

Chulalongkorn University

Chula Digital Collections

Chulalongkorn University Theses and Dissertations (Chula ETD)

2019

Free radical scavenging compounds from dendrobium lindleyi

Pichayatri Khoonrit

Faculty of Pharmaceutical Sciences

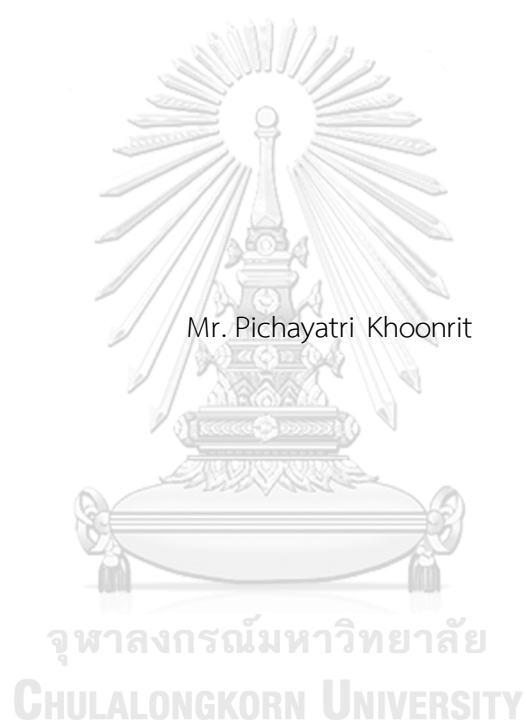
Follow this and additional works at: <https://digital.car.chula.ac.th/chulaetd>

Recommended Citation

Khoonrit, Pichayatri, "Free radical scavenging compounds from dendrobium lindleyi" (2019).
Chulalongkorn University Theses and Dissertations (Chula ETD). 8789.
<https://digital.car.chula.ac.th/chulaetd/8789>

This Thesis is brought to you for free and open access by Chula Digital Collections. It has been accepted for inclusion in Chulalongkorn University Theses and Dissertations (Chula ETD) by an authorized administrator of Chula Digital Collections. For more information, please contact ChulaDC@car.chula.ac.th.

FREE RADICAL SCAVENGING COMPOUNDS FROM *DENDROBIUM LINDLEYI*



Mr. Pichayatri Khoonrit

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Pharmaceutical Sciences and Technology

Common Course

FACULTY OF PHARMACEUTICAL SCIENCES

Chulalongkorn University

Academic Year 2019

Copyright of Chulalongkorn University

สารदानอนุมูลิสรจากเอื้องผึ้ง



นายพิชญาตรี ชุนฤทธิ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาเภสัชศาสตร์และเทคโนโลยี ไม่สังกัดภาควิชา/เทียบเท่า

คณะเภสัชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2562

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

Thesis Title	FREE RADICAL SCAVENGING COMPOUNDS FROM <i>DENDROBIUM LINDLEYI</i>
By	Mr. Pichayatri Khoonrit
Field of Study	Pharmaceutical Sciences and Technology
Thesis Advisor	Associate Professor BOONCHOO SRITULARAK, Ph.D.
Thesis Co Advisor	Professor KITTISAK LIKHITWITAYAWUID, Ph.D.

Accepted by the FACULTY OF PHARMACEUTICAL SCIENCES, Chulalongkorn
University in Partial Fulfillment of the Requirement for the Master of Science

..... Dean of the FACULTY OF
PHARMACEUTICAL SCIENCES
(Assistant Professor RUNGPETCH SAKULBUMRUNGSIL,
Ph.D.)

THESIS COMMITTEE

..... Chairman
(Assistant Professor TAKSINA CHUANASA, Ph.D.)
..... Thesis Advisor
(Associate Professor BOONCHOO SRITULARAK, Ph.D.)
..... Thesis Co-Advisor
(Professor KITTISAK LIKHITWITAYAWUID, Ph.D.)
..... Examiner
(Assistant Professor CHAISAK CHANSRINIYOM, Ph.D.)
..... External Examiner
(Duangpen Pattamadilok, Ph.D.)

พิชญาดรี ขุนฤทธิ์ : สารต้านอนุมูลอิสระจากเอื้องผึ้ง. (FREE RADICAL SCAVENGING COMPOUNDS FROM *DENDROBIUM LINDLEYI*) อ.ที่ปรึกษาหลัก : รศ. ภก. ดร.บุญชู ศรีตุลารักษ์, อ.ที่ปรึกษาร่วม : ศ. ภก. ดร.กิตติศักดิ์ ลิขิตวิทยาวุฒิ

อนุมูลอิสระก่อให้เกิด oxidative stress ซึ่งเป็นหนึ่งในสาเหตุสำคัญของการเกิดโรคหลายชนิด และในปัจจุบันมีการค้นพบสารที่มีฤทธิ์ยับยั้งอนุมูลอิสระจากพืชสกุล *Dendrobium* โดยเอื้องผึ้งเป็นพืชในสกุลนี้ที่ยังไม่เคยมีรายงานฤทธิ์ทางชีวภาพรวมถึงฤทธิ์ยับยั้งอนุมูลอิสระ งานวิจัยฉบับนี้จึงได้สกัดแยกสารสกัดเอทิลเอซีเทตของเอื้องผึ้งจนได้สารบริสุทธิ์ 5 ชนิด ซึ่งประกอบไปด้วยสารชนิดใหม่ 1 ชนิด โดยให้ชื่อว่า 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl และสารที่เคยค้นพบแล้วอีก 4 ชนิด ได้แก่ chrysotoxine gigantol cypripedin และ moscatilin ต่อมาจึงทดสอบฤทธิ์ยับยั้งอนุมูลอิสระโดยใช้ DPPH radical scavenging assay ร่วมกับ superoxide radical scavenging activity assay และ ORAC assay ผลการทดสอบพบว่า chrysotoxine gigantol และ moscatilin สามารถยับยั้ง DPPH radical ได้เทียบเท่า Trolox และเมื่อทดสอบด้วย superoxide radical scavenging activity assay และ ORAC assay พบว่า 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl chrysotoxine gigantol และ moscatilin มีฤทธิ์ยับยั้งอนุมูลอิสระมากกว่า Trolox ในขณะที่ cypripedin มีฤทธิ์น้อยที่สุดจากการทดสอบทั้งสามวิธี การค้นพบในครั้งนี้แสดงให้เห็นว่า 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl chrysotoxine gigantol และ moscatilin มีศักยภาพในการศึกษาเพิ่มเติมเพื่อพัฒนาไปเป็นยาที่ใช้รักษาโรคที่เกี่ยวข้องกับ oxidative stress

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

สาขาวิชา เกษษศาสตร์และเทคโนโลยี
ปีการศึกษา 2562

ลายมือชื่อนิสิต
ลายมือชื่อ อ.ที่ปรึกษาหลัก
ลายมือชื่อ อ.ที่ปรึกษาร่วม

6270019033 : MAJOR PHARMACEUTICAL SCIENCES AND TECHNOLOGY

KEYWORD: Dendrobium lindleyi, free radical, bibenzyls, phenanthrenequinones,
Dendrobium, Antioxidant

Pichayatri Khoonrit : FREE RADICAL SCAVENGING COMPOUNDS
FROM *DENDROBIUM LINDLEYI*. Advisor: Assoc. Prof. BOONCHOO
SRITULARAK, Ph.D. Co-advisor: Prof. KITTISAK LIKHITWITAYAWUID, Ph.D.

Free radicals lead to oxidative stress which plays an important role in the development of many diseases. *Dendrobium lindleyi* belongs to *Dendrobium*, a genus the secondary metabolites of which were reported as free radical scavenging compounds. However, the bioactivity of *D. lindleyi* has never been revealed. In this study, the EtOAc extract of *D. lindleyi* was fractionated to give five pure compounds identified by spectroscopic techniques as a new constituent named 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl along with four known compounds including chrysotoxine, gigantol, cyprisedin, and moscatilin. DPPH radical, superoxide radical, and ORAC assay were performed to evaluate their radical scavenging activities. Chrysotoxine, gigantol, and moscatilin exhibited comparable activity to Trolox in DPPH assay. In the superoxide radical and ORAC assays, the new compound, chrysotoxine, gigantol, and moscatilin were more potent than Trolox. Conversely, cyprisedin was a poor radical scavenger in all tests. These findings encourage further research of the four active components for the treatment of conditions related to oxidative stress.

Field of Study: Pharmaceutical Sciences
and Technology

Student's Signature

Academic Year: 2019

Advisor's Signature

Co-advisor's Signature

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude to my advisors, Associate Professor Boonchoo Sritularak, Ph.D. and Professor Kittisak Likhitwitayawuid, Ph.D., for their motivation, guidance, and extensive knowledge. It was a magnificent opportunity to research under their supervision. Everything they have offered is exceedingly appreciated.

