



UNIVERSITI PUTRA MALAYSIA

**FORMULATION AND STORAGE PROPERTIES OF TRASPARENT
SOAP PREPARED FROM ENZYMATICALLY AND NON-
ENZYMATICALLY TREATED PALM-BASED MATERIALS**

KOH SOO PENG.

FSMB 2004 7

**FORMULATION AND STORAGE PROPERTIES OF TRANSPARENT SOAP
PREPARED FROM ENZYMATICALLY AND NON-ENZYMATICALLY
TREATED PALM-BASED MATERIALS**

KOH SOO PENG

**MASTER OF SCIENCE
UNIVERSITY PUTRA MALAYSIA**

MARCH 2004



**FORMULATION AND STORAGE PROPERTIES OF TRANSPARENT SOAP
PREPARED FROM ENZYMATICALLY AND NON-ENZYMATICALLY
TREATED PALM-BASED MATERIALS**

By

KOH SOO PENG

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

March 2004



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

**FORMULATION AND STORAGE PROPERTIES OF TRANSPARENT SOAP
PREPARED FROM ENZYMATICALLY AND NON-ENZYMATICALLY
TREATED PALM-BASED MATERIALS**

By

KOH SOO PENG

March 2004

Chairman: Associate Professor Dr Lai Oi Ming, Ph.D.

Faculty: Food Science and Biotechnology

The study on the physical and chemical properties of 28 samples of commercial transparent soap provided valuable information that could be used as a guideline in the preparation of palm-based transparent soap formulation. Most of the commercial transparent soaps had good transparency (above 0.8) with a moderate total fatty matter of between 40% and 60%. They were mostly superfatted products and showed good foamability and hardness with a penetration value of less than 5 mm.

Differences in titer, acid and iodine values affected the ability of different palm-based fatty acid in accepting the amount of sodium salt into soap formulation and the hardness property. The proper combination of triethanolamine, glycerol and sugar solution played an important role in determining the transparency, hardness, foamability and moisture content of the soap produced. Transparent soap bar made from blends of distilled palm stearin fatty acid with ricinoleic acid covered a wide range of acceptability for triethanolamine (20-90%) with low amount of sugar



solution (less than 30%) and less than 70% of glycerol. However, in blends of distilled palm oil fatty acid-based soap with ricinoleic acid, the transparent soap region ranged between 40% and 80% triethanolamine, less than 40% of glycerol and between 20% to 50% of sugar solution. Both blends of distilled palm fatty acid-based transparent soap had transparency reading above 0.8 and penetration value of less than 8 mm with the majority of moisture content of soap falling between 15% and 20%. In the region of low percentage of triethanolamine (0%-20%) with 80-100% of glycerol and sugar solution used, both distilled palm fatty acids used in soap formulation produced soft and gummy opaque soap.

Lipase-catalysed acidolysis is a vital tool to tailor-make refined, bleached and deodorised palm oil (RBD palm oil) enriched with ricinoleic acid (RA). Lipozyme IM60 lipase performed better (12.33% RA/24 hours) than *Pseudomonas* sp. lipase (2.59% RA/24 hours) as it was able to incorporate more ricinoleic acid into RBD palm oil at a shorter time. The alteration in triglyceride composition of acidolysed oil had led to the changes in their slip melting point, iodine value, solid fat content, crystallisation and melting behaviour and also the viscosity of the acidolysed oil produced.

The differences in sodium salt content used in different fatty raw material-based soap formulation had caused an effect on the transparency, total fatty matter, penetration value, chloride content and foamability of soap made. In general, the presence of ricinoleic acid in the blends of distilled palm oil fatty acid soap, blends of distilled palm stearin fatty acid soap and acidolysed oil-based soap assisted in improving the

soap transparency, especially when high contents of sodium salt were used in the soap formulation.



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

**FORMULASI DAN CIRI-CIRI PENYIMPANAN SABUN LUTSINAR
DIHASILKAN SECARA BERENZIM DAN BUKAN BERENZIM BAHAN
MENTAH BERASASKAN MINYAK SAWIT**

Oleh

KOH SOO PENG

Mac 2004

Pengerusi: Profesor Madya Dr Lai Oi Ming, Ph.D.

