric Acid can helps to increase the rate of metabolism, increase level of good cholesterol (High Density Lipoproteins) and lower the level of bad cholesterol (Low Density Lipoproteins). In addition, as a good source of Vitamin E, it can keep organic systems functioning smoothly (RuralTech Services). Due to it special characteristics, it had been wider uses in functional foods, pharmaceuticals and cosmetics products.

2.8.1 Food Uses

As presented by Rethinam (2004), he found that virgin coconut oil (VCO) can be directly consumed in its pure form. It has a mild and sweet scent that suitable to use as an excellent exotic salad dressing, a good food seasoning and serves as healthy cooking oil due to its nutrition. Asides from this, as refers to Ilsi North America Special Conference, the definition that had been given to functional food was the food that supplies the nutritious component for health and energy. In virgin coconut oil (VCO), almost 50% of the fatty acid in it was made up by lauric acid, and 5 to 7% was capric acid. The content of VCO is shown in the following table:

Table 2. 7: Contents of Virgin Coconut Oil (VCO) (Adapted from Rethinam, 2004)

Contents	Percentage (%)
Protein	42.00
Carbohydrates	59.00
Total Fats	96.46
Fatty Acid	
Saturated	89.53
Mono-unsaturated	4.60
Poly-unsaturated	1.00
Lauric Acid	43.59
Myristic Acid	17.08
Caprylic Acid	7.94
Palmitic Acid	7.26
Capric Acid	5.53
Oleic Acid	4.40

Others		
Others	14.20	
Cholesterol	0.00	
Trans Fatty Acids	0.00	
Iodine Value	4.94	
Sodium (Na ⁺)	9.46	

In Philippines, VCO had been used for controlling weight, reducing constipation and to boost the immune system. Due to its easily digestible and absorbed in intestine, besides having an energy boosting effect, it had been widely used in controlling weight, reducing constipation and to boost immune system.

VCO contains medium chain fatty acid (MCFA) with main components lauric acid, C_{12} and capric acid, C_{10} . MCFA are saturated fats that found in VCO. They increase the rate of metabolism in human body, thereby aiding weight loss, increase level of good cholesterol (High Density Lipoproteins, HDL) and lower the level of bad cholesterol (Low Density Lipoproteins, LDL). Besides these, they also serve as a good source of energy for human body used (RuralTech Services).

According Rethinam (2004), lauric acid, C_{12} is useful to form monolaurin in human's body. Monolaurin plays an important role as antiviral, antibacterial, antimicrobial and antiprotozoal monoglyceride to destroy virus types like lipid layer or lipid cone and lipid coated DNA and RNA. The examples are HIV, herpes, cytomegalovirus, influenza, pathogen (listeria monocytogenes and helicobacter pylori), and protozoa (giardia lamblia).

2.8.2 Pharmaceuticals

The high contents of medium chain fatty acids (MCFAs) like caprylic acid, C_8 , capric acid, C_{10} and lauric acid, C_{12} in virgin coconut oil (VCO) make it as a valuable resource. By provide a variety of functional benefits, range from individuals with compromised immune systems, heart disease treatment and prevention, exposed to toxic food additives, growing children exposed to numerous viruses, and to the elderly whose immune system require extra support. VCO has unique properties in anti-microbial, immune-modulating, anti-toxic and metabolic-enhancing when consumed (Mary Enid, director of Nutritional Sciences Division at Enic Associates in the USA).

2.8.2.1 Anti-microbial

The characteristics of anti-microbial include antiviral, antibacterial, and antifungal/protozoa effects. All these were due to the medium chain fatty acids (MCFAs) in virgin coconut oil (VCO) and their derivatives formed in gastrointestinal tract.

Lauric acid, C_{12} in VCO plays an important role in forming it derivative, monoglyceride monolaurin in human body. Monoglyceride monolaurin acts as antiviral, antibacterial and antiprotozoa in destroying the lipid layer or cone of the virus. In addition, the antiviral action in monolaurin can helps to dilute lipid layer and phospholipids in cone or virus envelope, which could cause damage on the virus envelope. As a result, it will be easier for fatty acid and monoglycerides to destroy the double layer plasma membrane of the organism. Other than this, the rest of the significant advantages of monoglyceride monolaurin are tabulated in the table below: Table 2. 8:Advantages of monoglyceride monolaurin in Virgin Coconut Oil (VCO)
(Adapted from Bioasli Inc.)

Advantages	Description
Ulcers treatment	A greater effective against the bacteria that will cause ulcers had been shown by the co-antimicrobial properties of monoglyceride monolaurin. Therefore, it was widely used in ulcers treatment.
Improvement in heart disease	Individuals that involved with heart disease shown improvement in their health condition after consuming VCO. This is due to the viruses and bacteria that cause atherosclerosis are inhibited by monolaurin.
Enhance insulin released	VCO was making up of the majority contents of medium chain fatty acid (MCFA) like capric acid, C_{10} and laurin acid, C_{12} . According to the latest study, it is found that these MCFA can helps to enhance the insulin released in human body. Besides that, the laurin acid derivatives are also reported to have beneficial effect of damping adverse reactions to toxic forms of glutamate.

2.8.3 Cosmetics and Body Care

In recent research, it was found that the scented virgin coconut oil (VCO) can be used as a skin care products. This was contributed by its special characteristics in preventing wrinkles, sagging and premature aging. At the same time, it also helps moisture dry, flaky and itchy skin. In addition, it is also used to ease eczema and alleviate skin ailments such as diaper rash, insect bites and allergies. Therefore, it is suitable to use as moisturisesrs, body care lotions and hair conditioners, as well as massage oil. As reported by Sreenivasan (2010), the company – CMC Benefits Sdn. Bhd. in Malaysia, a direct selling company for health and beauty products, claims that, *"coconut oil is miracle oil" with wonderful anti-ageing benefits. VCO is cell food and an anti-oxidant"* during the launched of their new product – *Timeless*.

2.9 Summary

As a conclusion, from all the literature review, we will have a more clear idea with regards to the scientific terms and theories that used in this research. Besides that, by reviewing all the previous research, it will be easier for us in understanding all the concepts used when we conduct this research. It will also help us in predicting our experimental outcomes.

CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

Methodology is the methods used in solving the research problem that have been proposed in Chapter 1. The methodology that should employ should refer to the scope of research and it is a detail of our scope. Therefore, before carrying out this research, some preparation required to be done as discussed in the following sections.

3.2 Experimental Design

The main purpose of experimental design is to make sure that the experiment is running smoothly and successfully as planning in order to achieve the research objectives. In this study, which is the Production of Virgin Coconut Oil (VCO) via Water Soluble Material and Centrifugation Method, it can be separated into three main phases, which are investigation of stability characteristics; destabilization of coconut milk emulsion; and lastly the quality characterization of VCO extracted. Hence, the experimental design for this research had been formulated. At the same time, all the raw materials, apparatus and instruments estimated used will be listed in below subtopics.

PHASE I: ANALYSIS ON STABILITY OF COCONUT MILK EMULSION

i. Stability was analysed based on viscosity, density, shear rate, shear stress by using different temperature and agitation speeds, besides the measurement of surface tension and interfacial tension.

ii. Brookfield Device (Viscometer System), Tensiometer, and Microscope were used.



PHASE II: DEMULSIFICATION OF COCONUT MILK EMULSION

i. Destabilization of coconut milk emulsion to yield virgin coconut oil (VCO).

ii. Using demulsifiers that is oil soluble material, water soluble material, alcohol and centrifugation method.

iii. Instrument using is centifugal separator.



PHASE III: ANALYSIS OF VIRGIN COCONUT OIL (VCO) EXTRACTED

i. Analyzed fatty acids composition of virgin coconut oil (VCO) by using Gas Chromatogaphy – Mass Spectrometer (GC-MS).



3.3 Preparation of Raw Materials

The main material used in this research is coconut milk emulsion. Coconut milk is the raw material used in the pre-experimental stage and first phase of experiment in determining emulsion stability. For each run of experiment, the sample size of coconut milk needed is 200mL. It was purchased from the local market, but the quality of the coconut milk will be different for every usage. Hence, in this experiment, it is assumed that all the coconut milk used has the same quality (Raghavendra and Raghavarao, 2010).

As we proceed to the second phase of this experiment, which is the demulsification of coconut milk emulsion. Demulsifiers used in destabilized the coconut milk emulsion are oil soluble material (TERGITOLTM NP-4) and water soluble material (TERGITOLTM NP-8). The total amount of demulsifier used is 0.5v/v% in each sample since a small concentration of demulsifiers has high influence to the demulsification process. As cited from Nour et al. (2009), water soluble material, which refer to the demulsifier in this experiment has the following characteristics:

- i. accelerated the separation process
- ii. environmental friendly
- iii. high Hydrophilic Lipophilic Balance (HLB) value
- iv. non-toxic
- v. will not change the physical characteristic of coconut oil

According to Kirk-Othmer (2009), demulsifier is a type of surfactants. Surfactants can be divided into three groups, which are ionic surfactants, non-ionic surfactants, and cationic surfactants. In this study, non-ionic surfactants are choose as demulsifier due to the large chain branching in the structure that contributes to the increases in water solubility, chemically stable, and highly versatile properties. On the other hand, alcohol group solutions, which are methanol and ethanol with an amount of 0.5v/v % alcohol is use in each sample. By using the same interval time as the water soluble material, the performance of separation efficiency of o/w emulsion by alcohol is observed. From this, the influence of alcohols to the performance of emulsion separation process by water soluble material and centrifugation method is investigated.

Table 3.1:Summary Table for Raw Materials Used

No.	Runs of Experiment	Quantity Used	Amount	
	Analysis on Stability of Coconut Milk Emulsion			
1.	Coconut Milk	20 samples * 200mL	4.0L	
	Demulsification	on of Coconut Milk Emulsion		
1.	Coconut Milk	45 samples * 200mL	9.0L	
2.	Oil Soluble Material (TERGITOL TM NP-4)	9 samples * (0.5v/v%) / 100 * 200mL	9mL	
3.	Water Soluble Material (TERGITOL TM NP-8)	18 samples * (0.5v/v%) / 100 * 200mL	18mL	
4.	Methanol	18 samples * (0.5v/v%) / 100 * 300mL	18mL	
5.	Ethanol	9 samples * (0.5v/v%) / 100 * 300mL	9mL	

3.4 Equipments

In order to carry out this experiment, we need some equipments and instruments in helping us to analysis the data collect. Below are the equipments that will be used by us along the running of the research (Nour et al., 2009).

As for the Phase I of this experiment, which is the analysis of coconut milk emulsion stabilization, the equipments used are shown below:

i. Tensiometer

It is used to analyse the surface tension and interfacial tension of the coconut milk emulsion formed. Hence, the surface tension between oil phase and water phase surface with air will be measured, followed by the interfacial tension between oil and water layers of coconut milk in o/w emulsion. An average reading of surface tension and interfacial tension was taken.

ii. Brookfield Device (Viscometer System)

An instrument that used to measured the viscosity, density, shear stress, and shear rate of the coconut milk emulsion. Besides this, by varying the temperature and agitation speed used for the coconut milk emulsion, it can affect the results obtained for this research since viscosity is a temperature sensitive parameter. Again, an average reading was take for all the parameters measured.

iii. Microscope

This is the last part in the Phase I of this experiment, which is by using the microscope; we have to determine the size distribution of the diperse particles in the coconut milk emulsion.

As we proceed to the Phase II of the experiment, which is the demulsification of coconut milk emulsion, we need to perform destabilization on coconut milk emulsion in order to separate the oil-in-water layers. The instruments used were described as below (Nour et al., 2009):

i. Centrifugal Separator

Since our experiment was aim to use different rotational speed rate by centrifugal separator in producing the VCO, therefore, by varying the rotational speed, we can determine and compare the different in efficiency of the production of VCO in destabilization process of coconut milk emulsion.

As we proceed to the Phase III of the experiment, which is the analysis of Virgin Coconut Oil (VCO) extracted, we need to do some analysis to determine the structure and contents of the virgin coconut oil (VCO) produced. The instruments used were described as below (Nour et al., 2009):

i. Gas Chromatography – Mass Spectrometer (GC-MS)

After obtained the VCO extracted from coconut milk emulsion, we have to do some analysis on the contents of fatty acid in VCO. Before that, fatty acid transeterification was performed in order to change the fixed oil (VCO) to essential oil (volatile) for GC-MS analysi. From the analysis, we can identify which fatty acid composition in the VCO.

Table 3. 2:Summary Table for Equipments Used

No.	Equipments	Measurements		
	Analysis on Stability of Coconut Milk Emulsion			
1.	Tensiometer	- Surface Tension, Interfacial Tension		
2.	Brookfield	- Shear Stress, Shear Rate, Viscosity		
3.	Microscope	- Diameter of oil droplets		
Demulsification of Coconut Milk Emulsion				
1.	Centrifugal Separator	- Provide varying rotational speed rate in demulsification coconut milk emulsion		
Analysis of Virgin Coconut Oil (VCO) Extracted				
1.	Gas Chromatography – Mass	- Analysis the chemical components of		
	Spectrometer (GC-MS)	VCO		

3.5 Experimental and Analytical Procedures

In this section, the main flow of the experiment was discussed. The flow for the whole research study was begin with the emulsion stability investigation, demulsification of coconut milk emulsion follow by a 24hours gravity separation and lastly, the analysis of fatty acids composition of VCO extracted (Nour et al., 2009).

3.5.1 Phase I: Analysis on Stability of Coconut Milk Emulsion

This analysis can be done by using Brookfield and Tension Meter as discussion in section 3.4. By referring to the Stroke's Law (as cited in Nour et al., 2009),

$$v_{\rm o} = \frac{\left(\rho_{\rm w} - \rho_{\rm o}\right) \times r\omega^2 \times D^2}{18\,\mu_{\rm w}} \tag{3.1}$$

Where	v_o	=	settling velocity of oil droplets
	$\rho_{\rm w}$	=	density of water
	ρo	=	density of oil droplets
	r	=	radius of rotation
	ω	=	angular velocity if centrifugation
	D	=	diameter of drplets
	$\mu_{\rm w}$	=	viscosity of continuous phase (water)

the viscosity of the coconut milk emulsion can be determined.

As for the tension meter, it was used to determine the amount of pressure exerted by the coconut milk emulsion, no matter it is on external or internal surface. Since the phenomenon of surface tension and interfacial is formed, it is important to identify the maximum tension that can withstand by the emulsion.
In addition, by using different temperature, which are 30, 50, 70 and 90°C, each runs with 30, 50, 100, 150 and 200 RPM in Brookfield, the analysis on shear stress and shear rate was done; while viscosity and density of emulsion were calculate from Stroke's Law.

Lastly, we will use microscope to measure the oil droplets sizes. At here, the analysis of the effect of Brookfield's speed on the droplets size formation was done. The size distribution of the oil droplets was determined.

3.5.2 Phase II: Demulsification of Coconut Milk Emulsion

Destabilization of coconut milk emulsion can yield the formation of virgin coconut oil (VCO). By using water soluble materials and centrifugation method, destabilization process can be achieved by the emulsion.

For the method using water soluble materials, we have to make sure that the chemical used is hydrophilic solution that will not dissolve in oil droplets in oil-in-water (o/w) emulsion. In this experiment, the potentials demulsifier – TERGITOLTM NP-8 (nonylphenol ethoxylates) is used. While for the centrifugation method, we used different centrifugation speeds range 2000, 5000 and 8000 RPM; with interval time between 30, 60, and 90minutes; in the demulsification process (emulsion breaking). The effect of centrifugation speed on the demulsification process is investigated. In addition, by adding some alcohol, we will see whether the alcohol group, which are methanol and ethanol will make any separation on demulsification process. As a comparison, oil soluble material – TERGITOLTM NP-4 (nonylphenol ethoxylates) also will be used in the demulsification process. Table below had summarized the methods used in Phase II experiment:

Method	Description
Centrifugation	 Centrifugation Intervals time used: 30, 60, and 90 minutes Centrifugal Speed 2000, 5000 and 8000 RPM
Oil Soluble Materials + Centrifugation	 Non-ionic Demulsifiers: TERGITOL[™] NP-4 Centrifugation: Intervals time used: 30, 60, and 90 minutes Centrifugal Speed: 2000, 5000 and 8000 RPM
Water Soluble Materials + Centrifugation	 Non-ionic Demulsifiers: TERGITOLTM NP-8 Centrifugation: Intervals time used: 30, 60, and 90 minutes Centrifugal Speed: 2000, 5000 and 8000 RPM
Alcohols + Centrifugation	 Alcohols: Methanol Ethanol Centrifugation Intervals time used: 30, 60, and 90 minutes Centrifugal RPM:
Water Soluble Materials + Alcohols + Centrifugation	 Non-ionic Demulsifiers: TERGITOLTM NP-8 Alcohols: Methanol Ethanol Centrifugation: Intervals time used: 30, 60, and 90 minutes Centrifugal Speed: 2000, 5000 and 8000 RPM

Table 3. 3: Methodology for Phase II: Demulsification of Coconut Milk Emulsion

After centrifugation process, the samples were left for gravity settling for 24hours. The observation was done for every 30 minutes for the first 3hours, and then left for 24hours to extract the coconut oil recovery. Figure below shown theoretical result after gravity settling process.

Figure 3. 2: Different layers are often observed in an emulsion undergoing creaming: (i) an upper "cream" layer; (ii) a middle layer; (iii) a lower "serum" layer

In addition, by using the centrifugation method, it will produced layers of an aqueous phase (water) on the bottom, an emulsion phase (cream) in the middle, and an oil phase on top. The height of separated layers formed in the coconut milk emulsion was analysed with the formula below (Nour et al., 2009):

Layer (%) =
$$\frac{\text{The height of the separated layer}}{\text{Total height of the emulsion}} \times 100\%$$
 (3.2)

Lastly, for the composition of the fatty acids analysis, it was done based on the analysis data obtained from gas chromatography mass spectrometer (GC-MS). The dominant fatty acids group in the formation of VCO is determined.

3.5.3 Phase III: Analysis of Virgin Coconut Oil (VCO) Extracted

Before starting Gas Chromatography – Mass Spectrometer (GC-MS) analysis, the virgin coconut oil yield from demulsification process, which is categorized as fixed oil, should be transform into volatile oil, firstly. Therefore, by fatty acid transesterification process, a volatile coconut oil sample was prepared. The preparation steps were described in follow paragraph.

50 ml 2M methanolic KOH was prepared by dissolving 5.6 g KOH in 50 ml methanol (R&M, analytical grade). Esterification procedure was done according to Berdeux et al. (1999), with slight modification. 100 mg of oil sample were dissolved in 10 ml hexane (Merck, analytical grade) in test tube, then 1 ml of 2M methanolic KOH was added to the tube. Then the tube was vortex occasionally. After 15 min, the hexane phase was collected and washed twice with 4ml water, twice to get rid of remaining catalyst and methanol. The solution then was dried over sodium sulphate and filtered using filter paper.

According to (Abdurahman et al., 2009), the fatty acid compositions from VCO analysis was performed by GC machine, model Agilent, under condition as below:

- i. Column, glass column length 1.83m and 2mm ID
- ii. Injector temperature 250°C
- iii. Detector temperature 250 °C

Separation was done on a 100/120 Chmosorb-WAW column containing 10% SP2330. Oven temperature increased programmed from 80 to 180°C at a ramp rate of 8°C min⁻¹ for 8.0min and nitrogen at a flow of 20 mL min⁻¹. The FAME was identified and quantified. The results obtained by them were compared with the Asia and Pacific Coconut Community (APCC) Standard.

Fatty Acid	APCC Standard
C ₆	0.40 - 0.60
C_8	5.00 - 10.00
C_{10}	4.50 - 8.00
C_{12}	43.00 - 53.00
C_{14}	16.00 - 21.00
C_{16}	7.50 - 10.00
C _{18:0}	2.00 - 4.00
C _{18:1}	5.00 - 10.00
C _{18:2}	1.00 - 2.50
$C_{18:3}$	< 0.50

Table 3. 4: Fatty Acid Compositions of Virgin Coconut Oil (VCO)

3.7 Summary

As a conclusion, throughout the whole experiment, which is from the preexperimental stage, followed by Phase I, Phase II, and lastly the analysis of virgin coconut oil (VCO) produced. Tables below had summarized the total samples that are needed in the whole experiment:

No.	Runs of Experiment	Quantity Used	Amount
	Analysis on Stat	oility of Coconut Milk Emulsion	
1.	Brookfield Analysis	4 temperatures * 5 RPM	20
	Demuisificatio	on of Coconut Milk Emulsion	
1.	Centrifugation	3 interval time * 3 centrifugation speed	9
2.	Oil Soluble Material + Centrifugation	3 interval time * 3 centrifugation speed * 1 demulsifier	9
3.	Water Soluble Material + Centrifugation	3 interval time * 3 centrifugation speed * 1 demulsifier	9
4.	Alcohos + Centrifugation	3 interval time * 3 centrifugation speed * 2 alcohols	18
5.	Water Soluble Material + Alcohol + Centrifugation	3 interval time * 3 centrifugation speed * 1 demulsifier * 1 alcohol	9
	TOTAL	SAMPLES	65

Table 3. 5: Summary Table for Calculation of Total Samples Needed

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, which is results and discussions, all the experimental results were tabulated and analysed. This chapter was divided into a three main phases according to the previous chapter that is Chapter 3: Materials and Method. The first phase was the results of the analysis on the stability of coconut milk emulsion. It was followed by demulsification of coconut milk emulsion via water soluble materials and centrifugation. As for the last phase, it was the quality characterization of the Virgin Coconut Oil (VCO) yield from the demulsification of coconut milk emulsion by using Gas Chromatography – Mass Spectrometer (GC-MS). In each section, it was detailed out into observations, results obtained from experimental works, and data analysis and discussion.

4.2 Phase I: Analysis of the Stability of Coconut Milk Emulsion

In this study, the stability properties such as density, viscosity and droplets size of different batches for the coconut milk emulsion used were analysed. Through Brookfield Analysis, the viscosity, shear rate and shear stress were recorded. Apart from that, the droplets size for the emulsion was determined via microscope and the distribution was tabulated.

4.2.1 Microstructure of Emulsion

4.2.1.1 Microscopy

Optical microscopy is used to determine the shape, size, and size distribution of oil droplets in dispersion. Below figure illustrated the optical micrographs of the coconut milk emulsions used. The size distribution was tabulated in **Appendix A2**.



Figure 4.1: Optical micrograph using reflected fluorescent light showing Oil-inwater (O/W) emulsion. The continuous water phase (darker phase) shows dispersed oil droplets (bright droplets) for Batch 1 emulsion.



Figure 4. 2: Optical micrograph using reflected fluorescent light showing Oil-inwater (O/W) emulsion. The continuous water phase (darker phase) shows dispersed oil droplets (bright droplets) for Batch 2 emulsion.

The characterization of coconut milk emulsion as a food colloids are clearly shown in both optical micrographs above. The emulsions are stabilized by coconut milk proteins, such as casein micelles, which form a membrane around the oil droplets (Dickinson, 1989). This cause the oil droplets are approximately in spherical shape. On the other hand, the fluid flowing has impact on the shape of dispersed phase. The shape of oil droplets may deform in shear flow since they are not rigid spheres.

4.2.1.2 Size Distribution

Since the emulsion is polydisperse, so it will undergo some aggregation leading to a distribution of aggregate sizes. The characterization size-dispersed species is in terms of an average size as shown in **Appendix A.1** and **A.2**. Therefore, by using a histogram, the droplets size distribution is presented below:



Figure 4. 3: Histogram of size distribution for coconut milk emulsion (Batch 1)



Figure 4. 4: Histogram of size distribution for coconut milk emulsion (Batch 2)

From both histograms above, the distribution is skew to left. The statistical values were tabulated in below:

Statistical Value	Batch 1	Batch 2
Minimun (µm)	0.04	0.04
Maximum (µm)	0.95	0.85
Mode (µm)	0.11	0.13
Mean (µm)	0.21	0.17
Median (µm)	0.19	0.15

Table 4.1: Statistical Values for Size Distribution of Coconut Milk Emulsions

From the results obtained, it was found that the average fat droplets diameter for these two batches of coconut milk emulsion is 0.21 and 0.17 μ m, while, the most frequent droplet size is 0.11 and 0.13 μ m, respectively. The distribution illustrated an opposite result for average size and most frequent size due to the higher oil content in Batch 1 emulsion. Since the droplets size larger than 0.1 μ m and smaller than 180 μ m, emulsion was considered as Stoke's model.

On the other hand, the size distribution has important influence on the emulsion viscosity. For smaller size distribution, the dispersion viscosity will be higher. This is due to the increased in interfacial area and thinner films increased the resistance to the flow of fluid (Becher, 2001). Thus, it was predicted that the second batch of coconut milk emulsion will have higher viscosity.

4.2.2 Density of Coconut Milk Emulsion

The size distributions of these coconut milk emulsions are different, so they result in the different for their density. The density is 0.952 and 0.926 g/cm³, respectively.

Coconut milk is an O/W emulsion make up by water, fats, carbohydrates, protein and ash. Hence, the different in the compositions percentage had contributed to the different of density for each emulsion. Besides that, from visual observation, it was found that the second batch emulsion is creamier, cause lighter density. While from the point of view of size distribution, it was found that the mode of droplets size for Batch 1 emulsion is smaller, which contributed to a larger interfacial contact area in dispersed phase, causing the increase in density of emulsion.

4.2.3 Rheology Properties Analysis

In rheology study, the deformation and the flow of emulsion is investigated. The results were tabulated in **Table A.1 and A.2** in Appendix A. From the results obtained, a few analysis were done, which was discussed in the below section. However, there are some errors in the reading of rheometer.

For Batch 1 emulsion, when temperature increases, the coconut milk emulsion will start to boil and become more viscous. At the same time, when emulsion is boiled at 90°C, its volume will increase due to the entrained air in dispersion. As a result, coconut milk changed its colloid system from emulsion to mixed dispersions, which is a combination of emulsion and foam (Damodaran, 1997). Therefore, it will formed two

layers, which is foam with lighter density on the top and emulsion on the bottom. This changed had result in the error of the reading from rheometer since it cannot determine the viscosity of foam at low agitation speed.

While for the second batch of emulsion, when temperature rises, the coconut milk emulsion will start to boil and become more viscous until it solidified due to the water that has completely evaporated. This "solidified" O/W emulsions is due to the oil droplets are covered by a protein membrane and dispersed in a gel (Damodaran, 1997). This result in the error of the reading from rheometer since the spindle cannot rotate at high speed in solidified emulsion.

4.2.3.1 Viscosity versus Temperature

Table 4. 2: Viscosity versus Temperature for Coconut Milk Emulsion (Batch 1)

Temperature, T (°C)	Viscosity, μ (cP)				
Agitation Speed	30 RPM	50 RPM	100 RPM	150 RPM	200 RPM
30	91.00	71.60	54.30	44.93	39.57
50	79.67	59.40	41.80	31.87	27.97
70	78.00	54.60	41.90	33.13	30.47
90	$EEEE^*$	$EEEE^*$	267.90	149.33	129.00
* EEEE		- +			

* EEEE : Error in viscometer reading



Figure 4. 5: Effect of Temperature to Viscosity of Coconut Milk Emulsion for Different Agitation Speed (Batch 1)

Table 4. 3:	Viscosity versus	Temperature for	Coconut M	lilk Emulsion	(Batch 2)	
--------------------	------------------	-----------------	-----------	---------------	-----------	--

Temperature, T (°C)	Viscosity, µ (cP)			
Agitation Speed	30 RPM	50 RPM	100 RPM	150 RPM	200 RPM
30	108.00	85.20	65.30	56.13	50.13
50	68.00	58.60	48.80	41.47	38.33
70	191.33	146.80	105.10	85.40	74.37
90	642.90	441.10	255.40	199.80	$EEEE^*$
* EEEE :	Error in viscom	eter reading			



Figure 4. 6: Effect of Temperature to Viscosity of Coconut Milk Emulsion for Different Agitation Speed (Batch 2)

Figures above illustrated that the effect of temperature to viscosity at different agitation speed. Since the emulsions are Stoke's model and the viscosity is temperature dependent, so the general trend demonstrated for viscosity and temperature should be inversely proportional.

