

ห้องสมุดงานวิจัย สำนักงานคณะกรรมการการวิจัยแห่งชาติ



E46992

DEVELOPMENT OF NANOPARTICLES ENTRAPPED THANAKHA'S
(*Naringi crenulata*) BARK AND ALOE'S (*Aloe vera*) GEL EXTRACT FOR
APPLICATION IN SUNSCREEN PRODUCT

WEERAYUT MUANGTON

A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Master of Science Degree
in Pharmaceutical Sciences (International Program)

October 2010

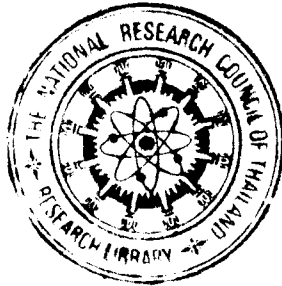
Copyright 2010 by Naresuan University

600246673



E46992

**DEVELOPMENT OF NANOPARTICLES ENTRAPPED THANAKHA'S
(*Naringi crenulata*) BARK AND ALOE'S (*Aloe vera*) GEL EXTRACT FOR
APPLICATION IN SUNSCREEN PRODUCT**




WEERAYUT MUANGTON

**A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Master of Science Degree
in Pharmaceutical Sciences (International Program)**

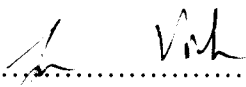
October 2010

Copyright 2010 by Naresuan University


This thesis entitled “Development of nanoparticles entrapped thanakha’s (*Naringi crenulata*) bark and aloe’s (*Aloe vera*) gel extract for application in sunscreen product” by Weerayut Muangton in partial fulfillment of the requirements for the Master of Science Degree in Cosmetic Sciences (International Program) is hereby approved.

.....Chair

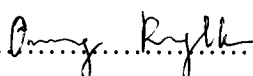
(Associate Professor Nantaka Khorana, Ph.D.)

.....Committee

(Associate Professor Jarupa Viyoch, Ph.D.)


.....Committee

(Assistant Professor Anan Ounaroorn, Ph.D.)

.....Committee

(Assistant Professor Onanong Pringsulaka, Ph.D.)

Approved

.....
(Assistant Professor Kanungnit Pupatwibul, Ph.D.)

Dean of the Graduate School

October 2010

ACKNOWLEDGEMENT

First of all, I would like to acknowledge Thailand Research Fund Master Research Grants (TRF-MAG) and the Center of Excellence for Innovation in Chemistry (PERCH-CIC), Commission on Higher Education, for the financial support to this study.

I would like to express my sincere gratitude to my advisor, Associate Professor Dr. Jarupa Viyoch for her invaluable advice, useful guidance and encouragement throughout my study. Her patience, kindness and understanding are also deeply appreciated.

Special thanks are expressed to co-advisor Assistance Professor Dr. Anan Ounaroon for his kind advice and encouragement throughout my study.

I also would like to thank all the members of thesis committee, Associate Professor Dr. Nantaka Khorana and Assistance Professor Dr. Onanong Pringsulaka, for their valuable comments.

I very grateful thank to BORN TRAS company for supporting some ingredients used in this study.

I am gratefully acknowledged to all staffs in Faculty of Pharmaceutical Sciences and Cosmetics & Natural Products Research Center (CosNat) for their help.

Finally, I would like to express my thanks to my family for their endless love, care and encouragement.

Weerayut Muangton

| | |
|-----------------------|--|
| Title | DEVELOPMENT OF NANOPARTICLES ENTRAPPED THANAKHA'S (<i>Naringi crenulata</i>) BARK AND ALOE'S (<i>Aloe vera</i>) GEL EXTRACT FOR APPLICATION IN SUNSCREEN PRODUCT |
| Author | Weerayut Muangton |
| Advisor | Associate Professor Jarupa Viyoch, Ph.D. |
| Co-Advisor | Assistant Professor Anan Ounaroorn, Ph.D. |
| Academic Paper | Thesis M.Sc. in Cosmetic Sciences (International Program), Naresuan University, 2010 |
| Keywords | Thanakha, Aloe, Nanoparticles, Sunscreen, Liposomes |

ABTRACT

E46992

This study was aimed to develop nanoparticles entrapped *Naringi crenulata* bark and *Aloe vera* gel extract for application in sunscreen product.