Fakulti: Sains Makanan dan Bioteknologi

Kajian terhadap ciri-ciri fiziko dan kimia bagi 28 sampel sabun lutsinar komersial membekalkan maklumat berguna dalam penyediaan formulasi sabun lutsinar berasaskan minyak sawit. Kebanyakan sabun lutsinar komersial mempunyai tahap lutsinar melebihi 0.8 dengan kandungan asid lemak yang sederhana di antara 40-60%. Kebanyakan sabun lutinar di pasaran adalah produk 'superfatted' dan mempunyai kebulihan yang baik dan kekerasan dengan nilai penembusan kurang daripada daripada 5 mm.

Perbezaan dalam nilai titer, nilai asid dan nilai iodin mempengaruhi keupayaan asid lemak berasaskan minyak sawit yang berlainan terhadap penerimaan kuantiti garam natrium dalam formulasi sabun dan ciri kekerasan. Kombinasi yang bersesuaian di antara triethanolamine, gliserol dan larutan gula memainkan peranan penting dalam penentuan kelutsinaran, kekerasan, kebulihan dan kandungan kelembapan sabun yang dihasilkan. Ketulan sabun lutsinar diperbuat daripada campuran hasil sulingan asid

lemak minyak stearin boleh menerima 20-90% triethanolamine, larutan gula kurang daripada 30% dan gliserol kurang daripada 70%. Manakala, bagi sabun lutsinar yang diperbuat daripada campuran hasil sulingan asid lemak minyak sawit, 40-80% triethanolamine dengan gliserol kurang daripada 40% dan larutan gula di antara 20% hingga 50% adalah diterima dalam formulasi sabun. Kedua-dua jenis sabun lutsinar yang diperbuat daripada campuran hasil sulingan asid lemak berlainan mempunyai tahap kelutsinaran melebihi 0.8 dan nilai penembusan kurang daripada 8 mm serta kandungan kelembapan antara 15% dan 20%. Dalam lingkungan 0-20% triethanolamine dan keseluruhan julat peratusan bagi gliserol dan larutan gula dalam formulasi sabun, kedua-dua jenis hasil sulingan asid lemak minyak sawit menghasilkan sabun lutcahaya yang lembut dan berperekat.

Asidolisis menggunakan lipase merupakan teknik penting dalam pembuatan RBD minyak sawit yang kaya dengan asid ricinoleic (RA). Lipase Lipozyme IM60 mempunyai prestasi yang lebih baik (12.33% RA/24 jam) berbanding lipase *Pseudomonas* sp. (2.59% RA/24 jam) kerana ia berupaya memasukkan asid ricinoleik dalam RBD minyak sawit dalam masa yang lebih singkat. Perubahan dalam komposisi trigliserida menyebabkan perubahan dalam takat lebur slip, nilai iodin, kandungan lemak pepejal, kelakuan pembekuan dan peleburan serta viskositi bagi minyak sawit yang telah diubahsuai melalui asidolisis.

Perbezaan dalam kandungan garam natrium bagi bahan mentah yang berlainan dalam formulasi sabun mempunyai kesan terhadap kelutsinaran, kandungan asid lemak, nilai penembusan, kandungan klorin dan kebuihan sabun lutsinar yang dihasilkan. Secara amnya, kehadiran asid ricinoleik dalam sabun lutsinar yang diperbuat

daripada campuran hasil sulingan asid lemak minyak sawit, campuran hasil sulingan asid lemak minyak stearin dan minyak sawit yang telah diasidolisis mampu memperbaiki kelutsinaran sabun, terutamanya bagi kandungan garam natrium yang tinggi dalam formulasi sabun.

ACKNOWLEDGEMENTS

I wish to express my most sincere appreciation to my main supervisor, Prof. Madya Dr Lai Oi Ming of Department of Biotechnology, Faculty Food Science and Biotechnology, members of supervisory committee, Prof. Hasanah Mohd. Ghazali (Department of Biotechnology, University Putra Malaysia), Dr Ainie Kuntom (Chemistry and Technology Division, Malaysian Palm Oil Board) and Dr Chong Chiew Let (Chemistry and Technology Division, Malaysian Palm Oil Board), for their willingness to share their expertise, knowledge and constant encouragement throughout the course of my study. The suggestions and insightful comments on the contents of my thesis are gratefully acknowledged.

My sincere thanks also go to the staffs in Malaysian Palm Oil Board (MPOB) and my lovely friends in Enzyme Lab at Department of Biotechnology for their technical assistance and support. Many thanks go to Miss Lee Yim Leng for her invaluable guidance, encouragement and patience in sharing my excitements and frustrations of research. And lastly, I am grateful for the support of my family and their endless love, understanding and encouragements throughout the period of completing this project.