From **Figure 4.5**, the results obtained followed two different trends as predicted up to 70°C for all agitation speed applied. However, when emulsion was heated up to 90°C, the rheometer showed error in reading for low agitation speed (30 and 50 RPM). As for higher agitation speed, that is 100, 150 and 200 rpm, the viscosity was not longer a function of temperature since it rose gradually. While from **Figure 4.6**, the results obtained followed two different trends as predicted up to 50°C for all agitation speed applied but increase rapidly when emulsion was heated up to 90°C. However, there is an except for the trend, which is at 90°C that agitated with 200 RPM, no reading is indicated from Brookfield device.

The minimum viscosity for Batch 1 coconut milk at higher agitation speed (100, 150 and 200 RPM) was achieved around 64°C, while for the Batch 2 coconut milk is around 50°C for all agitation speed applied. At this temperature, the emulsion changes from stabilizing Oil-in-Water (O/W) to Water-in-Oil (W/O) emulsion. This transition temperature is termed as Phase Inversion Temperature (PIT), where phase inversion is occurs. Coconut milk is a food emulsion, where the protein existed is function as surfactant that stabilised the O/W emulsion at low temperature. Hence, as temperature increased, W/O emulsion is preferred, where now the coalescence rate will be slow, a more stable emulsion is formed (Wadle et. al., 1997).

4.2.3.2 Viscosity versus Agitation Speed

Table 4. 4:Viscosity versus Agitation Speed for Coconut Milk Emulsion
(Batch 1)

Agitation Speed (RPM	(1)	Viscosit	y, µ (cP)	
Temperature, T (°C)) 30	50	70	90
30	91.00	79.67	78.00	$EEEE^*$
50	71.60	59.40	54.60	$EEEE^*$
100	54.30	41.80	41.90	267.90
150	44.93	31.87	33.13	149.33
200	39.57	27.97	30.47	129.00
* EEEE : Er	ror in viscometer	reading		



Figure 4.7: Effect of Agitation Speed to Viscosity of Coconut Milk Emulsion at Different Temperature (Batch 1)

Table 4. 5:Viscosity versus Agitation Speed for Coconut Milk Emulsion
(Batch 2)

Agitation Speed (RPM)	Viscosit	ty, μ (cP)	
Temperature, T	(°C) 30	50	70	90
30	108.00	68.00	191.33	642.90
50	85.20	58.60	146.80	441.10
100	65.30	48.80	105.10	255.40
150	56.13	41.47	85.40	199.80
200	50.13	38.33	74.37	$EEEE^*$
* EEEE :	Error in viscometer	reading		



Figure 4. 8: Effect of Agitation Speed to Viscosity of Coconut Milk Emulsion at Different Temperature (Batch 2)

Figures above illustrated that the effect of agitation speeds to viscosity under different temperature. The emulsions are Stoke's model. By applying Stoke's law, it that stated that the terminal velocity of dispersion is inversely proportional to viscosity. As a result, the general trend demonstrated for viscosity and agitation speed should be inversely proportional.

As observed from **Figure 4.7** and **4.8**, the results demonstrated for temperature 30°C, 50°C and 70°C for the agitation speed range from 30 to 200 rpm, they followed the normal trend for Stoke's model emulsions. However, there are exceptions for this two batch coconut milk emulsion at 90°C due to the failure of Brookfield device in obtaining it properties reading.

On the other hand, since viscosity is temperature sensitive, so viscosity of emulsion will decrease as temperature rise. However, from **Figure 4.7** and **4.8**, Batch 1 emulsion illustrated this relationship for temperature range from 30° C to 70° C, while Batch 2 emulsion demonstrated for 30° C and 50° C only. As for the rest of the temperature applied to the emulsion, they showed an opposite results as previous due to the phenomenon Phase Inversion from O/W to W/O emulsion at temperature 64°C and 50° C, respectively.

4.2.3.3 Shear Stress versus Shear Rate

Table 4. 6: Shear Stress versus Shear Rate for Coconut Milk Emulsion (Batch 1)

Shear Rate, y (1	/sec)	Shear Stres	ss, τ (D/cm ²)	
Temperature, T	(°C) 30	50	70	90
10.20	9.25	8.12	7.65	$EEEE^*$
17.00	12.10	10.10	9.28	$EEEE^*$
34.00	18.40	14.23	14.27	89.67
51.00	22.80	16.20	16.87	76.93
68.00	26.90	19.03	20.73	90.50
EEE : H	Error in viscometer r	eading		



Figure 4.9: Shear Stress versus Shear Rate at Different Temperature for Coconut Milk Emulsion (Batch 1)

Table 4. 7: Shear Stress versus Shear Rate for Coconut Milk Emulsion (Batch 2)

Shea	ar Rate, y (1	(1/sec) Shear Stress, τ (D/cm ²)			
Tem	perature, T	(°C) 30	50	70	90
	10.20	10.93	6.86	19.60	65.67
	17.00	14.40	9.96	24.97	75.40
	34.00	22.07	16.50	35.70	86.87
	51.00	28.63	21.17	43.50	101.90
	68.00	34.03	26.13	50.60	$EEEE^*$
* EEEE	: E	error in viscometer r	reading		



Figure 4. 10: Shear Stress versus Shear Rate at Different Temperature for Coconut Milk Emulsion (Batch 2)



Figure 4. 11: Typical flow curves of shear stress versus shear rate (Schramm, 1996).

The viscosity of two batches coconut milk emulsions are not constant, but performed as a function of shear rate. This characteristic proved that coconut milk emulsions are non-Newtonian fluids, and lead to different types of flow properties. The flow properties of coconut milk emulsions used can be determined by plotting flow curves of shear stress against shear rate. By comparing those with typical flow curves of shear stress versus shear rate in **Figure 4.11**, the rheological classification of the emulsion can be identified.

For the Batch 1 coconut milk emulsion in **Figure 4.9**, under the temperature of 30°C, 50°C and 70°C, it exhibit pseudoplastic characteristic. The same trend also goes with the second batch of coconut milk as shown in **Figure 4.10**. However, when the temperature is rise to 90°C, the flow properties changed to dilatant for the first batch of coconut milk emulsion, but Batch 2 emulsion only but exhibited a slightly different rheology classification – pseudoplastic with yield stress under the same temperature heated.

Pseudoplastic or shear-thinning characteristic is happened when shear rate increases, the viscosity decrases. Pseudoplasticity of emulsion is due to alignment, stretching, deformation or peptization of dispersed phase while being sheared. At a very slow shear rates, especially at 10.2 and 17.0 1/sec at 30°C, 50°C and 70°C from **Figures 4.9** and **4.10**, pseudoplastic emulsions will behave like a Newtonian fluid. This is due to the Brownian motion of dispersed phase (oil droplets) counteracts the orienting effects of the applied shear. Above a certain shear rate, the shear effects then dominate and pseudoplastic flow is observed (Schramm, 2005b).

As for Batch 1 emulsion at 90°C, it illustrated a "U" shape in the graph and did not follow any trend as discussed before by Schramm, 1996. At first, the shear stress decreased from 89.67 to 79.63 D/cm² as shear rate increased from 34.0 to 51.0 1/sec. Explanation for this phenomenon is mostly due to the disruption of the orientation of the dispersed phase, causing stretching and deformation when a higher agitation speed applied to the emulsion. This will further leads to more disaggregation of oil droplets in continuous phase, causing emulsion more easily to deform by lower shear stress. After that, shear stress increased from 79.63 to 90.50 D/cm² as shear rate increased 51.0 to 68.0 1/sec. This trend is similar to dilatancy or shear-thickening, except it exhibit until a threshold stress (yield stress, $\tau_{\rm Y}$) is reached at 51.0 1/sec. This yield stress is used to overcome the interparticle or intermolecular network formed by the previous changes in emulsion. Dilatancy or termed as shear-thickening, is happened when the shear rate increases, the viscosity of dispersions also increases. This is due to the dense packing of oil droplets in a very concentrated emulsion. Hence, at low shear, the droplets can move past each other. While for high shear, they become wedged together that is the fluid cannot fill or lubricate the increased void volume, and caused the viscosity to increase (Schramm, 2005b).

While for the pseudoplasiticity with yield stress or termed as plasticity behaviour that exhibited by Batch 2 emulsion at 90°C, the shear rate (flow) remains at zero until a threshold shear stress (yield stress, $\tau_{\rm Y}$) is reached, the Newtonian or pseudoplastic flow begins. This is due to the existence if an interparticle or intermolecular network which initially acts like a solid and offers resistance to any positional changes of the volume elements. In this case, flow only occurs when the applied stress exceeds the strength of the network, which is approximately at 50 D/cm² as described in **Figure 4.10** (Schramm, 2005b).

As a conclusion, phase inversion changed the stabilize emulsion from O/W to W/O had contributed to the different in flow properties for the same emulsion.

Table 4. 8: Viscosity versus Shear Rate for Coconut Milk Emulsion (Batch 1)

Shear Rate, y (1/se	c)	Viscosity, µ (cP)				
Temperature, T (°	C) 30	50	70	90		
10.20	91.00	79.67	78.00	$EEEE^*$		
17.00	71.60	59.40	54.60	$EEEE^*$		
34.00	54.30	41.80	41.90	267.90		
51.00	44.93	31.87	33.13	149.33		
68.00	39.57	27.97	30.47	129.00		
* EEEE :	Error in viscome	Error in viscometer reading				



Figure 4. 12: Viscosity versus Shear Rate at Different Temperature for Coconut Milk Emulsion (Batch 1)

Shear Rate, γ (1/sec	Viscosity, µ (cP)			
Temperature, T (°C	C) 30	50	70	90
10.20	108.00	68.00	191.33	642.90
17.00	85.20	58.60	146.80	441.10
34.00	65.30	48.80	105.10	255.40
51.00	56.13	41.47	85.40	199.80
68.00	50.13	38.33	74.37	$EEEE^*$
* EEEE :	Error in viscome	ter reading		

Table 4. 9:Viscosity versus Shear Rate for Coconut Milk Emulsion (Batch 2)



Figure 4. 13: Viscosity versus Shear Rate at Different Temperatures for Coconut Milk Emulsion (Batch 2)



Figure 4. 14: Typical flow curves of viscosity versus shear rate (Schramm, 1996).

The viscosity of two batches coconut milk emulsions are not constant, but performed as a function of shear rate. This characteristic proved that coconut milk emulsions are non-Newtonian fluids, and lead to different types of flow properties. The flow properties of coconut milk emulsions used can be determined by plotting flow curves of viscosity against shear rate. By comparing those with typical flow curves of shear stress versus shear rate in **Figure 4.14**, the rheological classification of the emulsion can be identified.

For the Batch 1 coconut milk emulsion in **Figure 4.12**, under the temperature of 30°C, 50°C and 70°C, it exhibit pseudoplastic characteristic. The same trend also goes with the second batch of coconut milk as shown in **Figure 4.13**. However, when the temperature is rise to 90°C, the flow properties exhibited by both batches is pseudoplastic with yield stress.

Pseudoplastic or shear-thinning characteristic is happened when shear rate increases, the viscosity decrases. Pseudoplasticity of emulsion is due to alignment, stretching, deformation or peptization of dispersed phase while being sheared. At a very high shear rates, especially at 51.0 and 68.0 1/sec at 30°C, 50°C and 70°C from **Figures 4.12** and **4.13**, pseudoplastic emulsions will behave like a Newtonian fluid. This is due to the Brownian motion of dispersed phase (oil droplets) counteracts the orienting effects of the applied shear. Above a certain shear rate, the shear effects then dominate and pseudoplastic flow is observed (Schramm, 2005b).

On the other hand, for the pseudoplasiticity with yield stress or termed as plasticity behaviour that exhibited by both batches of emulsions at 90°C, the shear rate (flow) remains at zero until a threshold shear stress (yield stress, τ_Y) is reached, the Newtonian or pseudoplastic flow begins. This is due to the existence if an interparticle or intermolecular network which initially acts like a solid and offers resistance to any positional changes of the volume elements. For Batch 1 emulsion, as the shear rate increased from 62.0 to 68.0 1/sec, it exhibits a trend that is almost similar to Newtonian. This is due to the high agitation speed applied that deformed the intermolecular network formed in emulsion, causing the emulsion become an ideal fluid (Schramm, 2005b).

As a conclusion, phase inversion changed the stabilize emulsion from O/W to W/O had contributed to the different in flow properties for the same emulsion.

4.2.4 Surface and Interfacial Tensions

The surface tension for both oil and water in air is 30.431 and 70.023 mN/m, respectively. As for the interfacial tension between oil and water phases, it is less than the individual surface tension of each liquid, recorded a value 7.987 mN/m. This is due to the mutual attraction had been moderated by all the molecules involved (Moules, Camtel Ltd.).

4.3 Phase II: Demulsification of Coconut Milk Emulsion

In this part of experiment, demulsification of coconut milk emulsion is done by using various combinations of demulsifiers such as oil soluble metrial, water soluble material and alcohol, assisted with centrifugal forces with different processing time and processing speed. Observations for the first three hours were recorded, and then the samples were leaved to gravity separation for one day (24 hours). After that, the Virgin Coconut Oil (VCO) yield from coconut milk emulsions was collected in a sealed vial and store in refrigerator.

4.3.1 Observation of Demulsification Process

The demulsification process of the coconut milk emulsion was observed for the 24 hours. The results observations were tabulated in the table below according to the methods employed:

Table 4. 10: Observations for Demulsification of Coconut Milk Emulsion viaCentrifugation Method after 24hours.



followed by creaming part and bottom is aqueous phase.



25.0 mL

18.0 mL





Three layers observed: top with virgin coconut oil (VCO), followed by creaming part and bottom is aqueous phase.



19.0 mL



26.0 mL



15.0 mL

Three layers observed: top with virgin coconut oil (VCO), followed by creaming part and bottom is aqueous phase.

5,000 rpm

8,000 rpm



The characteristic of the virgin coconut oil (VCO) extracted were described as follow:

- i. Color is not clear, have suspended immicible particles.
- ii. Retains the distinct scent of coconuts
- **Table 4. 11:** Observations for Demulsification of Coconut Milk Emulsion via a
Concentration of 0.5 v/v% Oil Soluble Material and Centrifugation
Method after 24hours

Centrifugal Conditions	30 min	60 min	90 min	
2,000 rpm	So minSo min90 minSo minSo min90 minSo minSo min90 minSo		coconut oil (VCO), is aqueous phase.	
	33.0 mL	33.0 mL	43.0 mL	
5,000 rpm				



Three layers observed: top with virgin coconut oil (VCO), followed by creaming part and bottom is aqueous phase.



64.0 mL



65.0 mL



60.0 mL



Three layers observed: top with virgin coconut oil (VCO), followed by creaming part and bottom is aqueous phase.



The characteristic of the virgin coconut oil (VCO) extracted were described as follow:

- i. Clear coconut oil extracted with some suspended immicible particles.
- ii. Retains the distinct scent of coconuts.

8,000 rpm

Table 4. 12: Observations for Demulsification of Coconut Milk Emulsion via a
Concentration of 0.5 v/v% Water Soluble Material and Centrifugation
Method after 24hours

Centrifugal Conditions	30 min	60 min	90 min	
			Three	lavars
	Two layers observe	ved: creaming part	observed:	top
	bottom.	r water phase on	coconut	virgin

2,000 rpm

(VCO), followed

by creaming part and bottom is aqueous phase.

30.0 mL



Two layers observed: creaming part on top and clear water phase on bottom.

5,000 rpm



8,000 rpm

Two layers observed: creaming part on top and clear water phase on bottom.

The characteristic of the virgin coconut oil (VCO) extracted were described as follow:

- i. Color is not clear, have suspended immicible particles.
- ii. Retains the distinct scent of coconuts
- **Table 4. 13:** Observations for Demulsification of Coconut Milk Emulsion via a
Concentration of 0.5 v/v% Methanol and Centrifugation Method after
24hours

Centrifugal Conditions	30 min	60 min	90 min	



2,000 rpm

Four layers observed: top with soft creaming part (jelly), second upper layer is virgin coconut oil (VCO), followed

by solidified creaming part and the bottom is aqueous phase.





47.0 mL



41.0 mL



Three layers observed: top with virgin coconut oil (VCO), followed by creaming part and bottom is aqueous phase.



35.0 mL

45.0 mL





Three layers observed: top with virgin coconut oil (VCO), followed by creaming part and bottom is aqueous phase.

5,000 rpm

8,000 rpm



The characteristic of the virgin coconut oil (VCO) extracted were described as follow:

- i. Color is not clear, have suspended immicible particles.
- ii. Retains the distinct scent of coconuts

For sample with centrifugal processing speed 2,000rpm with processing time 30min, 60min and 90min, the creaming part of coconut milk emulsion is separated into two layers, which have different densities. The above layer is soft (jelly) creaming while the bottom part was solidified creaming part. This is due to the concentration of alcohols used is not concentrated enough in order to penetrate through the particles of O/W emulsion at a lower centrifugal processing speed. In theoretical (Schramm, 2005a), the addition of a second, immicisble liquid (methanol) adheres to the particles and bridges between them, which is term as agglomeration. The particles may agglomerate in the form of flocs, or large rounded lumps ("speherical agglomeration"), or they may transformed into a second liquid phase, depending on the concentration of bridging liquid added, and the degree of agitation present. Besides that, the alcohol content include making the aqueous phase a poorer solvent for proteins in ruptures the proactive membrane surrounding that the oil droplets, leaving droplets that are coated with casein protein (Stainsby and Dickinson, 1988).



- Figure 4. 15: Separation of creaming part itself for samples runs at 2,000rpm for 30, 60 and 90 minutes.
- **Table 4. 14:** Observations for Demulsification of Coconut Milk Emulsion via a
Concentration of 0.5 v/v% Ethanol and Centrifugation Method after
24hours




50.0 mL

60.0 mL

34.0 mL



Three layers observed: top with virgin coconut oil (VCO), followed by creaming part and bottom is aqueous phase.





55.0 mL



Three layers observed: top with virgin coconut oil (VCO), followed by creaming part and bottom is aqueous phase.

8,000 rpm

5,000 rpm



The characteristic of the virgin coconut oil (VCO) extracted were described as follow:

- i. Color is not clear, have suspended immicible particles.
- ii. Retains the distinct scent of coconuts
- **Table 4. 15:** Observations for Demulsification of Coconut Milk Emulsion via a
Concentration of 0.5 v/v% Water Soluble Material and Methanol with
Centrifugation Method after 24hours

Centrifugal Conditions	30 min	60 min	90 min
2,000 rpm	Two layers obser emulsion phase on	ved: creaming part bottom.	on top and o/w
5,000 rpm			

Two layers observed: creaming part Three layers on top and o/w emulsion phase on bottom. With virgin coconut oil (VCO), followed by creaming part



and bottom is aqueous phase.

2.0 mL



Two layers observed: creaming part on top and o/w emulsion phase on bottom.



Three layers observed: top with virgin coconut oil (VCO), followed by creaming part and bottom is aqueous phase.



44.0 mL

8,000 rpm

The characteristic of the virgin coconut oil (VCO) extracted were described as follow:

- i. Color is not clear, have suspended immicible particles.
- ii. Retains the distinct scent of coconuts

4.3.2 Phase Separation of Demulsification Process

•

During demulsification process of coconut milk emulsion, phase separation occurred, which were coconut oil on top, creaming phase in the middle and lastly aqueous phase on the bottom. The percentage of each phase volume was calculated according to equation (3) for different method employed in demulsification process and tabulated. The original data for calculation can be referred to **Appendix B.1** to **B.6** and were presented in a graphical way as demonstrated below:



Figure 4. 16: Phase Separation of Demulsification of Coconut Milk Emulsion via Centrifugation Method



Figure 4. 17: Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v% Oil Soluble Material and Centrifugation Method



Figure 4. 18: Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v% Water Soluble Material and Centrifugation Method



Figure 4. 19: Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v% Methanol and Centrifugation Method



Figure 4. 20: Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v% Ethanol and Centrifugation Method



Figure 4. 21: Phase Separation for Demulsification of Coconut Milk Emulsion via a Concentration of 0.5 v/v% Water Soluble Material and Methanol with Centrifugation Method

Based on the graphical data, the results had been analyzed and discussed as follow. The phase will separated and settle down according to theirs density, respectively, which was the virgin coconut oil (VCO) on top surface, followed by creaming part in the middle, and the heavier aqueous phase on the bottom. From the Stability Part, there were two batches of coconut milk emulsions used in this experiment. For the demulsification process via centrifugation, oil soluble material with centrifugation, methanol with centrifugation, and lastly ethanol with centrifugation method, they used Batch 1 emulsion. While for the water soluble material with centrifugation and water soluble material and methanol with centrifugation part used the second batch of coconut milk emulsion.

In Figure 4.16, 4.17, 4.19 and 4.20, Batch 1 coconut milk emulsion was used in these parts of experiments. The water phase has almost the same amount (around 50 v/v %) under constant centrifugation speed. Besides that, it was observed that the

creaming part was kept reducing as centrifugal speed increases at constant centrifugal processing time. Cream is the fat-rich portion of coconut milk that separated by skimming, and it still remains in the form of an O/W emulsion (Sogo et al., 1989). Thus, it can yield coconut oil via gravity separation. As a result, the coconut oil yield increasing as centrifugal speed increases at constant centrifugal processing time. However, for **Figure 4.16**, which was under a low centrifugation processing speed (2,000 rpm), it did not show any significant changing for the creaming process. Thus, it result in the almost equally of the virgin coconut oil (VCO) yield.

From Figure 4.18 and 4.21, they showed that cream layer was kept increasing when the centrifugal processing speed increased from 2000 to 8000 rpm. Cream is the fat-rich portion of coconut milk that separated by skimming, and it still remains in the form of an O/W emulsion (Sogo et al., 1989). Hence, as centrifugal processing time increase, the time for coalescence to happen will be longer. This increased the opportunity for the cream formation. Since Batch 2 emulsion has lower oil content was used for this part of experiment, so there was no significant oil recovery. Besides that, according to Schramm (2005), at lower pH of aqueous phase, coconut milk emulsion will be stabilized by its protein globules, resisted to demulsification process. This phenomenon was known as clustering. It was achieved when oil droplets in coconut milk emulsion was greater than the surface-covering capability of the adsorbing proteins. This leads to proteins bridging between pairs of droplets – bridging flocculation (Schramm, 1982; Campbell and Jones, 1997). As for the coconut oil recovery yield, it will be detailed discussed in the following sections, which are Section 4.3.3 and 4.3.4.

4.3.3 Effect of Centrifugation Speed on on Virgin Coconut Oil (VCO) Recovery

From equation (1), which was settling velocity of oil droplets given by Stoke's Law as stated earlier:

$$v_{\rm o} = \frac{(\rho_{\rm w} - \rho_{\rm o}) x \, r \omega^2 x \, D^2}{18 \, \mu_{\rm w}}$$
 4.1

Where ;

$v_{\rm o}$ = settling velocity (m/s)	
$\rho_{\rm w}$ = water density = 1000	kg/m ³
$\rho_{\rm o}$ = oil density = 850 kg/r	m^3
r = radius of rotation = 1	1.0 cm
ω = angular velocity of cer	ntrifugation (rpm)
d = diameter of droplets (μ	um)
$\mu_{\rm w}$ = viscosity of water phase	se = 8×10^{-4} kg/m.s

Equation 4.1 showed that the settling velocity of oil droplets is directly proportional to the square of coconut milk emulsion dispersed phase droplets size, centrifugal acceleration and the difference between water and oil phase densities. However, this equation demonstrated a reciprocal relationship with the water viscosity, which on the other hand was sensitive towards temperature. By centrifugal rotation (centrifugation acceleration takes place), heat was generated to the coconut milk emulsion. Therefore, the viscosity of emulsion will decrease as temperature increase due to the heat generated. Since the viscosity decrease in a faster rate compare to the density difference between oil and water, so it will result in the increase of oil droplets size. As a result, the centrifugal acceleration increased the settling velocity of oil droplets and thus will accelerate the demulsification process (Abdurahman et al., 2009).

The figures below showed the result obtained from various combinations of demulsification methods that employed in this experiment with the effect of centrifugal processing speed.



Figure 4. 22: Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Time of 30 minutes.



Figure 4. 23: Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 60 minutes.



Figure 4. 24: Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 90minutes.

Indicators:

С	-	Centrifugation
O+C	-	Oil Soluble Material and Centrifugation
W+C	-	Water Soluble Material and Centrifugation
M+C	-	Methanol and Centrifugation
E+C	-	Ethanol and Centrifugation
W+M+C	-	Water Soluble Material, Methanol and Centrifugation

From the Stability Part, there were two batches of coconut milk emulsions used in this experiment. For the demulsification process via centrifugation, oil soluble material with centrifugation, methanol with centrifugation, and lastly ethanol with centrifugation method, they used Batch 1 emulsion. While for the water soluble material with centrifugation and water soluble material and methanol with centrifugation part used the second batch of coconut milk emulsion. The settling velocity at ambient conditions for these two batches of coconut milk emulsion was tabulated in **Table 4.1** as shown below:

Batch of Emulsion	Oil Droplets Diameter (µm)	Centrifugal Processing Speed (rpm)	Settling Velocity of Oil Droplets (m/s)
		2,000	1.06E-08
1	0.21 x 10 ⁻⁶	5,000	2.65E-08
		8,000	4.23E-08
		2,000	6.94E-09
2	0.17 x 10 ⁻⁶	5,000	1.73E-08
		8,000	2.77E-08

Table 4. 16:Settling Velocity of Oil Droplets of Two Batches of Coconut MilkEmulsion with Different Centrifugal Processing Speed

From the settling velocity result in **Table 4.16**, it demonstrated a general trend that the settling velocity is directly proportional to the centrifugal processing speed and droplets diameter. As a result, the oil droplets creaming at a faster rate under higher centrifugation speed theoretically.

However, from the results obtained, this theory was not necessary valid when a combination of demulsifiers and centrifugation are used in demulsification process. From experimental works, it was found that an optimum condition will occurs for these two different batches of coconut milk emulsions. Batch 1 emulsion was used for demulsification via centrifugation; oil soluble material and centrifugation; methanol and centrifugation; and lastly followed by ethanol and centrifugation methods. As for batch 2 emulsion, it was only used for water soluble material with centrifugation; and water soluble material, methanol and centrifugation methods.

At centrifugation processing time for 30min, the highest yield of Virgin Coconut Oil (VCO) is 39.3 v/v%, achieved by a centrifugation speed of 8,000rpm via O+C methods. For the Batch 1 coconut milk emulsion, when it was compared between methods as shown in Figure 4.22, methods O+C and M+C, with a value of 39.9 and 22.4 v/v%, respectively. They are both performed the same trend on the effect of centrifugation speed to the VCO yield, which is as the degree of centrifugation speed increased, the higher the VCO recovery. As for the C and E+C methods, they shared almost the same trend, in which their optimum condition falling on 2,000rpm, with 27.2 and 26.3 v/v% respectively. For C method, the VCO recovery remained constant at 5,000 and 8,000 rpm, illustrated that the VCO yield reached a saturated value of 19.8 v/v%. It showed that the demulsification process did not have any effect to the separation of oil droplets, due to the phase inversion phenomenon. Centrifugation is purely a mechanical means that employed in phase separation process by the application of shear (Scheamm and Hackman). As centrifugal processing speed increased, more heat was generated under the application of shear. Under a moderate or high shear application, phase inversion (irreversible inversion) occurred, so O/W emulsion was invert into W/O emulsion and thus affected the demulsification performance since demulsifier was not added. A minimum value occurs on E+C method, showing that the concentration of ethanol added was overdose, since demulsifier cannot diffuse to the emulsion interface rapidly during demulsification process. While for the second batch of emulsion used, the W+C and W+M+C methods did not show any significant coconut oil recovery. This is due to the clustering of oil droplets during aggregation process. The viscosity of the emulsions was increase, and partially gel the cream layers, providing an appearance of thickness. All these were contributed to the difficulties in VCO recovery process.