The *N. crenulata* bark was extracted using methanol while that of the *A. vera* gel was precipitated protein with 35% ammonium sulfate saturation at 4 °C, respectively. Subsequently, *N. crenulata* bark extract was examined the antioxidant activity by comparing with vitamin E (α -tocopherol) based on DPPH assay. The obtained EC₅₀ value of *N. crenulata* bark extract was 146.1±1.1 µg/mL while vitamin E, a well known as anti-oxidative substance, provided EC₅₀ of 11.1±1.1 µg/mL. *A. vera* gel extract was examined the anti-inflammatory activity by comparing with prednisolone based on inhibitory TNF- α production released from RAW 264.7 macrophage cell lines with LPS activating. The results revealed that *A. vera* gel extract could inhibit production of TNF- α by LPS induced macrophages with IC₅₀ of 71.3±1.5 µg/mL while prednisolone had IC₅₀ of 25.6±1.2 µg/mL. In addition, the cytotoxic test of *N. crenulata* bark extract and *A. vera* gel extract on viable human keratinocyte cell lines (HaCat cells) was investigated by XTT assay kit. The results showed that the toxic effect of *N. crenulata* bark extract on cell viability of HaCat cells was in the dose-dependent manner while that of *A. vera* gel extract showed toxic dose at high concentration.

LIST OF CONTENTS

| Chapter | Page |
|--|-----------|
| I INTRODUCTION..... | 1 |
| The rational for the study..... | 1 |
| The objective of the study..... | 2 |
| The expected output of the study..... | 2 |
| II LITERATURE REVIEWS..... | 3 |
| Biological structure of skin..... | 3 |
| Effect of UV radiation to human skin..... | 6 |
| Skin immune system with UV radiation..... | 8 |
| Free radicals with UV radiation..... | 10 |
| Antioxidant property with DPPH assay..... | 11 |
| Mechanism of sunscreen action..... | 12 |
| Natural compounds..... | 13 |
| Hot melt microemulsion technique..... | 17 |
| Liposomes..... | 18 |
| Reverse phase evaporation technique..... | 19 |
| Evaluation of <i>in vitro</i> and <i>in vivo</i> sun protection..... | 19 |
| III RESEARCH METHADODOLOGY..... | 24 |
| Plant materials..... | 24 |
| Chemical and Reagents..... | 24 |
| Instruments..... | 26 |

LIST OF CONTENTS (CONT.)

| Chapter | Page |
|---|------------|
| Cell lines..... | 27 |
| The experimental designs..... | 28 |
| VI RESULTS AND DISCUSSION..... | 43 |
| Plant Extracts..... | 43 |
| Qualification of the extracts..... | 44 |
| Biological activities of the extracts..... | 46 |
| Cytotoxicity..... | 54 |
| Characterization of nanoparticles..... | 62 |
| Entrapment efficiency of <i>N. crenulata</i> bark extract incorporated into SLNs..... | 78 |
| Stability studies..... | 86 |
| Study of <i>in vitro</i> sun protection property..... | 94 |
| Preliminary study of <i>in vivo</i> sun protection factor (SPF) and ability of anti-inflammatory action..... | 97 |
| V CONCLUSIONS | 103 |
| REFERENCES..... | 105 |
| APPENDIX..... | 115 |
| BIOGRAPHY..... | 117 |

LIST OF TABLES

| Table | Page |
|--|------|
| 1 The percentage of free radical scavenging of <i>N. crenulata</i> bark extract dissolved in methanol..... | 47 |
| 2 The percentage of free radical scavenging of vitamin E (α -tocopherol) dissolved in methanol..... | 48 |
| 3 The inhibitory effects of inflammatory activity of <i>A. vera</i> gel extract dissolved in sterile water..... | 52 |
| 4 The inhibitory effects on inflammatory activity of prednisolone dissolved in ethanol..... | 53 |
| 5 Morphology of human keratinocyte cell line (HaCat) after treatment with various concentrations of <i>N. crenulata</i> bark extract of day 3 at magnification of 10X and 20X, respectively..... | 57 |
| 6 Morphology of human keratinocyte cell line (HaCat) after treatment with various concentrations of <i>A. vera</i> gel extract of day 3 at magnification of 10X and 20X, respectively..... | 60 |
| 7 Compositions of the formula studied: effect of cetyl palmitate content on particle size and polydispersity index..... | 65 |
| 8 Compositions of the formula studied: effect of cetyl alcohol content on particle size and polydispersity index..... | 67 |
| 9 Compositions of the formula studied: effect of rheodol TW-O120 content on particle size and polydispersity index..... | 70 |
| 10 Compositions of the formula studied: effect of disodium laureth sulfosuccinate content on particle size and polydispersity index..... | 70 |
| 11 Compositions of the final SLNs formulation..... | 75 |
| 12 The physicochemical properties of SLNs free and loading <i>N. crenulata</i> bark extract..... | 76 |

