TABLE OF CONTENTS

TABLE OF CONTENTS	
	Page
ACKNOWLEDGEMENT	iii
ABSTRACT (ENGLISH)	v
ABSTRACT (THAI)	viii
LIST OF TABLES	xxiii
LIST OF FIGURES	xxvi
ABBREVIATIONS AND SYMBOLS	xxxii
CHAPTER 1 INTRODUCTION	-1
1.1 Statement and significance of the problems	
1.2 Objective	3
1.3 Scope of the study	3
1.4 Literature reviews	5
1.4.1 Hair	5
1.4.1.1 Hair structure	5
A. Hair follicle	7
B. Hair shaft	8
C. Other components of hair follicle	909
1.4.1.2 Hair functions	11
A. Hair growth cycle	
B. Hair pigmentation	13

		C. Association of hair growth cycle and	14
		hair pigmentation	
1.4.2	Canitie	s	16
	1.4.2.1	Causes and factors affecting hair pigmentation	16
		A. Regulation of hair pigmentation	16
		B. Causes of hair depigmentation	17
	1.4.2.2	Treatment of hair depigmentation	19
		A. Radiation	19
		B. Vitamin and mineral supplement	20
		C. Topical treatment with minoxidil	20
		D. Melanogenesis induction compounds	20
		from natural and synthesis	
1.4.3	Fatty ac	cids and esters	21
	1.4.3.1	Classification of fatty acids and esters	21
		A. Classification of fatty acids	21
		B. Classification of esters	23
	1.4.3.2	Application of fatty acids and esters in	24
		medicines, pharmaceutics and cosmetics	
		A. Application of fatty acids	24
		B. Application of esters	25
	1.4.3.3	Sources of fatty acids and esters	26
		A. Natural sources	26
		B. Synthesis	27

1.4.3.4	The relationship between fatty acids, esters	30
	and hair melanogenesis	
1.4.3.5	Problems of fatty acids and esters for the	31
	application in medicines, pharmaceutics	
	and cosmetics	
	A. In-process product preparation	31
	B. The administration of products	32
1.4.4 Niosom	nes	33
1.4.4.1	Compositions and characteristics	34
	A. Niosomal compositions	34
	B. Physical characteristics of niosomes	35
1.4.4.2	Classification of niosomes	38
	A. Multilamellar vesicles	38
	B. Large unilamellar vesicles	38
	C. Small unilamellar vesicles	39
1.4.4.3	Niosome preparation methods	39
1.4.4.4	Application of niosomes in medicines,	39
	pharmaceutics and cosmetics	
	A. Application in medicines	39
	B. Application in pharmaceutics	41
	C. Application in cosmetics	44
1.4.5 Transfo	ollicular delivery	45
1.4.5.1	Target sites of transfollicular delivery	45
	A. Follicular infundibulum	46

		B. Sebaceous gland	46
		C. Bulge region	47
		D. Hair matrix cells	48
	1.4.5.2	Factors affecting the transfollicular delivery	48
		A. Hair cycle	48
		B. Sebum	49
		C. Size selectivity	50
	1.4.5.3	Transfollicular delivery system	51
		A. Penetration enhancement formulations	51
		B. Penetration enhancement instrumentations	53
	1.4.5.4	Transfollicular delivery evaluation methods	54
	111011	A Skin sandwich system	54
		 B. Selective follicular blocking 	56
		C. Differential stringing	50
		C. Differential suppling	57
1.4.6	In vitro	melanogenesis induction assays	59
	1.4.6.1	Cell cytotoxicity by sulforhodamine B (SRB)	59
	1.4.6.2	Melanin content	60
	1.4.6.3	Tyrosinase activity	61
	1.4.6.4	Tyrosinase-related protein-2 activity	62
	1.4.6.5	Total protein content	64
1.4.7	In vivo	irritation and melanogenesis induction evaluation	65
	1.4.7.1	In vivo irritation determination	65
	1.4.7.2	In vivo melanogenesis induction evaluation	68
51.4.8	Comme	ercial products for canities treatment	70
		L	