I certify that an Examination Committee met on 18th March 2004 to conduct the final examination of Koh Soo Peng on her Master of Science thesis entitled “Formulation and Storage Properties of Transparent Soap Prepared from Enzymatically and Non-Enzymatically Treated Palm-Based Materials” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Suhaila Mohamed, Ph.D.

Professor
Faculty of Food Science and Biotechnology
Universiti Putra Malaysia
(Chairman)

Lai Oi Ming, Ph.D.

Associate Professor
Faculty of Food Science and Biotechnology
Universiti Putra Malaysia
(Member)

Hasanah Mohd. Ghazali, Ph.D.

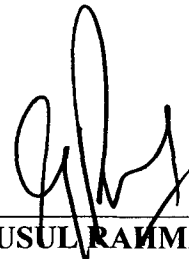
Professor
Faculty of Food Science and Biotechnology
Universiti Putra Malaysia
(Member)

Ainie Kuntom, Ph.D.

Malaysian Palm Oil Board
(Member)

Chong Chiew Let, Ph.D.

Malaysia Palm Oil Board
(Member)



GULAM RUSUL RAHMAT ALI, Ph.D.

Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 17 JUN 2004




This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Lai Oi Ming, Ph.D.
Associate Professor
Faculty Food Science and Biotechnology
University Putra Malaysia
(Chairwoman)

Hasanah Mohd. Ghazali, Ph.D.
Professor
Faculty Food Science and Biotechnology
University Putra Malaysia
(Member)

Ainie Kuntom, Ph.D.
Malaysia Palm Oil Board
(Member)

Chong Chiew Let, Ph.D.
Malaysia Palm Oil Board
(Member)



AINI IDERIS, Ph.D.
Professor/Dean,
School of Graduate Studies
Universiti Putra Malaysia

Date: 09 JUL 2004



DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at University Putra Malaysia or other institutions.



KOH SOO PENG

Date: 10 JUN 2004

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ABSTRAK	v
ACKNOWLEDGEMENTS	viii
APPROVAL	ix
DECLARATION	xi
LIST OF TABLES	xvii
LIST OF FIGURES	xx
LIST OF ABBREVIATIONS	xxvii
CHAPTER	
1 INTRODUCTION	1
2 LITERATURE REVIEW	5
History of Transparent Soap	5
The Structure of Transparent Soap	13
Basic Raw Materials Utilized in Transparent Soap Formulation	16
Tallow	16
Rosin	17
Castor Oil and Ricinoleic Acid	17
Lauric Oil	18
Superfating Agents	18
Salt Contents	19
Alcohol	20
Glycerin	21
Sugar or Polyols	21
Triethanolamine	22
Alkali Solution	23
Perfuming and Dyestuffs	23
Foaming Agents	24
Citric Acid	24
Water	25
Other Ingredients	25
Factors Influencing Transparent Soap Making	26
Balancing of the Fat Stocks	26
Selection of Non-soap Additives	28
The Rate of Cooling	28
Phase Change due to Mechanical Treatment	29
Purity of the Ingredients	29
Shock or Physical strain	30
Transparency Measurement	30
Lipase	32
Enzymatic Interesterification	33
Application of Lipase-catalysed Interesterification	34
Immobilization of Lipase	37



3	PHYSICAL AND CHEMICAL PROPERTIES OF COMMERCIAL TRANSPARENT SOAP FOUND IN MALAYSIA	39
	Introduction	39
	Materials and Methods	41
	Materials	41
	Methods	42
	Transparency Measurement	42
	Penetration Value	44
	Total Fatty Matter	44
	Moisture Content	46
	Foambility	46
	Free Caustic or Free Acid Content	47
	Results and Discussion	48
	Transparency Measurement	48
	Penetration Value	50
	Total Fatty Matter	50
	Moisture Content	53
	Foambility	55
	Free Caustic or Free Acid Content	57
	Summary	59
4	PALM-BASED TRANSPARENT SOAP FORMULATION	61
	Introduction	61
	Materials and Methods	62
	Materials	62
	Methods	63
	Physical and Chemical Analysis on Fatty Stocks Used	63
	Acid Value	63
	Titer Value	64
	Iodine Value	64
	Preparation of Palm-based Transparent Soap	66
	Preparation of Sodium Salt (Neutralization Process)	67
	Preparation of Soap Bar using Casting Method	67
	Physical and Chemical Analysis on Transparent Soap Bar	68
	Differential Scanning Calorimetry	68
	Transparency Measurement	68
	Foamability	69
	Penetration Value	69
	Surface Tensiometer	69
	Free Acid Content	70
	Weight loss	70
	Results and Discussion	70
	Distilled Palm Oil Fatty Acid as Fatty Stock in Soap Formula	70
	Differential Scanning Calorimetry	71
	Transparency Measurement	73
	Foamability	76
	Penetration Value	79
	Surface Tension	79
	Free Acid Content	81
	Changes in Soap Property after Storage	83