I would like to extend my sincere thanks to Miss Kaskamol Chanpokapaiboon as well as Miss Thamonwan Trakranrungsie, supportive friends and research partners who mutually initiated this research. I express my special thanks to Mr. Virunh Kongkatitham, a doctoral student, who provided practical suggestions from his experiences. I also thank staff members of the Department of Pharmacognosy and Pharmaceutical Botany for their assistance and generousness throughout my study period.

The Chulalongkorn University Graduate scholarship to commemorate the 72nd anniversary of his Majesty King Bhumibala Aduladeja from the Graduate school and instrumental supports from Pharmaceutical Research Instrument Center, Faculty of Pharmaceutical Sciences, Chulalongkorn University, are gratefully acknowledged.

Besides, I cannot leave my family without mentioning. I greatly appreciate their encouragement, caring, and love, especially, when the times got rough. It was a comfort and relief to know that they were always behind.

Pichayatri Khoonrit

TABLE OF CONTENTS

	Page
ABSTRACT (THAI)	iii
ABSTRACT (ENGLISH).....	iv
ACKNOWLEDGEMENTS	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xii
LIST OF FIGURES	xiv
ABBREVIATIONS AND SYMBOLS	1
CHAPTER I INTRODUCTION	5
CHAPTER II HISTORICAL	16
1. Chemical constituents of <i>Dendrobium</i> species	16
2. Free radical scavenging activities of <i>Dendrobium</i> species	90
CHAPTER III EXPERIMENTAL	94
1. Source of plant materials	94
2. Extraction and isolation	94
2.1 General techniques	94
2.1.1 Thin-layer chromatography (TLC)	94
2.1.2 Adsorption column chromatography	94
2.1.3 Size-exclusion chromatography	94
2.2 Extraction	95
2.3 Isolation	95
2.3.1 Isolation of 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl	96

2.3.2 Isolation of chrysotoxine, gigantol, and cypripedin.....	96
2.3.3 Isolation of moscatilin.....	96
2.4 Solvents.....	96
3. Identification of isolated compounds.....	97
3.1 General techniques.....	97
3.1.1 Mass spectrometry (MS).....	97
3.1.2 Nuclear magnetic resonance (NMR) spectroscopy.....	97
3.1.3 Ultraviolet (UV) spectroscopy.....	98
3.1.4 Infrared (IR) spectroscopy.....	98
3.2 Physical and spectral data.....	98
3.2.1 compound 1 (4,5-dihydroxy-3,3',4'-trimethoxybibenzyl).....	98
3.2.2 compound 2 (chrysotoxine).....	98
3.2.3 compound 3 (gigantol).....	99
3.2.4 compound 4 (cypripedin).....	99
3.2.5 compound 5 (moscatilin).....	99
4. Free radical scavenging assay.....	100
4.1 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay.....	100
4.1.1 Materials and instruments.....	101
4.1.2 DPPH radical scavenging method.....	101
4.2 Superoxide radical scavenging activity assay.....	101
4.2.1 Materials and instruments.....	102
4.2.2 Superoxide radical scavenging activity method.....	102
4.3 Oxygen radical absorbance capacity (ORAC) assay.....	103
4.3.1 Materials and instruments.....	104

4.3.2 ORAC method.....	105
CHAPTER IV RESULTS AND DISCUSSION	107
1. Identification of isolated compounds	107
1.1 Identification of compound 1 (4,5-dihydroxy-3,3',4'-trimethoxybibenzyl) ..	107
1.2 Identification of compound 2 (chrysotoxine).....	110
1.3 Identification of compound 3 (gigantol)	113
1.4 Identification of compound 4 (cypripedin).....	116
1.5 Identification of compound 5 (moscatilin)	119
2. Free radical scavenging activities	122
CHAPTER V CONCLUSION	129
REFERENCES	130
APPENDICES.....	145
Appendix A: The spectral data of compound 1	145
A.1 Mass spectrum of compound 1	145
A.2 Infrared spectrum of compound 1	145
A.3 UV spectrum of compound 1	146
A.4 ^1H NMR (500 MHz) spectrum of compound 1 in CDCl_3	146
A.5 ^1H NMR (500 MHz) spectrum of compound 1 in CDCl_3 (expansion from δ_{H} 6.00-7.00).....	147
A.6 ^1H NMR (500 MHz) spectrum of compound 1 in CDCl_3 (expansion from δ_{H} 2.60-4.10).....	147
A.7 ^{13}C NMR (125 MHz) spectrum of compound 1 in CDCl_3	148
A.8 HSQC spectrum of compound 1 in CDCl_3	148

A.9 HSQC spectrum of compound 1 in CDCl ₃ (expansion from δ_C 98.0-140.0 (F1) and δ_H 2.60-3.96 (F2)).....	149
A.10 HSQC spectrum of compound 1 in CDCl ₃ (expansion from δ_C 24.0-64.0 (F1) and δ_H 2.60-4.80 (F2)).....	149
A.11 HSQC spectrum of compound 1 in CDCl ₃ (expansion from δ_C 50.0-62.0 (F1) and δ_H 3.68-4.06 (F2)).....	150
A.12 HSQC spectrum of compound 1 in CDCl ₃ (expansion from δ_C 48.0-62.0 (F1) and δ_H 3.72-4.01 (F2)).....	150
A.13 HSQC spectrum of compound 1 in CDCl ₃ (expansion from δ_C 52.5-60.0 (F1) and δ_H 3.80-3.89 (F2)).....	151
A.14 HMBC spectrum of compound 1 in CDCl ₃	151
A.15 HMBC spectrum of compound 1 in CDCl ₃ (expansion from δ_C 100.0-160.0 (F1) and δ_H 1.40-7.00 (F2)).....	152
A.16 HMBC spectrum of compound 1 in CDCl ₃ (expansion from δ_C 28.0-66.0 (F1) and δ_H 2.60-6.90 (F2)).....	152
A.17 HMBC spectrum of compound 1 in CDCl ₃ (expansion from δ_C 143.0-154.0 (F1) and δ_H 3.50-4.20 (F2)).....	153
A.18 HMBC spectrum of compound 1 in CDCl ₃ (expansion from δ_C 52.5-60.8 (F1) and δ_H 3.48-4.20 (F2)).....	153
A.19 NOESY spectrum of compound 1 in CDCl ₃	154
A.20 NOESY spectrum of compound 1 in CDCl ₃ (expansion from δ_H 1.10-4.00 (F1) and δ_H 4.80-7.05 (F2)).....	154
A.21 NOESY spectrum of compound 1 in CDCl ₃ (expansion from δ_H 2.60-3.18 (F1) and δ_H 6.00-6.95 (F2)).....	155

A.22 NOESY spectrum of compound 1 in CDCl ₃ (expansion from δ_{H} 3.70-4.18 (F1) and δ_{H} 6.05-7.00 (F2)).....	155
Appendix B: The spectral data of compound 2	156
B.1 Mass spectrum of compound 2.....	156
B.2 ¹ H NMR (300 MHz) spectrum of compound 2 in acetone- <i>d</i> ₆	156
B.3 ¹³ C NMR (75 MHz) spectrum of compound 2 in acetone- <i>d</i> ₆	157
B.4 ¹³ C NMR (75 MHz) spectrum of compound 2 in acetone- <i>d</i> ₆ (expansion from δ_{C} 30.0-160.0).....	157
B.5 HSQC spectrum of compound 2 in acetone- <i>d</i> ₆	158
B.6 HMBC spectrum of compound 2 in acetone- <i>d</i> ₆	158
B.7 NOESY spectrum of compound 2 in acetone- <i>d</i> ₆	159
B.8 NOESY spectrum of compound 2 in acetone- <i>d</i> ₆ (expansion from δ_{H} 2.50-4.15 (F1) and δ_{H} 6.19-7.14 (F2)).....	159
Appendix C: The spectral data of compound 3	160
C.1 Mass spectrum of compound 3	160
C.2 ¹ H NMR (300 MHz) spectrum of compound 3 in acetone- <i>d</i> ₆	160
C.3 ¹³ C NMR (75 MHz) spectrum of compound 3 in acetone- <i>d</i> ₆	161
C.4 HSQC spectrum of compound 3 in acetone- <i>d</i> ₆	161
C.5 HMBC spectrum of compound 3 in acetone- <i>d</i> ₆	162
C.6 HMBC spectrum of compound 3 in acetone- <i>d</i> ₆ (expansion from δ_{C} 92.5-172.5 (F1) and δ_{H} 2.70-6.90 (F2)).....	162
C.7 NOESY spectrum of compound 3 in acetone- <i>d</i> ₆	163
C.8 NOESY spectrum of compound 3 in acetone- <i>d</i> ₆ (expansion from δ_{H} 2.45-4.12 (F1) and δ_{H} 6.13-6.95 (F2)).....	163