xiv

1.4.9	Research on canities treatment	70
	1.4.9.1 Natural approaches	70
	1.4.9.2 Synthetic approaches	73
CHAPTER 2 MATERI	ALS AND METHODS	75
2.1 Mater	rials and equipments	75
2.1.1	Chemicals	75
2.1.2	Cell lines	77
2.1.3	Animals	77
2.1.4	Equipments	78
2.2 Metho	ods	79
2.2.1	Preparation of saturated fatty acid methyl esters	79
	2.2.1.1 Synthesis of saturated fatty acid methyl esters	79
	2.2.1.2 Purification of the crude saturated fatty acid	80
	methyl esters	
	2.2.1.3 Identification of the purified saturated fatty acid	80
	methyl esters	
	2.2.1.4 Physical characteristics and stability of the	81
	purified saturated fatty acid methyl esters	
2.2.2	In vitro cell cytotoxicity and melanogenesis induction	81
	assays of the saturated fatty acid methyl esters	
	2.2.2.1 Cell culture	82
	2.2.2.2 Sample preparation	82
	2.2.2.3 Cell cytotoxicity by SRB assay	82
	2.2.2.4 Melanin content measurement	83

	2.2.2.5 Tyrosinase activity measurement	83
	2.2.2.6 Selection of the saturated fatty acid methyl	84
	ester to load in the selected blank niosomes	
2.2.3	Development of the blank niosomes	84
	2.2.3.1 Formulations of the blank niosomes	84
	2.2.3.2 Physical characteristics of the blank niosomes	85
	2.2.3.3 Selection of the blank niosomes to load with	86
	the selected saturated fatty acid methyl ester	
2.2.4	Development of the selected saturated fatty acid methyl	86
	ester loaded in the selected niosomes	
	2.2.4.1 Preparation of myristic acid methyl ester or	86
	methyl myristate (MM) loaded in the	
	selected niosomes	
	2.2.4.2 Maximum loading of MM in the selected	87
	niosomes	
	2.2.4.3 Entrapment efficiency of MM at the maximum	87
	loading concentrations in the selected niosomes	
	2.2.4.4 Morphological study of the selected niosomes	88
	loaded with MM	
	2.2.4.5 Physical and chemical stability of MM loaded	88
	in the selected niosomes	<i>.</i>
vright ^O 225	<i>In vitro</i> cell cytotoxicity, melanogenesis induction	88
	activity and transfollicular penetration assays of	
	MM loaded in the selected piesomes	
	141141 IOAUCU III UIC SCICCICU IIIOSOIIICS	

	2.2.5.1	Cell culture	89
	2.2.5.2	Sample preparation	89
	2.2.5.3	Cell cytotoxicity by SRB assay in human skin	89
		fibroblasts and B16F10 melanoma cells	
	2.2.5.4	Melanin content measurement	90
	2.2.5.5	Tyrosinase activity measurement	90
	2.2.5.6	Tyrosinase-related protein-2 activity	90
		measurement	
	2.2.5.7	Transfollicular penetration	91
		A. Skin sample	91
		B. Preparation of the porcine skin	91
		C. Selective follicular blocking technique	91
		D. Sample preparation	92
		E. Transfollicular penetration study	92
		F. Analysis of transfollicular penetration	93
	2.2.5.8	Selection of MM loaded in the selected	93
		niosomes to incorporate in the hair lotion	
		formulation	
2.2.6	Develop	pment of the hair lotion bases	94
	2.2.6.1	Interaction study of the non-ionic surfactants	94
		and the MM loaded in the selected niosomes	
	2.2.6.2	Selection of the non-ionic surfactants for hair	94
		lotion base formulations	
	2.2.6.3	Preparation of the hair lotion base formulations	95