For **Figure 4.23**, demulsification of coconut milk emulsion at 60min, all the methods used demonstrated the same VCO recovery trend by 30min centrifugation time. It has highest yield of Virgin Coconut Oil (VCO) is 45.2 v/v%, achieved by a centrifugation speed of 8,000rpm via O+C methods. For the Batch 1 coconut milk emulsion, when it was compared between methods as shown in **Figure 4.23**, methods O+C and M+C, with a value of 45.2 and 33.3 v/v%, respectively. They are both

performed the same trend on the effect of centrifugation speed to the VCO yield, which is as the degree of centrifugation speed increased, the higher the VCO recovery. As for the C method, its optimum condition fallen on 2,000rpm, with 24.7 v/v%. For E+C method, the maximum VCO recovery is 35.7 v/v% at 5,000rpm. Again, for the second batch of emulsion used, the W+C and W+M+C methods did not show any significant coconut oil recovery. This is due to the clustering of oil droplets during aggregation process. The viscosity of the emulsions was increase, and partially gel the cream layers, providing an appearance of thickness. All these were contributed to the difficulties in VCO recovery process.

While from **Figure 4.24** (centrifugal processing time of 90min), it demonstrated an outstanding result for the demulsification via W+C and W+M+C methods for the second batch coconut milk emulsion. For W+C method, its optimum VCO recovery yield can be achieved by centrifuged at 2,000 rpm with 20.7 v/v %. While for W+M+C, it needed 8,000 rpm in order to achieve its optimum VCO recovery for a value of 26.8 v/v %. While for the batch 1 emulsion, they still follow the same trend as in Figure 4.1 and 4.2, with VCO recovery of 44.1 and 28.6 v/v% for O+C and M+C methods at 8,000rpm; 32.1 and 28.9 v/v% for C and E+C at 5,000rpm.

From there, it can be concluded that the types of demulsifiers added will gradually changed the optimum condition for VCO recovery yield. Different types of demulsifiers will have different effect on demulsification mechanism since it had a significant effect on the results obtained. Therefore, the optimum centrifugal speed required was depended on both the demulsifiers and centrifugation processing speed.

4.3.4 Effect of Centrifugal Processing Time on Virgin Coconut Oil (VCO) Recovery

Centrifugal processing time was another parameter that needed to be investigated in order to determine its relationship with the virgin coconut oil (VCO) recovery yield. Figures below illustrated the effect of centrifugation time towards VCO yield.



Figure 4. 25: Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 2,000rpm



Figure 4. 26: Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 5,000rpm



Figure 4. 27: Comparison of VCO Yield via Various Combination of Demulsification Method under a Centrifugal Processing Speed of 8,000rpm

Indicators:

С	-	Centrifugation
O+C	-	Oil Soluble Material and Centrifugation
W+C	-	Water Soluble Material and Centrifugation
M+C	-	Methanol and Centrifugation
E+C	-	Ethanol and Centrifugation
W+M+C	-	Water Soluble Material, Methanol and Centrifugation

From the Stability Part, there were two batches of coconut milk emulsions used in this experiment. For the demulsification process via centrifugation, oil soluble material with centrifugation, methanol with centrifugation, and lastly ethanol with centrifugation method, they used Batch 1 emulsion. While for the water soluble material with centrifugation and water soluble material and methanol with centrifugation part used the second batch of coconut milk emulsion. For the first batch of coconut milk emulsion, they illustrated different approach for the effect of centrifugal processing time to the yield of VCO. From **Figures 4.25**, **4.26** and **4.27**, it shows a variable in centrifugation time effect for the highest yield of VCO. At higher centrifugal speed, the longer the centrifugation time that was up to 90 minutes, the better the VCO yield. However, this was not true at low centrifugation speed at 2,000 rpm that showed a better result at 30 minutes. This was due to others effects that act as a domain in determining the VCO recovery such as the age of emulsion used in this experiment. Other than this, for O+C, M+C and E+C methods, they demonstrated an optimum centrifugal processing time at 60 minutes. This was due to the effect of demulsifiers added to the demulsification process, which was domain the result of VCO recovery process.

From the results of VCO yield by using second batch of coconut milk emulsion via W+C and W+M+C methods, they demonstrated that increasing of centrifugation time results in better VCO recovery yield at a centrifugation time of 90 minutes. This is due to the demulsification process have a longer separation times that allowed the oil droplets to separated out from the coconut milk emulsion.

4.4 Quality Characterization of Coconut Oil Extracted

This was the last part that needed to proceed for this research. Ten samples were chosen based on the highest coconut oil recovery from each part of demulsification process under three set of centrifugal processing time. As a comparison, the effect of alcohol on the demulsification process was also analyzed with the combination of a 0.5 v/v% concentration of water soluble material, methanol and centrifugation. The chosen samples were tabulated in below table:

Sample No.	Method Employed in Demulsification	Centrifugal Processing Speed (rpm)	Centrifugal Processing Time (minutes)
1	Centrifugation	2,000	30
2	Centrifugation	5,000	90
3	Centrifugation	8,000	90
4	Oil Soluble Material and Centrifugation	2,000	90
5	Oil Soluble Material and Centrifugation	5,000	60
6	Oil Soluble Material and Centrifugation	8,000	60
7	Methanol and Centrifugation	2,000	60
8	Methanol and Centrifugation	5,000	60
9	Methanol and Centrifugation	8,000	60
10	Water Soluble Material, Methanol and Centrifugation	8,000	90

 Table 4. 17:
 Chosen Samples for Gas Chromatography – Mass Spectrometer (GC-MS)

 Analysis

4.4.1 Critical Results from Gas Chromatography – Mass Spectrometer (GC-MS) Analysis

Analysis results obtained from Gas Chromatography – Mass Spectrometer (GC-MS) were attached in the **Appendix C**. The critical parts from the analysis were the composition of major straight chain fatty acids that existed in the coconut oil extracted. For the good quality virgin coconut oil (VCO), the specification of the chemical composition was compared with the Asia Pacific Coconut Community (APCC) Standard, which had the major class of medium straight chain fatty acids distribution as tabulated in **Table 4.18** below:

Major Fatty Acids						Co	ontent (%)			
Sample No.	1	2	3	4	5	6	7	8	9	10	APCC Standard
Caproic acid, C6:0	0.00	0.00	0.23	0.22	0.25	0.23	0.26	0.24	0.26	0.25	0.4-0.6
Caprylic acid, C8:0	6.30	6.59	3.77	3.60	3.97	3.83	4.30	4.11	4.19	4.05	5.0-10.0
Capric acid, C10:0	6.57	6.42	3.58	3.41	3.67	3.62	4.06	3.99	3.92	3.67	4.5-8.0
Lauric acid, C12:0	48.39	46.86	25.40	24.33	25.66	25.33	26.42	26.44	25.50	24.7	43.0-53.0
Myristic acid, C14:0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.0-21.0
Palmitic acid, C16:0	9.45	10.02	5.91	4.93	5.27	5.23	5.33	5.41	5.13	4.91	7.5-10.0
Palmitoleic acid, C16:1	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	2.0-4.0
Stearic acid, C18:0	2.57	2.62	1.70	1.47	1.67	1.56	1.44	1.48	1.41	1.40	5.0-10.0
Oleic acid, C18:1	4.77	4.71	3.01	2.65	2.90	2.89	3.30	2.97	3.12	2.88	0.0
Linoleic acid, C18:2	1.09	1.05	0.67	0.63	0.68	0.67	0.67	0.60	0.64	0.61	1.0-2.5
C 18:3 – C 24:1	0.04	0.04	0.03	0.01	0.05	0.05	0.05	0.05	0.05	0.04	< 0.5
Others dominant components (%)											
Methyl tetradecanoate	20.71	21.58	11.96	10.27	10.99	10.81	10.93	11.17	10.46	10.39	0.00
6,6-dimethyltetrahydro-2H- pyran-2-one	0.00	0.00	24.78	25.47	25.59	25.80	24.74	24.95	26.65	27.24	0.00

Table 4. 18:Quality Characteristics of Coconut Oil Recovery Samples



Figure 4. 28: Comparison of Fatty Acid Composition of VCO Yield under Different Centrifugation

4.4.2 Data Analysis

Medium chain fatty acid – $C_{8:0}$, $C_{10:0}$ and $C_{12:0}$ are the major components in VCO. In this experiment, the Lauric Acid, $C_{12:0}$ was found significant (fall in APCC range) in samples prepared by centrifugation method, with a value of 48.39 and 46.86 %, respectively for 2,000rpm and 5,000rpm.

From **Table 4.18**, the distribution of samples straight chain fatty acid components did not reach the target range value of APCC Standard Virgin Coconut Oil (VCO). As refered to Rethinam (2004), the major composition of fatty acid methyl ester (FAME) in standard VCO were Lauric acid, $C_{12:0}$ and Myristic acid, $C_{14:0}$. However, from the results obtained, it was found that only the first two samples (1 & 2) reached the target standard percentage content of $C_{12:0}$, while the rest of the samples (2 – 10) were below the standard range. As for the standard percentage content of $C_{14:0}$, it was totally cannot be detected in the samples analysed.

According to Honkanen (1969), the sudden decreased of $C_{12:0}$ can be contributed by the absence of $C_{14:0}$, in which both of them were reacted to form methyl tetradecanoate by cleavage $C_{14:0}$ methyl group. Methyl tetradecanoate, also known as methyl myristate, is methyl esters of saturated branched-chain fatty acids with anteisoseries. Despite of this, 6,6-dimethyltetrahydro-2H-pyran-2-one or 5-methyl-5hydroxyhexanoic acid lactone, which is a branched-chain lactone (cyclic ester). Unlike the straight chain fatty acids, both of them are produced biosynthetically via the conventional mechanisms for the synthesis of saturated fatty acids in bacteria (Christie, 2011). The present of bacteria is due to the storage condition for unfreezing process of raw material before conducting experiment. The coconut milk emulsion is directly exposed to ambient condition for a long period. Humidity in air will increase the moisture content and provide a suitable breeding ground to bacteria at this optimum condition. Therefore, it degraded the quality of coconut oil yield.



Figure 4. 29: Comparison of Lauric Acid, C₁₂ Content in VCO Yield under Different Conditions



Figure 4. 30: Comparison of Myristic Acid, C₁₄ Content in VCO Yield under Different Conditions

Another factor that must be highlighted from this abnormal analysis results was from the age of emulsion used in the demulsification process. As discussed in previous **Section 4.2**, two batches of coconut milk emulsions were used with different age of emulsion. The comparison of the age of emulsion with the content percentage of acid lactone (6,6-dimethyltetrahydro-2H-pyran-2-one) was done, it demonstrated a relationship of directly proportional of the age of emulsions to the amount of ketone existed.

Table 4. 19: Age of Coconut Milk Emulsion with the Content Percentage of AcidLactone (6,6-dimethyltetrahydro-2H-pyran-2-one) Existed

Sample No.	Age of Coconut Milk Emulsion (hours)	Content of Acid Lactone (%)				
Batch 1						
3	7.5	24.78				
4	15.5	25.74				
5	16.0	25.59				
6	16.5	25.80				
Batch 2						
7	5.5	24.74				
8	10.0	24.95				
9	15.5	26.65				
10	25.0	27.24				

From **Table 4.19** above and **Figure 4.31** and **4.32** below, it was clearly illustrated that the longer the age of coconut milk emulsion, the larger the amount of acid lactone existed in the coconut oil extracted. The age of emulsion will have adversely effects on the oil particles movement. For a longer storage duration (larger

age of emulsion) had caused the movement of oil particles became slower due to the reduced in particles settling velocities, gradually increased the difficulties of the demulsification process.



Figure 4. 31: Relationships between Age of Batch 1 Coconut Milk Emulsion with Amount of Acid Lactone Content



Figure 4. 32: Relationships between Age of Batch 2 Coconut Milk Emulsion with Amount of Acid Lactone Content

While for Sample 1 and 2, although the Lauric acid content reached the target APCC value, Mystric Acid still cannot be detected within those samples. Besides that, the existence of branched-chain medium acid (Methyl tetradecanoate) proved that the chemical reduction between $C_{12:0}$ and $C_{14:0}$ happened. As a result, all the quality analyzed for the coconut oil yield performed almost the same characterization.

4.5 Summary

As seen from overall performance, it showed that centrifugal processing speed and time do play an important role in demulsification of coconut milk emulsion. In addition, the optimum conditions for VCO recovery yield was not necessary directly proportional to centrifugal processing speed and time, but also depend on the types of demulsifiers used. This is due to the characteristics of demulsifiers' behaviour has significant effect on emulsion destabilization mechanism on O/W emulsion. As for the quality characterization of VCO recovery, it was found that medium chain fatty acid – $C_{8:0}$, $C_{10:0}$ and $C_{12:0}$ are the major components in VCO. In this experiment, the Lauric Acid, $C_{12:0}$ was found significant (fall in APCC range) in samples prepared by centrifugation method, with a value of 48.39 and 46.86 %, respectively for 2,000rpm and 5,000rpm.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In this research of study, the main objectives are to investigate the separation and filtration of Virgin Coconut Oil (VCO) using water soluble materials and centrifugation method. Besides this, this research also study for the potentials water soluble demulsifiers in demulsification (emulsion breaking) of VCO emulsion. By conducting this research, the results outcome had been discussed in the previous chapter, which involved a few parameters that will directly and indirectly affect the demulsification and quality characterization of the VCO recovery. In this chapter, the whole research was concluded based on the research founding.

5.2 Conclusion

The conclusions were made based on a few section, which are emulsion stability, performance of demulsification process and lastly the quality characterization of Virgin Coconut Oil (VCO) recovery.

5.2.1 Emulsion Stability Analysis

By analyzed all the parameters such as density, viscosity, shear rate, shear stress, droplets size distribution, surface tension and interfacial tension, a conclusion was reached out for the stability of two batches of emulsion used.

For the droplets size distribution of the two batches of emulsions used, it was found that the average fat droplets diameter for these two batches of coconut milk emulsion was 0.21 and 0.17 μ m, while, the most frequent droplet size was 0.11 and 0.13 μ m, respectively. The distribution illustrated an opposite result for average size and most frequent size due to the higher oil content in Batch 1 emulsion. Since the droplets size larger than 0.1 μ m and smaller than 180 μ m, these emulsions were considered as Stoke's model. It implied that Stoke's law was applied on these two batches of coconut milk emulsion viscosity. For smaller size distribution, the dispersion viscosity will be higher. This is due to the increased in interfacial area and thinner films increased the resistance to the flow of fluid. Thus, it was proved that the second batch of coconut milk emulsion will have higher viscosity, which was 65.30cP at ambient condition as compared to the Batch 1 emulsion with a value of 54.30cP.

Despite of this, since the size distribution of these coconut milk emulsions were different, so they result in the different for their density. The density is 0.952 and 0.926 g/cm³, respectively. Coconut milk is an O/W emulsion make up by water, fats, carbohydrates, protein and ash. Hence, the different in the compositions percentage had contributed to the different of density for each emulsion. Besides that, from visual observation, it was found that the second batch emulsion is creamier, cause lighter density. While from the point of view of size distribution, it was found that the mode of droplets size for Batch 1 emulsion was smaller, which contributed to a larger interfacial contact area in dispersed phase, causing the increase in density of emulsion. The surface tension for both oil and water was 30.431 and 70.023 mN/m, respectively. For the interfacial tension of oil and water, it was less than the individual surface tension of each liquid, recorded a value 7.987 mN/m. This is due to the mutual attraction had been moderated by all the molecules involved.

Another crucial part for the conclusion in the O/W coconut milk emulsion stability part was the effect of temperature to the viscosity. Viscosity is a temperature dependent property and it is inversely proportional to density. At ambient condition, the viscosity for emulsion is 54.30 and 65.30 cP, for Batches 1 and 2, which match with the result from density part. In addition, the general trend for the viscosity and temperature also should be inversely proportional to each other.



Figure 5. 1: Effect of viscosity to temperature at 100RPM

From **Figure 5.1** presented above, the results obtained followed two different trends, in which it followed the normal trend at low temperature, but viscosity kept on increasing at higher temperature. The minimum viscosity achieved by Batch 1 coconut milk emulsion at temperature 64°C was around 25.0 cP, while Batch 2 at 50°C was 48.8 cP. At this temperature, the emulsion changed from stabilizing Oil-in-Water (O/W) to Water-in-Oil (W/O) emulsion. This transition temperature is termed as Phase Inversion Temperature (PIT), where phase inversion is occurs. Since coconut milk is a food emulsion, where the protein existed is function as surfactant that will stabilised the O/W emulsion at low temperature. Hence, as temperature increased, W/O emulsion was preferred, where now the coalescence rate will be slow, a more stable emulsion is formed.

5.2.2 Demulsification of Coconut Milk Emulsion

In this research of study, a few combination of methods have been employed, which are by centrifugation; water soluble materials with centrifugation; oil soluble materials with centrifugation; alcohols that included methanol and ethanol with centrifugation; and lastly the combination of water soluble materials, methanol with centrifugation method. The percentage of demulsifiers used for this experiment was 0.5 v/v % since it has high influence in demulsification of emulsions. The centrifuge speed was varied from 2000 rpm to 8000 rpm and the separation time was varied from 30 minutes to 90 minutes.

Since there are two batches of coconut milk emulsion used in this research, it was found that the Batch 2 emulsion did not have significant result for the virgin coconut oil recovery. This is due to the lower coconut oil content in the emulsion, which had been investigated by the stability part experiment.

As for the comparison of method used, it was found that the combination of oil soluble material with centrifugation, with a maximum of 45.2 v/v% of coconut oil recovery yield achieved by using Batch 1 emulsion. However, it was not encourage use oil soluble material in demulsification process since the VCO produced was consumed by human being. Therefore, the potential of using water soluble material with centrifugation method was investigate. However, in this part of experiment that used the lower content of coconut oil emulsion, the coconut oil recovery result was not as promise as the oil soluble material part. Still, from this experiment, it proved that the using of water soluble material and centrifugation method was feasible. This was due to under centrifugation conditions with processing speed 2,000 rpm and 90 minutes, 20.7 v/v % of the coconut oil was recovery and collected.

While for the using of alcohols in demulsification process, a special phenomenon was observed for sample with centrifugal processing speed 2,000rpm with processing time 30min, 60min and 90min. The creaming part was separated into two different density layers, with a soft cream on top while the solidified cream in bottom. This is due to the concentration of alcohols used is not concentrated enough in order to penetrate through the particles of O/W emulsion at a lower centrifugal processing speed at 2000 rpm. Besides that, the alcohol content include making the aqueous phase a poorer solvent for proteins in ruptures the proactive membrane surrounding that the oil droplets, leaving droplets that are coated with casein protein.

Lastly, by using water soluble materials, methanol and centrifugation method, it was found that the oil recovery was not significant since the raw material used was Batch 2 emulsions. However, with the effect of the methanol adding, it showed a coconut oil recovery at 5,000 and 8,000 rpm for 90 minutes samples. The percentage of oil recovery was 1.1 and 26.8 v/v %, respectively. Another main reason for the failure in the emulsion separation process was due to the clustering phenomenon. Clustering was achieved when oil droplets in coconut milk emulsion were subdivided to the point where the total interfacial area in the emulsion was greater than the surface-covering

capability of the adsorbing proteins. This leads to proteins bridging between pairs of droplets – bridging flocculation, and caused the failure of demulsification process.

5.2.3 Quality Characterization

Medium chain fatty acid $- C_{8:0}$, $C_{10:0}$ and $C_{12:0}$ are the major components in VCO. In this experiment, the Lauric Acid, $C_{12:0}$ was found significant (fall in APCC range) in samples prepared by centrifugation method, with a value of 48.39 and 46.86 %, respectively for 2,000rpm and 5,000rpm. However, the sudden decrease of $C_{12:0}$ for the rest of the samples were due to the reaction with $C_{14:0}$ to form methyl tetradecanoate by cleavage its methyl group. Methyl tetradecanoate, also known as methyl myristate, is methyl esters of saturated branched-chain fatty acids with anteiso-series. Despite of this, 6,6-dimethyltetrahydro-2H-pyran-2-one or 5-methyl-5-hydroxyhexanoic acid lactone, which is a branched-chain lactone (cyclic ester). Unlike the straight chain fatty acids, both of them are produced biosynthetically via the conventional mechanisms for the synthesis of saturated fatty acids in bacteria. The present of bacteria is due to the storage condition for unfreezing process of raw material before conducting experiment. The coconut milk emulsion is directly exposed to ambient condition for a long period. Humidity in air will increase the moisture content and provide a suitable breeding ground to bacteria at this optimum condition. Therefore, it degraded the quality of coconut oil yield.

5.3 **Recommendations for Future Experimental Works**

In conducting experimental works, some cases that out of expectations were happened and thus affect the results obtained. Besides that, these also caused a large deviation on the results study, and further caused the failure of experiment in obtaining a reasonable result. Therefore, some recommendations were suggested in order to prevent these incidents and thus improved the results at the same time.

5.3.1 Recommendations on Emulsion Stability Analysis

The important parameters that will be analyzed were viscosity and size distribution of oil droplets. However, these parameters are sensitive towards temperature, hence, the storage condition for the coconut milk emulsions were very crucial for this part of analysis. The emulsions should be store in a refrigerator at 4°C, in order to preserve the movement of oil droplets in O/W emulsion, besides protected the O/W emulsion from phase inversion phenomenon. Always make sure that the coconut milk emulsion was stored in refrigerator after using it, so that bacteria in atmosphere will not get into contact with the emulsion, and thus destroyed the emulsion structure. Other than this, the aging of emulsion is another important issue in stability analysis. Since we cannot avoid the aging of emulsion, what we can do is try to longer the preservation period of emulsion. There is one thing that cannot be avoided was, the raw material brought from supplier. We cannot make sure that whether this batch of emulsion was an old emulsion or fresh. Therefore, it was important to conduct emulsion stability analysis in order to determine the original characteristics of the emulsion used in research study.

5.3.2 Recommendation on Demulsification of Coconut Milk Emulsion

In demulsification process, the used of the concentration of demulsifiers need to be strictly controlled. This was due to the demulsifiers used has high influence to demulsification process, so a small amount of demulsifiers was needed. Therefore, any extra of the usage of demulsifiers was considered as a wasting to the VCO manufacturing process, besides increased its production cost. Other than that, for the gravity settling process, one should make sure that the coconut oil yield from demulsification process was collected or extracted on time in order to prevent any degradation of the quality of VCO recovery. This is due to the higher moisture contain in ambient condition will encourage the breeding of bacteria, which will cause the vanished of some major fatty acids components of VCO and further downgrade its quality. In addition, the extraction method employed in extracted out the coconut oil is very important. One must be technically well in extracting the top surface layer – coconut oil, not including others phases like cream and aqueous phase. This can help to prevent the existence of impurities in the VCO extracted. Lastly, make sure that the gravity settling process was carried out under ambient temperature in order to prevent the frozen of the creaming part. It will seriously lead to the failure of demulsification process.

5.3.3 Recommendation on Quality Characterization

Since the extracted virgin coconut oil (VCO) is a fixed oil, so, it needed to be converted into essential oil (volatile oil), firstly. By doing so, only the Gas Chromatography – Mass Spectrometer can analyze for the chemical composition of the fatty acid methyl ester (FAME). Therefore, fatty acid transesterification is needed. During transesterification process, some precaution steps were highlighted, such as the parallax errors preparation of the standard 2M of methanolic KOH solution, and extraction of hexane phase. 2M of Methanolic KOH solution was function as a catalyst in the transeterification process. Therefore, if the concentration of methanolic KOH solution prepared was not accordingly to the standard, the esterification reaction will be affected, and caused the chemical composition to reacted and formed others side products. While by having a poor skill in hexane extraction, it will leave the remaining hexane in the analyzed samples, and hence affected the chemical composition analyzed results for a significant hexane composition.

5.4 Summary

In a nutshell, there are three conclusions can be drawn from this study, which are VCO can be extracted by using water soluble materials and centrifugation method, a shorter duration is needed in the separation of VCO, and lastly, it is an environmental friendly process compared to the conventional method.

By using water soluble materials and centrifugation method, the VCO extracted can retain its own chemical characteristics since it did not extracted by heating. Therefore, the volatile components in VCO will not vaporize easily, and thus yield a high quality product of VCO. Besides that, with the addition of methanol, it can increase the VCO recovery yield with the increase of degree of centrifugation speed and time. However, the storage conditions for the VCO extracted had significant effect in degrading its quality. From the GC-MS analysis, it was found that the existence of bacteria due to improper storage of VCO had caused the major chemical compositions, which are the decrease of the percentage of straight chain fatty acid – Lauric Acid ($C_{12:0}$) and vanish of Mystric Acid ($C_{14:0}$) due to the chemical reaction, which will form a branch-chain methyl fatty acid (methyl tetradecanoate).

When compare to the conventional method, which is by fermentation, it needs seven days in extracted the VCO from coconut milk emulsion. Hence, in order to reduce the separation duration, the centrifugation separation was introduced. By using centrifugation that needed up to 90 minutes as maximum for its optimum coconut oil recovery, which was then the heavy phase (water) settles out from a lighter phase (coconut oil). As seen from overall performance, it showed that centrifugal processing speed and time do play an important role in demulsification of coconut milk emulsion. In addition, the optimum conditions for VCO recovery yield was not necessary directly proportional to centrifugal processing speed and time, but also depend on the types of demulsifiers used. This is due to the characteristics of demulsifiers' behaviour has significant effect on emulsion destabilization mechanism on O/W emulsion. Last but not least, as an engineer, it is important for us to come out with a solution that will not create any problems to our environment. As a result, the using of environmental friendly water soluble material that will not produce waste to the environment had been proposed. Due to it hydrophilic characteristic, it is also will not produce any hazardous effect to the VCO consumers.

REFERENCES

- AOCS (1996). Official Methods and Recommended Practice of the America Oil Chemists' Society, 1996. Methods Ca 5a-40, Cd 1d-92, Cd 3-25, Cd 8-53, and Cd 18-90, vol 5. AOCS Press, Champaign.
- Arancon, R.N. (2008). Price outlook of coconut (lauric oil) 2008/09. Paper presented at the 19th Annual Palm & Lauric Oils Conference & Exhibition; Kuala Lumpur, Malaysia.
- Becher, P. (1983). Encyclopedia of Emulsion Technology, Vol. 1: Basic Theory. Marchel Dekker, New York, NY.
- Becher, P. (1985). Hydrophile Lipophile balance: An updated bibliography. Encyclopaedia of Emulsion Technology, Vol. 2. Becher, P. (Ed.), Marcel Dekker, New York, NY.
- Becher, P. (2001). Emulsion: Theory and Practice, 3rd ed., American Chemical Society. Washington.
- Bergenstahl, G. (1997). Physiochemical aspects of an emulsifier functionality. *Food Emulsifiers and Their Applications*. Hasenhuettl, G.L., and Hartel, R.W. (Eds.), Chapman & Hall, New York, NY, Chap. 6.
- Bergenstahl, G. (1997). Physiochemical aspects of an emulsifier functionality. *Food Emulsifiers and Their Applications*. Hasenhuettl, G.L. and Hartel, R.W. (Eds.), Chapman & Hall, New York, NY, Chap. 9.
- Bio-asli (2010). *Definition of Virgin Coconut Oil*. [Brochure]. Retrieved on 2010, September 11, from <u>http://bio-asli.make-money-parttime.com/english-bio-asli/</u>.
- Birosel, D.M., Gonzales, A.L. and Santos, M.P. (1963). The nature and properties of the emulsifier system of oil glubolins in coconut milk and cream. *The Philippine J. Sci.*, p: 92, 1 15.
- Campbell, I.J. and Jones, M.G. (1997). *Cream Alternatives. Lipid Technologies and Applications*. Gunstone, F.D. and Padley, F.B. (Eds.). Dekker: New York, pp: 355 368.
- Cancel, L.E. (1979). Coconut Food Products and Bases. In: *Coconuts: Production, Processing, Products.* Woodroof, J.G. (Ed.). AVI Publishing, Westport, CT., pp: 202 239.
- Capes, C.E.; Mcllhinney, A.E. and Sirianni, A.F. (1977). Agglomeration from Liquid Suspension – Research and Applications. *Agglomeration*. Sastry, K.V.S. (Ed.). Am. Inst. Mining, Metal. Petrol. Engineers: New York. (77), pp: 910 – 930.
- Carandang, E.V. (2005). Philippine Coconut Research and Development Foundation (PCRDF). Health Benefits of Virgin Coconut Oil Explained. Retrieved on November 16, 2010, from <u>http://www.docstoc.com/docs/16440071/HEALTH-BENEFITS-OF-VIRGIN-COCONUT-OIL-EXPLAINED</u>.
- Cengel, Y.A. and Cimbala, J.M. (2006). *Fluid Mechanics Fundamentals and Application*. 1st Edition in SI Units. McGraw Hill Companies, Inc., New York, NY, pp: 46 50.
- Chiralt, A. (2005). Emulsion Stability & Destabilization Mechanisms. *Food Emulsion*. Food Engineering: Encyclopedia of Life Support System. Paris, UNESCO: France. (2), pp: 339 – 354.
- Christie, W.W. (2011). The AOCS Lipid Library. *Fatty Acids: Branched Chain Structure, Occurrence and Biosynthesis*. James Hutton Institute (and Mylnefield Lipid Analysis), Invergowrie, Dundee (DD2 5DA), Scotland.
- Convergent Cosmetics. [Brochure]. *Emulsions and the HLB system*. Retrieved on February 23, 2011, from http://www.lotioncrafter.com/pdf/Emulsions & HLB System.pdf.
- Coulson, J.M. and Richardson, J.F. (1991). Chemical Engineering, 4th Edn, *Particle Technology and Separation Processes*, USA.
- Dalgleish, D.G. (1990). Aspects of Stability in Milk and Milk Products in Food Colloids. Bee, R.D., Richmond, P., and Mingins, J. (Eds.), Royal Society of Chemistry, Cambridge, pp. 295 – 305.
- Damodaran, S. (1997). Protein-Stabilized Foams and Emulsions. Food Proteins and Their Applications, Damodaran, S.; Paraf, A. (Eds.), Dekker, New York, pp. 57 - 110.
- Davis, H.T. (1994). Factors determining emulsion type: Hydrophile-lipophile balance and beyond. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, pp: 91, 9.
- de Wit, J.N. and van Kessel, T. (1996). Effects of ionic strength on the solubility of whey protein products: A colloid chemical approach. *Food Hydrocolloids*, pp: 10, 143.
- Demetraides, K., Coupland, J.N., and McClements, D.J. (1997a). Physical properties of whey protein stabilized emulsions as related to pH and NaCl, *Journal of Food Science*, pp: 62, 342.