Appendix D: The spectral data of compound 4	164
D.1 Mass spectrum of compound 4	164
D.2 ^1H NMR (300 MHz) spectrum of compound 4 in acetone- d_6	164
D.3 ^{13}C NMR (75 MHz) spectrum of compound 4 in acetone- d_6	165
D.4 HSQC spectrum of compound 4 in acetone- d_6	165
D.5 HMBC spectrum of compound 4 in acetone- d_6	166
D.6 HMBC spectrum of compound 4 in acetone- d_6 (expansion from δ_{C} 132.0- 172.0 (F1) and δ_{H} 3.74-4.11 (F2))	166
D.7 NOESY spectrum of compound 4 in acetone- d_6	167
Appendix E: The spectral data of compound 5	168
E.1 Mass spectrum of compound 5	168
E.2 ^1H NMR (300 MHz) spectrum of compound 5 in acetone- d_6	168
E.3 ^{13}C NMR (75 MHz) spectrum of compound 5 in acetone- d_6	169
E.4 HSQC spectrum of compound 5 in acetone- d_6	169
E.5 HMBC spectrum of compound 5 in acetone- d_6	170
E.6 HMBC spectrum of compound 5 in acetone- d_6 (expansion from δ_{C} 98.0- 151.0 (F1) and δ_{H} 2.70-7.10 (F2))	170
E.7 HMBC spectrum of compound 5 in acetone- d_6 (expansion from δ_{C} 31.3- 45.5 (F1) and δ_{H} 2.70-6.90 (F2))	171
E.8 NOESY spectrum of compound 5 in acetone- d_6	171
E.9 NOESY spectrum of compound 5 in acetone- d_6 (expansion from δ_{H} 2.60- 3.96 (F1) and δ_{H} 6.37-7.06 (F2))	172
VITA	172

LIST OF TABLES

	Page
Table 1 Stilbenoids from <i>Dendrobium</i>	17
Table 2 Flavonoids from <i>Dendrobium</i>	52
Table 3 Terpenoids from <i>Dendrobium</i>	58
Table 4 Miscellaneous compounds from <i>Dendrobium</i>	68
Table 5 Radical scavenging compounds from <i>Dendrobium</i>	91
Table 6 The reagents added in 96-well microplate for superoxide radical scavenging activity assay	103
Table 7 The reagents added in black 96-well microplate for ORAC assay	105
Table 8 The setting of microplate reader (CLARIOstar®) for ORAC assay	106
Table 9 ¹ H NMR (500 MHz) and ¹³ C NMR (125 MHz) spectral data of compound 1 in CDCl ₃	109
Table 10 ¹ H NMR (300 MHz) and ¹³ C NMR (75 MHz) spectral data of compound 2 in acetone- <i>d</i> ₆ and ¹ H NMR (500 MHz) and ¹³ C NMR (100 MHz) of chrysotoxine in CDCl ₃	112
Table 11 ¹ H NMR (300 MHz) and ¹³ C NMR (75 MHz) spectral data of compound 3 in acetone- <i>d</i> ₆ and ¹ H NMR (500 MHz) and ¹³ C NMR (125 MHz) of gigantol in acetone- <i>d</i> ₆	115
Table 12 ¹ H NMR (300 MHz) and ¹³ C NMR (75 MHz) spectral data of compound 4 and cypripedin in acetone- <i>d</i> ₆	118
Table 13 ¹ H NMR (300 MHz) and ¹³ C NMR (75 MHz) spectral data of compound 5 in acetone- <i>d</i> ₆ and ¹ H NMR (500 MHz) and ¹³ C NMR (125 MHz) of moscatilin in acetone- <i>d</i> ₆	121
Table 14 IC ₅₀ values of DPPH radical scavenging activity	123

Table 15 IC_{50} values of superoxide radical scavenging activity125

Table 16 Trolox equivalent (TE) values of superoxide radical scavenging activity126



LIST OF FIGURES

	Page
Figure 1 <i>Dendrobium lindleyi</i> Steud.....	15
Figure 2 Structures of stilbenoids from <i>Dendrobium</i>	34
Figure 3 Structures of flavonoids from <i>Dendrobium</i>	55
Figure 4 Structures of terpenoids from <i>Dendrobium</i>	62
Figure 5 Structures of miscellaneous compounds from <i>Dendrobium</i>	78
Figure 6 Extraction of <i>Dendrobium lindleyi</i>	95
Figure 7 Isolation of the EtOAc extract from <i>Dendrobium lindleyi</i>	97
Figure 8 The reaction between DPPH and antioxidant (A).....	100
Figure 9 The reaction in riboflavin-light-NBT system	102
Figure 10 The production of peroxy radical from AAPH.....	104
Figure 11 Chemical structure of compound 1 [374] and key correlations of HMBC and NOESY	108
Figure 12 Chemical structure of compound 2 [7] and key correlations of HMBC and NOESY	111
Figure 13 Chemical structure of compound 3 [16], and key correlations of HMBC and NOESY	114
Figure 14 Chemical structure of compound 4 [92] and key correlations of HMBC and NOESY	117
Figure 15 Chemical structure of compound 5 [21] and key correlations of HMBC and NOESY	120
Figure 16 Concentration-dependent DPPH radical scavenging activity of compound 1, chrysotoxine, gigantol, cypripedin, moscatilin, and Trolox.....	123

Figure 17 Concentration-dependent superoxide radical scavenging activity of compound 1, chrysotoxine, gigantol, moscatilin, and Trolox.	124
Figure 18 Signal curve for different Trolox concentrations (A) and Trolox standard curve (B).....	126
Figure 19 Signal curve for compound 1, chrysotoxine, gigantol, cypripedin, and moscatilin.....	127



ABBREVIATIONS AND SYMBOLS

AAPH	=	2,2'-Azobis(2-amidinopropane) dihydrochloride
Acetone- d_6	=	Deuterated acetone
Ara	=	Arabinose
AUC	=	Area under a curve
α	=	Alpha
β	=	Beta
<i>br s</i>	=	Broad singlet (for NMR spectra)
<i>br d</i>	=	Broad doublet (for NMR spectra)
BuOH	=	Butanol
°C	=	Degree Celsius
CAT	=	Catalase
CDCl ₃	=	Deuterated chloroform
cm	=	Centimeter
conc	=	Concentration
¹³ C-NMR	=	Carbon-13 nuclear magnetic resonance
C4H	=	Cinnamate-4-hydroxylase
4CL	=	4-Coumaroyl CoA ligase
2D NMR	=	Two-dimensional nuclear magnetic resonance
<i>d</i>	=	Doublet (for NMR spectra)
<i>dd</i>	=	Doublet of doublets (for NMR spectra)
δ	=	Chemical shift
DMSO	=	Dimethyl sulfoxide
DPPH	=	2,2-Diphenyl-1-picrylhydrazyl

ϵ	=	Molar absorptivity
EDTA	=	Ethylenediamine tetraacetic acid
Em-filter	=	Emission filter
ESI-MS	=	Electrospray ionization mass spectrometry
EtOAc	=	Ethyl acetate
Ex-filter	=	Excitation filter
g	=	Gram
Gal	=	Galactose
Glc	=	Glucose
HMBC	=	^1H -detected heteronuclear multiple bond correlation
HR-ESI-MS	=	High resolution electrospray ionization mass spectrometry
^1H -NMR	=	Proton nuclear magnetic resonance
HSQC	=	^1H -detected heteronuclear single quantum coherence
Hz	=	Hertz
IC_{50}	=	Half maximal inhibitory concentration
IR	=	Infrared
J	=	Coupling constant
kg	=	Kilogram
L	=	Liter
LED	=	Light emitting diode
λ_{max}	=	Wavelength at maximal absorption
$[\text{M}+\text{Na}]^+$	=	Sodium-adduct molecular ion
m	=	Multiplet (for NMR spectra)

MeOH	=	Methanol
MEP	=	Methylerythritol phosphate pathway
mg	=	Milligram
MHz	=	Megahertz
min	=	Minute
mL	=	Milliliter
mm	=	Millimeter
mM	=	Millimolar
mol	=	Mole
MS	=	Mass spectrum
MW	=	Molecular weight
MVA	=	Mevalonic acid pathway
m/z	=	Mass to charge ratio
μg	=	Microgram
μL	=	Microliter
μM	=	Micromolar
NBT	=	Nitro blue tetrazolium
nm	=	Nanometer
nM	=	Nanomolar
NMR	=	Nuclear magnetic resonance
NOESY	=	Nuclear overhauser effect spectroscopy
OEt	=	Ethoxy group
OMe	=	Methoxy group
ORAC	=	Oxygen radical absorbance capacity