xvii

	2.2.6.4 F	Physical characteristics and thermodynamic	95
	s s	tability of the hair lotion base formulations	
	2.2.6.5 \$	Selection of the hair lotion base formulation to	95
	i	ncorporate the MM loaded and not loaded in	
	с	cationic niosomes	
2.2.7	Developm	nent of the hair lotion containing MM	97
	loaded an	nd not loaded in cationic niosomes	
	2.2.7.1 F	Preparation of the hair lotion containing MM	97
	le	oaded and not loaded in cationic niosomes	
	2.2.7.2 N	Morphological study of cationic niosomes	98
	10	oaded with MM in the hair lotion	
	2.2.7.3 F	Physical and chemical stability of MM loaded	99
	а	nd not loaded in cationic niosomes	
	i	ncorporated in the hair lotion	
2.2.8	In vitro tr	cansfollicular penetration and in vivo rabbit	99
	skin irrita	tion and melanogenesis induction of the	
	hair lotio	n containing MM loaded and not loaded in	
	cationic r	niosomes	
	2.2.8.1 I	<i>n vitro</i> transfollicular penetration of the hair	99
	1	otion containing MM loaded and not loaded	
	i	n cationic niosomes	
	y C	A. Skin sample	99
	• • • • •	3. Sample preparation	99
		C. Transfollicular penetration study	100

	2.2.8.2 In vivo rabbit skin irritation by the single	100
	closed patch test	
	2.2.8.3 In vivo melanogenesis induction in aged mice	101
	A. Animals	101
	B. Melanogenesis induction evaluation	101
	C. Histological examination	102
2.2	9 Statistical analysis	102
CHAPTER 3 RESUL	TS AND DISCUSSION	104
3.1 Pre	paration of saturated fatty acid methyl esters	104
3.1	1 Synthesis of saturated fatty acid methyl esters	104
3.1	2 Physical and chemical stability of saturated fatty acid	104
	methyl esters	
3.2 In v	itro cell cytotoxicity and melanogenesis induction assays	108
of t	he saturated fatty acid methyl esters	
3.2	1 Cell cytotoxicity by SRB assay	108
3.2	2 Melanin content measurement	112
3.2	3 Tyrosinase activity measurement	115
3.2	4 Selection of the saturated fatty acid methyl ester to	116
	load in the selected blank niosomes	
3.3 Dev	velopment of the blank niosomes	117
3.3.	1 Physical characteristics of the blank niosomes	117
opyright 3.3	2 Selection of the blank niosomes to load with the	122
	selected saturated fatty acid methyl ester	

3.4	Devel	lopment of the selected saturated fatty acid methyl ester	122
	loade	d in the selected niosomes	
	3.4.1	Maximum loading of myristic acid methyl ester or	122
		methyl myristate (MM) in the selected niosomes	
	3.4.2	Entrapment efficiency of MM at the maximum loading	123
		concentrations in the selected niosomes	
	3.4.3	Morphology of the selected niosomes loaded with MM	124
	3.4.4	Physical stability of the selected niosomes loaded	124
		with MM	
	3.4.5	Chemical stability of MM loaded in the selected	127
		niosomes	
3.5	In viti	ro cell cytotoxicity, melanogenesis induction activity	129
	and tr	ansfollicular penetration assays of MM loaded in the	
	select	ed niosomes	
	3.5.1	Cell cytotoxicity by SRB assay in human skin	129
		fibroblasts and B16F10 melanoma cells	
	3.5.2	Melanin content measurement	134
	3.5.3	Tyrosinase activity measurement	135
	3.5.4	Tyrosinase-related protein-2 activity measurement	137
	3.5.5	Transfollicular penetration	139
	3.5.6	Selection of MM loaded in the selected niosomes in	144
		order to further incorporate in the hair lotion	
		formulation	
3.6	Devel	lopment of the hair lotion bases	144

	3.6.1	Interaction study of the non-ionic surfactants and	144
		the selected niosomes loaded with MM	
	3.6.2	Selection of the non-ionic surfactants for hair lotion	146
		base formulations	
	3.6.3	Physical characteristics and thermodynamic stability	147
		of the hair lotion base formulations	
	3.6.4	Selection of the hair lotion base formulation to	150
		incorporate cationic niosomes loaded with MM	
3.7	Devel	lopment of the hair lotion containing MM loaded	151
	and n	ot loaded in cationic niosomes	
	3.7.1	Physical characteristics of hair lotion containing MM	151
		loaded and not loaded in cationic niosomes	
	3.7.2	Morphology of cationic niosomes loaded with	153
		MM in the hair lotion	
	3.7.3	Physical stability of cationic niosomes loaded and not	154
		loaded with MM when incorporated in the hair lotion	
	3.7.4	Chemical stability of MM loaded and not loaded in	157
		cationic niosomes incorporated in the hair lotion	
3.8	In viti	ro transfollicular penetration and in vivo rabbit skin	159
	irritat	ion and melanogenesis induction of the hair lotion	
	conta	ining MM loaded and not loaded in cationic niosomes	