- Demetraides, K., Coupland, J.N., and McClements, D.J. (1997b). Physicochemical properties of whey protein stabilized emulsions as affected by heating and ionic strength. *Journal of Food Science*, pp: 62, 462.
- Dickinson, E. and Stainsby, G. (1982). Colloids in Food. Elsevier, London, UK, Chapter 1.

Dickinson, E. (1989). Colloid Surfactant. 42, 191 – 204.

- Dickinson, E., Golding, M. and Povey, M.J.W. (1997). Creaming and flocculation of oil-in-water emulsions containing sodium caseinate. *Journal of Colloid and Interface Science*, 185(2), 515 – 529.
- EAC Industrial Integrals. [Brochure]. *Cosmetic Emulsions*. Retrieved on February 23, 2011, from <u>http://www.chemeng.lth.se/exjobb/E284.pdf</u>.
- Friberg, S.E. (1997). Emulsion Stability. In: *Food Emulsions*, Friberg, S.E. and K. Larrson (Eds.). Marcel Dekker, New York, NY, pp: 1-55.
- Geankoplis, C.J. (2003). *Transport Processes and Separation Process Principle*. 4th ed., Prentice Hall Press, Upper Saddle River, New Jersey, USA.
- Gonzalez, O.N. (1990). Coconut Milk. In: *Coconut as Food*, Banzon, J.A., O.N. Gonzalez, S.Y. de Leon and P.C. Sanchez (Eds.). Philippine Coconut Research and Development Foundation, Quenzon City, Philippines, pp: 45-48.
- Gunstone, F.D. (2002). Vegetable Oils in Food Technology: Composition, Properties and Uses. CRC Press LLC, United States of America, pp: 157 173.
- Hartley, G.S. (1936). Aqueous Solutions of Paraffin Chain Salts. Hermann and Cie: Paris.
- Henderson, B., Henry, L., MacAulay, G. and Tatuh, J. (2010). Potential payoff from R&D in the coconut industry of North Sulawesi, Indonesia. *Asian Economic Journal 2010, Vol. 24*, pp: 1, 69 – 85.
- Hiemenz, P.C. and Rajagopalan, R. (1997). *Principles of Colloid and Surface Chemistry*, (3rd Ed.), Marcel Dekker, New York, NY.
- Honkanen, E.; Moisio, T. and Karvonen, P. (1969). Mass Spectra of Some Branched-Chain Aliphatic Lactones. Acta Chemica Scandinavica. (23), pp: 531-536.
- Hunt, D.G. and Dalgleish, D.G. (1995). Heat stability in oil-in-water emulsions containing milk proteins: Effect of ionic strength and pH. *Journal of Food Science*, pp: (60) 1120.
- Hunter, R.J. (1989). *Foundations of Colloids Science*. Volume 1, Oxford University Press, Oxford, UK.

- Kim, H.J., Decker, E.A., and McClements, D.J. (2002). Role of postadsorption conformation changes of beta-lactoglobulin on its ability to stabilize oil droplets against flocculation during heating at neutral pH. *Langmuir*, pp: 18, 7577.
- Kirk-Othmer (2009). Encyclopedia of Chemical Technology. *Surfactants: Alkylphenol Ethoxylates*. 4th Edition. John Wiley & Sons, Inc. Canada, pp: 481 511.
- Kwon, K.S., Park, K.H. and Rhee, K.C. (1996). Fractionation and characterization of proteins from coconut (*Cocos nucifera L.*). Journal of Agricultural and Food *Chemistry*, 44(7): 1741-1745.
- Lissant, K.J. (1983). *Demulsification: Industrial Applications*. Marcel Dekker, New York, NY.
- Luyten, H., Jonkman, M., Kloek, W., and van Vliet, T. (1993). Creaming behaviour of dispersed particles in dilute xanthan solutions. *Food Colloids and Polymers: Stability and Mechanical Properties*. Dickinson, E. and Walstra P., Eds., Royal Society of Chemistry, Cambridge, UK, pp: 224.
- Marina, A.M., Che Man, Y.B. and Amin, I. (2009a). Virgin Coconut Oil: Emerging Functional Food Oil. *Food Science and Technology*, pp: 20, 481 487.
- Marina, A.M., Che Man, Y.B., Nazimah, S.A.H. and Amin, I. (2009b). Chemical Properties of Virgin Coconut Oil. J. Am Oil Chem. Soc, pp: 86, 301 307.
- McClements, D.J. (2005). Food Emulsions: Principles, Practices and Techniques. 2nd Edition, CRC Press, USA.
- Menon, W.B. and Wasan, D.T. (1985). Demulsification. Encyclopedia of Emulsion Technology, Vol. 2, Applications. Becher, P. (Ed.), Marcel Dekker, New York, NY, Chapter 1.
- Monahan, F.J., McClements, D.J., and German, J.B. (1996). Disulfide-mediated polymerization reactions and physical properties of heated WPI-stabilized emulsions. *Journal of Food Science*, pp: (61) 504.
- Monera, O.D. and del Rosario, E.J. (1982). Physico-chemical evaluation of the natural stability of coconut milk emulsion. *Ann. Trop. Res.*, pp: 4, 47 54.
- Moules, C., Camtel Ltd. [Brochure]. *The Role of Interfacial Tension Measurement in the Oil Industry*.
- Muhammad Romli (2003). Clearner Production in the Manufacturing of Virgin Coconut Oil. *Cleaner Production and Regulatory of VCO*, pp: 49 – 57. Retrieved on May 23, 2011, from <u>http://repository.ipb.ac.id/bitstream/handle/123456789/40321/Muhammad%20R</u> <u>omli_2.pdf?sequence=1</u>

- Nik Norulaini, N.A., Setianto, W.B., Zaidul, I.S.M., Nawi, A.H., Azizi, C.Y.M. and Mohd Omar, A.K. (2009). Effects of Supercritical Carbon Dioxide Extraction Parameters on Virgin Coconut Oil Yield and Medium-Chain Triglyceride Content. *Food Chemistry*, pp: 116, 193 – 197.
- Nour, Abdurahman H., Mohammed, F.S., Yunus, Rosli M. and Aman, A. (2009). Demulsification of Virgin Coconut Oil by Centrifugation Method: A Feasibility Study. *International Journal of Chemical Technology*, pp: 1(2), 59-64.
- Onsaard, E., Vittauanont, M., Sringam, S. and McClements, D.J. (2006). Comparison of properties of oil-in-water emulsions stabilized by coconut cream protein with those stabilized by whey protein isolate. *Food Research International*, pp: 39(1), 78-86.
- Peamprasart, T. and Chiewchan, N. (2006). Effect of fat content and preheat treatment on the apparent viscosity of coconut milk after homogenization. *Journal of Food Engineering*, pp: 77, 653 658.
- Raghavendra, S.N. and Raghavarao, K.S.M.S. (2010). Effect of different treatments for the destablization of coconut milk emulsion. *Journal of Food Engineering*, pp: 97, 341-347.
- Rethinam, P. (2004). Asian & Pacific Coconut Community. Virgin coconut oil applications: Dr. Ponniah Rethinam writes on how naturally-processed virgin coconut oil can be used in functional foods, pharmaceuticals and cosmetics. Retrieved on September 3, 2010, from <u>http://www/allbusiness.com/manufacturing/food-manufacturing-grain-oilseedmilling/334663.html</u>.
- Robins, M.M. (2000). Lipid emulsions. Grasas Y Aceites, pp: 51, 26 34.
- Robins, M.M., and Hibberd, D.J. (1998). Emulsion flocculation and creaming. *Modern Aspects of Emulsion Science*. Binks, B.P. (Ed.). The Royal Society of Chemistry, Cambridge, UK, Chapter 4.
- RuralTech Services (2010). Organic facts. Aparup Mukherjee. *Nutritional Properties*. [Brochure]. Retrieved on 2010, September 23, from <u>http://www.organicfacts.net/organic-oils/organic-coconut-oil/properties-of-coconut-oil.html</u>.
- Schramm, L.L. (1996). Suspensions: Basic Principles. Suspensions: Fundamentals and Applications in the Petroleum Industry, Schramm, L.L. (Ed.). American Chemical Society, Washington, pp. 3 – 44.
- Schramm, L.L. (2005a). Colloid Stability. *Emulsions, Foams and Suspensions: Fundamentals and Applications*. Laurier L. Schramm, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, pp. 117 – 154.

- Schramm, L.L. (2005b). Colloid Rheology. Emulsions, Foams and Suspensions: Fundamentals and Applications. Laurier L. Schramm, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, pp. 155 – 200.
- Schramm, L.L. (2005c). Dispersion and Dispersed Species Characterization. *Emulsions, Foams and Suspensions: Fundamentals and Applications*. Laurier L. Schramm, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, pp. 13 52.
- Schramm, L.L. (2005d). Food Product and Agricultural Applications. *Emulsions, Foams and Suspensions: Fundamentals and Applications*. Laurier L. Schramm, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, pp. 301 324.
- Schramm, L.L. (2005e). Surfactants and Micelles. *Emulsions, Foams and Suspensions: Fundamentals and Applications*. Laurier L. Schramm, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, pp. 76 – 88.
- Schramm, L.L. (2005f). Preparation, Inhibition, and Destruction of Disperisions. *Emulsions, Foams and Suspensions: Fundamentals and Applications*. Laurier L. Schramm, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, pp. 201 – 222.
- Schramm, L.L. and Heckman, L.P. Unpublished results.
- Schramm, L.L. and Kwak, J.C.T. (1982). Can. J. Chem. 60, pp: 486 494.
- Seow, C.C. and Gwee, C.N. (1997). Coconut milk: Chemistry and technology. *Int J. Food Sci. Technol*, pp: 32, 189-201.
- Simuang, J., Chiewchan, N. and Tansakul, A. (2004). Effects of fat content and temperature on the apparent viscosity of coconut milk. *Journal of Food Engineering*, pp: 64, 193 197.
- Sirianni, A.F.; Capes, C.E. and Puddington, I.E. (1969). Can. J. Chem. Eng. (47), pp: 166-170.
- Sogo, Y., Taneya, S., and Kako, M. (1989). Whipping Cream Emulsifiers in Food Emulsifiers: Chemistry, Technology, Functional Properties and Applications. G. Charalambous and G. Doxastakis (Eds.), Elsevier, Amsterdam, pp. 449 – 472.
- Sparks, B.D.; Farnand, J.R. and Capes, C.E. (1982). J. Separ. Proc. Technol. (3), pp:1-15.
- Sreenivasan, M. (2010, December 8). There's good in coconut oil. *News Strait Times*, pp: 2.
- Stainsby, G. and Dickinson, E. (1988). L'actualité Chemique, (3), pp: 35 39.
- Starobinets, S., Yakhot, V., and Esterman, L. (1979). Critical Dynamics of a Binary Fluid Mixture in a Cemtrifugal Field, Phy. Rev. A, pp: 20, 2582 2589.

Stauffer, C.E. (1999). Emulsifiers. Eagen Press Handbook. St. Paul, MN.

- Tan, C.T. (2004). Beverage emulsions. *Food Emulsions*, 4th Ed., Fridberg, S., Larsson, K., and Sjoblom, J., Eds., Marcel Dekker, New York, NY, Chapter 12.
- Tanford, C. (1980). *The Hydrophobic Effect, The Formation of Micelles and Biological Membranes, 2 ed., Wiley: New York.*
- Tangsuphoom, N., and Coupland, J.N. (2008). Effect of surface-active stabilizers on the microstructure and stability of coconut milk emulsions. *Food Hydrocolloids*, pp: 22, 1233 – 1242.
- Tangsuphoom, N. and Coupland, J.N. (2009a). Effect of surface-active stabilizers on the surface properties of coconut milk emulsions. *Food Hydrocolloids*, pp: 23, 1801 – 1809.
- Tangsuphoom, N. and. Coupland, J.N (2009b). Effect of thermal treatments on the properties of coconut milk emulsions prepared with surface-active stabilizers. *Food Hydrocolloids*, pp: 23, 1792 1800.
- Tansakul, A. and Chaisawang, P. (2005). Thermophysical properties of coconut milk. J. *Food Eng.*, pp: 73, 276 280.
- Tropical Traditions (2002). *Virgin Coconut Oil*. [Brochure]. Retrieved on 2010, September 3, from <u>http://tropicaltrditions.com/what_is_virgin_coconut_oil.htm</u>.
- Todaro, C.L. and Vogel, H.C. (1996). Centrifugation. In: Fermentation and Bioengineering Chemical Handbook – Principles, Process Design and Equipment. Noyes Publication, pp: 781 – 799.
- Villarino, B.J., Dy, L.M., and Lizada, C.C. (2007). Descriptive sensory evaluation of virgin coconut oil and refined, bleached and deodorized coconut oil. *LWT-Food Science and Technology*, pp: 40, 193 – 199.
- Wadle, A., Tesmann, H., Leonard, M., and Förster, T. (1997). Phase Inversion in Emulsions: CAPICO – Concept and Application. Surfactants in Cosmetics, 2nd ed., Rieger, M.M., Rhein, L.D. (Eds.), Dekker: New York, pp. 207 – 224.
- Walstra, P. (1996a). Emulsion stability. *Encyclopaedia of Emulsion Technology*. Vol. 4, Becher, P. (Ed.), Marcel Dekker, New York, NY, Chapter 1.
- Walstra, P. (1996b). Disperse systems: Basic considerations. *Food Chemistry*. 3rd ed., Fennema, O.R. (Ed.), Marcel Dekker, New York, NY, Chapter 3.

APPENDICES

A.1. OPTICAL MICROGRAPH OF COCONUT MILK EMULSIONS



(a)

(b)

Figure A. 1: Optical Micrograph using Reflected Fluorescent Light Showing Oil-In-Water (O/W) Coconut Milk Emulsions for Droplets Size Measurement: (a) Batch 1; (b) Batch 2

A.2. DROPLETS SIZE DISTRIBUTION FOR COCONUT MILK EMULSIONS

Table A. 1:	Droplets Size	Distribution of	Coconut	Milk Emulsion	(Batch	1)
-------------	---------------	-----------------	---------	---------------	--------	----

Droplets Diameter (µm)	Frequency	Droplets Diameter (µm)	Frequency
0.04	2	0.32	4
0.05	2	0.33	17
0.06	6	0.34	8
0.07	11	0.35	12
0.08	7	0.36	3
0.09	26	0.37	5
0.10	17	0.38	7
0.11	43	0.39	3
0.12	24	0.40	4
0.13	30	0.41	2
0.14	18	0.42	3
0.15	34	0.43	1
0.16	22	0.44	1
0.17	33	0.45	2
0.18	12	0.46	3
0.19	27	0.48	3
0.20	17	0.50	1
0.21	29	0.52	2
0.22	10	0.54	2
0.23	23	0.62	1
0.24	11	0.64	1
0.25	25	0.66	1
0.26	13	0.75	1
0.27	21	0.76	1
0.28	8	0.81	1
0.29	17	0.93	1
0.30	11	0.95	1
0.31	20		

Droplets Diameter (µm)	Frequency	Droplets Diameter (µm)	Frequency
0.04	1	0.32	6
0.05	19	0.33	11
0.06	12	0.34	4
0.07	68	0.35	6
0.08	45	0.36	1
0.09	86	0.37	7
0.10	45	0.38	7
0.11	82	0.39	5
0.12	49	0.41	1
0.13	92	0.42	1
0.14	33	0.43	3
0.15	80	0.45	2
0.16	37	0.47	1
0.17	53	0.48	3
0.18	26	0.49	2
0.19	48	0.50	2
0.20	21	0.51	1
0.21	38	0.52	2
0.22	26	0.53	3
0.23	29	0.54	1
0.24	8	0.58	3
0.25	33	0.59	1
0.26	15	0.62	1
0.27	19	0.64	1
0.28	11	0.66	1
0.29	12	0.67	2
0.30	10	0.68	1
0.31	13	0.85	1

Table A. 2: Droplets Size Distribution of Coconut Milk Emulsion (Batch 2)

A.3 RHEOLOGY PROPERTIES OF COCONUT MILK EMULSION (BATCH 1)

Table A. 3: Results from Viscometer for Coconut Milk Emulsion (Batch 1) at
Temperature, $T = 30^{\circ}C$

	Agitation Spe	eed = 30 RPM				
	Reading 1	Reading 2	Reading 3	Average		
Torque (%)	9.70	9.10	9.00	9.27		
Viscosity (cP)	93.00	90.00	90.00	91.00		
Shear Stress (D/cm ²)	9.38	9.18	9.18	9.25		
Shear Rate (1/sec)	10.20	10.20	10.20	10.20		
	Agitation Spe	eed = 50 RPM				
	Reading 1	Reading 2	Reading 3	Average		
Torque (%)	12.00	11.90	11.90	11.93		
Viscosity (cP)	72.00	71.40	71.40	71.60		
Shear Stress (D/cm ²)	12.10	12.10	12.10	12.10		
Shear Rate (1/sec)	17.00	17.00	17.00	17.00		
	Agitation Speed = 100 RPM					
	Reading 1	Reading 2	Reading 3	Average		
Torque (%)	18.60	18.10	17.80	18.17		
Viscosity (cP)	55.20	54.30	53.40	54.30		
Shear Stress (D/cm ²)	18.60	18.40	18.20	18.40		
Shear Rate (1/sec)	34.00	34.00	34.00	34.00		
	Agitation Spe	ed = 150 RPM	[
	Reading 1	Reading 2	Reading 3	Average		
Torque (%)	22.90	22.50	22.30	22.57		
Viscosity (cP)	45.40	44.80	44.60	44.93		
Shear Stress (D/cm ²)	23.00	22.80	22.60	22.80		
Shear Rate (1/sec)	51.00	51.00	51.00	51.00		
	Agitation Spe	ed = 200 RPM	[
	Reading 1	Reading 2	Reading 3	Average		
Torque (%)	26.30	26.30	26.30	26.30		
Viscosity (cP)	40.30	39.30	39.10	39.57		
Shear Stress (D/cm ²)	27.30	26.90	26.50	26.90		
Shear Rate (1/sec)	68.00	68.00	68.00	68.00		

	Agitation Speed = 30 RPM			
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	8.60	8.00	7.90	8.17
Viscosity (cP)	82.00	79.00	78.00	79.67
Shear Stress (D/cm ²)	8.26	8.16	7.95	8.12
Shear Rate (1/sec)	10.20	10.20	10.20	10.20
	Agitation Spe	eed = 50 RPM		
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	10.10	9.90	9.90	9.97
Viscosity (cP)	59.40	59.40	59.40	59.40
Shear Stress (D/cm ²)	10.10	10.10	10.10	10.10
Shear Rate (1/sec)	17.00	17.00	17.00	17.00
	Agitation Spe	ed = 100 RPM	-	
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	14.00	14.00	13.90	13.97
Viscosity (cP)	42.00	42.00	41.40	41.80
Shear Stress (D/cm ²)	14.30	14.30	14.10	14.23
Shear Rate (1/sec)	34.00	34.00	34.00	34.00
	Agitation Spe	ed = 150 RPM	-	
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	16.00	15.90	15.90	15.93
Viscosity (cP)	32.00	31.80	31.80	31.87
Shear Stress (D/cm ²)	16.30	16.20	16.10	16.20
Shear Rate (1/sec)	51.00	51.00	51.00	51.00
	Agitation Spe	ed = 200 RPM	-	
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	19.00	18.70	18.50	18.73
Viscosity (cP)	28.30	27.90	27.70	27.97
Shear Stress (D/cm ²)	19.20	19.00	18.90	19.03
Shear Rate (1/sec)	68.00	68.00	68.00	68.00

Table A. 4: Results from Viscometer for Coconut Milk Emulsion (Batch 1) at
Temperature, $T = 50^{\circ}C$

	Agitation Speed = 30 RPM				
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	8.50	7.80	7.30	7.87	
Viscosity (cP)	83.00	78.00	73.00	78.00	
Shear Stress (D/cm ²)	7.95	7.55	7.44	7.65	
Shear Rate (1/sec)	10.20	10.20	10.20	10.20	
	Agitation Speed = 50 RPM				
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	9.10	9.10	9.10	9.10	
Viscosity (cP)	54.60	54.60	54.60	54.60	
Shear Stress (D/cm ²)	9.28	9.28	9.28	9.28	
Shear Rate (1/sec)	17.00	17.00	17.00	17.00	
	Agitation Spe	ed = 100 RPM	[
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	14.00	14.00	14.00	14.00	
Viscosity (cP)	42.00	42.00	41.70	41.90	
Shear Stress (D/cm ²)	14.30	14.30	14.20	14.27	
Shear Rate (1/sec)	34.00	34.00	34.00	34.00	
	Agitation Spe	ed = 150 RPM	[
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	16.60	16.60	16.60	16.60	
Viscosity (cP)	33.20	33.20	33.00	33.13	
Shear Stress (D/cm ²)	16.90	16.90	16.80	16.87	
Shear Rate (1/sec)	51.00	51.00	51.00	51.00	
	Agitation Spe	ed = 200 RPM	[
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	20.30	20.30	20.30	20.30	
Viscosity (cP)	30.40	30.60	30.40	30.47	
Shear Stress (D/cm ²)	20.80	20.70	20.70	20.73	
Shear Rate (1/sec)	68.00	68.00	68.00	68.00	

Table A. 5: Results from Viscometer for Coconut Milk Emulsion (Batch 1) at
Temperature, $T = 70^{\circ}C$

	Agitation Speed = 30 RPM				
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	$EEEE^*$	EEEE^*	$EEEE^*$	$EEEE^*$	
Viscosity (cP)	$EEEE^*$	EEEE^*	$EEEE^*$	$EEEE^*$	
Shear Stress (D/cm ²)	$EEEE^*$	$EEEE^*$	$EEEE^*$	$EEEE^*$	
Shear Rate (1/sec)	$EEEE^*$	$EEEE^*$	$EEEE^*$	$EEEE^*$	
	Agitation Speed = 50 RPM				
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	$EEEE^*$	$EEEE^*$	$EEEE^*$	$EEEE^*$	
Viscosity (cP)	$EEEE^*$	$EEEE^*$	$EEEE^*$	$EEEE^*$	
Shear Stress (D/cm ²)	$EEEE^*$	$EEEE^*$	$EEEE^*$	$EEEE^*$	
Shear Rate (1/sec)	$EEEE^*$	$EEEE^*$	$EEEE^*$	$EEEE^*$	
	Agitation Speed = 100 RPM				
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	89.70	87.80	92.60	90.03	
Viscosity (cP)	250.10	272.60	281.00	267.90	
Shear Stress (D/cm ²)	79.50	93.20	96.30	89.67	
Shear Rate (1/sec)	34.00	34.00	34.00	34.00	
	Agitation Spe	ed = 150 RPM	[
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	74.70	75.20	75.90	75.27	
Viscosity (cP)	147.80	150.20	150.00	149.33	
Shear Stress (D/cm ²)	75.20	76.00	79.60	76.93	
Shear Rate (1/sec)	51.00	51.00	51.00	51.00	
	Agitation Spe	ed = 200 RPM	[
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	90.00	92.30	91.15	91.15	
Viscosity (cP)	119.40	138.60	129.00	129.00	
Shear Stress (D/cm ²)	82.60	98.40	90.50	90.50	
Shear Rate (1/sec)	68.00	68.00	68.00	68.00	
EE : error i	reading on Broc	kfield Device	(viscometer)		

Table A. 6: Results from Viscometer for Coconut Milk Emulsion (Batch 1) at
Temperature, $T = 90^{\circ}C$

A.4 RHEOLOGY PROPERTIES OF COCONUT MILK EMULSION (BATCH 2)

Table A. 7: Results from Viscometer for Coconut Milk Emulsion (Batch 2) at
Temperature, $T = 30^{\circ}C$

	Agitation Spe	eed = 30 RPM			
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	12.20	10.90	10.50	11.20	
Viscosity (cP)	110.00	109.00	105.00	108.00	
Shear Stress (D/cm ²)	11.20	10.90	10.70	10.93	
Shear Rate (1/sec)	10.20	10.20	10.20	10.20	
	Agitation Spe	eed = 50 RPM			
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	15.10	14.10	13.90	14.37	
Viscosity (cP)	87.60	84.60	83.40	85.20	
Shear Stress (D/cm ²)	14.60	14.40	14.20	14.40	
Shear Rate (1/sec)	17.00	17.00	17.00	17.00	
Agitation Speed = 100PM					
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	22.20	21.60	21.50	21.77	
Viscosity (cP)	66.60	64.80	64.50	65.30	
Shear Stress (D/cm ²)	22.30	22.00	21.90	22.07	
Shear Rate (1/sec)	34.00	34.00	34.00	34.00	
	Agitation Spe	ed = 150 RPM	[
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	28.20	28.00	27.90	28.03	
Viscosity (cP)	57.00	55.80	55.60	56.13	
Shear Stress (D/cm ²)	29.10	28.60	28.20	28.63	
Shear Rate (1/sec)	51.00	51.00	51.00	51.00	
	Agitation Spe	ed = 200 RPM	[
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	33.90	33.50	33.20	33.53	
Viscosity (cP)	50.50	50.10	49.80	50.13	
Shear Stress (D/cm ²)	34.30	34.10	33.70	34.03	
Shear Rate (1/sec)	68.00	68.00	68.00	68.00	