PAL	=	Phenylalanine ammonia-lyase
ppm	=	Part per million
PRX	=	Peroxiredoxins
Rha	=	Rhamnose
ROS	=	Reactive oxygen species
<i>s</i>	=	Singlet (for NMR spectra)
STS	=	Stilbene synthase
<i>t</i>	=	Triplet (for NMR spectra)
TCM	=	Traditional Chinese medicine
TE	=	Trolox equivalent
TLC	=	Thin layer chromatography
TOF	=	Time-of-flight
UV	=	Ultraviolet
ν_{\max}	=	Wave number at maximal absorption
Xyl	=	Xylose

CHAPTER I

INTRODUCTION

A free radical can be described as an unstable atom or molecule with one or more unpaired electrons. It is a strongly reactive agent which able to attack other molecules by trapping their electrons to stabilize itself. This process is the initiation of a chain reaction because the attacked molecules become free radicals themselves. Both free radicals and molecules that can generate free radicals are called reactive oxygen species (ROS) (Halliwell, 2006; Phaniendra, Jestadi and Periyasamy, 2015). ROS is generally produced from metabolism in the cell, especially, organelles with high oxygen consumption including mitochondria, peroxisomes, and endoplasmic reticulum (Kontoghiorghes and Kontoghiorghes, 2019). On the other side, it can be generated from exogenous sources, for instance, alcohols, heavy metals, pesticides, radiations, and cigarette smoke (Phaniendra, Jestadi and Periyasamy, 2015). There are two different types of ROS which are radicals and non-radicals. The examples of radicals are superoxide radical ($\bullet\text{O}_2^-$), hydroxyl radical ($\bullet\text{OH}$), alkoxy radical ($\text{RO}\bullet$), and peroxy radical ($\text{ROO}\bullet$). Non-radical species, for example, hydrogen peroxide (H_2O_2), hypochlorous acid (HOCl), hypobromous acid (HOBr), ozone (O_3), and singlet oxygen ($^1\text{O}_2$), are also harmful. Even if they might not directly harm to other molecules, they involve in the formation of the destructive radicals in organisms (Phaniendra, Jestadi and Periyasamy, 2015).

ROS level in our body is normally regulated by antioxidants, molecules that protect cells or tissues from ROS damage (Halliwell, 2011, Kontoghiorghes and Kontoghiorghes, 2019). It might alleviate ROS production or directly eliminate ROS (Jain and Ramawat, 2013). Superoxide dismutases, catalases, peroxiredoxins, and glutathione are examples of endogenous antioxidants. However, several types of food provide exogenous antioxidants such as vitamins C and E (Halliwell, 2012). Occasionally, excessive production of ROS and deficiency of antioxidants lead to oxidative stress. In the state, biomolecules including lipid, protein, and DNA can be damaged (Phaniendra, Jestadi and Periyasamy, 2015). As a consequence, organelles,

cells, tissues, and organs will be impaired (Phaniendra, Jestadi and Periyasamy, 2015). These are causes of the various diseases, for example, cancer, diabetes mellitus, Parkinson's disease, Alzheimer's disease, cardiovascular disease, cataract, asthma, and rheumatoid arthritis (Phaniendra, Jestadi and Periyasamy, 2015; Prescott and Bottle, 2017). The molecules that possess antioxidant properties would be used for the treatment or prevention of these conditions.

The research and development of antioxidant compounds were reviewed by Kontoghiorghe and Kontoghiorghe (2019). These include N-acetylcysteine which acts as an antioxidant via the promotion of glutathione production. It has been used for the treatment of overdose acetaminophen in clinical settings and studied to treat several oxidative stress-related diseases including traumatic brain injury, psychosis, cancer, and Parkinson's disease in clinical trials. MitoQ, a coenzyme Q10 derivative, and vitamin C have been investigated for the treatment of Parkinson's disease and cancer, respectively. Various plant-derived compounds, such as ellagic acid (Rahimi et al., 2020) and quercetin (Tang et al., 2020), have also been researched for clinical cancer therapy.

Dendrobium, one of the largest genera in Orchidaceae, comprises of more than 1500 species distributing throughout tropical and subtropical regions of Asia and North Australia (Hou et al., 2017; Lam et al., 2015). Approximately forty species have been used in traditional Chinese medicine (TCM) for different indications (Cheng et al., 2019) including increasing body fluid production, reducing throat dryness, and nourishing eyes (Ng et al., 2012). Many secondary metabolites from *Dendrobium* were reported, for example, bibenzyls, phenanthrenes, alkaloids, fluorenones, coumarins, and sesquiterpenoids. Many compounds display considerable bioactivities including antioxidant, neuroprotective, antitumor, antidiabetic, antimicrobial, and immunomodulatory activities (Lam et al., 2015; Ng et al., 2012).

Thailand is one of the distribution areas of more than 150 *Dendrobium* species. They are listed in scientific and Thai names as follows (Office of the Forest Herbarium, 2014).

<i>D. acerosum</i> Lindl.	กล้วยไม้มือนาง Kluai mai mue nang (Chumphon)
<i>D. aciculare</i> Lindl.	เอื้องใบเข็ม
<i>D. acinaciforme</i> Roxb.	เอื้องยอดสร้อย Ueang yot soi (Northern)
<i>D. aduncum</i> Lindl.	N/A
<i>D. albosanguineum</i> Lindl.	เอื้องตางัว Ueang ta ngua (Mae Hong Son)
<i>D. aloifolium</i> (Blume) Rchb.f.	เอื้องมณี Ueang mani (Bangkok)
<i>D. anceps</i> Sw.	N/A
<i>D. angulatum</i> Lindl.	N/A
<i>D. anosmum</i> Lindl.	เอื้องสาย Ueang sai (Chiang Mai, Peninsular)
<i>D. aphyllum</i> (Roxb.) C.E.C. Fisch.	เอื้องวงช้าง Ueang nguang chang (Mae Hong Son)
<i>D. bellatulum</i> Rolfe	เอื้องแซะภู Ueng sae phu
<i>D. bensoniae</i> Rchb.f.	เอื้องสายดอกขาว
<i>D. bicameratum</i> Lindl.	เอื้องเข็ม Ueang khem (Northern)
<i>D. bifarium</i> Lindl.	N/A
<i>D. bilobulatum</i> Seidenf.	กล้วยไม้ก้างปลา Kluai mai kang pla (General)
<i>D. blumei</i> Lindl.	N/A
<i>D. brevimentum</i> Seidenf.	N/A
<i>D. brymerianum</i> Rchb.f.	เอื้องคำฝอย Ueang kham foi (Northern)
<i>D. calicopsis</i> Ridl.	N/A
<i>D. capillipes</i> Rchb.f.	เอื้องคำกั้ว Ueang kham kio (Lampang, Phrae)
<i>D. cariniferum</i> Rchb.f.	เอื้องกาจก Ueang kachok (Chiang Mai)
<i>D. chittimae</i> Seidenf.	เอื้องจิตติมา Ueang chittima (General)
<i>D. christyanum</i> Rchb.f.	เอื้องแซะภูกระดิ่ง Ueang sae phu kradueng (Loei)
<i>D. chrysanthum</i> Lindl.	เอื้องสายมรกต Ueang sai morakot (Bangkok)

<i>D. chrysotoxum</i> Lindl.	เอื้องคำ Ueang kham (Northern)
<i>D. ciliatilabellum</i> Seidenf.	หาวายเขาเขียว Wai khao khiao (General)
<i>D. clavator</i> Ridl.	N/A
<i>D. compactum</i> Rolfe ex Hackett	เอื้องข้าวตอก Ueang khao tok (Northern)
<i>D. compressum</i> Lindl.	หาวายแบนตะนาวศรี Wai baen tanao si (General)
<i>D. concinnum</i> Miq.	หางเปีย Hang pia (Narathiwat)
<i>D. confinale</i> Kerr	N/A
<i>D. cowenii</i> P. O'Byrne & J.J. Verm.	N/A
<i>D. crepidatum</i> Lindl. & Paxton	เอื้องสายน้ำเขียว Ueang sai nam khiao (General)
<i>D. cretaceum</i> Lindl.	N/A
<i>D. crocatum</i> Hook.f.	เอื้องนางนวล Ueang nang nuan (Peninsular)
<i>D. cruentum</i> Rchb.f.	เอื้องนกแก้ว Ueang nok kao (Bangkok)
<i>D. crumenatum</i> Sw.	หาวายตะมอย Wai tamoi (Central, Peninsular)
<i>D. crystallinum</i> Rchb.f.	เอื้องนางพอน Ueang nang fon (Chiang Mai)
<i>D. cumulatum</i> Lindl.	เอื้องสายสีตอก Ueang sai si dok (Northern, Southeastern)
<i>D. curviflorum</i> Rolfe	N/A
<i>D. cuspidatum</i> Lindl.	เอื้องข้าวตอกปากแหลม
<i>D. dantaniense</i> Guillaumin	เอื้องเข็ม Ueang khem (Chiang Mai)
<i>D. delacourii</i> Guillaumin	เอื้องดอกมะขาม Ueang dok ma kham (General)
<i>D. deltatum</i> Seidenf.	N/A
<i>D. denneanum</i> Kerr	N/A
<i>D. densiflorum</i> Lindl.	เอื้องมอนไข่ Ueang mon khai (Northern)
<i>D. denudans</i> D. Don	เอื้องสายจำปา Ueang sai champa (General)