3.8.1 In vitro transfollicular penetration of the hair lotion	159
containing MM loaded and not loaded in cationic	
niosomes	
3.8.2 <i>In vivo</i> rabbit skin irritation by the single closed	163
patch test	
3.8.3 <i>In vivo</i> melanogenesis induction in aged mice	166
A. Melanogenesis induction evaluation	166
B. Histological examination	167
CHAPTER 4 CONCLUSION	170
REFERENCES	176
APPENDICES	209
APPENDIX A	210
APPENDIX B	213
APPENDIX C	215
CURRICULUM VITAE	217

ลิ<mark>ปสิทธิ์มหาวิทยาลัยเชียงใหม่</mark> Copyright[©] by Chiang Mai University All rights reserved

xxiii

LIST OF TABLES

Table		Page
1	Examples of esters and their physical properties	23
2	Niosome preparation methods	40
3	The potential barriers and resolving strategies associated with	48
	transfollicular delivery	
4	Draize scoring system	67
5	The examples of the commercial products available in the market	71
	for canities treatment	
6	Niosomal compositions of twelve blank niosomes prepared by the	85
	chloroform film method with sonication	
7	Compositions of the hair lotion base formulations containing	96
	different concentrations of the non-ionic surfactant system	
8	Concentrations of the non-ionic surfactant system used in the	97
	hair lotion base formulations	
9	Compositions of the selected hair lotion formulation containing MM	98
	loaded and not loaded in cationic niosomes and the base formulation	
10	Percentage yields, physical characteristics and identification data of	105
	saturated fatty acid methyl ester derivatives	
511	Characteristics of blank neutral niosomes prepared by chloroform	119
	film method with sonication when kept at 4 ± 2 , room temperature	
	(RT: $30+2$) and $45+2$ °C for 3 months	

- 12 Characteristics of blank cationic niosomes prepared by chloroform 120 film method with sonication when kept at 4±2, room temperature (RT; 30±2) and 45±2°C for 3 months
- 13 Characteristics of blank anionic niosomes prepared by chloroform 121 film method with sonication when kept at 4 ± 2 , room temperature (RT; 30 ± 2) and 45 ± 2 °C for 3 months
- 14 Characteristics of various charged niosomes loaded with MM prepared 126 by chloroform film method with sonication when kept at 4±2, room temperature (RT; 30±2) and 45±2°C for 3 months
- 15 The cumulative amounts (μ g/cm²), fluxes (μ g/cm²/h) and follicular 142 penetration per one hair follicle (μ g/one hair follicle) by follicular closing technique using vertical Franz diffusion cells at 6 h of MM from solution and various niosomal formulations
- Physical characteristics (appearance, odor, specific gravity and 148 viscosity) of the hair lotion base formulations at initial and after 6 cycles of heating and cooling (45/4°C)
- Physical characteristics (pH, Z-zeta potential, particle diameter 149 and polydispersity index) of the hair lotion base formulations at initial and after 6 cycles of heating and cooling (45/4°C)
- 18 Physical characteristics of hair lotions containing MM loaded and not 152 loaded in cationic niosomes and the hair lotion base
- 9 Characteristics of MM loaded and not loaded in cationic niosomes when incorporated in hair lotions when kept at 4 ± 2 , room temperature (RT; 30 ± 2) and $45\pm 2^{\circ}$ C for 3 months

20 The cumulative amounts (μ g/cm²), fluxes (μ g/cm²/h) and follicular 162 penetration per one hair follicle (μ g/one hair follicle) of MM loaded and not loaded in cationic niosomes incorporated in hair lotions by follicular closing technique using vertical Franz diffusion cells at 6 h