LIST OF TABLES (CONT.)

| Table | Page |
|---|------|
| 13 The physicochemical properties of liposomes free, loading <i>A. vera</i> gel and coating with chitosan..... | 82 |
| 14 UVA effectiveness-the Boot's star system..... | 94 |
| 15 UVA effectiveness-critical wavelength..... | 95 |
| 16 Test results of <i>in vitro</i> sun protection of each formulation..... | 95 |
| 17 Test results of <i>in vitro</i> water resistance of each sunscreen product..... | 96 |
| 18 Test results of SPF value of each sunscreen product measured by <i>in vivo</i> method..... | 98 |
| 19 The absorbance of free radical scavenging of <i>N. crenulata</i> bark Extract dissolved in methanol..... | 117 |
| 20 The absorbance of free radical scavenging of vitamin E (α -tocopherol) dissolved in methanol..... | 118 |
| 21 The cell viability of macrophage cell lines treated <i>A. vera</i> gel extract at various concentrations..... | 119 |
| 22 The cell viability of macrophage cell lines treated prednisolone at various concentrations..... | 120 |
| 23 The absorbance of TNF- α production released from RAW 264.7 macrophage cell lines with LPS activation of <i>A. vera</i> gel extract by using TNF- α elisa kit..... | 120 |
| 24 The absorbance of TNF- α production released from RAW 264.7 macrophage cell lines with LPS activation of prednisolone by using TNF- α elisa kit..... | 121 |
| 25 The cell viability of HaCat cell lines treated <i>N. crenulata</i> bark extract at day 1..... | 122 |
| 26 The cell viability of HaCat cell lines treated <i>N. crenulata</i> bark extract at day 2..... | 123 |

LIST OF TABLES (CONT.)

| Table | Page |
|---|------|
| 27 The cell viability of HaCat cell lines treated <i>N. crenulata</i> bark extract at day 3..... | 123 |
| 28 The cell viability of HaCat cell lines treated <i>A. vera</i> gel extract at day 1..... | 124 |
| 29 The cell viability of HaCat cell lines treated <i>A. vera</i> gel extract at day 2..... | 124 |
| 30 The cell viability of HaCat cell lines treated <i>A. vera</i> gel extract at day 3..... | 125 |
| 31 Effect of cetyl palmitate on mean particle size and size distribution..... | 126 |
| 32 Effect of cetyl alcohol on mean particle size and size distribution.. | 126 |
| 33 Effect of rheodol TW-O120 on mean particle size and size distribution..... | 127 |
| 34 Effect of disodium laureth sulfosuccinatae on mean particle size and size distribution..... | 127 |
| 35 The physicochemical properties of SLNs free..... | 127 |
| 36 The physicochemical properties of SLNs loading <i>N. crenulata</i> bark extract..... | 128 |
| 37 Effect of ratios of phospholipids:cholesterol on mean particle size and size distribution..... | 128 |
| 38 The physicochemical properties of liposomes free..... | 128 |
| 39 The physicochemical properties of liposomes loading <i>A. vera</i> gel extract..... | 129 |
| 40 The physicochemical properties of liposomes loading <i>A. vera</i> gel extract with coating chitosan..... | 129 |
| 41 The absorbance of <i>N. crenulata</i> bark extract in various concentrations at wavelength 330 nm..... | 130 |

LIST OF TABLES (CONT.)