<i>D. devonianum</i> Paxton	เอื้องเมี่ยง Ueang miang (Chiang Mai)
<i>D. dickasonii</i> L. O. Williams	เอื้องเคี้ยว Ueang khia (Chiang Mai)
<i>D. dixanthum</i> Rchb.f.	เอื้องเทียน Ueang thian (Northern)
<i>D. dixonianum</i> Rolfe ex Downie	เอื้องข้าวตอกเหลือง
<i>D. draconis</i> Rchb.f.	เอื้องเงิน Ueang ngoen (Northern)
<i>D. elliotianum</i> P. O'Byrne	หวายเจดีย์ Wai chedi (Kanchanaburi)
<i>D. ellipsophyllum</i> Tang & Wang	เอื้องทอง Ueang thong (General)
<i>D. erostelle</i> Seidenf.	N/A
<i>D. erosum</i> (Blume) Lindl.	N/A
<i>D. eserre</i> Seidenf.	N/A
<i>D. exile</i> Schltr.	เอื้องเสี้ยน Ueang sian (General)
<i>D. falconeri</i> Hook.	เอื้องสายวิสูตร Ueang sai wisut (Bangkok)
<i>D. farmeri</i> Paxton	เอื้องมัจฉานุ Ueang matchanu (Bangkok)
<i>D. fimbriatum</i> Hook.	เอื้องค่าน้อย Ueang kham noi (Chiang Mai)
<i>D. findlayanum</i> E.C.Parish & Rchb.f.	พวงหยก Phuang yok (Bangkok)
<i>D. flexile</i> Ridl.	N/A
<i>D. formosum</i> Roxb. ex Lindl.	เอื้องเงินหลวง Ueang ngoen luang (Chiang Mai)
<i>D. friedericksianum</i> Rchb.f.	เอื้องเหลืองจันทบูร Ueang lueang chantabun (Bangkok)
<i>D. fuerstenbergianum</i> Schltr.	เอื้องแซะภูกระดึง Ueang sae phukradueng (General)
<i>D. fytchianum</i> Bateman ex Rchb.f.	หวายพม่า Wai phama (General)
<i>D. garrettii</i> Seidenf.	หวายการ์เร็ต Wai karet (General)
<i>D. gibsonii</i> Paxton	เอื้องคำสาย Ueang kham sai (Northern)
<i>D. grande</i> Hook.f.	เอื้องแพงใบใหญ่ Ueang pheang bai yai (Peninsular)

<i>D. gratiotissimum</i> Rchb.f.	เอื้องกิ่งดำ Ueang king dam (Bangkok)
<i>D. gregulus</i> Seidenf.	เอื้องมะต๋อม Ueang ma tom (Chiang Mai)
<i>D. griffithianum</i> Lindl.	เอื้องมัจฉาเหลือง Ueang matcha lueang (Bangkok)
<i>D. harveyanum</i> Rchb.f.	เอื้องคำฝอย Ueang kham foi (Chiang Mai)
<i>D. hendersonii</i> Hawkes & Heller	หวายตะมอยน้อย Wai tamoi noi (Peninsular)
<i>D. henryi</i> Schltr.	เอื้องสุริยัน Ueang suriyan (Loei)
<i>D. hercoglossum</i> Rchb.f.	เอื้องดอกมะเขือ Ueang dok ma kuea (Bangkok)
<i>D. heterocarpum</i> Lindl.	เอื้องสีตาล Ueang si tan (Chiang Mai)
<i>D. hymenanthum</i> Rchb.f.	เอื้องน้อยกลีบบาง Ueang noi klip bang (Chiang Mai, Kanchanaburi)
<i>D. hymenopterum</i> Hook.f.	N/A
<i>D. incurvum</i> Lindl.	N/A
<i>D. indivisum</i> (Blume) Miq. var. <i>indivisum</i>	ตานเสี้ยนไม้ Tan sian mai (Chumphon)
<i>D. indivisum</i> (Blume) Miq. var. <i>lampangense</i> Rolfe	N/A
<i>D. indivisum</i> (Blume) Miq. var. <i>pallidum</i> Seidenf.	ก้างปลา Kang pla (General)
<i>D. indragiriense</i> Schltr.	N/A
<i>D. infundibulum</i> Lindl.	เอื้องตาเหิน Ueang ta hoen (General)
<i>D. intricatum</i> Gagnep.	เอื้องชมพู Ueang chomphu (Chanthaburi)
<i>D. jenkinsii</i> Wall. ex Lindl.	เอื้องผึ้งน้อย Ueang phueng noi (Chiang Mai)
<i>D. kanburiense</i> Seidenf.	หวายเมืองกาญจน์ Wai muang kan (Kanchanaburi)
<i>D. keithii</i> Ridl.	หางเปีย Hang pia (General)
<i>D. kentrophyllum</i> Hook.f.	ก้างปลาใหญ่

<i>D. kontumense</i> Gagnep.	เอื้องเงินวิลาศ Ueang ngoen wilat (Northeastern)
<i>D. kratense</i> Kerr	N/A
<i>D. lagarum</i> Seidenf.	N/A
<i>D. lanpongense</i> J.J.Sm.	N/A
<i>D. lamyaiiae</i> Seidenf.	N/A
<i>D. leonis</i> (Lindl.) Rchb.f.	เอื้องตะขาบใหญ่ Ueang ta khap yai (General)
<i>D. lindleyi</i> Steud.	เอื้องผึ้ง Ueang phueng (Northern)
<i>D. linguella</i> Rchb.f.	N/A
<i>D. lituiflorum</i> Lindl.	เอื้องสายม่วง Ueang sai muang (Northern, Bangkok)
<i>D. lueckelianum</i> Fessel & Wolff	N/A
<i>D. mannii</i> Ridl.	เอื้องหางปลา Ueang hang pla (General)
<i>D. metachilinum</i> Rchb.f.	N/A
<i>D. monticola</i> Hunt & Summerh	N/A
<i>D. moschatum</i> (Buch.-Ham.) Sw.	เอื้องจำปา Ueang champa (Northern)
<i>D. mucronatum</i> Seidenf.	N/A
<i>D. nanocompactum</i> Seidenf.	N/A
<i>D. nathanielis</i> Rchb.f.	เกล็ดน้ยม Klet nim (Chantaburi)
<i>D. ochreatum</i> Lindl.	เอื้องตะขาบ Ueang ta khap (Chiang Mai)
<i>D. oligophyllum</i> Gagnep.	ข้าวตอกปราจีน Khao tok prachin (General)
<i>D. pachyglossum</i> Parish & Rchb.f.	เอื้องขนหมู Ueang khon mu (Mae Hong Son)
<i>D. pachyphyllum</i> (Kuntze) Bakh.f.	เอื้องน้อย Ueang noi (General)
<i>D. palpebrae</i> Lindl.	เอื้องมัจฉา Ueang matcha (Bangkok)
<i>D. pandaneti</i> Ridl.	N/A
<i>D. panduriferum</i> Hook.f.	N/A