165

21 The *in vivo* rabbit skin irritation of MM solution, solvent (ethanol), blank cationic niosomes and MM loaded in cationic niosomes, hair lotion base and hair lotions containing MM loaded and not loaded in cationic niosomes, the untreated area, distilled water and sodium lauryl sulfate by the single closed patch test

ลิ<mark>ปสิทธิ์มหาวิทยาลัยเชียงให</mark>ม่ Copyright[©] by Chiang Mai University All rights reserved

LIST OF FIGURES

Figure Page			
1	1 Hair classification based of the length, pigmentation and composition		
	of hair shaft		
2	Hair follicle structure (a) and the enlarged hair bulb (b)	7	
3	Hair shaft composition	9	
34	Melanocyte distribution in the human anagen scalp hair follicle	10	
5	Hair growth cycle	11	
6	Melanogenesis process	15	
7	Configurations of unsaturated fatty acid	022	
8	Major areas of lipid biotechnology	28	
9	Lipase-catalyzed synthesis of bioesters	28	
10	Chemical synthesis of acetic acid by fermentation (a), catalysis of	29	
	ethylene (b) and rhodium-catalyzed reaction of methanol (c)		
11	Synthesis of ester by the Fischer esterification	30	
12	Schematic representation of a non-ionic surfactant vesicle and	33	
	the loaded hydrophilic and hydrophobic drugs		
13	Target sites of transfollicular delivery	46	
14	Penetration depths in micrometer of different sizes of particles	52	
	in relation to the target sites within terminal hair follicle (THF)		
	and vellus hair follicle (VHF)		
15	Skin sandwich system	54	

16	Scheme of transfollicular evaluation through epidermal membrane	55	
	and skin sandwich system		
17	Selective follicular blocking before (a) and after (b) nail varnish	56	
	application		
18	S Scheme of transfollicular evaluation using selective follicular	57	
	blocking method		
19	O Cyanoacrylate skin surface stripping technique after tape stripping	58	
20	Scheme of transfollicular evaluation by differential stripping	58	
	technique consisted of tape stripping and cyanoacrylate		
	skin surface stripping		
21	Scheme of cell cytotoxicity by SRB assay	60	
22	Scheme of melanin content evaluation <i>in vitro</i>	62	
23	Scheme of twosingse activity evaluation	63	
20	Scheme of TDD 2 activity evaluation	61	
24	Scheme of TRP-2 activity evaluation	04	
25	Scheme of total protein content evaluation	66	
26	5 Scheme of <i>in vivo</i> irritation determination	67	
27	Scheme of <i>in vivo</i> melanogenesis induction evaluation	69	
28	FTIR spectra of myristic acid (MA; a) and myristic acid methyl	106	
	ester (MM; b)		
29	GC/MS spectra of standard palmitic acid methyl ester (standard PM; a)	107	
	and synthesized palmitic acid methyl ester (PM; b)		
30	Percentage remaining of lauric acid methyl ester (LM; a), myristic	109	
	acid methyl ester (MM; b), palmitic acid methyl ester (PM; c) and		
	stearic acid methyl ester (SM; d)		

xxvii

- 31 Percentage cell viability (a), percentage relative ratio of melanin 110 content (b) and percentage relative ratio of tyrosinase activity (c) of B16F10 melanoma cells treated with theophylline, a positive control, at 2.5, 5.0 and 10.0 μ g/ml
- 32 Percentage cell viability of B16F10 melanoma cells treated with 1 various concentrations of esters [lauric acid methyl ester (LM), myristic acid methyl ester (MM), palmitic acid methyl ester (PM) and stearic acid methyl ester (SM)] and their corresponding saturated fatty acids [lauric acid (LA), myristic acid (MA), palmitic acid (PA) and stearic acid (SA)]
- 33 Percentage relative ratio of melanin content of B16F10 melanoma cells 113 treated with various concentrations of esters [lauric acid methyl ester (LM), myristic acid methyl ester (MM), palmitic acid methyl ester (PM) and stearic acid methyl ester (SM)] and their corresponding saturated fatty acids [lauric acid (LA), myristic acid (MA), palmitic acid (PA) and stearic acid (SA)]
- Percentage relative ratio of tyrosinase activity of B16F10 melanoma 116
 cells treated with various concentrations of esters [lauric acid methyl
 ester (LM), myristic acid methyl ester (MM), palmitic acid methyl ester
 (PM) and stearic acid methyl ester (SM)] and their corresponding
 saturated fatty acids [lauric acid (LA), myristic acid (MA), palmitic
 acid (PA) and stearic acid (SA)]