	Agitation Speed = 30 RPM				
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	7.00	6.70	6.80	6.83	
Viscosity (cP)	68.00	68.00	68.00	68.00	
Shear Stress (D/cm ²)	6.73	6.93	6.93	6.86	
Shear Rate (1/sec)	10.20	10.20	10.20	10.20	
	Agitation Speed = 50 RPM				
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	9.90	9.80	9.80	9.83	
Viscosity (cP)	58.20	58.80	58.80	58.60	
Shear Stress (D/cm ²)	9.89	9.99	9.99	9.96	
Shear Rate (1/sec)	17.00	17.00	17.00	17.00	
	Agitation Spec	ed = 100 RPM			
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	16.50	16.20	16.20	16.30	
Viscosity (cP)	49.20	48.60	48.60	48.80	
Shear Stress (D/cm ²)	16.50	16.50	16.50	16.50	
Shear Rate (1/sec)	34.00	34.00	34.00	34.00	
	Agitation Spee	ed = 150 RPM			
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	26.70	20.80	20.70	22.73	
Viscosity (cP)	41.40	41.60	41.40	41.47	
Shear Stress (D/cm ²)	21.20	21.20	21.10	21.17	
Shear Rate (1/sec)	51.00	51.00	51.00	51.00	
	Agitation Spee	ed = 200 RPM			
	Reading 1	Reading 2	Reading 3	Average	
Torque (%)	25.40	25.60	25.50	25.50	
Viscosity (cP)	38.20	38.40	38.40	38.33	
Shear Stress (D/cm ²)	26.00	26.20	26.20	26.13	
Shear Rate (1/sec)	68.00	68.00	68.00	68.00	

Table A. 8: Results from Viscometer for Coconut Milk Emulsion (Batch 2) at
Temperature, $T = 50^{\circ}C$

	Agitation Speed = 30 RPM			
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	18.40	19.10	19.30	18.93
Viscosity (cP)	188.00	193.00	193.00	191.33
Shear Stress (D/cm ²)	19.30	19.70	19.80	19.60
Shear Rate (1/sec)	10.20	10.20	10.20	10.20
	Agitation Spe	eed = 50 RPM		
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	24.30	24.20	24.70	24.40
Viscosity (cP)	145.20	146.40	148.80	146.80
Shear Stress (D/cm ²)	24.40	25.10	25.40	24.97
Shear Rate (1/sec)	17.00	17.00	17.00	17.00
	Agitation Spe	ed = 100 RPM	-	
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	35.20	34.90	35.00	35.03
Viscosity (cP)	105.30	105.00	105.00	105.10
Shear Stress (D/cm ²)	35.70	35.70	35.70	35.70
Shear Rate (1/sec)	34.00	34.00	34.00	34.00
	Agitation Spe	ed = 150 RPM	-	
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	42.80	42.70	42.50	42.67
Viscosity (cP)	85.60	85.20	85.40	85.40
Shear Stress (D/cm ²)	43.60	43.50	43.40	43.50
Shear Rate (1/sec)	51.00	51.00	51.00	51.00
	Agitation Spe	ed = 200 RPM	-	
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	49.50	49.40	49.60	49.50
Viscosity (cP)	74.20	74.40	74.50	74.37
Shear Stress (D/cm ²)	50.50	50.60	50.70	50.60
Shear Rate (1/sec)	68.00	68.00	68.00	68.00

Table A. 9: Results from Viscometer for Coconut Milk Emulsion (Batch 2) at
Temperature, $T = 70^{\circ}C$

	Agitation Spe	eed = 30 RPM		
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	64.40	65.20	64.70	64.77
Viscosity (cP)	637.90	640.90	649.90	642.90
Shear Stress (D/cm ²)	65.00	65.90	66.10	65.67
Shear Rate (1/sec)	10.20	10.20	10.20	10.20
	Agitation Spe	eed = 50 RPM		
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	68.10	73.00	75.90	72.33
Viscosity (cP)	407.90	449.30	466.10	441.10
Shear Stress (D/cm ²)	71.90	77.60	76.70	75.40
Shear Rate (1/sec)	17.00	17.00	17.00	17.00
	Agitation Speed = 100 RPM			
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	85.60	84.90	85.10	85.20
Viscosity (cP)	255.50	254.60	256.10	255.40
Shear Stress (D/cm ²)	86.80	86.60	87.20	86.87
Shear Rate (1/sec)	34.00	34.00	34.00	34.00
	Agitation Spe	ed = 150 RPM	-	
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	99.60	99.80	99.80	99.73
Viscosity (cP)	199.80	199.60	200.00	199.80
Shear Stress (D/cm ²)	101.80	101.90	102.00	101.90
Shear Rate (1/sec)	51.00	51.00	51.00	51.00
	Agitation Spe	ed = 200 RPM	-	
	Reading 1	Reading 2	Reading 3	Average
Torque (%)	$EEEE^*$	$EEEE^*$	$EEEE^*$	$EEEE^*$
Viscosity (cP)	$EEEE^*$	$EEEE^*$	$EEEE^*$	$EEEE^*$
Shear Stress (D/cm ²)	$EEEE^*$	$EEEE^*$	$EEEE^*$	EEEE*
Shear Rate (1/sec)	$EEEE^*$	$EEEE^*$	$EEEE^*$	EEEE [*]
EEE : error i	reading on Broc	kfield Device	(viscometer)	

Table A. 10: Results from Viscometer for Coconut Milk Emulsion (Batch 2) at
Temperature, $T = 90^{\circ}C$

A.5 DENSITY, SURFACE TENSION AND INTERFACIAL TENSION

Table A. 11: Density if Coconut Milk Emulsions

Batch	Mass (g)	Volume (cm ³)	Density (g/cm ³)
1	1000	1050	0.952
2	1000	1080	0.926

 Table A. 12:
 Surface and Interfacial Tensions of Coconut Milk Emulsion

Phases	Reading 1	Reading 2	Reading 3	Reading 4	Average Reading
	Surface T	ension (mN	N/m)		
Oil	30.809	30.411	30.094	30.411	30.431
Water	69.849	70.11	70.023	70.11	70.023
	Interfacial	Tension (n	nN/m)		
Oil and Water Interface	7.987	7.905	8.055	7.999	7.987

B.1 RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA CENTRIFUGATION METHOD

 Table B. 1:
 Demulsification of Coconut Milk Emulsion by Centrifugation Method with Centrifugal Speed 2000rpm

Centrifugation	VC	C O	Cre	eam	Wa	ter	Total	Lo	DSS	Volume		Age o	f Emuls	ion
Time (minutes)	mL	%	mL	%	mL	%	Volume (mL)	mL	%	Centrifuge (mL)	Batch	Packet	Day	Unfreeze (hours)
30	25.0	27.2	34.0	37.0	33.0	35.9	92.0	8.0	8.0	100.0	1	1	5	6
60	18.0	24.7	30.0	41.1	25.0	34.2	73.0	17.0	18.9	90.0	1	1	5	4
90	14.0	17.9	36.0	46.2	28.0	35.9	78.0	22.0	22.0	100.0	1	2	2	14

Table B. 2: Demulsification of Coconut Milk Emulsion by Centrifugation Method with Centrifugal Speed 5000rpm

Centrifugation	V	C O	Cre	eam	Wa	ater	Total	Lo	DSS	Volume		1Age	e of En	nulsion
Time (minutes)	mL	%	mL	%	mL	%	Volume (mL)	mL	%	Centrifuge (mL)	Batch	Packet	Day	Unfreeze (hours)
30	19.0	20.7	15.0	16.3	58.0	63.0	92.0	5.0	5.2	97.0	1	1	6	4.5
60	15.0	18.3	11.0	13.4	56.0	68.3	82.0	18.0	18.0	100.0	1	1	6	3.5
90	26.0	32.1	15.0	18.5	40.0	49.4	81.0	18.0	18.2	99.0	1	3	5	14

Table B. 3:Demulsification of Coconut Milk Emulsion by Centrifugation Method with Centrifugal Speed 8000rpm

Centrifugation	V	CO	Cre	eam	Wa	ter	Total	Lo	DSS	Volume		Age	of Em	ulsion
Time (minutes)	mL	%	mL	%	mL	%	Volume (mL)	mL	%	Centrifuge (mL)	Batch	Packet	Day	Unfreeze (hours)
30	19.0	19.8	15.0	15.6	62.0	64.6	96.0	4.0	4.0	100.0	1	1	7	6
60	20.0	22.2	12.0	13.3	58.0	64.4	90.0	10.0	10.0	100.0	1	1	7	5
90	26.0	29.5	22.0	25.0	40.0	45.5	88.0	14.0	13.7	102.0	1	3	5	15

B.2 RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA OIL SOLUBLE MATERIAL AND CENTRIFUGATION METHOD

 Table B. 4:
 Demulsification of Coconut Milk Emulsion by Adding 0.5v% Oil Soluble Material and Centrifugation Method with

 Centrifugal Speed 2000rpm

Centrifugation	V	C O	Cre	eam	Wa	iter	Total	Lo	DSS	Volume		Age	of Emu	lsion
Time	mL	%	mL	%	mL	%	Volume	mL	%	Centrifuge	Batch	Packet	Dav	Unfreeze
(minutes)	me	/0	me	/0	me	/0	(mL)	me	/0	(mL)	Butth	1 uenee	Duy	(hours)
30	33.0	18.3	60.0	33.3	87.0	48.3	180.0	20.0	10.0	200.0	1	1	14	15.5
60	33.0	19.6	55.0	32.7	80.0	47.6	168.0	32.0	16.0	200.0	1	1	14	14.5
90	43.0	25.1	40.0	23.4	88.0	51.5	171.0	29.0	14.5	200.0	1	1	14	13.0

 Table B. 5:
 Demulsification of Coconut Milk Emulsion by Adding 0.5v% Oil Soluble Material and Centrifugation Method with

 Centrifugal Speed 5000rpm

Centrifugation	V	C O	Cre	eam	Wa	ter	Total	Lo	DSS	Volume		Age	of Em	ulsion
Time (minutes)	mL	%	mL	%	mL	%	Volume (mL)	mL	%	Centrifuge (mL)	Batch	Packet	Day	Unfreeze (hours)
30	64.0	37.9	25.0	14.8	80.0	47.3	169.0	31.0	15.5	200.0	1	1	15	18
60	65.0	40.6	15.0	9.4	80.0	50.0	160.0	40.0	20.0	200.0	1	1	15	13
90	60.0	34.7	28.0	16.2	85.0	49.1	173.0	27.0	13.5	200.0	1	1	14	16

 Table B. 6:
 Demulsification of Coconut Milk Emulsion by Adding 0.5v% Oil Soluble Material and Centrifugation Method with

 Centrifugal Speed 8000rpm

Centrifugation	V	C O	Cre	eam	Wa	ater	Total	Lo	DSS	Volume		Age	of Em	ulsion
Time (minutes)	mL	%	mL	%	mL	%	Volume (mL)	mL	%	Centrifuge (mL)	Batch	Packet	Day	Unfreeze (hours)
30	68.0	39.3	25.0	14.5	80.0	46.2	173.0	27.0	13.5	200.0	1	1	15	16.5
60	70.0	45.2	20.0	12.9	65.0	41.9	155.0	45.0	22.5	200.0	1	1	15	15.5
90	75.0	44.1	15.0	8.8	80.0	47.1	170.0	30.0	15.0	200.0	1	1	15	14

B.3 RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA WATER SOLUBLE MATERIAL AND CENTRIFUGATION METHOD

 Table B. 7:
 Demulsification of Coconut Milk Emulsion by Adding 0.5v% Water Soluble Material and Centrifugation Method with

 Centrifugal Speed 2000rpm

Centrifugation	VO	C O	Cre	eam	Wa	ter		Total	Lo	DSS	Volume		Age	of Em	ulsion
Time	mI	0/	mI	0/	mI	0/	pН	Volume	mI	0/	Centrifuge	Datah	Doolvot	Day	Unfreeze
(minutes)	IIIL	/0	IIIL	/0	IIIL	/0		(mL)	IIIL	/0	(mL)	Daten	I acket	Day	(hours)
30	0.0	0.0	60.0	40.8	87.0	59.2	4.29	147.0	53.0	26.5	200.0	2	5	1	2.0
60	0.0	0.0	65.0	48.1	70.0	51.9	4.30	135.0	65.0	32.5	200.0	2	5	1	1.0
90	30.0	20.7	50.0	34.5	65.0	44.8		145.0	55.0	27.5	200.0	2	5	5	16.0

 Table B. 8:
 Demulsification of Coconut Milk Emulsion by Adding 0.5v% Water Soluble Material and Centrifugation Method with

 Centrifugal Speed 5000RPM

Centrifugation	VC	C O	Cre	am	Wa	ıter		Total	Lo	SS	Volume		Age	e of Em	ulsion
Time	mI	0/_	mĬ	0/_	mI	0/_	pН	Volume	mI	0/_	Centrifuge	Ratch	Packat	Dav	Unfreeze
(minutes)		/0	IIIL	70	11112	70		(mL)	11112	/0	(mL)	Datti	I acket	Day	(hours)
30	0.0	0.0	120.0	64.9	65.0	35.1	4.32	185.0	15.0	7.5	200.0	2	5	2	3.0
60	0.0	0.0	130.0	68.4	60.0	31.6	4.28	190.0	10.0	5.0	200.0	2	5	2	2.5
90	0.0	0.0	135.0	67.5	65.0	32.5	4.37	200.0	0.0	0.0	200.0	2	5	2	1.0

 Table B. 9:
 Demulsification of Coconut Milk Emulsion by Adding 0.5v% Water Soluble Material and Centrifugation Method with

 Centrifugal Speed 8000rpm

Centrifugation	VC	CO	Cre	am	Wa	ter		Total	Lo	SS	Volume		Age	of Em	ulsion
Time	mI	0/	mI	0/	mI	0/	pН	Volume	mI	0/	Centrifuge	Datah	Doolvot	Dav	Unfreeze
(minutes)	IIIL	70	IIIL	70		70		(mL)		70	(mL)	Daten	гаске	Day	(hours)
30	0.0	0.0	130.0	72.2	50.0	27.8	4.30	180.0	20.0	10.0	200.0	2	5	3	15.0
60	0.0	0.0	135.0	71.1	55.0	28.9	4.32	190.0	10.0	5.0	200.0	2	5	3	14.5
90	0.0	0.0	130.0	70.3	55.0	29.7	4.33	185.0	15.0	7.5	200.0	2	5	3	13.0

B.4 RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA METHANOL AND CENTRIFUGATION METHOD

 Table B. 10:
 Demulsification of Coconut Milk Emulsion by Adding 0.5v% Methanol and Centrifugation Method with Centrifugal Speed

 2000rpm

Centrifugation	V	C O	Cre	eam	Wa	ter	Total	Lo	SS	Volume		Age	of En	nulsion
Time	mL	%	mL	%	mL	%	Volume	mL	%	Centrifuge	Batch	Packet	Dav	Unfreeze (hours)
(minutes)	me	/0	me	/0	me	/0	(mL)	me	/0	(mL)	Dutth	Tucket	Duy	
30	35.0	18.1	80.0	41.5	78.0	40.4	193.0	7.0	3.5	200.0	1	2	1	6.5
60	47.0	25.1	70.0	37.4	70.0	37.4	187.0	13.0	6.5	200.0	1	2	1	5.5
90	41.0	22.7	55.0	30.4	85.0	47.0	181.0	19.0	9.5	200.0	1	2	1	4.0

 Table B. 11: Demulsification of Coconut Milk Emulsion by Adding 0.5v% Methanol and Centrifugation Method with Centrifugal Speed

 5000rpm

Centrifugation	V	C O	Cre	eam	Wa	ıter	Total	Lo	DSS	Volume		Age	of En	ulsion
Time (minutes)	mL	%	mL	%	mL	%	Volume (mL)	mL	%	Centrifuge (mL)	Batch	Packet	Day	Unfreeze (hours)
30	35.0	21.9	60.0	37.5	65.0	40.6	160.0	40.0	20.0	200.0	1	2	2	20.0
60	45.0	25.0	50.0	27.8	85.0	47.2	180.0	20.0	10.0	200.0	1	2	2	10.0
90	38.0	22.6	75.0	44.6	55.0	32.7	168.0	32.0	16.0	200.0	1	2	1	2.0

 Table B. 12:
 Demulsification of Coconut Milk Emulsion by Adding 0.5v% Methanol and Centrifugation Method with Centrifugal Speed
 8000rpm

Centrifugation	V	VCO Cream		Water		Total	Loss		Volume		Age of Emulsion			
Time (minutes)	mL	%	mL	%	mL	%	Volume (mL)	mL	%	Centrifuge (mL)	Batch	Packet	Day	Unfreeze (hours)
30	36.0	22.4	60.0	37.3	65.0	40.4	161.0	39.0	19.5	200.0	1	2	3	14.0
60	64.0	33.3	43.0	22.4	85.0	44.3	192.0	18.0	8.6	210.0	1	2	2	15.5
90	62.0	28.6	55.0	25.3	100.0	46.1	217.0	23.0	9.6	240.0	1	2	2	14.0

B.5 RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA ETHANOL AND CENTRIFUGATION METHOD

 Table B. 13: Demulsification of Coconut Milk Emulsion by Adding 0.5v% Ethanol and Centrifugation Method with Centrifugal Speed 2000rpm

Centrifugation	VCO		Cream		Water		Total	Loss		Volume	Age of Emulsion				
Time	mL %		mL	0/0	mL	0/0	Volume	mL	0/0	Centrifuge	Ratch	Packet	Dav	Unfreeze (hours)	
(minutes)	mL	70	mi	70	1111.2	70	(mL)	me	, 0	(mL)	Dutth	Tacket	Day	enneeze (nours)	
30	50.0	26.3	60.0	31.6	80.0	42.1	190.0	10.0	5.0	200.0	1	3	1	6.0	
60	60.0	30.8	45.0	23.1	90.0	46.2	195.0	5.0	2.5	200.0	1	3	1	5.0	
90	34.0	18.9	91.0	50.6	55.0	30.6	180.0	20.0	10.0	200.0	1	2	4	13.0	

 Table B. 14:
 Demulsification of Coconut Milk Emulsion by Adding 0.5v% Ethanol and Centrifugation Method with Centrifugal Speed

 5000rpm

Centrifugation	VCO Cream		Water		Total Loss		Volume		Age of Emulsion					
Time (minutes)	mL	%	mL	%	mL	%	Volume (mL)	mL	%	Centrifuge (mL)	Batch	Packet	Day	Unfreeze (hours)
30	1.0	0.7	85.0	56.3	65.0	43.0	151.0	49.0	24.5	200.0	1	3	2	15.0
60	61.0	35.7	20.0	11.7	90.0	52.6	171.0	29.0	14.5	200.0	1	3	1	4.0
90	55.0	28.9	45.0	23.7	90.0	47.4	190.0	10.0	5.0	200.0	1	3	1	2.5

Table B. 15: Demulsification of Coconut Milk Emulsion by Adding 0.5v% Ethanol and Centrifugation Method with Centrifugal Speed8000rpm

Centrifugation	VCO Cream		Wa	ter	Total	Total Loss		Volume	Age of Emulsion					
Time (minutes)	mL	%	mL	%	mL	%	Volume (mL)	mL	%	Centrifuge (mL)	Batch	Packet	Day	Unfreeze (hours)
30	26.0	16.7	55.0	35.3	75.0	48.1	156.0	34.0	17.9	190.0	1	3	2	16.0
60	30.0	19.0	58.0	36.7	70.0	44.3	158.0	42.0	21.0	200.0	1	3	2	14.0
90	50.0	23.8	60.0	28.6	100.0	47.6	210.0	10.0	4.5	220.0	1	3	2	12.5

B.6 RESULTS FOR DEMULSIFICATION OF COCONUT MILK EMULSION VIA WATER SOLUBLE MATERIAL AND METHANOL WITH CENTRIFUGATION METHOD

Table B. 16:Demulsification of Coconut Milk Emulsion by Adding 0.5v% Water Soluble Material, 0.5 v% Methanol and CentrifugationMethod with Centrifugal Speed 2000rpm

Centrifugation	VCO Cream		Water			Total		DSS	Volume	Age of Emulsion					
Time	mI %		mI	0/2	mI	0/_	рН	Volume	mI	0/2	Centrifuge	Ratch	Packat	Dav	Unfreeze
(minutes)	IIIL 70	IIIL/	/0	11112	/0	(mL)		IIIL	70	(mL)	Datti		Day	(hours)	
30	0.0	0.0	110.0	61.1	70.0	38.9	4.13	180.0	20.0	10.0	200.0	2	5	1	3.0
60	0.0	0.0	100.0	57.1	75.0	42.9	4.15	175.0	25.0	12.5	200.0	2	5	1	2.5
90	0.0	0.0	95.0	57.6	70.0	42.4	4.12	165.0	35.0	17.5	200.0	2	5	1	1.0

Table B. 17: Demulsification of Coconut Milk Emulsion by Adding 0.5v% Water Soluble Material, 0.5 v% Methanol and CentrifugationMethod with Centrifugal Speed 5000rpm

Centrifugation	VCO Cream		am	Water			Total	Loss		Volume		Age of Emulsion			
Time	mI	0/	mI	0/	mI	0/	pН	Volume	mI	0/	Centrifuge	Datah	Doolvot	Dav	Unfreeze
(minutes)	IIIL	70	IIIL	70	11117	70		(mL)		70	(mL)	Daten	гаске	Day	(hours)
30	0.0	0.0	100.0	62.5	60.0	37.5	4.19	160.0	40.0	20.0	200.0	2	5	2	15.5
60	0.0	0.0	125.0	74.4	43.0	25.6	4.18	168.0	32.0	16.0	200.0	2	5	2	14.5
90	2.0	1.1	100.0	54.9	80.0	44.0		182.0	18.0	9.0	200.0	2	5	2	13.0

Table B. 18: Demulsification of Coconut Milk Emulsion by Adding 0.5v% Water Soluble Material, 0.5 v% Methanol and CentrifugationMethod with Centrifugal Speed 8000rpm

Centrifugation	VCO		Cream		Water			Total	Loss		Volume	Age of Emulsion				
Time	mI	0/_	mĬ	0/_	mI	0/_	pН	Volume	mI	0/_	Centrifuge	Ratch	Packat	Dav	Unfreeze	
(minutes)	11112	/0	IIIL	/0		70		(mL)		70	(mL)	Datti	I acket	Day	(hours)	
30	0.0	0.0	130.0	72.2	50.0	27.8	4.15	180.0	20.0	10.0	200.0	2	5	3	15.5	
60	0.0	0.0	135.0	71.1	55.0	28.9	4.13	190.0	10.0	5.0	200.0	2	5	3	14.5	
90	44.0	26.8	35.0	21.3	85.0	51.8		164.0	36.0	18.0	200.0	2	5	3	13.0	

C GAS CHROMATOGRAPHY – MASS SPECTROMETER ANALYSIS RESULTS



Library Search Report

Data Path : D:\Data\KHOO\ Data File : 1.D : 26 Jul 2011 12:03 Acg On Operator Sample Misc ALS Vial : 1 Sample Multiplier: 1 Minimum Quality: 0 Search Libraries: C:\Database\NIST05a.L Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e CAS# Qual Library/ID Ref# Pk# RT Area& 1 8.866 6.30 C:\Database\NIST05a.L 28923 000111-11-5 90 Octanoic acid, methyl ester 28914 000111-11-5 90 28925 000111-11-5 86 Octanoic acid, methyl ester Octanoic acid, methyl ester 2 18.159 6.57 C:\Database\NIST05a.L 47245 000110-42-9 96 Decanoic acid, methyl ester Decanoic acid, methyl ester Decanoic acid, 2-methyl-47246 000110-42-9 70 47223 024323-23-7 64 3 22.315 0.03 C:\Database\NIST05a.L 57095 001731-86-8 96 57097 001731-86-8 94 Undecanoic acid, methyl ester Undecanoic acid, methyl ester 57098 001731-86-8 90 Undecanoic acid, methyl ester 4 27.186 48.39 C:\Database\NIST05a.L 67169 000111-82-0 80 47245 000110-42-9 49 Dodecanoic acid, methyl ester Decanoic acid, methyl ester 77300 001731-88-0 47 Tridecanoic acid, methyl ester 5 30.283 0.04 C:\Database\NIST05a.L 77299 001731-88-0 97 77298 001731-88-0 96 Tridecanoic acid, methyl ester Tridecanoic acid, methyl ester Tridecanoic acid, methyl ester 77302 001731-88-0 96 6 34.396 20.71 C:\Database\NIST05a.L 86750 000124-10-7 95 Methyl tetradecanoate Methyl tetradecanoate Methyl tetradecanoate 86753 000124-10-7 93 86752 000124-10-7 91 7 37.398 0.01 C:\Database\NIST05a.L 96259 213617-69-7 93 Methyl 9-methyltetradecanoate 96272 007132-64-1 93 Pentadecanoic acid, methyl ester 96270 007132-64-1 91 Pentadecanoic acid, methyl ester 8 40.987 9.45 C:\Database\NIST05a.L Pentadecanoic acid, 14-methyl-, me 105662 005129-60-2 97 thyl ester Hexadecanoic acid, methyl ester Hexadecanoic acid, methyl ester 105644 000112-39-0 96 105646 000112-39-0 94 9 45.676 1.09 C:\Database\NIST05a.L 9,12-Octadecadienoic acid (Z,Z)-, 121106 000112-63-0 99 methyl ester 11,14-Octadecadienoic acid, methyl 121099 056554-61-1 99 ester 10,13-Octadecadienoic acid, methyl 121100 056554-62-2 99 ester 10 46.125 4.71 C:\Database\NIST05a.L 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 9-Octadecenoic acid (2)-, methyl e 122323 000112-62-9 99 ster 11 46.178 0.06 C:\Database\NIST05a.L DINGFAME.M Thu Jul 28 14:57:24 2011

152

Library Search Report Data Path : D:\Data\KHOO\ 1.0 Data File : 1.D : 26 Jul 2011 12:03 Acq On Operator . Sample Misc ALS Vial : 1 Sample Multiplier: 1 Minimum Quality: 0 Search Libraries: C:\Database\NIST05a.L Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Ref# CAS# Qual Library/ID Pk# RT Area% 11-Octadecenoic acid, methyl ester 122316 052380-33-3 99 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 12 47.001 2.57 C:\Database\NIST05a.L 123709 000112-61-8 99 Octadecanoic acid, methyl ester 123700 000112-61-8 98 123708 000112-61-8 98 Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester 13 51.637 0.02 C:\Database\NIST05a.L 11-Eicosenoic acid, methyl ester 139171 003946-08-5 96 9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 64 ster 55891 001892-12-2 49 Cyclododecanemethanol 14 52.502 0.04 C:\Database\NIST05a.L Eicosanoic acid, methyl ester Eicosanoic acid, methyl ester 140314 001120-28-1 98 140313 001120-28-1 98 140312 001120-28-1 96 Eicosanoic acid, methyl ester

153



Library Search Report Data Path : D:\Data\KHOO\ Data File : 2.D : 26 Jul 2011 14:57 Acq On Operator Sample Misc ALS Vial : 2 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Ref# CAS# Qual Pk# Library/ID RT Area% 1 8.876 6.59 C:\Database\NIST05a.L 28914 000111-11-5 90 Octanoic acid, methyl ester 28923 000111-11-5 90 28925 000111-11-5 86 Octanoic acid, methyl ester Octanoic acid, methyl ester 2 18.148 6.42 C:\Database\NIST05a.L 47245 000110-42-9 96 47237 000110-42-9 94 47246 000110-42-9 70 Decanoic acid, methyl ester Decanoic acid, methyl ester Decanoic acid, methyl ester 3 22.304 0.03 C:\Database\NIST05a.L 57095 001731-86-8 97 57097 001731-86-8 91 Undecanoic acid, methyl ester Undecanoic acid, methyl ester Undecanoic acid, methyl ester 57096 001731-86-8 87 4 27.164 46.86 C:\Database\NIST05a.L 67169 000111-82-0 80 47245 000110-42-9 49 Dodecanoic acid, methyl ester Decanoic acid, methyl ester Nonanoic acid, methyl ester 37541 001731-84-6 47 5 30.283 0.04 C:\Database\NIST05a.L 77299 001731-88-0 96 77297 001731-88-0 95 Tridecanoic acid, methyl ester Tridecanoic acid, methyl ester Tridecanoic acid, methyl ester 77300 001731-88-0 95 6 34.406 21.58 C:\Database\NIST05a.L 86750 000124-10-7 95 Methyl tetradecanoate 86751 000124-10-7 91 Methyl tetradecanoate Methyl tetradecanoate 86752 000124-10-7 87 7 37.397 0.01 C:\Database\NIST05a.L Pentadecanoic acid, methyl ester Pentadecanoic acid, methyl ester 96272 007132-64-1 93 96270 007132-64-1 91 96259 213617-69-7 90 Methyl 9-methyltetradecanoate 8 39.843 0.01 C:\Database\NIST05a.L 7-Hexadecenoic acid, methyl ester, 104151 056875-67-3 90 (2)-11-Hexadecenoic acid, methyl ester 104135 055000-42-5 89 9-Hexadecenoic acid, methyl ester, 104152 001120-25-8 86 (Z) -9 40.997 10.02 C:\Database\NIST05a.L Pentadecanoic acid, 14-methyl-, me 105662 005129-60-2 97 thyl ester 105644 000112-39-0 96 Hexadecanoic acid, methyl ester 105646 000112-39-0 94 Hexadecanoic acid, methyl ester 10 45.676 1.05 C:\Database\NIST05a.L 8,11-Octadecadienoic acid, methyl 121095 056599-58-7 99 ester 9,12-Octadecadienoic acid, methyl 121112 002566-97-4 99 ester, (E,E)-10,13-Octadecadienoic acid, methyl 121100 056554-62-2 99 ester 11 46.124 4.65 C:\Database\NIST05a.L