| Table | Page |
|--|------|
| 42 Entrapment efficiency of 1% (w/w) <i>N. crenulata</i> bark extract in 10 mL of SLNs..... | 131 |
| 43 The absorbance of bovine serum albumin (BSA) in various concentrations at wavelength 750 nm..... | 133 |
| 44 The total protein content in <i>A. vera</i> gel extract..... | 134 |
| 45 Entrapment efficiency of 0.06% (w/w) of <i>A. vera</i> gel extract in 6 mL liposomes coated chitosan..... | 135 |
| 46 Percent remaining of <i>N. crenulata</i> bark extract in the developed sunscreen product containing nano-encapsulated the extracts. | 137 |
| 47 Percent remaining of <i>N. crenulata</i> bark extract in the developed sunscreen product containing the extracts..... | 138 |
| 48 Percent remaining of total protein in the developed sunscreen product containing nano-encapsulated the extracts..... | 141 |
| 49 Percent remaining of total protein content in the developed sunscreen product containing the extracts..... | 142 |
| 50 Rheology of the developed sunscreen product containing nano-encapsulated the extracts..... | 144 |
| 51 Rheology of the developed sunscreen product containing the extracts..... | 145 |
| 52 pH of the developed sunscreen product containing nano-encapsulated the extracts..... | 146 |
| 53 pH of the developed sunscreen product containing the extracts... | 147 |
| 54 The sun protection value of each sunscreen product..... | 148 |
| 55 The sun protection value of the developed sunscreen product before and after testing water resistance..... | 149 |
| 56 Times of an appearance minimal erythema minimal with different sunscreen products..... | 150 |

LIST OF TABLES (CONT.)

| Table | Page |
|---|------|
| 57 Sun protection factor (SPF) with different sunscreen products..... | 151 |
| 58 Summarizes of erythema values of subjects treated with different sunscreen products before exposure to sunlight..... | 152 |
| 59 Summarizes of erythema values of subjects treated with different sunscreen products after exposure to sunlight..... | 152 |
| 60 Erythema values of subject A treated with different sunscreen products..... | 153 |
| 61 Erythema values of subject B treated with different sunscreen products..... | 154 |
| 62 Erythema values of subject C treated with different sunscreen products..... | 155 |
| 63 Erythema values of subject D treated with different sunscreen products..... | 156 |
| 64 Erythema values of subject E treated with different sunscreen products..... | 157 |
| 65 Erythema values of subject F treated with different sunscreen products..... | 158 |
| 66 Erythema values of subject G treated with different sunscreen products..... | 159 |
| 67 Erythema values of subject H treated with different sunscreen products..... | 160 |
| 68 Erythema values of subject I treated with different sunscreen products..... | 161 |
| 69 Erythema values of subject J treated with different sunscreen products..... | 162 |

LIST OF TABLES (CONT.)

| Table | Page |
|---|------|
| 70 Summarizes of melanin values of subjects treated with different sunscreen products before exposure to sunlight..... | 163 |
| 71 Summarizes of melanin values of subjects treated with different sunscreen products after exposure to sunlight..... | 163 |
| 72 Melanin values of subject A treated with different sunscreen products..... | 164 |
| 73 Melanin values of subject B treated with different sunscreen products..... | 165 |
| 74 Melanin values of subject C treated with different sunscreen products..... | 166 |
| 75 Melanin values of subject D treated with different sunscreen products..... | 167 |
| 76 Melanin values of subject E treated with different sunscreen products..... | 168 |
| 77 Melanin values of subject F treated with different sunscreen products..... | 169 |
| 78 Melanin values of subject G treated with different sunscreen products..... | 170 |
| 79 Melanin values of subject H treated with different sunscreen products..... | 171 |
| 80 Melanin values of subject I treated with different sunscreen products..... | 172 |
| 81 Melanin values of subject J treated with different sunscreen products..... | 173 |

LIST OF FIGURES

| Figure | Page |
|---|------|
| 1 Diagrammatic illustration of skin structure..... | 3 |
| 2 The structure of epidermis..... | 4 |
| 3 Diagram of UV-induced immunosuppression..... | 10 |
| 4 (left) Free radical form of DPPH and (right) reduced form of DPPH after accepted an electron or hydrogen atom..... | 11 |
| 5 The illustration of <i>Naringi crenulata</i> | 13 |
| 6 Illustration of structure of active components in <i>N. crenulata</i> bark..... | 14 |
| 7 The illustration of <i>Aloe vera</i> | 15 |
| 8 Models of incorporation of active compound into SLNs: (I) homogeneous matrix model, (II) active compound-enriched shell model and (III) active compound-enriched core model | 16 |
| 9 Schematic of lipids incorporated into a bilayer membrane to form liposomes..... | 18 |
| 10 Models of liposomes depending on size and number of lamellae | 18 |
| 11 Illustration of compositions of Mexameter® MX 18..... | 22 |
| 12 Illustration shows divided test sites of each subject from shoulder to waist..... | 40 |
| 13 The appearance of <i>N. crenulata</i> bark extract..... | 43 |
| 14 The appearance of <i>A. vera</i> gel extract..... | 44 |
| 15 TLC profiles of <i>N. crenulata</i> bark extract with a solvent system of hexane and ethyl acetate under UV illumination..... | 45 |
| 16 SDS-PAGE analysis of protein in <i>A. vera</i> gel extract on 12% Bis-Tris gel stained with coomassie brilliant blue..... | 46 |
| 17 The sigmoid curves of antioxidant activity of <i>N. crenulata</i> bark extract and vitamin E dissolved in methanol..... | 49 |