35 GC/MS spectrum of myristic acid methyl ester (MM)

111

117

- The negative staining TEM images of blank neutral niosomes (a), 125
 neutral niosomes loaded with MM (b), blank cationic niosomes (c),
 cationic niosomes loaded with MM (d), blank anionic niosomes (e)
 and anionic niosomes loaded with MM (f)
- 37 Percentage remaining of the dry free form of MM (a) and that loaded 128 in neutral (b), cationic (c) and anionic (d) niosomes when kept at 4 ± 2 , room temperature (30±2) and 45±2°C for 3 months
- Percentage cell viability of B16F10 melanoma cells treated with the 130 blank neutral (Blank N) and the blank cationic (Blank C) niosomes at the concentrations of 0.20, 0.50, 1.00 and 2.00 mM at 24- (_1d), 48-(_2d) and 72- (_3d) h incubation times

132

- 39 Cytotoxicity of theophylline (TP), free MM (FMM), blank neutral niosomes (Blank N) and neutral niosomes loaded with MM (MM N), blank cationic niosomes (Blank C) and cationic niosomes loaded with MM (MM C), blank anionic niosomes (Blank A) and anionic niosomes loaded with MM (MM A) in human skin fibroblasts (a), B16F10 melanoma cells (b) and cytotoxic ratio (c) of cell viability in normal and cancer cells
- 40 Percentage relative ratio of melanin content of B16F10 melanoma 136 cells treated with theophylline (TP), free MM (FMM), blank neutral niosomes (Blank N) and neutral niosomes loaded with MM (MM N), blank cationic niosomes (Blank C) and cationic niosomes loaded with MM (MM C), blank anionic niosomes (Blank A) and anionic niosomes loaded with MM(MM A)

- Percentage relative ratio of tyrosinase activity of B16F10 melanoma 137 cells treated with theophylline (TP), free MM (FMM), blank neutral niosomes (Blank N) and neutral niosomes loaded with MM (MM N), blank cationic niosomes (Blank C) and cationic niosomes loaded with MM (MM C), blank anionic niosomes (Blank A) and anionic niosomes loaded with MM (MM A)
- 42 Percentage relative ratio of TRP-2 activity of B16F10 melanoma cells 139 treated with theophylline (TP), free MM (FMM), blank neutral niosomes (Blank N) and neutral niosomes loaded with MM (MM N), blank cationic niosomes (Blank C) and cationic niosomes loaded with MM (MM C), blank anionic niosomes (Blank A) and anionic niosomes loaded with MM (MM A)
 - Cumulative amounts of MM (μ g/cm²) from solution (MM), cationic 141 niosomes (MM C), neutral niosomes (MM N) and anionic niosomes (MM A) in skin (a) and the receiver (b) by follicular closing technique using vertical Franz diffusion cells at 0, 1, 2, 4 and 6 h
- Percentage changes of turbidity obtained from the mixture of non-ionic 145 surfactants, including HC-60, HC-100, TS-10V, PEN-4620, GT-20IS, Decaglyn 1-IS, Sunsoft Q-192Y, L-1695 and Tween20, and cationic niosomes loaded with MM

147

45 Percentage changes of vesicular size of the mixture of non-ionic surfactant, including HC-60, HC-100, TS-10V, PEN-4620, GT-20IS, Decaglyn 1-IS, Sunsoft Q-192Y, L-1695 and Tween20, and cationic niosomes loaded with MM