DINGFAME.M Thu Jul 28 15:01:23 2011

Page: 1
Library Search Report Data Path : D:\Data\KHOO\ Data File : 2.D : 26 Jul 2011 14:57 Acq On Operator . Sample Misc ALS Vial : 2 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Pk# Library/ID Ref# CAS# Qual RT Areas 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 9-Octadecenoic acid (Z)-, methyl e 122323 000112-62-9 99 ster 12 46.178 0.06 C:\Database\NIST05a.L 11-Octadecenoic acid, methyl ester 122331 001937-63-9 99 (2) -9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 13 47.000 2.62 C:\Database\NIST05a.L Octadecanoic acid, methyl ester 123709 000112-61-8 99 Octadecanoic acid, methyl ester 123708 000112-61-8 98 Octadecanoic acid, methyl ester 123700 000112-61-8 98 14 51.636 0.02 C:\Database\NIST05a.L 11-Eicosenoic acid, methyl ester 139171 003946-08-5 96 Cvclododecanemethanol 55891 001892-12-2 49 Cyclopentadecanone, 2-hydroxy-85349 004727-18-8 43 15 52.501 0.04 C:\Database\NIST05a.L
 Eicosanoic acid, methyl ester
 140314 001120-28-1 98

 Eicosanoic acid, methyl ester
 140312 001120-28-1 98

 Eicosanoic acid, methyl ester
 140310 001120-28-1 98



Library Search Report · Data Path : D:\Data\KHOO\ Data File : 3.D : 26 Jul 2011 16:26 Acg On Operator Sample Misc ALS Vial : 3 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Ref# CAS# Qual Library/ID RT Area% Pk# 1.070 6.11 C:\Database\NIST05a.L 1 1427 000592-41-6 40 1-Hexene 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 38 ethyl-1633 000625-38-7 33 3-Butenoic acid 1.658 24.78 C:\Database\NIST05a.L 2 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 64 ethyl-60 000075-19-4 53 Cyclopropane 1658 000079-41-4 47 2-Propenoic acid, 2-methyl-1.775 4.51 C:\Database\NIST05a.L 3 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 45 ethyl-1790 000110-54-3 22 Hexane 1791 000110-54-3 18 Hexane 1.903 8.29 C:\Database\NIST05a.L 4 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 36 ethyl-1791 000110-54-3 14 Hexane 1790 000110-54-3 12 Hexane 2.534 0.23 C:\Database\NIST05a.L 5 13053 000106-70-7 93 Hexanoic acid, methyl ester 13040 000106-70-7 72 13052 000106-70-7 72 Hexanoic acid, methyl ester Hexanoic acid, methyl ester 7.383 3.77 C:\Database\NISTO5a.L 6 28914 000111-11-5 90 Octanoic acid, methyl ester 28923 000111-11-5 83 Octanoic acid, methyl ester 37541 001731-84-6 80 Nonanoic acid, methyl ester 7 16.591 3.58 C:\Database\NIST05a.L 47245 000110-42-9 96 Decanoic acid, methyl ester 37540 001731-84-6 74 Nonanoic acid, methyl ester 47246 000110-42-9 70 Decanoic acid, methyl ester 8 20.704 0.02 C:\Database\NIST05a.L 57095 001731-86-8 94 57097 001731-86-8 94 57096 001731-86-8 80 Undecanoic acid, methyl ester Undecanoic acid, methyl ester Undecanoic acid, methyl ester 9 25.671 25.40 C:\Database\NIST05a.L 67169 000111-82-0 78 47245 000110-42-9 50 Dodecanoic acid, methyl ester Decanoic acid, methyl ester Nonanoic acid, methyl ester 37541 001731-84-6 47 10 28.672 0.02 C:\Database\NIST05a.L
 Tridecanoic acid, methyl ester
 77299 001731-88-0 97

 Tridecanoic acid, methyl ester
 77298 001731-88-0 96

 Tridecanoic acid, methyl ester
 77300 001731-88-0 94
 11 32.860 11.96 C:\Database\NIST05a.L 86750 000124-10-7 95 86753 000124-10-7 93 Methyl tetradecanoate Methyl tetradecanoate DINGFAME.M Thu Jul 28 15:01:58 2011

158

Library Search Report Data Path : D:\Data\KHOO\ 141 Data File : 3.D : 26 Jul 2011 16:26 Acq On Operator Sample Misc ALS Vial : 3 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Ref# CAS# Qual Pk# Library/ID RT Area% Tridecanoic acid, 12-methyl-, meth 86778 005129-58-8 91 yl ester 12 35.754 0.01 C:\Database\NIST05a.L Pentadecanoic acid, methyl ester 96270 007132-64-1 99 Pentadecanoic acid, methyl ester Pentadecanoic acid, methyl ester 96271 007132-64-1 97 96272 007132-64-1 94 13 38.179 0.01 C:\Database\NIST05a.L 9-Hexadecenoic acid, methyl ester, 104152 001120-25-8 93 (2) -9-Hexadecenoic acid, methyl ester, 104156 001120-25-8 87 (2) -9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 70 ster 14 39.418 5.91 C:\Database\NIST05a.L 105644 000112-39-0 96 Hexadecanoic acid, methyl ester 105639 000112-39-0 95 Hexadecanoic acid, methyl ester Hexadecanoic acid, methyl ester 105646 000112-39-0 94 15 44.001 0.67 C:\Database\NIST05a.L 10,13-Octadecadienoic acid, methyl 121100 056554-62-2 99 ester 9,12-Octadecadienoic acid, methyl 121112 002566-97-4 99 ester, (E,E)-9,12-Octadecadienoic acid (Z,Z)-, 121106 000112-63-0 99 methyl ester 16 44.492 2.99 C:\Database\NIST05a.L 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 9-Octadecenoic acid (2)-, methyl e 122323 000112-62-9 99 ster 17 45.368 1.70 C:\Database\NIST05a.L Octadecanoic acid, methyl ester 123709 000112-61-8 99 Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester 123708 000112-61-8 98 123700 000112-61-8 98 18 49.919 0.02 C:\Database\NIST05a.L 12-Octadecenoic acid, methyl ester 122311 056554-46-2 64 11-Octadecenoic acid, methyl ester 122331 001937-63-9 64 (Z) -10-Octadecenoic acid, methyl ester 122312 013481-95-3 60 19 50.805 0.03 C:\Database\NIST05a.L Eicosanoic acid, methyl ester Eicosanoic acid, methyl ester 140312 001120-28-1 98 140314 001120-28-1 98 140313 001120-28-1 96 Eicosanoic acid, methyl ester



Data Path : D:\Data\KHOO\ 1.00 Data File : 4.D : 27 Jul 2011 8:06 Acg On Operator Sample Misc ALS Vial : 4 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Ref# CAS# Qual Pk# RT Area% Library/ID 1.070 7.12 C:\Database\NIST05a.L 1 1427 000592-41-6 40 1-Hexene 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 38 ethyl-23090 000107-81-3 36 Pentane, 2-bromo-1.658 25.47 C:\Database\NIST05a.L 2 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 64 ethyl-60 000075-19-4 53 Cyclopropane 1658 000079-41-4 47 2-Propencic acid, 2-methyl-1.743 4.35 C:\Database\NIST05a.L 3 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 45 ethvl-1790 000110-54-3 22 Heyane 1791 000110-54-3 18 Hexane 1.893 11.48 C:\Database\NIST05a.L 4 1-Propene, 2-methyl-2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 36 ethyl-1791 000110-54-3 25 Hexane 5 2.544 0.22 C:\Database\NIST05a.L EC:\Database\NISIUGA.2 Hexanoic acid, methyl ester 13053 000106-70-7 97 13051 000106-70-7 87 Hexanoic acid, methyl ester Pentanoic acid, methyl ester 7932 000624-24-8 59 7.373 3.60 C:\Database\NIST05a.L 6 Octanoic acid, methyl ester Octanoic acid, methyl ester Nonanoic acid, methyl ester 28914 000111-11-5 90 28923 000111-11-5 83 37541 001731-84-6 80 7 16.570 3.41 C:\Database\NIST05a.L 47245 000110-42-9 96 37542 001731-84-6 76 Decanoic acid, methyl ester Nonanoic acid, methyl ester 47246 000110-42-9 70 Decanoic acid, methyl ester 57095 001731-86-8 96 57096 001731-86 0 8 20.704 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester Undecanoic acid, methyl ester 57097 001731-86-8 86 Undecanoic acid, methyl ester 9 25.596 24.33 C:\Database\NIST05a.L Decanoic acid, methyl ester Nonanoic acid, methyl ester 47245 000110-42-9 50 37540 001731-84-6 49 37539 001731-84-6 47 Nonanoic acid, methyl ester 10 28.662 0.02 C:\Database\NIST05a.L Tridecanoic acid, methyl ester Tridecanoic acid, methyl ester Tridecanoic acid, methyl ester 77298 001731-88-0 97 77299 001731-88-0 96 77300 001731-88-0 96 11 32.774 10.27 C:\Database\NIST05a.L 86750 000124-10-7 96 Methyl tetradecanoate Methyl tetradecanoate 86753 000124-10-7 96

Library Search Report

DINGFAME.M Thu Jul 28 15:03:00 2011

Page: 1

Data Path : D:\Data\KHOO\ Data File : 4.D : 27 Jul 2011 Acq On 8:06 Operator Sample Misc ALS Vial : 4 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Pk# RT Area% Library/ID Ref# CAS# Qual Methyl tetradecanoate 86752 000124-10-7 94 12 35.744 0.01 C:\Database\NIST05a.L Pentadecanoic acid, methyl ester 96270 007132-64-1 96 Methyl 9-methyltetradecanoate 96259 213617-69-7 93 Pentadecanoic acid, methyl ester 96271 007132-64-1 90 13 39.354 4.93 C:\Database\NIST05a.L Pentadecanoic acid, 14-methyl-, me 105662 005129-60-2 97 thyl ester 105644 000112-39-0 96 Hexadecanoic acid, methyl ester Hexadecanoic acid, methyl ester 105646 000112-39-0 94 14 43.980 0.63 C:\Database\NIST05a.L 10,13-Octadecadienoic acid, methyl 121100 056554-62-2 99 ester 9,12-Octadecadienoic acid, methyl 121112 002566-97-4 99 ester, (E,E)-9,12-Octadecadienoic acid (Z,Z)-, 121106 000112-63-0 99 methyl ester 15 44.460 2.65 C:\Database\NIST05a.L 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -9-Octadecenoic acid (Z)-, methyl e 122323 000112-62-9 99 ster 8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 16 45.336 1.47 C:\Database\NIST05a.L 123709 000112-61-8 99 Octadecanoic acid, methyl ester 123700 000112-61-8 98 123708 000112-61-8 98 Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester 17 49.919 0.01 C:\Database\NIST05a.L 11-Eicosenoic acid, methyl ester 139171 003946-08-5 99 9-Octadecenoic acid (2)-, methyl e 122321 000112-62-9 62 ster 113353 000112-80-1 49 Oleic Acid 18 50.795 0.03 C:\Database\NIST05a.L Eicosanoic acid, methyl ester Eicosanoic acid, methyl ester 140314 001120-28-1 98 140313 001120-28-1 98 Heptadecanoic acid, 16-methyl-, me 123729 005129-61-3 96 thyl ester

Page: 2



Library Search Report Data Path : D:\Data\KHOO\ Data File : 5.D : 27 Jul 2011 9:13 Acg On Operator Sample Misc ALS Vial : 5 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Pk# CAS# Qual RT Area% Library/ID Ref# 1.070 6.58 C:\Database\NIST05a.L 1 1-Hexene 1427 000592-41-6 40 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 38 ethvl-1633 000625-38-7 33 3-Butenoic acid 2 1.668 25.59 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 64 ethyl-Cyclopropane 60 000075-19-4 53 1657 000079-41-4 47 2-Propenoic acid, 2-methyl-1.754 3.16 C:\Database\NISTO5a.L 3 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 38 ethyl-1790 000110-54-3 22 Hexane 1791 000110-54-3 18 Hexane 1.786 2.07 C:\Database\NIST05a.L 4 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 36 ethyl-1790 000110-54-3 22 Hexane Hexane 1791 000110-54-3 18 1.861 3.97 C:\Database\NIST05a.L 5 183 000115-11-7 42 1-Propene, 2-methyl-1-Propene, 2-methyl-184 000115-11-7 42 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 38 ethyl-1.903 3.38 C:\Database\NIST05a.L 6 1-Propene, 2-methyl-184 000115-11-7 53 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 36 ethyl-1791 000110-54-3 14 Hexane 7 2.566 0.25 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 91 13052 000106-70-7 83 Hexanoic acid, methyl ester 13040 000106-70-7 72 Hexanoic acid, methyl ester 7.405 3.97 C:\Database\NIST05a.L 8 Octanoic acid, methyl ester Octanoic acid, methyl ester Nonanoic acid, methyl ester 28914 000111-11-5 90 28924 000111-11-5 80 37541 001731-84-6 80 9 16.602 3.67 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 95 Undecanoic acid, methyl ester 57095 001731-86-8 72 Decanoic acid, methyl ester 47246 000110-42-9 70 10 20.704 0.02 C:\Database\NIST05a.L 57095 001731-86-8 96 57096 001731-86-8 90 Undecanoic acid, methyl ester Undecanoic acid, methyl ester Decanoic acid, methyl ester 47245 000110-42-9 80 11 25.660 25.75 C:\Database\NIST05a.L

-

Page: 1

Data Path : D:\Data\KHOO\ Data File : 5.D Acg On : 27 Jul 2011 9:13 Operator ÷ Sample Misc ALS Vial : 5 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Ref# CAS# Qual Pk≢ RT Area% Library/ID Dodecanoic acid, methyl ester 67169 000111-82-0 78 Decanoic acid, methyl ester 47245 000110-42-9 50 Nonanoic acid, methyl ester 37541 001731-84-6 47 12 28.662 0.02 C:\Database\NIST05a.L Tridecanoic acid, methyl ester 77299 001731-88-0 96 Tridecanoic acid, methyl ester 77300 001731-88-0 94 Tridecanoic acid, methyl ester 77298 001731-88-0 93 13 32.828 10.99 C:\Database\NIST05a.L Methyl tetradecanoate 86753 000124-10-7 96 Methyl tetradecanoate 86750 000124-10-7 95 Methyl tetradecanoate 86751 000124-10-7 78 14 35.744 0.01 C:\Database\NIST05a.L 96270 007132-64-1 96 Pentadecanoic acid, methyl ester Pentadecanoic acid, methyl ester 96271 007132-64-1 96 Methyl 9-methyltetradecanoate 96259 213617-69-7 93 15 38.169 0.01 C:\Database\NIST05a.L 9-Hexadecenoic acid, methyl ester, 104152 001120-25-8 96 (Z) -9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 60 ster Cyclopropaneoctanoic acid, 2-hexyl 113415 010152-61-1 47 -, methyl ester 16 39.386 5.27 C:\Database\NIST05a.L Hexadecanoic acid, methyl ester Hexadecanoic acid, methyl ester 105644 000112-39-0 96 105646 000112-39-0 93 Pentadecanoic acid, 14-methyl-, me 105659 005129-60-2 91 thyl ester 17 43.990 0.68 C:\Database\NIST05a.L 10,13-Octadecadienoic acid, methyl 121100 056554-62-2 99 ester 9,12-Octadecadienoic acid, methyl 121112 002566-97-4 99 ester, (E,E)-9,12-Octadecadienoic acid, methyl 121093 002462-85-3 99 ester 18 44.482 2.90 C:\Database\NIST05a.L 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -9-Octadecenoic acid (Z)-, methyl e 122323 000112-62-9 99 ster 8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 19 45.358 1.67 C:\Database\NIST05a.L 123709 000112-61-8 99 123708 000112-61-8 98 Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester 123700 000112-61-8 98 20 49.908 0.02 C:\Database\NIST05a.L 11-Eicosenoic acid, methyl ester 139171 003946-08-5 98 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 62 (E) -DINGFAME.M Thu Jul 28 15:03:29 2011

Library Search Report Data Path : D:\Data\KHOO\ Data File : 5.D Acq On : 27 Jul 2011 9:13 141 Acq On Operator . Sample Misc ALS Vial : 5 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Pk# RT Area% Library/ID Ref# CAS# Qual

		6-Octadecenoic aci (Z)-	d, methyl e	ster, 122327	002777-58-4	42
21	50.795	0.03 C:\Database\NISTO	5a.L			
		Eicosanoic acid, m	ethyl ester	140314	001120-28-1	98
		Eicosanoic acid, m	ethyl ester	140313	001120-28-1	98
		Eicosanoic acid, m	ethyl ester	140312	001120-28-1	95

DINGFAME.M Thu Jul 28 15:03:29 2011



-

		Library Search	Report		
. Da Da Ac Op Sa	ta Path ta File cq On erator mple	: D:\Data\KHOO\ : 6.D : 27 Jul 2011 10:20 :			
AI	S Vial	: 6 Sample Multiplier: 1			
Se	arch Li	braries: C:\Database\NIST05a.L	Mi	nimum Qualit	;y;
Ur Ir	known S tegrati	pectrum: Apex on Events: ChemStation Integrator - auto	intl.e		
Pk#	RT	Area% Library/ID	Ref#	CAS	Qua
1	1,081	7.08 C:\Database\NIST05a.L Cyclopropane 2-Propenoic acid, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl-	60 1658 11923	000075-19-4 000079-41-4 002610-95-9	1 53 1 50 9 50
2	1.690	<pre>25.80 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl-</pre>	11923	002610-95-9	9 64
		Cyclopropane 2-Propenoic acid, 2-methyl-	60 1658	000075-19-4	53 50
3	1.850	8.66 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim ethyla	11923	002610-95-9	38
		Hexane Aziridine, 2-ethyl-	1791 598	000110-54-3 002549-67-9	8 25 9 14
4	1,903	4.18 C:\Database\NIST05a.L 1-Propene, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl-	184 11923	000115-11-7	53
5	2.544	Hexane 0.23 C:\Database\NIST05a.L Hexanoic acid, methyl ester Hexanoic acid, methyl ester Hexanoic acid, methyl ester	13053 13051 13040	000110-54-3 000106-70-7 000106-70-7	97 97 91 90
6	7.394	3.83 C:\Database\NIST05a.L Octanoic acid, methyl ester Octanoic acid, methyl ester Nonanoic acid, methyl ester	28914 28923 37541	000111-11-5 000111-11-5 001731-84-6	90 83 80
7	16.591	3.62 C:\Database\NIST05a.L Decanoic acid, methyl ester Nonanoic acid, methyl ester Nonanoic acid, methyl ester	47245 37542 37540	000110-42-9 001731-84-6 001731-84-6	96 76 74
8	20.704	0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester Undecanoic acid, methyl ester Nonanoic acid, methyl ester	57095 57096 37540	001731-86-8 001731-86-8 001731-84-6	93 83 80
9	25.649	25.33 C:\Database\NIST05a.L Decanoic acid, methyl ester Nonanoic acid, methyl ester Nonanoic acid, methyl ester	47245 37540 37541	000110-42-9 001731-84-6 001731-84-6	50 47 47
10	28.662	0.02 C:\Database\NIST05a.L Tridecanoic acid, methyl ester Tridecanoic acid, methyl ester Tridecanoic acid, methyl ester	77298 77302 77300	001731-88-0 001731-88-0 001731-88-0	95 94 94
11	32.806	10.81 C:\Database\NIST05a.L Methyl tetradecanoate	86753	000124-10-7	97 96

Library Search Report Data Path : D:\Data\KHOO\ . Data File : 6.D : 27 Jul 2011 10:20 Acq On Operator Sample Misc ALS Vial : 6 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e CAS# Qual Library/ID Ref# Pk# RT Area% Methyl tetradecanoate 86751 000124-10-7 90 12 35.744 0.01 C:\Database\NIST05a.L Pentadecanoic acid, methyl ester 96270 007132-64-1 96 96271 007132-64-1 95 Pentadecanoic acid, methyl ester 96272 007132-64-1 93 Pentadecanoic acid, methyl ester 13 38.169 0.01 C:\Database\NIST05a.L 9-Hexadecenoic acid, methyl ester, 104152 001120-25-8 95 (2) -7-Hexadecenoic acid, methyl ester, 104151 056875-67-3 49 (Z) · 9-Hexadecenoic acid, methyl ester, 104156 001120-25-8 45 (2) -14 39.376 5.23 C:\Database\NIST05a.L 105644 000112-39-0 96 Hexadecanoic acid, methyl ester 105646 000112-39-0 93 Hexadecanoic acid, methyl ester Pentadecanoic acid, 14-methyl-, me 105662 005129-60-2 92 thyl ester 15 43.990 0.67 C:\Database\NIST05a.L 10,13-Octadecadienoic acid, methyl 121100 056554-62-2 99 ester 9,12-Octadecadienoic acid (Z,Z)-, 121106 000112-63-0 99 methyl ester 9,12-Octadecadienoic acid, methyl 121112 002566-97-4 99 ester, (E,E)-16 44.482 2.89 C:\Database\NIST05a.L 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 9-Octadecenoic acid (Z)-, methyl e 122323 000112-62-9 99 ster 17 45.347 1.56 C:\Database\NIST05a.L 123709 000112-61-8 99 123708 000112-61-8 98 Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester 123700 000112-61-8 98 18 49.919 0.02 C:\Database\NIST05a.L 11-Eicosenoic acid, methyl ester 139171 003946-08-5 91 Cyclopropaneoctanoic acid, 2-hexyl 113415 010152-61-1 50 -, methyl ester 7-Hexadecenoic acid, methyl ester, 104151 056875-67-3 46 (2) -19 50.805 0.03 C:\Database\NIST05a.L 140314 001120-28-1 98 140312 001120-28-1 95 Eicosanoic acid, methyl ester Eicosanoic acid, methyl ester Heptadecanoic acid, methyl ester 114853 001731-92-6 89

DINGFAME.M Thu Jul 28 15:05:08 2011

-



-

Library Search Report Data Path : D:\Data\KHOO\ 141 Data File : 7N.D Acq On : 27 Jul 2011 12:16 Operator : : 7N Sample Misc ALS Vial : 7 Sample Multiplier: 1 Minimum Quality: Search Libraries: C:\Database\NIST05a.L 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Pk₿ RT Area% Library/ID Ref# CAS# Qual 1.070 6.33 C:\Database\NIST05a.L 1 1427 000592-41-6 40 1-Hexene 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 38 ethyl-1633 000625-38-7 33 3-Butenoic acid 2 1.658 24.74 C:\Database\NISTO5a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 64 ethyl-60 000075-19-4 53 Cyclopropane 525 000930-22-3 47 Oxirane, ethenyl-1.818 6.45 C:\Database\NIST05a.L 3 1-Propene, 2-methyl-2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 36 ethyl-1791 000110-54-3 25 Hexane 1.861 2.28 C:\Database\NIST05a.L 4 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 38 ethyl-1791 000110-54-3 25 Hexane Aziridine, 2-ethyl-598 002549-67-9 14 1.904 3.38 C:\Database\NIST05a.L 5 183 000115-11-7 42 1-Propene, 2-methyl-2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 38 ethvl-1791 000110-54-3 14 Hexane 2.534 0.26 C:\Database\NIST05a.L 6 13053 000106-70-7 90 13052 000106-70-7 83 Hexanoic acid, methyl ester Hexanoic acid, methyl ester 13040 000106-70-7 72 Hexanoic acid, methyl ester 7.394 4.30 C:\Database\NIST05a.L 7 Octanoic acid, methyl ester Octanoic acid, methyl ester 28914 000111-11-5 90 28924 000111-11-5 80 37541 001731-84-6 80 Nonanoic acid, methyl ester 8 16.634 4.06 C:\Database\NIST05a.L Decanoic acid, methyl ester Decanoic acid, methyl ester 47245 000110-42-9 95 47237 000110-42-9 80 57095 001731-86-8 72 Undecanoic acid, methyl ester 20.704 0.02 C:\Database\NIST05a.L 57095 001731-86-8 95 Undecanoic acid, methyl ester Undecanoic acid, methyl ester 57097 001731-86-8 91 57096 001731-86-8 87 Undecanoic acid, methyl ester 10 25.703 26.42 C:\Database\NIST05a.L Dodecanoic acid, methyl ester 67169 000111-82-0 78 Decanoic acid, methyl ester 47245 000110-42-9 52 77300 001731-88-0 47 Tridecanoic acid, methyl ester 11 28.673 0.02 C:\Database\NIST05a.L Tridecanoic acid, methyl ester 77298 001731-88-0 96 DINGFAME.M Thu Jul 28 15:06:48 2011

2

171

· Data Path : D:\Data\KHOO\ Data File : 7N.D : 27 Jul 2011 12:16 Acg On Operator : : 7N Sample Misc 2 ALS Vial : 7 Sample Multiplier: 1 Minimum Quality: 0 Search Libraries: C:\Database\NIST05a.L Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Ref# CAS# Oual Library/ID Pk# RT Areas 77302 001731-88-0 96 Tridecanoic acid, methyl ester Tridecanoic acid, methyl ester 77299 001731-88-0 95 12 32.839 10.93 C:\Database\NIST05a.L 86753 000124-10-7 96 Methyl tetradecanoate 86750 000124-10-7 95 Methyl tetradecanoate 86751 000124-10-7 78 Methyl tetradecanoate 13 35.755 0.01 C:\Database\NIST05a.L Pentadecanoic acid, methyl ester 96271 007132-64-1 81 Methyl tetradecanoate 86750 000124-10-7 72 Methyl tetradecanoate Tridecanoic acid, methyl ester 77302 001731-88-0 70 14 38.179 0.01 C:\Database\NIST05a.L 9-Hexadecenoic acid, methyl ester, 104152 001120-25-8 99 (Z) -7-Hexadecenoic acid, methyl ester, 104151 056875-67-3 74 (2) -9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 49 ster 15 39.397 5.33 C:\Database\NIST05a.L 105644 000112-39-0 96 Hexadecanoic acid, methyl ester 105639 000112-39-0 95 Hexadecanoic acid, methyl ester 105646 000112-39-0 94 Hexadecanoic acid, methyl ester 16 44.001 0.67 C:\Database\NIST05a.L 8,11-Octadecadienoic acid, methyl 121095 056599-58-7 99 ester 10,13-Octadecadienoic acid, methyl 121100 056554-62-2 99 ester 9,12-Octadecadienoic acid (2,2)-, 121106 000112-63-0 99 methyl ester 17 44.514 3.30 C:\Database\NIST05a.L 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -9-Octadecenoic acid (Z)-, methyl e 122323 000112-62-9 99 ster 8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 18 45.358 1.44 C:\Database\NIST05a.L 123709 000112-61-8 99 Octadecanoic acid, methyl ester 123708 000112-61-8 98 Octadecanoic acid, methyl ester 123700 000112-61-8 98 Octadecanoic acid, methyl ester 19 49.919 0.02 C:\Database\NIST05a.L 11-Eicosenoic acid, methyl ester 139171 003946-08-5 99 85349 004727-18-8 52 Cyclopentadecanone, 2-hydroxy-9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 50 ster 20 50.806 0.03 C:\Database\NIST05a.L Elcosanoic acid, methyl ester 140314 001120-28-1 98 Eicosanoic acid, methyl ester 140312 001120-28-1 98 140312 001120-28-1 98