Distilled Palm Stearin Fatty Acid as Fatty Stock in Soap Formula	85
Differential Scanning Calorimetry	88
Transparency Measurement	90
Foamability	93
Penetration Value	96
Surface Tension	96
Free Acid Content	99
Changes in Soap Property after Storage	99
Summary	102
5 EFFECT OF DIFFERENT INGREDIENTS AND PROCESSING TEMPERATURE ON PALM-BASED SOAP FORMULATION	105
Introduction	105
Materials and Methods	106
Materials	106
Methods	106
Preparation of Palm-based Transparent Soap	106
Physical and Chemical Analysis on Transparent Soap Bar	107
Experimental Design	107
Results and Discussion	107
Effect of Different Ingredients on Soap Transparency	107
Transparency Measurement and Penetration Value	108
Effect of Sodium Salt on Palm Olein Polyols-based Transparent Soap	110
Transparency Measurement and Penetration Value	111
Foamability	113
Effect of Different Sugar Type on Soap Transparency	113
Transparency Measurement, Penetration Value and Foamability	113
Effect of Different Processing Temperature on Soap Transparency	116
Transparency Measurement, Penetration Value and Foamability	117
Effect of Triethanolamine, Glycerol and Sugar Solution on Palm Oil Polyols-based Transparent Soap	117
Transparency Measurement	119
Penetration Value	122
Foamability	122
Summary	125
6 TERNARY DIAGRAM ON PALM-BASED TRANSPARENT SOAP	127
Introduction	127
Materials and Methods	128
Materials	128
Methods	128
Preparation of Palm-based Transparent Soap	128
Physical and Chemical Analysis on Transparent Soap Bar	129
Results and Discussion	129
Distilled Palm Stearin Fatty Acid as Fatty Raw Material	129
Transparency Measurement	129
Penetration Value	131
Moisture Content	133
Foamability and Free Acid Content	135
Distilled Palm Oil Fatty Acid as Fatty Raw Material	135



	Transparency Measurement	138
	Penetration Value	140
	Moisture Content	140
	Foamability and Free Acid Content	143
	Summary	143
7	ACIDOLYSIS OF RBD PALM OIL WITH RICINOLEIC ACID	147
	Introduction	147
	Materials and Methods	148
	Materials	148
	Methods	149
	Immobilization of Lipase	149
	Preparation of Lipase-catalysed acidolysis of RBD Palm Oil with Ricinoleic Acid	149
	Physical and Chemical Characteristics of Lipase-catalysed RBD Palm Oil and Ricinoleic Acid Blends	151
	Determination of Hydrolytic Activity	151
	Removal of Free Fatty Acid	151
	Determination of Fatty Acid Composition using Gas Chromatography	152
	Determination of Triglyceride Composition using High Performance Liquid Chromatography	153
	Determination of Melting and Cooling Profile using Differential Scanning Calorimetry	153
	Determination of Kinematic Viscosity using U-tube Viscometer	154
	Solid Fat Content	156
	Slip Melting Point	157
	Apparent Density in Air of Oils	157
	Iodine Value	158
	Saponification Value	158
	Results and Discussion	159
	Changes in Hydrolytic Activity	159
	Changes in the Fatty Acid Composition in Acidolysed RBD Palm Oil	162
	Changes in Triglyceride Profile	166
	Thermograms of Acidolysed RBD Palm Oil	183
	Changes in Iodine Value	197
	Changes in Solid Fat Content and Slip Melting Point of Acidolysed RBD Palm Oil	200
	Changes in Viscosity of Acidolysed RBD Palm Oil	203
	Summary	206
8	EFFECT OF DIFFERENT FATTY STOCKS ON THE TRANSPARENCY OF PALM-BASED SOAP FORMULATION	209
	Introduction	209
	Materials and Methods	210
	Materials	210
	Methods	210
	Preparation of Palm-based Transparent Soap	210
	Preparation of Sodium Salt (Neutralization Process)	210
	Preparation of Sodium Salt (Saponification Process)	211