46	The negative staining TEM images of cationic niosomes loaded	154
	with MM (a) and those incorporated in hair lotion (b)	
47	Percentage remaining of MM loaded (a) and not loaded (b) in	158
	cationic niosomes in the hair lotions when kept at 4 ± 2 , room	
	temperature (RT; 30 ± 2) and $45\pm2^{\circ}$ C for 3 months	
48	Cumulative amounts in skin (a) and the receiver (b) of MM (μ g/cm ²)	161
	loaded (MM Cf) and not loaded (MM f) in cationic niosomes	
	incorporated in hair lotion by follicular closing technique using	
	vertical Franz diffusion cells at 0, 1, 2, 4 and 6 h	
49	Pigmentation scores in mice ($n = 3$ per group) treated with hair lotions	167
	containing theophylline (TP), MM loaded (MM Cf) and not loaded	
	(MM f) in cationic niosomes, and hair lotion base (F)	
50	Histological examination of skin specimens treated with hair lotions	168
	containing theophylline (a), MM loaded (b) and not loaded (c) in	
	cationic niosomes, and hair lotion base (d) using melanin bleach	
	staining technique	
A.1	Chemical structure of polyoxyethylene-2-stearyl ether	210
A.2	Chemical structure of cholesterol	211
A.3	Chemical structure of dimethyl dioctadecyl ammonium bromide	211
A.4	Chemical structure of dicetyl phosphate	212

ABBREVIATIONS AND SYMBOLS

α	alpha
β	beta
γ	gamma
%	percentage
>	is greater than
<	is less than
o	degree
°C	degree Celcius
μg	microgram
μl	microliter
μm	micrometer
μM	micromolar
ACTH	adrenocorticotropic hormone
ATPase	adenosine triphosphate
Brij72	polyethylene-2-stearyl ether
C	carbon
cAMP	cyclic adenosine monophosphate
CO ₂	carbon dioxide
cm	centimeter
cm ²	square centimeter

xxxiii

СМС	carboxy methyl cellulose
CREB	cAMP responsive element binding protein
d	day
DDAB	dimethyl dioctadecyl ammonium bromide
DHI	5,6-dihydroxyindole
DHICA	5,6-dihydroxy carboxylic acid
DLS	dynamic light scattering
DMEM	Dulbecco's modified eagle medium
DNA	deoxyribonucleic acid
DP	Dicetyl phosphate
EDTA	ethylenediaminetetraacetic acid
FBS	fetal bovine serum
FTIR	Fourier transform infrared spectroscopy
g	gram
GC/MS	gas chromatography-mass spectrometry
h	hour
H^+	proton
HF	hair follicle
HLB	hydrophilic-lipophilic balance
HPLC	high performance liquid chromatography
НРМС	hydroxyl propyl methyl cellulose
kDa	kilodalton Chiang Mai University
kg	kilogram
IR	infrared

xxxiv

L-	levo form
LA	lauric acid
LM	lauric acid methyl ester
Log Ko/w	partition coefficient value
LUV	large unilamellar vesicles
m	meter
MC1	melanocortin 1 receptor
min	minute
mg	milligram
ml	milliliter
mm	millimeter
mM	millimolar
mRNA	messenger ribonucleic acid
mV	millivolt
МА	myristic actid
МАРК	mitogen-activated protein kinase
MITF	microphthalmia-associated transcription factor
MLV	multilamellar vesicles
MM	myristic acid methyl ester, methyl myristate
MSH	melanocyte-stimulating hormone
MTT	3-(4,5-dimethyl thiazol-2-yl)-2,5-diphenyl tetrazolium bromide
MW	molecular weight
n-	straight-chain, unbranched isomer
nm	nanometer

OECD	Organization for Economic Co-operation and Development
р-	para Para
РА	palmitic acid
PBS	phosphate buffer saline
PII	primary irritation index
РОМС	proopiomelanocortin
РМ	palmitic acid methyl ester
psi	pounds per square inch
RH	relative humidity
rpm	revolutions per minute
S	second
SA	stearic acid
S.E.	standard error of mean
SM	stearic acid methyl ester
SRB	sulforhodamine B
SUV	small unilamellar vesicles
TEM	transmission electron microscope
TYR	tyrosinase
TRP-1	tyrosinase-related protein-1
TRP-2	tyrosinase-related protein-2
UV	ultraviolet
v/v	volume by volume ang Mai University
w/v	weight by volume
w/w	weight by weight