DINGFAME.M Thu Jul 28 15:06:48 2011



Library Search Report Data Path : D:\Data\KHOO\ Data File : 8.D Acg On : 27 Jul 2011 13:24 Operator . : 8 Sample Misc ALS Vial : 8 Sample Multiplier: 1 Minimum Quality: 0 Search Libraries: C:\Database\NIST05a.L Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Ref# CAS# Oual RT Area% Library/ID Pk# 1.070 6.30 C:\Database\NIST05a.L 1427 000592-41-6 40 1-Hexene 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 38 ethvl-Pentane, 2-bromo-23090 000107-81-3 36 1.690 24.95 C:\Database\NIST05a.L 2 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 64 ethyl-60 000075-19-4 53 Cyclopropane 1633 000625-38-7 50 3-Butenoic acid 1.743 2.62 C:\Database\NIST05a.L 3 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 45 ethyl-1791 000110-54-3 22 Hexane 1790 000110-54-3 22 Hexane 1.807 3.46 C:\Database\NIST05a.L 4 184 000115-11-7 42 1-Propene, 2-methyl-2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 36 ethyl-1791 000110-54-3 25 Hexane 1.903 6.16 C:\Database\NIST05a.L 5 184 000115-11-7 53 1-Propene, 2-methyl-2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 36 ethyl-1791 000110-54-3 14 Hexane 2.576 0.24 C:\Database\NIST05a.L 6 13053 000106-70-7 91 Hexanoic acid, methyl ester 13051 000106-70-7 72 Hexanoic acid, methyl ester Hexanoic acid, methyl ester 13052 000106-70-7 72 7.405 4.11 C:\Database\NIST05a.L 7 28914 000111-11-5 90 Octanoic acid, methyl ester Nonanoic acid, methyl ester Octanoic acid, methyl ester 37541 001731-84-6 80 28924 000111-11-5 80 16.623 3.99 C:\Database\NIST05a.L 8 47245 000110-42-9 96 47237 000110-42-9 90 Decanoic acid, methyl ester Decanoic acid, methyl ester Nonanoic acid, methyl ester 37540 001731-84-6 74 20.704 0.02 C:\Database\NIST05a.L 9 57097 001731-86-8 95 Undecanoic acid, methyl ester 57095 001731-86-8 95 Undecanoic acid, methyl ester 57098 001731-86-8 90 Undecanoic acid, methyl ester 10 25.703 26.44 C:\Database\NIST05a.L 67169 000111-82-0 78 Dodecanoic acid, methyl ester 47245 000110-42-9 50 Decanoic acid, methyl ester Undecanoic acid, methyl ester 57098 001731-86-8 47 11 28.672 0.02 C:\Database\NIST05a.L 77298 001731-88-0 96 Tridecanoic acid, methyl ester

DINGFAME.M Thu Jul 28 15:07:10 2011

100

Library Search Report Data Path : D:\Data\KHOO\ Data File : 8.D : 27 Jul 2011 13:24 Acq On Operator . Sample : 8 Misc ALS Vial : 8 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Pk# RT Area& Library/ID Ref# CAS# Qual Tridecanoic acid, methyl ester 77299 001731-88-0 96 77300 001731-88-0 94 Tridecanoic acid, methyl ester 12 32.849 11.17 C:\Database\NIST05a.L Methyl tetradecanoate Methyl tetradecanoate 86750 000124-10-7 95 86753 000124-10-7 94 Tridecanoic acid, 12-methyl-, meth 86778 005129-58-8 93 yl ester 13 35.755 0.01 C:\Database\NIST05a.L Pentadecanoic acid, methyl ester 96272 007132-64-1 95 96259 213617-69-7 93 Methyl 9-methyltetradecanoate 96271 007132-64-1 93 Pentadecanoic acid, methyl ester 14 38.169 0.01 C:\Database\NIST05a.L 9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 81 ster 9-Hexadecenoic acid, methyl ester, 104152 001120-25-8 76 (2) trans-2-methyl-4-n-pentylthiane, S 69543 1000215-75-3 55 ,S-dioxide 15 39.397 5.41 C:\Database\NIST05a.L Hexadecanoic acid, methyl ester 105644 000112-39-0 96 Pentadecanoic acid, 14-methyl-, me 105662 005129-60-2 93 thyl ester Hexadecanoic acid, methyl ester 105646 000112-39-0 93 16 43.990 0.60 C:\Database\NIST05a.L 9,12-Octadecadienoic acid, methyl 121112 002566-97-4 99 ester, (E,E). 9,12-Octadecadienoic acid (Z,Z)-, 121106 000112-63-0 99 methyl ester 10,13-Octadecadienoic acid, methyl 121100 056554-62-2 99 ester 17 44.492 2.97 C:\Database\NIST05a.L 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -9-Octadecenoic acid (Z)-, methyl e 122323 000112-62-9 99 ster 8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 18 45.358 1.48 C:\Database\NIST05a.L Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester 123709 000112-61-8 99 123708 000112-61-8 98 123700 000112-61-8 98 Octadecanoic acid, methyl ester 19 49.919 0.02 C:\Database\NIST05a.L 11-Eicosenoic acid, methyl ester 139171 003946-08-5 99 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 68 (E) -12-Octadecenoic acid, methyl ester 122311 056554-46-2 58 20 50.805 0.03 C:\Database\NIST05a.L Eicosanoic acid, methyl ester 140314 001120-28-1 98 Heptadecanoic acid, methyl ester 114853 001731-92-6 93

Library Search Report Data Path : D:\Data\KHOO\ Data File : 8.D Acq On : 27 Jul 2011 13:24 Operator : Sample : 8 Misc : ALS Vial : 8 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Pk# RT Area% Library/ID Ref# CAS# Qual

Heptadecanoic acid, methyl ester 114851 001731-92-6 92



Search Libraries: C:\Database\NISTO5a.L Minimum Quality: Unknown Spectrum: Integration Events: Apex Library/ID Ref# CAS# Qu 1 1.070 5.97 C:\Database\NISTO5a.L 1427 000552-41-6 4 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 3 2 1.679 26.65 C:\Database\NISTO5a.L 1427 000052-41-6 4 3-Butenoic acid 1633 000625-38-7 3 2 1.679 26.65 C:\Database\NISTO5a.L 11923 002610-95-9 6 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 4 3 1.754 3.84 C:\Database\NISTO5a.L 179 000110-54-3 2 4 1.860 5.42 C:\Database\NISTO5a.L 183 000115-11-7 4 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 3 4 1.860 5.42 C:\Database\NISTO5a.L 183 000115-11-7 5	Op Sa Mi AL	erator mple sc S Vial	:9 :9 :9 Sa	mple Multipli¢	er: 1			
Unknown Spectrum: Apex Integration Events: Chemštation Integrator - autointl.e PK# RT Area% Library/ID Ref# CAS# Qu 1 1.070 5.97 C:\Database\NISTO5a.L 1427 000592-41-6 4 2 1.079 26.56 C:\Database\NISTO5a.L 1427 000592-41-6 4 3 -Butencic acid 1633 000625-38-7 3 2 1.679 26.65 C:\Database\NISTO5a.L 11923 002610-95-9 6 2 -Pryran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 4 3 1.754 3.84 C:\Database\NISTO5a.L 1923 002610-95-9 4 4 1.860 5.42 C:\Database\NISTO5a.L 1923 002610-95-9 3 4 1.860 5.42 C:\Database\NISTO5a.L 193 000110-54-3 2 4 1.860 5.42 C:\Database\NISTO5a.L 194 000110-54-3 2 5 1.903 3.40	Se	arch Li	braries:	C:\Database\	NIST05a.L	Mi	nimum Qualit	y:
Pk# RT Area% Library/ID Ref# CAS# Quadratic 1 1.070 5.97 C:\Database\NIST05a.L 1427 000592-41-6 4 2 1.679 26.65 C:\Database\NIST05a.L 11923 002610-95-9 3 2 1.679 26.65 C:\Database\NIST05a.L 11923 002610-95-9 6 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 4 3 1.754 3.84 C:\Database\NIST05a.L 11923 002610-95-9 4 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 4 4 1.860 5.42 C:\Database\NIST05a.L 1923 002610-95-9 3 1.903	Un In	known S tegrati	pectrum: on Events	Apex : ChemStation	Integrator - au	tointl.e		
1 1.070 5.97 C:\Database\NIST05a.L 1427 000592-41-6 4 1 1-Hexene 1427 000592-41-6 4 2 1.679 26.65 C:\Database\NIST05a.L 1633 00025-38-7 3 2 1.679 26.65 C:\Database\NIST05a.L 11923 002610-95-9 6 2 1.679 26.65 C:\Database\NIST05a.L 11923 002610-95-9 4 3 1.754 3.84 C:\Database\NIST05a.L 11923 002610-95-9 4 3 1.754 3.84 C:\Database\NIST05a.L 11923 002610-95-9 4 4 1.860 5.42 C:\Database\NIST05a.L 11923 002610-95-9 3 4 1.860 5.42 C:\Database\NIST05a.L 193 000115-11-7 4 2 1.903 3.40 C:\Database\NIST05a.L 193 000110-54-3 2 4 1.860 5.42 C:\Database\NIST05a.L 194 000110-54-3 2 4 1.860 5.42 C:\Database\NIST05a.L 194	₽k#	RT	Area%	Library	/ID	Ref#	CAS#	Qual
 1-mexene 2 Herahydro-6,6-dim 11923 002510-95-9 33 2 1.679 26.65 C: Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 64 2 1.679 26.65 C: Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 64 2 1.754 3.84 C: \Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 44 3 1.754 3.84 C: \Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 44 4 1.860 5.42 C: \Database\NIST05a.L 1+Propene, 2-methyl- 193 000110-54-3 24 4 1.860 5.42 C: \Database\NIST05a.L 1+Pryran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 34 4 1.860 5.42 C: \Database\NIST05a.L 1+Pryran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 34 5 1.903 3.40 C: \Database\NIST05a.L 1+Pryran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 34 6 2.576 0.26 C: \Database\NIST05a.L 1+Pryran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 34 6 2.576 0.26 C: \Database\NIST05a.L 1+Pryran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 34 6 2.576 0.26 C: \Database\NIST05a.L 1+Pryran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 34 6 2.576 0.26 C: \Database\NIST05a.L 1+Pryran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 34 6 2.576 0.26 C: \Database\NIST05a.L 1+Pryran-2-0ne, tetrahydro-6,6-dim 11923 002610-95-9 34 6 2.576 0.26 C: \Database\NIST05a.L 1+15 000106-70-7 97 7 4.04 4.19 C: \Database\NIST05a.L 2000111-11-5 90 8 16.612 3.92 C: \Database\NIST05a.L 2Hexanoic acid, methyl ester 28924 000111-11-5 90 8 16.612 3.92 C: \Database\NIST05a.L 2Hexanoic acid, methyl ester 47245 000110-42-9 97 9 20.714 0.02 C: \Database\NIST05a.L 2Hexanoic acid, methyl ester 57097 001731-86-8 91 9 20.714 0.02 C: \Database\NIST05a.L 2Hexanoic acid, methyl ester 57097 001731-86-8 91 10 25.660 25.50 C: \Database\NIST05a.L 2Hexanoic acid, methyl ester 57096 001731-86-8 91	1	1.070	5.97 C:	\Database\NIST	05a.L	1407	000502-41-6	10
ethyl- 3-Butenoic acid 1633 000625-38-7 3 2 1.679 26.65 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 6 ethyl- Cyclopropane 2-Propenoic acid, 2-methyl- 60 000075-19-4 5 3 1.754 3.84 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 4' ethyl- 4 1.860 5.42 C:\Database\NIST05a.L 1-Propene, 2-methyl- 183 000115-11-7 4' 2H-Pyran-2-one, tetrahydro-6,6-dim 4 1.860 5.42 C:\Database\NIST05a.L 1-Propene, 2-methyl- 183 000115-11-7 5' 1990 000110-54-3 2' 5 1.903 3.40 C:\Database\NIST05a.L 1-Porpene, 2-methyl- 184 000115-11-7 5' 2H-Pyran-2-one, tetrahydro-6,6-dim 5 1.903 3.40 C:\Database\NIST05a.L 1-Porpene, 2-methyl- 184 000116-11-7 5' 2H-Pyran-2-one, tetrahydro-6,6-dim 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 9' Hexanoic acid, methyl ester 6 2.576 0.26 C:\Database\NIST05a.L Dctanoic acid, methyl ester 28914 000111-11-5 9' 0Ctanoic acid, methyl ester 7 7.404 4.19 C:\Database\NIST05a.L Dccanoic acid, methyl ester 28914 000111-11-5 9' 0Ctanoic acid, methyl ester 8 16.612 3.92 C:\Database\NIST05a.L Dccanoic acid, methyl ester 47245 000110-42-9 9' Dccanoic acid, methyl ester 9 20.714 0.02 C:\Database\NIST05a.L Dccanoic acid, methyl ester 57095 001731-			2H-	exene Pyran-2-one, t	etrahydro-6,6-d	im 11923	002610-95-9	38
3-Buttenic acid 1633 000023-36-7 5 2 1.679 26.65 C: \Database\NISTO5a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 6 ethyl- Cyclopropane 2-Propenoic acid, 2-methyl- 1657 000079-41-4 4 3 1.754 3.84 C: \Database\NISTO5a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 4 ethyl- Hexane 1791 000110-54-3 2 4 1.860 5.42 C: \Database\NIST05a.L 1-Propene, 2-methyl- Hexane 183 000115-11-7 4 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 3 ethyl- Hexane 1791 000110-54-3 2 5 1.903 3.40 C: \Database\NIST05a.L 1-Propene, 2-methyl- Hexane 184 000115-11-7 5 5 1.903 3.40 C: \Database\NIST05a.L 1-Propene, 2-methyl- Hexane 184 000115-11-7 5 6 2.576 0.26 C: \Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 9 4 Hexanoic acid, methyl ester 13051 000106-70-7 9 7 7.404 4.19 C: \Database\NIST05a.L Octanoic acid, methyl ester 28914 000111-11-5 9 8 16.612 3.92 C: \Database\NIST05a.L Decanoic acid, methyl ester 28924 000111-11-5 9 9 20.714 0.02 C: \Database\NIST05a.L Decanoic acid, methyl ester 7095 001731-86-8 94 9 20.714 0.02 C: \Database\NIST05a.L Decanoic acid, methyl ester			eth	y1-		1622	000625-29-7	22
2 1.679 26.65 C: NDatabase\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim Cyclopropane 11923 002610-95-9 60 3 1.754 3.84 C: NDatabase\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 44 3 1.754 3.84 C: NDatabase\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 44 4 1.860 5.42 C: NDatabase\NIST05a.L 1-Propene, 2-methyl- 4Exane 183 000115-11-7 42 4 1.860 5.42 C: NDatabase\NIST05a.L 1-Propene, 2-methyl- 4Exane 183 000115-11-7 42 5 1.903 3.40 C: NDatabase\NIST05a.L 1-Propene, 2-methyl- 4Exane 184 000115-11-7 52 5 1.903 3.40 C: NDatabase\NIST05a.L 1-Propene, 2-methyl- 4Exanci 184 000110-54-3 14 6 2.576 0.26 C: NDatabase\NIST05a.L 1-Propene, 2-methyl ester 13053 000106-70-7 9 6 2.576 0.26 C: NDatabase\NIST05a.L 1-Propene, 2-methyl ester 13050 000106-70-7 9 7 7.404 4.19 C: NDatabase\NIST05a.L Decancic acid, methyl ester <td></td> <td></td> <td>3-B</td> <td>utenoic acid</td> <td></td> <td>1033</td> <td>000625-36-7</td> <td>22</td>			3-B	utenoic acid		1033	000625-36-7	22
2H-Fyran-2-one, tetranydro-6, 6-dim 11923 002010-93-9 60 000075-19-4 567 000079-41-4 3 1.754 3.84 C:\Database\NIST05a.L 11923 002610-95-9 2H-Pyran-2-one, tetrahydro-6, 6-dim 11923 002610-95-9 4 1.860 5.42 C:\Database\NIST05a.L 1791 000110-54-3 Hexane 1791 000110-54-3 4 1.860 5.42 C:\Database\NIST05a.L 183 000115-11-7 1-Propene, 2-methyl- 183 000115-11-7 2H-Pyran-2-one, tetrahydro-6, 6-dim 11923 002610-95-9 4 1.860 5.42 C:\Database\NIST05a.L 1903 002610-95-9 1-Propene, 2-methyl- 184 000115-11-7 2H-Pyran-2-one, tetrahydro-6, 6-dim 11923 002610-95-9 9 1.903 3.40 C:\Database\NIST05a.L 184 000115-11-7 1-Propene, 2-methyl- 184 000115-11-7 1-Propen, 2-methyl- 184 000110-54-3 1-Hexane 1791 000110-54-3 6 2.576 0.26 C:\Database\NIST05a.L 1923 002610-95-9 Hexanoic acid, methyl ester 13053 000106-70-7 Hexanoic acid, methyl ester 13050 000106-70-7 7 7.404 4.19 C:\Database\NIST05a.L 1000110-11-15 0ctanoic acid, methyl ester 28914 000111-11-5 0ctanoic acid, methyl ester 2	2	1.679	26.65 C:	\Database\NIST	05a.L	m 11022	002610-95-9	64
Cyclopropane 60 000075-19-4 5: 2-Propenoic acid, 2-methyl- 1657 000079-41-4 4: 3 1.754 3.84 C:\Database\NIST05a.L 11923 002610-95-9 4: ethyl- Hexane 11923 002610-95-9 4: ethyl- Hexane 4 1.860 5.42 C:\Database\NIST05a.L 1790 000110-54-3 2: 9: 000110-54-3 2: 000110-54-3 1: 000110-54-3 1: 000110-54-3 1: 000110-54-3 1: 000110-54-3 1: 000110-54-3 1: 000110-70-7 9: Hexanoic acid, methyl ester 13053 000106-70-7 9: Hexanoic acid, methyl ester 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 9: Hexanoic acid, methyl ester 7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 28924 000111-11-5 9: 00110-11-15 9: 00110-12-29 7: Decanoic acid, methyl ester 47245 000110-42-9 9: 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 57095 001731-86-8 9: 001731-86-8 4:			2H-	ryran-2-one, t vl-	etranydro=0,6=d.	11925	002010-35-3	0.4
2-Propendic acid, 2-methyl- 1657 00007944144 3 1.754 3.84 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6, 6-dim Hexane 11923 002610-95-9 4 1.860 5.42 C:\Database\NIST05a.L 1-Propene, 2-methyl- 1791 000110-54-3 4 1.860 5.42 C:\Database\NIST05a.L 1-Propene, 2-methyl- 183 000115-11-7 5 1.903 3.40 C:\Database\NIST05a.L 1-Propene, 2-methyl- 184 000115-11-7 5 1.903 3.40 C:\Database\NIST05a.L 1-Propene, 2-methyl- 184 000115-11-7 2H-Pyran-2-one, tetrahydro-6, 6-dim 11923 002610-95-9 30 ethyl- Hexane 1791 000110-54-3 17 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13040 000106-70-7 7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 28914 000111-11-5 8 16.612 3.92 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 47245 000110-42-9 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 57095 0			Cyc	lopropane	0	60	000075-19-4	53
3 1.754 3.84 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl- Hexane 11923 002610-95-9 43 ethyl- Hexane 4 1.860 5.42 C:\Database\NIST05a.L 1-Propene, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl- Hexane 183 000115-11-7 43 1923 002610-95-9 33 ethyl- Hexane 5 1.903 3.40 C:\Database\NIST05a.L 1-Propene, 2-methyl- Hexane 184 000115-11-7 53 11923 002610-95-9 33 ethyl- Hexane 5 1.903 3.40 C:\Database\NIST05a.L 1-Propene, 2-methyl- Hexane 184 000115-11-7 53 11923 002610-95-9 33 ethyl- Hexane 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 93 Hexanoic acid, methyl ester 7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 13040 000110-11-5 96 00ctanoic acid, methyl ester 8 16.612 3.92 C:\Database\NIST05a.L Decanoic acid, methyl ester 28924 000111-11-5 86 00ctanoic acid, methyl ester 9 20.714 0.02 C:\Database\NIST05a.L Decanoic acid, methyl ester 57095 001731-86-8 96 Undecanoic acid, methyl ester 9 20.714 0.02 C:\Database\NIST05a.L Decanoic acid, methyl ester 57095 001731-86-8 96 Undecanoic acid, methyl ester 57096 001731-86-8 96 Undecanoic acid, methyl ester 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 37540 001731-86-8 97 Undecanoic acid, methyl es			2-P	ropenoic acid,	2-methy1-	1001	0000/9-41-4	47
2H-Pyran-2-one, tetranydro-6, 6-dim 11923 002610-95-9 4 ethyl- Hexane Hexane 1791 000110-54-3 2 4 1.860 5.42 C:\Database\NIST05a.L 1-Propene, 2-methyl- 183 000115-11-7 4 2H-Pyran-2-one, tetrahydro-6, 6-dim 11923 002610-95-9 3 ethyl- 11923 002610-95-9 3 ethyl- 184 000115-11-7 4 Hexane 1791 000110-54-3 2 5 1.903 3.40 C:\Database\NIST05a.L 1-Propene, 2-methyl- 184 000115-11-7 5 2H-Pyran-2-one, tetrahydro-6, 6-dim 11923 002610-95-9 3 ethyl- Hexane Hexane 1791 000110-54-3 2 5 1.903 3.40 C:\Database\NIST05a.L 1-Propene, 2-methyl- 184 000115-11-7 5 2H-Pyran-2-one, tetrahydro-6, 6-dim 11923 002610-95-9 3 ethyl- Hexanoi 11923 002610-95-9 3 Hexanoi 21-14 Hexanoi 11923 002610-95-9 3 ethyl- Hexanoi 13053 000106-70-7 9 Hexanoi C:\Database\NIST05a.L 1000110-54-3 2 Octanoic acid, methyl ester 13051 000106-70-7 8 Hexanoic acid, methyl ester	3	1.754	3.84 C:	\Database\NIST	05a.L	11003	000000 05 0	AE
Hexane 1791 000110-54-3 22 4 1.860 5.42 C:\Database\NIST05a.L 1 -Propene, 2-methyl- 183 000115-11-7 42 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 33 ethyl- 11923 002610-95-9 33 ethyl- 184 000115-11-7 42 Hexane 1791 000110-54-3 22 5 1.903 3.40 C:\Database\NIST05a.L 1-Propene, 2-methyl- 184 000115-11-7 52 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 33 ethyl- 184 000110-54-3 14 Hexane 1791 000110-54-3 14 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 97 Hexanoic acid, methyl ester 13051 000106-70-7 87 Hexanoic acid, methyl ester 13051 000106-70-7 87 Hexanoic acid, methyl ester 28914 000111-11-5 90 Octanoic acid, methyl ester 28914 000111-11-5 92 Octanoic acid, methyl ester 28923 000111-11-5 80 8 16.612 3.92 C:\Database\NIST05a.L 28914 000111-11-5 92 Decanoic acid, methyl ester 47245 000110-42-9 97 Decanoic acid, methyl ester 57095 001731-86-8 94			2H-1 eth:	Pyran-2-one, t vl-	etrahydro-6,6-d	LM 11923	002610-95-9	40
Hexane 1790 000110-54-3 2.4 4 1.860 5.42 C:\Database\NIST05a.L 183 000115-11-7 4.2 1-Propene, 2-methyl- 11923 002610-95-9 3.3 11923 002610-95-9 3.3 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 3.3 5 1.903 3.40 C:\Database\NIST05a.L 184 000115-11-7 5.2 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 3.4 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 3.4 ethyl- 184 000115-11-7 5.2 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 3.4 ethyl- 11923 002610-95-9 3.4 Hexane 1791 000110-54-3 1.4 B 0.26 C:\Database\NIST05a.L 184 000115-11-7 6.7 Hexanoic acid, methyl ester 13053 000106-70-7 9.7 Hexanoic acid, methyl ester 13051 000106-70-7 8.7 Hexanoic acid, methyl ester 13051 000106-70-7 8.7 Nexanoic acid, methyl ester 28914 000111-11-5 8.0 Octanoic acid, methyl ester 28924 000111-11-5 8.0 Octanoic acid, methyl ester 47245 000110-42-9 9.4 Decanoic acid, methyl ester 47245 000110-42-9 9.4 Decanoic acid, methyl ester 57095 001731-86-8.94			Hex	ane		1791	000110-54-3	22
 4 1.860 5.42 C:\Database\NIST05a.L 1-Propene, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl- Hexane 1923 002610-95-9 33 ethyl- Hexane 1903 3.40 C:\Database\NIST05a.L 1-Propene, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl- Hexane 1923 002610-95-9 33 ethyl- Hexane 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 97 Hexanoic acid, methyl ester 13053 000106-70-7 97 Hexanoic acid, methyl ester 13053 000106-70-7 97 Hexanoic acid, methyl ester 13051 000106-70-7 87 Hexanoic acid, methyl ester 2.576 0.26 C:\Database\NIST05a.L Octanoic acid, methyl ester 2.576 0.26 C:\Database\NIST05a.L 0ctanoic acid, methyl ester 3040 000106-70-7 87 Hexanoic acid, methyl ester 2.576 0.26 C:\Database\NIST05a.L 0ctanoic acid, methyl ester 2.576 0.26 C:\Database\NIST05a.L Decanoic acid, methyl ester 2.576 0.27 C:\Database\NIST05a.L Decanoic acid, methyl ester 2.576 0.27 C:\Database\NIST05a.L Undecanoic acid, methyl ester 2.5 660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 25.66			Hexa	ane		1790	000110-54-3	22
1-Propene, 2-methyl- 183 000115-11-7 4: 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 33 ethyl- Hexane 1-Propene, 2-methyl- 1-Propene, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim 1923 002610-95-9 33 ethyl- Hexane 1-Propene, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim interpreter ethyl- Hexane 1923 002610-95-9 33 ethyl- Hexane 1923 002610-95-9 34 ethyl- Hexane 1923 002610-95-9 34 Hexane 1920 000110-54-3 14 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13050 000106-70-7 8' Hexanoic acid, methyl ester 28914 000111-11-5 9' Octanoic acid, methyl ester 28923 000111-11-5 8' Octanoic acid, methyl ester 28924 000111-11-5 8' Octanoic acid, methyl ester 47245 000110-42-9 9' Decanoic acid, methyl ester 47245 000110-42-9 9' Decanoic acid, methyl ester 57095 001731-86-8	4	1.860	5.42 C:	\Database\NIST	05a.L			
21.971an 2-016, Certainful 0.0,0 clim 11920 control 0.0 0.0 0.0 ethyl- 1791 000110-54-3 23 1.903 3.40 C:\Database\NIST05a.L 184 000115-11-7 55 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 33 ethyl- 184 000115-11-7 55 Hexane 1791 000110-54-3 14 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 97 Hexanoic acid, methyl ester 13051 000106-70-7 87 7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 28914 000111-11-5 97 Octanoic acid, methyl ester 28923 000111-11-5 87 Octanoic acid, methyl ester 28924 000111-11-5 87 Octanoic acid, methyl ester 28924 000111-11-5 87 Octanoic acid, methyl ester 47245 000110-42-9 97 Decanoic acid, methyl ester 47246 000110-42-9 97 Decanoic acid, methyl ester 57095 001731-86-8 94 Undecanoic acid, methyl ester 57095 001731-86-8 94 Undecanoic acid, methyl ester 57098 001731-86-8 94 Undecanoic acid, methyl ester 37540 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L 47245			1-P:	ropene, 2-meth	yl- etrabydro-6.6-di	183 m 11923	000115-11-7	42
Hexane 1791 000110-54-3 25 5 1.903 3.40 C:\Database\NIST05a.L 1-Propene, 2-methyl- 184 000115-11-7 55 2H-Pyran-2-one, tetrahydro-6, 6-dim 11923 002610-95-9 36 ethyl- 11923 002610-95-9 36 Hexane 1791 000110-54-3 14 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 97 Hexanoic acid, methyl ester 13040 000106-70-7 87 7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 28914 000111-11-5 96 Octanoic acid, methyl ester 28924 000111-11-5 86 0ctanoic acid, methyl ester 28924 000111-11-5 86 0ctanoic acid, methyl ester 47245 000110-42-9 96 Decanoic acid, methyl ester 47246 000110-42-9 97 Decanoic acid, methyl ester 47246 000110-42-9 76 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 57095 001731-86-8 94 Undecanoic acid, methyl ester 57097 001731-86-8 94 Undecanoic acid, methyl ester 57096 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L 74245 000110-42-9 56 <t< td=""><td></td><td></td><td>ethy</td><td>yl-</td><td>ecranydro-o, o-d.</td><td>11 11020</td><td>002010 55 5</td><td>00</td></t<>			ethy	yl-	ecranydro-o, o-d.	11 11020	002010 55 5	00
5 1.903 3.40 C:\Database\NIST05a.L 184 000115-11-7 5: 1-Propene, 2-methyl- 11923 002610-95-9 3: 2H-Pyran-2-one, tetrahydro-6, 6-dim 11923 002610-95-9 3: ethyl- Hexane 1791 000110-54-3 1- 6 2.576 0.26 C:\Database\NIST05a.L 13053 000106-70-7 9: Hexanoic acid, methyl ester 13040 000106-70-7 9: 13040 000106-70-7 9: Hexanoic acid, methyl ester 13051 000106-70-7 9: 13051 000106-70-7 9: 7 7.404 4.19 C:\Database\NIST05a.L 28914 000111-11-5 9: Octanoic acid, methyl ester 28914 000111-11-5 8: 0ctanoic acid, methyl ester 8 16.612 3.92 C:\Database\NIST05a.L 28924 000111-11-5 8: 0ctanoic acid, methyl ester 47245 000110-42-9 9: 0ctanoic acid, methyl ester 9 20.714 0.02 C:\Database\NIST05a.L 7095 001731-86-8 9: 9 20.714 0.02 C:\Database\NIST05a.L 57095 001731-86-8 9: 9 20.714 0.02 C:\Database\NIST05a.L 57098 001731-86-8 9: 10 25.660 25.50 C:\Database\NIST05a.L 57098 001731-86-8 9: 11 28.662 0.02 C:\Database\NIST05a.L 37540 001731-86-8 9: <td></td> <td></td> <td>Hexa</td> <td>ane</td> <td></td> <td>1791</td> <td>000110-54-3</td> <td>25</td>			Hexa	ane		1791	000110-54-3	25
1-Propene, 2-methyl- 184 000115-11-7 5: 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 30 ethyl- Hexane 11923 002610-95-9 30 11923 002610-95-9 30 ethyl- Hexane 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 97 Hexanoic acid, methyl ester 7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 28914 000111-11-5 90 Octanoic acid, methyl ester 8 16.612 3.92 C:\Database\NIST05a.L Decanoic acid, methyl ester 28924 000111-11-5 80 00110-42-9 90 Decanoic acid, methyl ester 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 47245 000110-42-9 90 47246 000110-42-9 70 Decanoic acid, methyl ester 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 57095 001731-86-8 90 Undecanoic acid, methyl ester 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 57098 001731-86-8 91 Undecanoic acid, methyl ester 10 25.660 25.50 C:\Database\NIST05a.L Undecanoic acid, methyl ester 37540 00110-42-9 50 Nonanoic acid, methyl ester 10 25.660 25.50 C:\Database\NIST05a.L Undecanoic acid, methyl ester 57098 001731-86-8 91 Undecanoic acid, methyl ester 11 28 662 0 02 C:\Database\NIST05a.L 57098 001731-86-8 45	5	1.903	3.40 C:	\Database\NIST	05a.L	227	2012920 CO 1	11
athyl- Hexane 1791 000110-54-3 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 9 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 000106-70-7 9 20.714 0.12 C:\Database\NIST05a.L Decanoic acid, methyl ester 28914 000111-11-5 9 20.714 0.02 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 57095 001731-86-8 9 20.714 0.02 C:\Database\NIST05a.L Decanoic acid, methyl ester 57095 001731-86-8 9 20.714 0.02 C:\Database\NIST05a.L Decanoic acid, methyl ester 57095 001731-86-8 9 20.714 0.02 C:\Database\NIST05a.L Decanoic acid, methyl ester 57098 001731-86-8 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 37540 00110-42-9 10 25.662 0.02 C:\Database\NIST05a.L Decanoic acid, methyl ester 37540 001731-86-8 11 28 662 0.02 C:\Database\NIST05a.L 37540 001731-86-8			1-P:	copene, 2-meth	yl- etrahydro-6.6-di	m 11923	000115-11-7	53
Hexane 1791 000110-54-3 14 6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester Hexanoic acid, methyl ester 13053 000106-70-7 9' 13040 000106-70-7 8' 13040 000106-70-7 8' 13051 000106-70-7 8' 13051 000106-70-7 8' 7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 28914 000111-11-5 9' 28923 000111-11-5 8' 0ctanoic acid, methyl ester 8 16.612 3.92 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 9' 47246 000110-42-9 7' Decanoic acid, methyl ester 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 57095 001731-86-8 9' 57097 001731-86-8 9' 57098 001731-86-8 9' 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 5' 37540 001731-86-8 9' 57098 001731-86-8 9' 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 11 28 662 0.02 C:\Database\NIST05a.L			ethy	yl-	ecranyaro of o a			
6 2.576 0.26 C:\Database\NIST05a.L Hexanoic acid, methyl ester Hexanoic acid, methyl ester 13053 000106-70-7 9' 13040 000106-70-7 8' 13051 000110-11-5 8' 13051 000110-12-9 9' 13051 000110-42-9 9' 47245 000110-42-9 7' 47245 000110-42-9 7' 47245 0001731-86-8 9' 14062anoic acid, methyl ester Nonanoic acid, methyl ester			Hexa	ane		1791	000110-54-3	14
Hexanoic acid, methyl ester 13053 000106-70-7 9' Hexanoic acid, methyl ester 13040 000106-70-7 8' 7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 28914 000111-11-5 9' Octanoic acid, methyl ester 28923 000111-11-5 8' Octanoic acid, methyl ester 28924 000111-11-5 8' 0ctanoic acid, methyl ester 28924 000111-11-5 8' 0ctanoic acid, methyl ester 47245 000110-42-9 9' Decanoic acid, methyl ester 47246 000110-42-9 9' Decanoic acid, methyl ester 47246 000110-42-9 7' Decanoic acid, methyl ester 47246 000110-42-9 7' Decanoic acid, methyl ester 47246 000110-42-9 7' Decanoic acid, methyl ester 57095 001731-86-8 9' Undecanoic acid, methyl ester 57095 001731-86-8 9' Undecanoic acid, methyl ester 57098 001731-86-8 9' 10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 5' Decanoic acid, methyl ester 37540 001731-86-8 9' Undecanoic acid, methyl ester 57098 001731-86-8 9' Undecanoic acid, methyl ester 57098 001731-86-8 9' Undecanoic acid, methyl ester 57098 001731-86-8 9' Undecanoic acid, me	6	2.576	0.26 C:	\Database\NIST	05a.L	0.0000000000		0012020
 Hexanoic acid, methyl ester 7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 11 28 662 0.02 C:\Database\NIST05a.L 			Hexa	anoic acid, me	thyl ester	13053	000106-70-7	97 87
7 7.404 4.19 C:\Database\NIST05a.L Octanoic acid, methyl ester 28914 000111-11-5 90 28923 000111-11-5 80 28924 000111-11-5 80 28924 000111-11-5 80 8 16.612 3.92 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 90 47246 000110-42-9 90 47246 000110-42-9 70 47226 024323-23-7 66 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester Undecanoic acid, methyl ester 57095 001731-86-8 90 57097 001731-86-8 90 57098 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 50 57098 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 50 57098 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 50 37540 001731-86-8 91 11 28 662 0.02 C:\Database\NIST05a.L 57098 001731-86-8 45			Hexa	anoic acid, me	thyl ester	13051	000106-70-7	87
7 7.404 4.19 Cr(h)atabase(NISTOSath) 28914 000111-11-5 90 Octanoic acid, methyl ester 28923 000111-11-5 80 0 Ctanoic acid, methyl ester 28924 000111-11-5 80 8 16.612 3.92 C:\Database\NISTO5a.L 28924 000111-11-5 80 Decanoic acid, methyl ester 47245 000110-42-9 90 Decanoic acid, methyl ester 47246 000110-42-9 90 Undecanoic acid, methyl ester 57095 001731-86-8 90 Undecanoic acid, methyl ester 57098 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 Decanoic acid, methyl ester 37540 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 Decanoic acid, methyl ester 37540 001731-86-8 45 Undecanoic acid, methyl ester 57098 001731-86-8 45 11 28 662 0.02 C:\Database\NIST05a.L		7 404	4 10 0.1	Databaga NTCT	05a t			
Octanoic acid, methyl ester Octanoic acid, methyl ester 28923 000111-11-5 8: 28924 000110-42-9 9: 47245 000110-42-9 9: 57095 001731-86-8 9: 57098 001731-86-8 9: 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester Nonanoic acid, methyl ester Undecanoic acid, methyl ester Undecanoic acid, methyl ester S7098 001731-86-8 4: 57098 00173	2	1.404	Q.19 C.	anoic acid, me	thyl ester	28914	000111-11-5	90
8 16.612 3.92 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 96 Decanoic acid, methyl ester 47246 000110-42-9 96 Decanoic acid, methyl ester 47226 024323-23-7 68 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 57095 001731-86-8 96 Undecanoic acid, methyl ester 57098 001731-86-8 96 Undecanoic acid, methyl ester 37540 00110-42-9 50 10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 Decanoic acid, methyl ester 37540 001731-86-8 47 Undecanoic acid, methyl ester 57098 001731-86-8 47 11 28 662 0 02 C:\Database\NIST05a.L			Octa	anoic acid, me	thyl ester	28923	000111-11-5	83
8 16.612 3.92 C:\Database\NIST05a.L Decanoic acid, methyl ester Decanoic acid, methyl ester Decanoic acid, 2-methyl- 47245 000110-42-9 96 47246 000110-42-9 76 47226 024323-23-7 66 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester Undecanoic acid, methyl ester Undecanoic acid, methyl ester Undecanoic acid, methyl ester 57095 001731-86-8 96 57097 001731-86-8 96 57098 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester Nonanoic acid, methyl ester 47245 000110-42-9 56 57098 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 56 37540 001731-86-8 91 10 25.660 25.00 C:\Database\NIST05a.L Decanoic acid, methyl ester 57098 001731-86-8 45 11 28 662 0.02 C:\Database\NIST05a.L 57098 001731-86-8 45			Octa	inoic acid, me	thyi ester	20324	000111-11-5	
Decanoic acid, methyl ester 47245 000110-42-9 70 Decanoic acid, 2-methyl- 47246 000110-42-9 70 9 20.714 0.02 C:\Database\NIST05a.L Undecanoic acid, methyl ester 57095 001731-86-8 96 Undecanoic acid, methyl ester 57097 001731-86-8 96 Undecanoic acid, methyl ester 57098 001731-86-8 96 Undecanoic acid, methyl ester 57098 001731-86-8 96 Undecanoic acid, methyl ester 57098 001731-86-8 96 Undecanoic acid, methyl ester 47245 000110-42-9 50 10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 Decanoic acid, methyl ester 37540 001731-86-8 45 Undecanoic acid, methyl ester 57098 001731-86-8 45	8	16.612	3.92 C:	\Database\NIST	05a.L	47245	000110-42-9	96
Decanoic acid, 2-methyl- 47226 024323-23-7 68 9 20.714 0.02 C:\Database\NIST05a.L 57095 001731-86-8 96 Undecanoic acid, methyl ester 57097 001731-86-8 96 Undecanoic acid, methyl ester 57098 001731-86-8 96 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 56 Nonanoic acid, methyl ester 37540 001731-86-8 47 Undecanoic acid, methyl ester 57098 001731-86-8 47 11 28 662 0.02 C:\Database\NIST05a.L			Deca	anoic acid, me	thyl ester	47246	000110-42-9	70
9 20.714 0.02 C:\Database\NIST05a.L 57095 001731-86-8 94 Undecanoic acid, methyl ester 57095 001731-86-8 94 Undecanoic acid, methyl ester 57098 001731-86-8 94 Undecanoic acid, methyl ester 57098 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 10 25.660 25.00 C:\Database\NIST05a.L 57098 001731-86-8 47 11 28 662 0.02 C:\Database\NIST05a.L 57098 001731-86-8 47			Deca	anoic acid, 2-	methyl-	47226	024323-23-7	68
Undecanoic acid, methyl ester 57095 001731-86-8 96 Undecanoic acid, methyl ester 57097 001731-86-8 96 Undecanoic acid, methyl ester 57098 001731-86-8 96 Undecanoic acid, methyl ester 57098 001731-86-8 96 10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 Decanoic acid, methyl ester 37540 001731-86-8 45 Undecanoic acid, methyl ester 57098 001731-86-8 45	9	20 714	0.02 C+	Database\NIST	05a.L			
Undecanoic acid, methyl ester 57097 001731-86-8 94 Undecanoic acid, methyl ester 57098 001731-86-8 91 10 25.660 25.50 C:\Database\NIST05a.L Decanoic acid, methyl ester 47245 000110-42-9 50 Nonanoic acid, methyl ester 37540 001731-84-6 49 Undecanoic acid, methyl ester 57098 001731-86-8 47 11 28 662 0 02 C:\Database\NIST05a.L	્ય	20.714	Unde	acanoic acid,	methyl ester	57095	001731-86-8	96
10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 10 Decanoic acid, methyl ester 47245 000110-42-9 50 10 Nonanoic acid, methyl ester 37540 001731-84-6 45 11 28 662 0 02 C:\Database\NIST05a.L			Unde	acanoic acid, a	methyl ester methyl ester	57097	001/31-86-8	94
10 25.660 25.50 C:\Database\NIST05a.L 47245 000110-42-9 50 Decanoic acid, methyl ester 37540 001731-84-6 45 Undecanoic acid, methyl ester 57098 001731-86-8 47 11 28 662 0 02 C:\Database\NIST05a.L			01106	sequere geral	mornja over			
Nonanoic acid, methyl ester 37540 001731-84-6 49 Undecanoic acid, methyl ester 57098 001731-86-8 47	10	25.660	25.50 C:	Database\NIST	05a.L	47245	000110-42-9	50
Undecanoic acid, methyl ester 57098 001731-86-8 47			Nona	anoic acid, me	thyl ester	37540	001731-84-6	49
11 28 662 0 02 C·\Database\NIST05a.L			Unde	canoic acid,	methyl ester	57098	001731-86-8	47
	11	28.662	0.02 C:\	Database\NIST	05a.L			