Preparation of Soap Bar using Casting Method	212
Physical and Chemical Analysis on Fatty Acids and Oils	212
Saponification Value	212
Physical and Chemical Analysis on Transparent Soap Bar	213
Chlorides Content	213
Results and Discussion	214
Transparency Measurement	216
Total Fatty Matter	219
Penetration Value	221
Foamability	223
Moisture Content	225
Chlorides Content	225
Free Acid and Free Caustic Content	227
Change in Soap Property after Storage	230
Summary	233
9 CONCLUSION AND RECOMMENDATIONS	235
Conclusion	235
Recommendations	242
BIBLIOGRAPHY	243
APPENDICES	254
BIODATA OF THE AUTHOR	258



LIST OF TABLES

Table		Page
1	Average Free acid and free caustic content of commercial transparent soap.	58
2	Average Foamability and free acid content of blends soap made of distilled palm stearin fatty acid with ricinoleic acid in ternary diagram.	136
3	Average Foamability and free acid content of blends soap made of distilled palm oil fatty acid with ricinoleic acid in ternary diagram.	144
4	Percentage of free fatty acid of acidolysed oil catalysed by both Lipozyme IM60 and <i>Pseudomonas</i> sp. lipases under various incubation times ^a .	160
5	Percentage of free fatty acid of acidolysed oil catalysed by Lipozyme IM60 lipase at different ratio of RBD palm oil and ricinoleic acid ^a .	161
6	Percentage of free fatty acid of acidolysed oil catalysed by Lipozyme IM60 lipase at different incubation temperature ^a .	161
7	Percentage of ricinoleic acid of acidolysed oil catalysed by both Lipozyme IM60 and <i>Pseudomonas</i> sp. lipases under various incubation times ^a .	164
8	Percentage of ricinoleic acid of acidolysed oil catalysed by Lipozyme IM60 lipase at different ratio of RBD palm oil and ricinoleic acid ^a .	165
9	Percentage of ricinoleic acid of acidolysed oil catalysed by Lipozyme IM60 lipase at different incubation temperature ^a .	165
10	Melting properties of acidolysed oil catalysed by Lipozyme IM60 lipase with different reaction times.	186
11	Melting properties of acidolysed oil catalysed by <i>Pseudomonas</i> sp. lipase	

	with different reaction times.	186
12	Cooling properties of acidolysed oil catalysed by <i>Pseudomonas</i> sp. lipase with different reaction times.	193
13	Cooling properties of acidolysed oil catalysed by Lipozyme IM60 lipase with different reaction times.	193
14	Melting properties of acidolysed oil catalysed by Lipozyme IM60 lipase with different incubation temperature.	194
15	Cooling properties of acidolysed oil catalysed Lipozyme IM60 lipase with different incubation temperature.	194
16	Melting properties of acidolysed oil catalysed by Lipozyme IM60 lipase with different ratio of RBD palm oil and ricinoleic acid.	196
17	Cooling properties of acidolysed oil catalysed Lipozyme IM60 lipase with different ratio of RBD palm oil and ricinoleic acid.	196
18	Percentage of iodine value of acidolysed oil catalysed by both Lipozyme IM60 and <i>Pseudomonas</i> sp. lipases under various incubation times ^a .	198
19	Percentage of iodine value of acidolysed oil catalysed by Lipozyme IM60 lipase at different ratio of RBD palm oil and ricinoleic acid ^a .	199
20	Percentage of iodine value of acidolysed oil catalysed by Lipozyme IM60 lipase at different incubation temperature ^a .	199
21	Physical and chemicals properties of different fatty raw materials for Palm-based transparent soap making.	215
22	Transparency measurement of different sodium salt content under various fatty stock-based soap formulation ^a .	217
23	Total fatty matter of different sodium salt content under various fatty stock-based soap formulation ^a .	220