LIST OF FIGURES

| Figure | Page |
|--|------|
| 18 The cell viability of macrophage cell lines treated <i>A. vera</i> gel extract was determined by XTT assay..... | 50 |
| 19 The cell viability of macrophage cell lines treated prednisolone was determined by XTT assay..... | 51 |
| 20 Effect of <i>A. vera</i> gel extract on inhibition of TNF- α production of RAW 264.7 macrophage cell lines activated with LPS... | 52 |
| 21 Effect of prednisolone on inhibition of TNF- α production of RAW 264.7 macrophage cell lines activated with LPS..... | 54 |
| 22 The effect of <i>N. crenulata</i> bark extract on cell viability of HaCat cells at day 1, 2 and 3..... | 55 |
| 23 The effect of <i>A. vera</i> gel extract on cell viability of HaCat cells at day 1, 2 and 3..... | 56 |
| 24 The model of SLNs loaded <i>N. crenulata</i> bark extract..... | 64 |
| 25 Effect of cetyl palmitate concentration on the mean particle size and polydispersity index of SLNs..... | 65 |
| 26 Schematic representation of the influence of lipid concentration on particle size..... | 66 |
| 27 Effect of cetyl alcohol concentration on the mean particle size and polydispersity index of SLNs..... | 68 |
| 28 Schematic representation of the influence of cetyl alcohol on particle size..... | 69 |
| 29 Effect of rheodol TW-O120 concentration on the mean particle size and polydispersity index of SLNs..... | 71 |
| 30 Schematic representation of the influence of non-ionic surfactant concentration on particle size..... | 72 |
| 31 Effect of disodium laureth sulfosuccinate concentration on the mean particle size and polydispersity index of SLNs..... | 73 |

LIST OF FIGURES (CONT.)

| Figure | Page |
|---|------|
| 32 Schematic representation of the influence of ionic surfactant concentration on particle size..... | 74 |
| 33 Schematic representation of the size of SLN particle before and after loading <i>N. crenulata</i> bark extract..... | 77 |
| 34 SEM micrograph of solid lipid nanoparticles consisted of 1% (w/w) <i>N. crenulata</i> bark extract, 2% (w/w) cetyl palmitate, 3% (w/w) cetyl alcohol, 3% (w/w) almond oil, 3% (w/w) rheodol TW-O120 and 3% (w/w) disodium laureth sulfosuccinate..... | 78 |
| 35 Model of incorporation of <i>N. crenulata</i> bark extract into SLNs... | 79 |
| 36 Diagrammatic illustration of mechanism of liposomes preparation by reverse phase evaporation technique..... | 80 |
| 37 TEM micrograph of liposomes loading <i>A. vera</i> gel extract with coating chitosan at magnification of 13.5 kx..... | 83 |
| 38 Effect of the variation of ratios of PC:cholesterol on the mean particle size and polydispersity index of liposomes..... | 84 |
| 39 Diagrammatic illustration of the influence of phospholipids concentration on particle size by reverse phase evaporation... | 85 |
| 40 Percentage of <i>N. crenulata</i> bark extract remaining in the developed sunscreen product containing nano-encapsulated the extracts and the developed sunscreen product containing the extracts under normal condition for various periods and stress condition employing 10 heat-cool cycles and presence of light..... | 87 |

LIST OF FIGURES (CONT.)