<i>D. parciflorum</i> Rchb.f. ex Lindl.	เอื้องดอกขาวใบแบน Ueang dok khao bai baen (General)
<i>D. parcum</i> Rchb.f.	เอื้องก้านก๊ว Ueang kan kio (Bangkok)
<i>D. parishii</i> Rchb.f.	เอื้องครั่ง Ueang khrang (Northern)
<i>D. parvum</i> Seidenf.	N/A
<i>D. peguanum</i> Lindl.	หวายเปกัว Wai peku (General)
<i>D. pendulum</i> Roxb.	เอื้องไม้เท้าฤๅษี Ueang mai thao ruesi (Bangkok, Chiang Mai)
<i>D. perpaulum</i> Seidenf.	เอื้องข้าวตอกอินทนนท์ Ueang khao tok inthanon (General)
<i>D. planibulbe</i> Lindl.	N/A
<i>D. polyanthum</i> Wall. ex Lindl.	เอื้องสายประสาธ Ueang sai prasat (Bangkok)
<i>D. porphyrochilum</i> Lindl.	เอื้องเฉียว Ueang chawian (General)
<i>D. praecinctum</i> Rchb.f.	หวายภูหลวง Wai phu luang (General)
<i>D. proteranthum</i> Seidenf.	หายน้อยภูหลวง Wai noi phu luang (Loei)
<i>D. pulchellum</i> Roxb. ex Lindl.	เอื้องคำตาควาย Ueang kham ta khwai (Mae Hong Son)
<i>D. pychnostachyum</i> Lindl.	เสวตสอดสี Sawet sot si (Chiang Mai)
<i>D. rhodostele</i> Ridl.	N/A
<i>D. salaccense</i> (Blume) Lindl.	เอื้องใบไผ่ Ueang bai phai (Chiang Mai)
<i>D. sanguinolentum</i> Lindl.	N/A
<i>D. scabrilingue</i> Lindl.	เอื้องแซะ Ueang sae (Mae Hong Son)
<i>D. schilhaueri</i> Ormerod & Pedersen	N/A
<i>D. secundum</i> (Blume) Lindl.	เอื้องแปรงสีฟัน Ueang preang si fan (Bangkok)
<i>D. senile</i> Parish & Rchb.f.	เอื้องชะนี Ueang chani (Bangkok)

<i>D. setifolium</i> Ridl.	N/A
<i>D. signatum</i> Rchb.f.	เอื้องเค้าก๊ว Ueang khao kio (Northern)
<i>D. singaporense</i> Hawkes & Heller	N/A
<i>D. sinuatum</i> (Lindl.) Lindl. ex Rchb.f.	N/A
<i>D. sociale</i> J.J.Sm.	N/A
<i>D. strongylanthum</i> Rchb.f.	เอื้องเข้าลม Ueang yao lom (Northern)
<i>D. stuposum</i> Lindl.	เอื้องสาย Ueang sai (Chiang Mai)
<i>D. subulatum</i> (Blume) Lindl.	N/A
<i>D. sukhakulii</i> hort.	หาวายสุขะกุล Wai sukhakun (General)
<i>D. sulcatum</i> Lindl.	เอื้องจำปานาน Ueang champa nan (Bangkok)
<i>D. superbiens</i> Rchb.f.	หาวายคิง Wai khing (Bangkok)
<i>D. sutepense</i> Rolfe ex Downie	เอื้องมะลิ Ueang mali (Chiang Mai)
<i>D. terminale</i> Parish & Rchb.f.	เอื้องแพ่งโสภา Ueang phaeng sopha (Peninsular)
<i>D. thyrsiflorum</i> Rchb.f.	เอื้องมอนไขไบมอน Ueang mon khai bai mon (Northern)
<i>D. tortile</i> Lindl.	เอื้องไม้ตึง Ueang mai tueng (Mae Hong Son)
<i>D. trigonopus</i> Rchb.f.	เอื้องคำเหลี่ยม Ueang kham liam (Chiang Mai)
<i>D. trinervium</i> Ridl.	เทียนลิง Thian ling (Chumphon)
<i>D. truncatum</i> Lindl.	N/A
<i>D. umbonatum</i> Seidenf.	N/A
<i>D. unicum</i> Seidenf.	เอื้องครั่งแสด Ueang krang saet (General)
<i>D. uniflorum</i> Griff.	เอื้องทอง Ueang thong (Pattani)
<i>D. venustum</i> Teijsm. & Binn	ข้าวเหนียวลิง Khao niao ling (Central)
<i>D. villosulum</i> Lindl.	กล้วยหญาณา Kluai ya na (Bangkok)

<i>D. viridulum</i> Ridl.	N/A
<i>D. wardianum</i> R. Warner	เอื้องมณีไตรรงค์ Ueang mani trairong (Northern)
<i>D. wattii</i> (Hook.f.) Rchb.f.	เอื้องแซะ Ueang sae (Northern)
<i>D. williamsonii</i> Day & Rchb.f.	N/A
<i>D. xanthophlebium</i> Lindl.	เอื้องแซะภูลังกา
<i>D. ypsilon</i> Seidenf.	เอื้องแบนปากตัด Ueang baen pak tat (General)

Dendrobium lindleyi Steud, known as “Ueang Pueng” in Thailand (Vaddhanaphuti, 2005), distributes in India, China, Hongkong, Bhutan, Thailand, Myanmar, Laos, and Vietnam (Cheng et al., 2019). It is a 6-10-centimeter-tall epiphytic orchid. Leaves are in oblong-elliptic shape. It flowers with inflorescences having up to 20 pale to bright yellow flowers. Lip bases are golden yellow and pubescent, bordered with paler yellow (Vaddhanaphuti, 2005).

The chemical constituents of *D. lindleyi* have never been revealed until Shang, Li and Xiao (2020) recently published a short report describing the constituents including bibenzyls, 2,4-di-tert-butyl phenol ether, and β -sitosterol. Nevertheless, the pharmacological activities of this plant have never been revealed in any study. In this research, the methanol extract of *D. lindleyi* was firstly partitioned into ethyl acetate, *n*-butanol, and aqueous extracts. For the antioxidant activity screening, only ethyl acetate extract inhibited 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical by more than 70% at 100 μ g/mL. This research aimed to discover the chemical components of *D. lindleyi* and determine their antioxidant activities. The findings might fulfill the phytochemical study of this plant and benefit for the development of medicines with antioxidant properties.



Figure 1 *Dendrobium lindleyi* Steud

CHAPTER II

HISTORICAL

1. Chemical constituents of *Dendrobium* species

Chemical constituents of *Dendrobium* species were reported. Here, they were classified into four main groups including stilbenoids, flavonoids, terpenoids, and miscellaneous compounds and summarized in Tables 1-4 and Figures 2-5.

Table 1 and Figure 2 show compounds belonging to stilbenoids which can be divided into stilbenes, bibenzyls, bisbibenzyls, phenanthrenoids, and oligomeric stilbenes. The main structural skeleton of this group composes of two aromatic rings linked by an ethylene bridge. Stilbenoids are constructed from *trans*-cinnamic acid and three malonyl-CoA units. In phenylpropanoid biosynthesis, L-phenylalanine is deaminated by phenylalanine ammonia-lyase (PAL) to give *trans*-cinnamic which is then hydroxylated by cinnamate-4-hydroxylase (C4H) to yield 4-coumaric acid. This compound is then activated by 4-coumaroyl CoA ligase (4CL) to form 4-coumaroyl-CoA. Subsequently, three acetate extender units from malonyl-CoA are added to 4-coumaroyl-CoA by stilbene synthase (STS) to make tetraketide intermediate which consequently folds and cyclizes to shape as a chalcone or a stilbene structure (Tsopmo, Awah and Kuete, 2013).

Flavonoids are produced from the modifications of a chalcone structure in the biosynthesis pathway. These processes include glycosylation, methylation, and hydroxylation (Dewick, 2009). The flavonoid compounds from *Dendrobium* are shown in Table 2 and Figure 3.

Terpenoids (Table 3 and Figure 4) can be synthesized by the mevalonic acid pathway (MVA) or the methylerythritol phosphate pathway (MEP). The two systems provide different important precursor unit for various types of terpenoids including isoprenes (C₅), monoterpenes (C₁₀), sesquiterpenes (C₁₅), diterpenes (C₂₀), sesterterpenes (C₂₅), triterpenes (C₃₀) and tetraterpenes (C₄₀) (Tholl, 2015; Brahmkshatriya and Brahmkshatriya, 2013).

Other constituents not mentioned above are grouped as miscellaneous compounds and presented in Table 4 and Figure 5. These comprise aliphatic compounds, phenolic compounds, benzoic acid derivatives, lignans, neolignans, alkaloids, phenylpropanoids, fluorenones, and coumarins.