24	Penetration value of different sodium salt content under various fatty stock-based soap formulation ^a .	222
25	Foamability of different sodium salt content under various fatty stock-based soap formulation ^a .	224
26	Moisture content of different sodium salt content under various fatty stock-based soap formulation ^a .	226
27	Chloride content of different sodium salt content under various fatty stock-based soap formulation ^a .	228
28	Percentage of free acid and free caustic of different sodium salt content under various fatty stock-based soap formulation.	229
29	Transparency measurement of different sodium salt content under various fatty stock-based soap formulation after 1 month storage ^a .	231
30	Penetration value of different sodium salt content under various fatty stock-based soap formulation after 1 month storage ^a .	232



LIST OF FIGURES

Figure	Page
1	Transparent soap. 43
2	Transparency measurement of commercial transparent soap. 49
3	Penetration value (PV) of commercial transparent soap. 51
4	Total fatty matter of commercial transparent soap. 52
5	Moisture content of commercial transparent soap. 54
6	Foamability of commercial transparent soap. 56
7	Apparatus for titer value measurement. 65
8	Melting points of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm oil fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 72
9	Heat flow of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm oil fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 74
10	Transparency measurement of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm oil fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 75
11	Degree of transparency at different sodium salt content on distilled palm oil fatty acid-based soap. 77
12	Foamability of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm oil fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 78



- 13 Penetration value of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm oil fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 80
- 14 Surface tension of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm oil fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 82
- 15 Free acid content of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm oil fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 84
- 16 Percentage weight lost of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm oil fatty acid-based soap after 4 months storage (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 86
- 17 Transparency measurement of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm oil fatty acid-based soap after 4 months storage (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 87
- 18 Melting points of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm stearin fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 89
- 19 Heat flow of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm stearin fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 91
- 20 Transparency measurement of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm stearin fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 92
- 21 Degree of transparency at different sodium salt content on distilled palm stearin fatty acid-based soap. 94
- 22 Foamability of different ratio of triethanolamine (T), glycerol (G) and sugar



- solution (S) on distilled palm stearin fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 94
- 23 Penetration value of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm stearin fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 97
- 24 Surface tension of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm stearin fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S 98
- 25 Free acid content of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm stearin fatty acid-based soap (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S. 100
- 26 Percentage weight lost of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm stearin fatty acid-based soap after 4 months storage (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S 101
- 27 Transparency measurement of different ratio of triethanolamine (T), glycerol (G) and sugar solution (S) on distilled palm stearin fatty acid-based soap after 4 months storage (a) 7T:1G:4S (b) 6T:2G:4S (c) 5T:3G:4S (d) 4T:4G:4S (e) 3T:5G:4S and (f) 2T:6G:4S 103
- 28 Transparency measurement of different formulation of distilled palm stearin fatty acid-based soap. 109
- 29 Penetration value of different formulation of distilled palm stearin fatty acid-based soap. 109
- 30 Transparency measurement and penetration value of different percentage of sodium salt content on distilled palm stearin fatty acid-based soap containing palm olein polyols. 112
- 31 Average Foamability of different percentage of sodium salt content on distilled palm stearin fatty acid-based soap containing palm olein polyols. 114



32	(a) Transparency measurement (b) penetration value (c) average foamability of different types of sugar on distilled palm stearin fatty acid-based soap.	115
33	(a) Transparency measurement (b) penetration value (c) average foamability of different processing temperatures on distilled palm stearin fatty acid-based soap.	118
34	Transparency measurement of (a) GLY:TEA (b) TEA:SUG (c) SUG:GLY series of distilled palm stearin fatty acid-based soap.	120
35	Penetration value of (a) GLY:TEA (b) TEA:SUG (c) SUG:GLY series of distilled palm stearin fatty acid-based soap.	123
36	Average foamability of (a) GLY:TEA (b) TEA:SUG (c) SUG:GLY series of distilled palm stearin fatty acid-based soap.	124
37	Ternary diagram on transparency measurement of distilled palm stearin fatty acid-based soap.	130
38	Ternary diagram on penetration value of distilled palm stearin fatty acid-based soap.	132
39	Ternary diagram on moisture content of distilled palm stearin fatty acid-based soap.	134
40	Ternary diagram on transparency measurement of distilled palm oil fatty acid-based soap.	139
41	Ternary diagram on penetration value of distilled palm oil fatty acid-based soap.	141
42	Ternary diagram on moisture content of distilled palm oil fatty acid-based soap.	142
43	U-tube viscometer.	155
44	Triglycerides profile of RBD palm oil:ricinoleic acid mixtures after	