Data Path : D:\Data\KHOO\ (22)Data File : 9.D Acq On : 27 Jul 2011 14:31 Operator . : 9 Sample Misc ALS Vial : 9 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e CAS# Ref# Oual Library/ID Pk# RT Area% 77300 001731-88-0 94 Tridecanoic acid, methyl ester 77297 001731-88-0 93 Tridecanoic acid, methyl ester 12 32.806 10.46 C:\Database\NIST05a.L 86750 000124-10-7 96 Methyl tetradecanoate 86753 000124-10-7 96 Methyl tetradecanoate 86752 000124-10-7 94 Methyl tetradecanoate 13 35.744 0.01 C:\Database\NIST05a.L Pentadecanoic acid, methyl ester 96270 007132-64-1 98 96259 213617-69-7 89 Methyl 9-methyltetradecanoate 96272 007132-64-1 87 Pentadecanoic acid, methyl ester 14 38.168 0.01 C:\Database\NIST05a.L 9-Hexadecenoic acid, methyl ester, 104152 001120-25-8 98 (Z) -7-Hexadecenoic acid, methyl ester, 104151 056875-67-3 86 (2) -9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 64 ster 15 39.376 5.13 C:\Database\NIST05a.L Hexadecanoic acid, methyl ester 105639 000112-39-0 98 Pentadecanoic acid, 14-methyl-, me 105662 005129-60-2 96 thyl ester Hexadecanoic acid, methyl ester 105644 000112-39-0 96 16 43.990 0.64 C:\Database\NIST05a.L 10,13-Octadecadienoic acid, methyl 121100 056554-62-2 99 ester 8,11-Octadecadienoic acid, methyl 121095 056599-58-7 99 ester 9,12-Octadecadienoic acid, methyl 121113 002566-97-4 99 ester, (E,E)-17 44.492 3.12 C:\Database\NIST05a.L 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E)-8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 9-Octadecenoic acid (Z)-, methyl e 122323 000112-62-9 99 ster 123709 000112-61-8 99 18 45.347 1.41 C:\Database\NIST05a.L
 Octadecanoic acid, methyl ester
 123709 000112-61-8 99

 Octadecanoic acid, methyl ester
 123708 000112-61-8 98

 Octadecanoic acid, methyl ester
 123700 000112-61-8 98

 Octadecanoic acid, methyl ester
 123700 000112-61-8 98
 49.919 0.02 C:\Database\NIST05a.L 19 11-Eicosenoic acid, methyl ester 139171 003946-08-5 86 9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 58 ster 13-Octadecenoic acid, methyl ester 122313 056554-47-3 55 20 50.805 0.03 C:\Database\NIST05a.L 140314 001120-28-1 98 Eicosanoic acid, methyl ester 140312 001120-28-1 96 Eicosanoic acid, methyl ester Eicosanoic acid, methyl ester 140313 001120-28-1 96 DINGFAME.M Thu Jul 28 15:07:39 2011

179

		Library Searc	sh Report	
94	Data Path : D:\Da Data File : 9.D Acq On : 27 Ju Operator : Sample : 9 Misc : ALS Vial : 9 S	ata\KHOO\ 1 2011 14:31 Sample Multiplier: 1		
	Search Libraries:	C:\Database\NIST05a.L	Minimu	m Quality: 0
	Unknown Spectrum: Integration Event	Apex s: ChemStation Integrator - au	itointl.e	
	Pk# RT Area%	Library/ID	Ref#	CAS# Qual



Data Path : D:\Data\KHOO\ Data File : 10.D : 27 Jul 2011 15:38 ALS Vial : 10 Sample Multiplier: 1 Minimum Quality: 0 Search Libraries: C:\Database\NIST05a.L Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e CAS# Qual Ref# Library/ID RT Area% 1.081 6.50 C:\Database\NIST05a.L 60 000075-19-4 53 Cyclopropane 2-Propenoic acid, 2-methyl-1658 000079-41-4 50 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 50 ethyl-2 1.690 27.24 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 002610-95-9 64 ethyl-60 000075-19-4 53 Cyclopropane 2-Propenoic acid, 2-methyl-1658 000079-41-4 50

Library Search Report

1.828	9.22 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim	11923	002610-95-9	36
	ethy1-	1791	000110-54-3	18
	Aziridine, 2-ethyl-	598	002549-67-9	14
1.903	4.07 C:\Database\NIST05a.L			50
	1-Propene, 2-methyl-	184	000115-11-7	50
	2H-Pyran-2-one, tetrahydro-6,6-dim	11923	002610-95-9	39
	Hexane	1791	000110-54-3	14
2.544	0.25 C:\Database\NIST05a.L			
	Hexanoic acid, methyl ester	13053	000106-70-7	91
	Hexanoic acid, methyl ester	13051	000106-70-7	91
	Hexanoic acid, methyl ester	13052	000106-70-7	83
7.394	4.05 C:\Database\NIST05a.L	00014	000111 11 5	00
	1.828 1.903 2.544 7.394	 1.828 9.22 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl- Hexane Aziridine, 2-ethyl- 1.903 4.07 C:\Database\NIST05a.L 1-Propene, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl- Hexane 2.544 0.25 C:\Database\NIST05a.L Hexanoic acid, methyl ester Hexanoic acid, methyl ester Hexanoic acid, methyl ester 7.394 4.05 C:\Database\NIST05a.L 	<pre>1.828 9.22 C:\Database\NIST05a.L 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 ethyl- Hexane 1791 Aziridine, 2-ethyl- 598 1.903 4.07 C:\Database\NIST05a.L 1-Propene, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim 11923 ethyl- Hexane 1791 2.544 0.25 C:\Database\NIST05a.L Hexanoic acid, methyl ester 13053 Hexanoic acid, methyl ester 13051 Hexanoic acid, methyl ester 13052 7.394 4.05 C:\Database\NIST05a.L</pre>	 1.828 9.22 C: \Database \NISTO5a.L 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl- Hexane Aziridine, 2-ethyl- 1.903 4.07 C: \Database \NISTO5a.L 1-Propene, 2-methyl- 2H-Pyran-2-one, tetrahydro-6,6-dim ethyl- Hexane 2.544 0.25 C: \Database \NISTO5a.L Hexanoic acid, methyl ester Hexanoic acid, methyl ester Hexanoic acid, methyl ester Hexanoic acid, methyl ester 13053 000106-70-7 Hexanoic acid, methyl ester 13052 000106-70-7 7.394 4.05 C: \Database \NISTO5a.L

0	1.394	Octanoic acid, methyl ester Nonanoic acid, methyl ester Octanoic acid, methyl ester	28914 000111-11-5 90 37541 001731-84-6 80 28925 000111-11-5 74
7	16.591	3.67 C:\Database\NIST05a.L	47245 000110-42-9 96

80	10.001	Decanoic acid, Nonanoic acid,	methyl ester methyl ester	47245 37542	000110-42-9 001731-84-6	96
		Decanoic acid,	methyl ester	47246	000110-42-9	70
-20	101010-0100		TOTOS - I			

- 8 20.703 0.01 C:\Database\NIST05a.L 57095 001731-86-8 94 57097 001731-86-8 91 Undecanoic acid, methyl ester Undecanoic acid, methyl ester Undecanoic acid, 2-methyl-57076 024323-25-9 87
- 9 25.628 24.70 C:\Database\NIST05a.L Decanoic acid, methyl ester Nonanoic acid, methyl ester Undecanoic acid, methyl ester
- 10 28.662 0.02 C:\Database\NIST05a.L 77299 001731-88-0 96 Tridecanoic acid, methyl ester 77298 001731-88-0 96 Tridecanoic acid, methyl ester 77297 001731-88-0 95 Tridecanoic acid, methyl ester 11 32.806 10.39 C:\Database\NIST05a.L 86750 000124-10-7 97
- Methyl tetradecanoate Methyl tetradecanoate

DINGFAME.M Thu Jul 28 15:08:44 2011

-

Acq On Operator

Sample Misc

P¥#

1

1 : 10

47245 000110-42-9 50 37540 001731-84-6 49

57098 001731-86-8 47

86753 000124-10-7 97

Data Path : D:\Data\KHOO\ Data File : 10.D Acq On : 27 Jul 2011 15:38 Operator . Sample : 10 Misc ALS Vial : 10 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Quality: 0 Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autointl.e Pk# RT Area& Library/ID Ref# CAS# Onal Methyl tetradecanoate 86752 000124-10-7 94 12 35.744 0.01 C:\Database\NIST05a.L Pentadecanoic acid, methyl ester 96272 007132-64-1 94 Pentadecanoic acid, methyl ester 96271 007132-64-1 93 Methyl 9-methyltetradecanoate 96259 213617-69-7 93 13 38.169 0.01 C:\Database\NIST05a.L 9-Hexadecenoic acid, methyl ester, 104152 001120-25-8 91 (Z) · 9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 76 ster Cyclopropaneoctanoic acid, 2-hexyl 113415 010152-61-1 50 -, methyl ester 14 39.365 4.91 C:\Database\NIST05a.L Hexadecanoic acid, methyl ester Hexadecanoic acid, methyl ester 105644 000112-39-0 95 105646 000112-39-0 94 Pentadecanoic acid, 14-methyl-, me 105662 005129-60-2 92 thyl ester 15 43.990 0.61 C:\Database\NIST05a.L 9,12-Octadecadienoic acid (2,2)-, 121106 000112-63-0 99 methyl ester 9,12-Octadecadienoic acid, methyl 121112 002566-97-4 99 ester, (E,E)-11,14-Octadecadienoic acid, methyl 121099 056554-61-1 99 ester 16 44.471 2.88 C:\Database\NIST05a.L 9-Octadecenoic acid, methyl ester, 122326 001937-62-8 99 (E) -8-Octadecenoic acid, methyl ester 122297 002345-29-1 99 9-Octadecenoic acid (2)-, methyl e 122323 000112-62-9 99 ster 17 45.336 1.40 C:\Database\NIST05a.L 123709 000112-61-8 99 123708 000112-61-8 98 Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester Octadecanoic acid, methyl ester 123700 000112-61-8 98 18 47.782 0.01 C:\Database\NIST05a.L 1-(2-Fluoro-4-nitro-phenyl)-2-meth 83508 1000278-20-9 25 yl-piperidine Ethanol, 2-[2-[4-(1,1,3,3-tetramet 121000 002315-61-9 18 hylbutyl)phenoxy]ethoxy]-2-(3-Methylphenyl)isoindole-1,3-di 83159 1000308-99-7 14 one 19 49.919 0.01 C:\Database\NIST05a.L 11-Eicosenoic acid, methyl ester 139171 003946-08-5 99 9-Octadecenoic acid (Z)-, methyl e 122321 000112-62-9 62 ster 7-Hexadecenoic acid, methyl ester, 104151 056875-67-3 50 (2) -20 50.805 0.03 C:\Database\NIST05a.L

DINGFAME.M Thu Jul 28 15:08:44 2011

183

Integratic	n Ev	rents	: Cher	mStation	n Integrato	r - auto	pintl.e		
Unknown Sp	ecti	: mu	Ape:	x					
Search Lib	orari	es:	C:\	Database	e\NIST05a.L		Mini	mum Qual	ity:
ALS Vial	; 10) Si	ample	Multip.	lier: 1				
Misc	:								
Sample	: 10	2							
Operator	:		- 744 (3-54	S STREET					
Acg On	: 2	7 Jul	2011	15:38					
Data File	: 10	D. D							
Data Path	; D	:\Dat	а\кно	201					
					Library	Search	Report		
	Data Path Data File Acq On Operator Sample Misc ALS Vial Search Lift Unknown Sp Integratic	Data Path : D Data File : 10 Acq On : 2 Operator : Sample : 10 Misc : ALS Vial : 10 Search Librari Unknown Spectr	Data Path : D:\Dat Data File : 10.D Acq On : 27 Jul Operator : Sample : 10 Misc : ALS Vial : 10 Si Search Libraries: Unknown Spectrum: Integration Events	Data Path : D:\Data\KHO Data File : 10.D Acq On : 27 Jul 2011 Operator : Sample : 10 Misc : ALS Vial : 10 Sample Search Libraries: C:\ Unknown Spectrum: Ape Integration Events: Che	Data Path : D:\Data\KHOO\ Data File : 10.D Acq On : 27 Jul 2011 15:38 Operator : Sample : 10 Misc : ALS Vial : 10 Sample Multip Search Libraries: C:\Database Unknown Spectrum: Apex Integration Events: ChemStation	Library Data Path : D:\Data\KHOO\ Data File : 10.D Acq On : 27 Jul 2011 15:38 Operator : Sample : 10 Misc : ALS Vial : 10 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Unknown Spectrum: Apex Integration Events: ChemStation Integrato	Library Search Data Path : D:\Data\KHOO\ Data File : 10.D Acq On : 27 Jul 2011 15:38 Operator : Sample : 10 Misc : ALS Vial : 10 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Unknown Spectrum: Apex Integration Events: ChemStation Integrator - auto	Library Search Report Data Path : D:\Data\KHOO\ Data File : 10.D Acq On : 27 Jul 2011 15:38 Operator : Sample : 10 Misc : ALS Vial : 10 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minim Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autoint1 e	Library Search Report Data Path : D:\Data\KHOO\ Data File : 10.D Acq On : 27 Jul 2011 15:38 Operator : Sample : 10 Misc : ALS Vial : 10 Sample Multiplier: 1 Search Libraries: C:\Database\NIST05a.L Minimum Qual Unknown Spectrum: Apex Integration Events: ChemStation Integrator - autoint1 e

Eicosanoic	acid,	methyl	ester	140314	001120-28-1	98	-
Eicosanoic	acid,	methyl	ester	140313	001120-28-1	98	
Eicosanoic	acid,	methyl	ester	140312	001120-28-1	98	

DINGFAME.M Thu Jul 28 15:08:44 2011