Table 1 Stilbenoids from *Dendrobium*

Stilbenoids	Plant	Plant part	Reference
Aloifol I [1]	<i>D. longicornu</i>	Stem	Hu et al., 2008a
	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
	<i>D. infundibulum</i>	Whole plant	Na Ranong et al., 2019
Amoenylin [2]	<i>D. amoenum</i>	Whole plant	Majumder, Guha and Sen, 1999
	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018
Batatasin [3]	<i>D. longicornu</i>	Stem	Hu et al., 2008a
	<i>D. plicatile</i>	Stem	Yamaki and Honda, 1996
Batatasin III [4]	<i>D. aphyllum</i>	Whole plant	Chen et al., 2008a
		Stem	Yang et al., 2015
	<i>D. cariniferum</i>	Stem	Chen et al., 2008b
	<i>D. rotundatum</i>	Whole plant	Majumder and Pal, 1992
	<i>D. chrysotoxum</i>	Whole plant	Li et al., 2009d
	<i>D. draconis</i>	Stem	Sritularak, Anuwat and Likhitwitayawuid, 2011
	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
	<i>D. gratiosissimum</i>	Stem	Zhang et al., 2008a
	<i>D. loddigesii</i>	Stem	Ito et al., 2010
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
	<i>D. venustum</i>	Whole plant	Sukphan et al., 2014

Stilbenoids	Plant	Plant part	Reference
	<i>D. scabrilingue</i>	Whole plant	Sarakulwattana et al., 2018
	<i>D. infundibulum</i>	Whole plant	Na Ranong et al., 2019
Brittonin A [5]	<i>D. secundum</i>	Stem	Sritularak, Duangrak and Likhitwitayawuid, 2011
Chrysotobibenzyl [6]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang, Wang and Xu, 2006
	<i>D. capillipes</i>	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012
	<i>D. chrysanthum</i>	Stem	Yang et al., 2006
	<i>D. chryseum</i>	Stem	Ma et al., 1998
	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
	<i>D. nobile</i>	Stem	Zhang et al., 2007c
	<i>D. pulchellum</i>	Stem	Chanvorachote et al., 2013
	<i>D. scabrilingue</i>	Whole plant	Sarakulwattana et al., 2018
Chrysotoxine [7]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang, Wang and Xu, 2006
	<i>D. chrysanthum</i>	Stem	Yang et al., 2006
	<i>D. chryseum</i>	Stem	Ma et al., 1998
	<i>D. nobile</i>	Stem	Zhang et al., 2007c
	<i>D. pulchellum</i>	Stem	Chanvorachote et al., 2013
Crepidatin [8]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Whole plant	Liu et al., 2009b
	<i>D. capillipes</i>	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012
	<i>D. chrysanthum</i>	Stem	Yang et al., 2006

Stilbenoids	Plant	Plant part	Reference
	<i>D. crepidatum</i>	Whole plant	Majumder and Chatterjee, 1989
	<i>D. nobile</i>	Stem	Zhang et al., 2007c
	<i>D. pulchellum</i>	Stem	Chanvorachote et al., 2013
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
Cumulatin [9]	<i>D. cumulatum</i>	Whole plant	Majumder and Pal, 1993
Dendrobin A [10]	<i>D. nobile</i>	Stem	Wang, Zhao and Che, 1985; Ye and Zhao, 2002
3,3'-Dihydroxy-4,5-dimethoxybibenzyl [11]	<i>D. williamsonii</i>	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid, 2014
	<i>D. infundibulum</i>	Whole plant	Na Ranong et al., 2019
3,4'-Dihydroxy-5-methoxybibenzyl [12]	<i>D. amoenum</i>	Whole plant	Majumder, Guha and Sen, 1999
3,4'-Dihydroxy-5,5'-dimethoxydihydrostilbene [13]	<i>D. nobile</i>	Stem	Hwang et al., 2010
4,5-Dihydroxy-3,3'-dimethoxybibenzyl [14]	<i>D. nobile</i>	Stem	Ye and Zhao, 2002
Erianin [15]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
Gigantol [16]	<i>D. aphyllum</i>	Whole plant	Chen et al., 2008b
	<i>D. aphyllum</i>	Stem	Yang et al., 2015
	<i>D. aurantiacum</i> var. <i>denneanum</i>	Whole plant	Liu et al., 2009b
	<i>D. brymerianum</i>	Whole plant	Klongkumnuankarn et al., 2015
	<i>D. densiflorum</i>	Stem	Fan et al., 2001

Stilbenoids	Plant	Plant part	Reference
	<i>D. devonianum</i>	Whole plant	Sun et al., 2014
	<i>D. draconis</i>	Stem	Sritularak, Anuwat and Likhitwitayawuid, 2011
	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
	<i>D. gratiosissimum</i>	Stem	Zhang et al., 2008a
	<i>D. loddigesii</i>	Whole plant	Ito et al., 2010
	<i>D. longicornu</i>	Stem	Hu et al., 2008a
	<i>D. nobile</i>	Stem	Zhang et al., 2007c
	<i>D. officinale</i>	Stem	Zhao et al., 2018
	<i>D. polyanthum</i>	Stem	Hu et al., 2009
	<i>D. trigonopus</i>	Stem	Hu et al., 2008b
	<i>D. venustum</i>	Whole plant	Sukphan et al., 2014
	<i>D. scabrilingue</i>	Whole plant	Sarakulwattana et al., 2018
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019
4-Hydroxy-3,5,3'-trimethoxybibenzyl [17]	<i>D. nobile</i>	Stem	Ye and Zhao, 2002
5-Hydroxy-3,4,3',4',5'-pentamethoxybibenzyl [18]	<i>D. secundum</i>	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012
Isoamoenylin [19]	<i>D. amoenum</i>	Whole plant	Majumder, Guha and Sen, 1999
Moniliformine [20]	<i>D. candidum</i>	Stem	Li et al., 2008
	<i>D. signatum</i>	Whole plant	Mittraphab et al., 2016
	<i>D. tortile</i>	Whole plant	Limpanit et al., 2016
	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b

Stilbenoids	Plant	Plant part	Reference
Moscatilin [21]	<i>D. amoenum</i>	Whole plant	Majumder, Guha and Sen, 1999
	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang, Wang and Xu, 2006
	<i>D. brymerianum</i>	Whole plant	Klongkumnuankarn et al., 2015
	<i>D. chrysanthum</i>	Stem	Yang et al., 2006
	<i>D. densiflorum</i>	Stem	Fan et al., 2001
	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014
	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
	<i>D. gratiosissimum</i>	Stem	Zhang et al., 2008a
	<i>D. loddigesii</i>	Whole plant	Chen et al., 1994; Ito et al., 2010
	<i>D. longicornu</i>	Stem	Hu et al., 2008a
	<i>D. moscatum</i>	Whole plant	Majumder and Sen, 1987
	<i>D. nobile</i>	Stem	Miyazawa et al., 1999
	<i>D. polyanthum</i>	Stem	Hu et al., 2009
	<i>D. pulchellum</i>	Stem	Chanvorachote et al., 2013
	<i>D. secundum</i>	Stem	Sritularak, Duangrak and Likhithitayawuid, 2011
	<i>D. aphyllum</i>	Stem	Yang et al., 2015
	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
	<i>D. parishii</i>	Whole plant	Kongkatitham et al., 2018
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019

Stilbenoids	Plant	Plant part	Reference
	<i>D. infundibulum</i>	Whole plant	Na Ranong et al., 2019)
3,3',4-Trihydroxybibenzyl [22]	<i>D. longicornu</i>	Stem	Hu et al., 2008a
3,3',5-Trihydroxybibenzyl [23]	<i>D. cariniferum</i>	Whole plant	Liu et al., 2009a
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
3,5,4'-Trihydroxybibenzyl [24]	<i>D. graciosissimum</i>	Stem	Zhang et al., 2008a
4,5,4'-Trihydroxy-3,3'-dimethoxybibenzyl [25]	<i>D. secundum</i>	Stem	Sritularak, Duangrak and Likhitwitayawuid, 2011
	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014
	<i>D. parishii</i>	Whole plant	Kongkatitham et al., 2018
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019
Tristin [26]	<i>D. aphyllum</i>	Stem	Yang et al., 2015
	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
	<i>D. densiflorum</i>	Stem	Fan et al., 2001
	<i>D. graciosissimum</i>	Stem	Zhang et al., 2008a
	<i>D. longicornu</i>	Stem	Hu et al., 2008a
	<i>D. officinale</i>	Stem	Zhao et al., 2018
	<i>D. trigonopus</i>	Stem	Hu et al., 2008b
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
Dendromonilaside E [27]	<i>D. moniliforme</i>	Stem	Zhao et al., 2003
5,4'-Dihydroxy-3,4,3'-trimethoxybibenzyl [28]	<i>D. infundibulum</i>	Whole plant	Na Ranong et al., 2019