| Figure | Page |
|--|------|
| 41 Mechanism of <i>N. crenulata</i> bark extract expulsion during incorporation into gel formulation; transition to highly ordered lipid crystal..... | 89 |
| 42 Percentage of total protein remaining in the developed sunscreen product containing nano-encapsulated the extracts and the developed sunscreen product containing the extracts under normal condition for various periods and stress condition employing 10 heat cool-cycles and presence of light..... | 90 |
| 43 Viscosity of the developed sunscreen product containing nano-encapsulated the extracts and the developed sunscreen product containing the extracts under normal condition for various periods and stress condition employing 10 heat-cool cycles and presence of light..... | 91 |
| 44 Rheograms of the developed sunscreen product containing nano-encapsulated the extracts and the developed sunscreen product containing the extracts after preparation..... | 93 |
| 45 pH of the developed sunscreen product containing nano-encapsulated the extracts and the developed sunscreen product containing the extracts under normal condition for various periods and stress condition employing 10 heat-cool cycles and presence of light..... | 93 |
| 46 Average times of an appearance minimal erythema with different sunscreen products..... | 99 |
| 47 Comparison of sun protection factor (SPF) with different sunscreen products..... | 100 |

LIST OF FIGURES (CONT.)

| Figure | Page |
|---|------|
| 48 Erythema values of subjects treated with different sunscreen products after exposure to sunlight..... | 101 |
| 49 Melanin values of subjects treated with different sunscreen products after exposure to sunlight..... | 101 |
| 50 The calibration curve of total absorbance of <i>N. crenulata</i> bark extract..... | 131 |
| 51 The calibration curve of bovine serum albumin..... | 134 |

ABBREVIATIONS

| | | |
|------------------|---|---|
| <i>A. vera</i> | = | <i>Aloe vera</i> |
| α | = | alpha |
| BCC | = | basal carcinoma |
| BSA | = | bovine serum albumin |
| CC | = | carcinoma |
| °C | = | degree celsius |
| CHS | = | contact hypersensitivity |
| CI | = | confident interval |
| CPD | = | cyclobutane pyrimidine dimers |
| CV | = | coefficient of variation |
| Cont. | = | continued |
| DCs | = | dendritic cells |
| DMEM | = | Dulbecco's Modified Eagle's Medium |
| DNA | = | deoxyribonucleic acid |
| DPPH | = | 1,1- diphenyl-2-picrylhydrazyl radicals |
| EC ₅₀ | = | half maximal effective concentration |
| EI | = | erythema index |
| ELISA | = | Enzyme-linked immune-sorbent assay |
| g | = | gram |
| FBS | = | fetal bovine serum |
| hr | = | hour |
| IC ₅₀ | = | half maximal inhibitory concentration |
| IL | = | interleukin |
| IPD | = | immediate pigment-darkening reaction |
| IR | = | infrared |
| kDa | = | kilo dalton |
| μ l | = | micro liter |
| LCs | = | langerhan cells |

ABBREVIATIONS (CONT.)

| | | |
|---------------------|---|-------------------------------------|
| LPS | = | lipopolysaccharide |
| LUV | = | large unilamellar vesicles |
| MED | = | minimal erythema dose |
| mg | = | milligram |
| MI | = | melanin index |
| min | = | minute |
| mL | = | milliliter |
| MLV | = | multi lamellar vesicle |
| MM | = | malignant melanoma |
| mon | = | month |
| MW | = | molecular weight |
| <i>N. crenulata</i> | = | <i>Naringi crenulata</i> |
| NSMC | = | non-melanoma skin cancer |
| PAF | = | platelet activating factor |
| PC | = | phosphatidyl chlorine |
| pg | = | picogram |
| pH | = | power of hydrogen ion concentration |
| PI | = | polydispersity index |
| REV | = | relative erythema value |
| RMV | = | relative melanin value |
| rpm | = | revolutions per minute |
| ROS | = | radical oxygen species |
| S.D. | = | standard deviation |
| SDS | = | sodium dedocyl sulfate |
| SEM | = | scanning electron microscopy |
| SLNs | = | solid lipid nanoparticles |
| SPF | = | sun protection factor |

ABBREVIATIONS (CONT.)

| | | |
|-----|---|---|
| SUV | = | small unilamellar vesicle |
| TEM | = | transmission electron microscopy |
| TLC | = | thin layer chromatography |
| UCA | = | urocanic acid |
| UV | = | ultraviolet |
| UVA | = | ultraviolet A |
| UVB | = | ultraviolet B |
| v/v | = | volume by volume |
| w/v | = | weight by volume |
| w/w | = | weight by weight |
| XTT | = | sodium 3'-[1-(phenylamino carbonyl)-3,4-tetrazolium]-bis(4-methoxy-6-nitro) benzene sulfonic acid hydrate |