Stilbenoids	Plant	Plant part	Reference
4,3',4'-Trihydroxy-3,5-dimethoxybibenzyl [29]	<i>D. parishii</i>	Whole plant	Kongkatitham et al., 2018
Dendrophenol [30]	<i>D. candidum</i>	Stem	Li et al., 2008
4,4'-Dihydroxy-3,5-dimethoxybibenzyl [31]	<i>D. candidum</i>	Stem	Li et al., 2008
	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014
	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Loddigesinol C [32]	<i>D. loddigesii</i>	Whole plant	Ito et al., 2010
3-O-Methylgigantol [33]	<i>D. candidum</i>	Stem	Li et al., 2008
	<i>D. nobile</i>	Stem	Hwang et al., 2010
	<i>D. plicatile</i>	Stem	Yamaki and Honda, 1996
Dendrocandin A [34]	<i>D. candidum</i>	Stem	Li et al., 2008
Dendrocandin B [35]	<i>D. candidum</i>	Stem	Li et al., 2008
	<i>D. signatum</i>	Whole plant	Mittraphab et al., 2016
Dendrocandin C [36]	<i>D. candidum</i>	Stem	Li et al., 2009a
Dendrocandin D [37]	<i>D. candidum</i>	Stem	Li et al., 2009a
Dendrocandin E [38]	<i>D. candidum</i>	Stem	Li et al., 2009a
	<i>D. parishii</i>	Whole plant	Kongkatitham et al., 2018
Dendrocandin F [39]	<i>D. candidum</i>	Stem	Li et al., 2009b
Dendrocandin G [40]	<i>D. candidum</i>	Stem	Li et al., 2009b
Dendrocandin H [41]	<i>D. candidum</i>	Stem	Li et al., 2009b
Dendrosinen A [42]	<i>D. sinense</i>	Whole plant	Chen et al., 2014
Dendrosinen B [43]	<i>D. sinense</i>	Whole plant	Chen et al., 2014
	<i>D. infundibulum</i>	Whole plant	Na Ranong et al., 2019

Stilbenoids	Plant	Plant part	Reference
Dendrosinen C [44]	<i>D. sinense</i>	Whole plant	Chen et al., 2014
Dendroscabrol B [45]	<i>D. scabrilingue</i>	Whole plant	Sarakulwattana et al., 2018
Dendrosinen D [46]	<i>D. sinense</i>	Whole plant	Chen et al., 2014
Dendrocandin I [47]	<i>D. candidum</i>	Stem	Li et al., 2009c
	<i>D. signatum</i>	Whole plant	Mittraphab et al., 2016
Dendrocandin J [48]	<i>D. candidum</i>	Stem	Li et al., 2014b
Dendrocandin K [49]	<i>D. candidum</i>	Stem	Li et al., 2014b
Dendrocandin L [50]	<i>D. candidum</i>	Stem	Li et al., 2014b
Dendrocandin M [51]	<i>D. candidum</i>	Stem	Li et al., 2014b
Dendrocandin N [52]	<i>D. candidum</i>	Stem	Li et al., 2014b
Dendrocandin O [53]	<i>D. candidum</i>	Stem	Li et al., 2014b
Dendrocandin P [54]	<i>D. candidum</i>	Stem	Li et al., 2014b
Dendrocandin Q [55]	<i>D. candidum</i>	Stem	Li et al., 2014b
Densiflorol A [56]	<i>D. densiflorum</i>	Stem	Fan et al., 2001
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
Longicornuol A [57]	<i>D. longicornu</i>	Stem	Hu et al., 2008a
Trigonopol A [58]	<i>D. trigonopus</i>	Stem	Hu et al., 2008b
Trigonopol B [59]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
	<i>D. trigonopus</i>	Stem	Hu et al., 2008b
	<i>D. aphyllum</i>	Stem	Yang et al., 2015
Crepidatuol A [60]	<i>D. crepidatum</i>	Stem	Li et al., 2013
Crepidatuol B [61]	<i>D. crepidatum</i>	Stem	Li et al., 2013
Loddigesiinol D [62]	<i>D. loddigesii</i>	Whole plant	Ito et al., 2010
Dencryol A [63]	<i>D. crystallinum</i>	Stem	Wang et al., 2009
Dencryol B [64]	<i>D. crystallinum</i>	Stem	Wang et al., 2009

Stilbenoids	Plant	Plant part	Reference
Dengraol A [65]	<i>D. gratiosissimum</i>	Stem	Zhang et al., 2008a
Dengraol B [66]	<i>D. gratiosissimum</i>	Stem	Zhang et al., 2008a
4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol [67]	<i>D. longicornu</i>	Stem	Hu et al., 2008a
Nobilin A [68]	<i>D. nobile</i>	Stem	Zhang et al., 2006
Nobilin B [69]	<i>D. nobile</i>	Stem	Zhang et al., 2006
Nobilin C [70]	<i>D. nobile</i>	Stem	Zhang et al., 2006
Nobilin D [71]	<i>D. nobile</i>	Stem	Zhang et al., 2007c
Nobilin E [72]	<i>D. nobile</i>	Stem	Zhang et al., 2007c
Dendrofalconerol A [73]	<i>D. falconeri</i>	Stem	Sritularak and Likhitwitayawuid, 2009
	<i>D. signatum</i>	Whole plant	Mittraphab et al., 2016
	<i>D. tortile</i>	Whole plant	Limpanit et al., 2016
Dendrofalconerol B [74]	<i>D. falconeri</i>	Stem	Sritularak and Likhitwitayawuid, 2009
Dendrosignatol [75]	<i>D. signatum</i>	Whole plant	Mittraphab et al., 2016
2,2'-Dihydroxy-3,3',4,4',7,7'-hexamethoxy-9,9',10,10'-tetrahydro-1,1'-biphenanthrene [76]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
2,2'-Dimethoxy-4,4',7,7'-tetrahydroxy-9,9',10,10'-tetrahydro-1,1'-biphenanthrene [77]	<i>D. plicatile</i>	Stem	Yamaki and Honda, 1996
Flavanthrin [78]	<i>D. aphyllum</i>	Whole plant	Chen et al., 2008b
Phoyunnanin C [79]	<i>D. venustum</i>	Whole plant	Sukphan et al., 2014

Stilbenoids	Plant	Plant part	Reference
Phoyunnanin E [80]	<i>D. venustum</i>	Whole plant	Sukphan et al., 2014
Amoenumin [81]	<i>D. amoenum</i>	Whole plant	Veerraju et al., 1989
Crystalltone [82]	<i>D. crystallinum</i>	Stem	Wang et al., 2009
Dendropalpebrone [83]	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019
Chrysotoxol A [84]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
Chrysotoxol B [85]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
Confusarin [86]	<i>D. chryseum</i>	Stem	Ma et al., 1998
	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
	<i>D. nobile</i>	Stem	Zhang et al., 2008c
	<i>D. officinale</i>	Stem	Zhao et al., 2018
Denthyrsinin [87]	<i>D. densiflorum</i>	Stem	Fan et al., 2001
	<i>D. thysiflorum</i>	Stem	Zhang et al., 2005
	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019
Dendrochrysanene [88]	<i>D. chrysanthum</i>	Stem	Yang et al., 2006
Bulbophyllanthrin [89]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
5-Hydroxy-2,4-dimethoxyphenanthrene [90]	<i>D. loddigesii</i>	Whole plant	Ito et al., 2010
3-Hydroxy-2,4,7-trimethoxyphenanthrene [91]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
Cypripedin [92]	<i>D. densiflorum</i>	Stem	Fan et al., 2001
Densiflorol B [93]	<i>D. densiflorum</i>	Stem	Fan et al., 2001
	<i>D. venustum</i>	Whole plant	Sukphan et al., 2014
Denbinobin [94]	<i>D. moniliforme</i>	Stem	Lin et al., 2001

Stilbenoids	Plant	Plant part	Reference
	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
Fimbriatone [95]	<i>D. nobile</i>	Stem	Zhang et al., 2008c
	<i>D. pulchellum</i>	Stem	Chanvorachote et al., 2013
Dendroscabrol A [96]	<i>D. scabrilingue</i>	Whole plant	Sarakulwattana et al., 2018
Loddigesiinol B [97]	<i>D. loddigesii</i>	Whole plant	Ito et al., 2010
Dendronone [98]	<i>D. cariniferum</i>	Whole plant	Chen et al., 2008b
	<i>D. longicornu</i>	Stem	Hu et al., 2008a
Ephemeranthoquinone [99]	<i>D. plicatile</i>	Stem	Yamaki and Honda, 1996
5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [100]	<i>D. draconis</i>	Stem	Sritularak, Anuwat and Likhitwitayawuid, 2011
	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
Moniliformin [101]	<i>D. moniliforme</i>	Stem	Lin et al., 2001
Moscatin [102]	<i>D. aphyllum</i>	Whole plant	Chen et al., 2008b
	<i>D. chrysanthum</i>	Stem	Yang et al., 2006
	<i>D. chrysotoxum</i>	Whole plant	Li et al., 2009d
	<i>D. densiflorum</i>	Stem	Fan et al., 2001
	<i>D. polyanthum</i>	Stem	Hu et al., 2009
	<i>D. rotundatum</i>	Whole plant	Majumder and Pal, 1992
Coelonin [103]	<i>D. nobile</i>	Stem	Hwang et al., 2010
	<i>D. aphyllum</i>	Whole plant	Chen et al., 2008b
	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
	<i>D. scabrilingue</i>	Whole plant	Sarakulwattana et al., 2018

Stilbenoids	Plant	Plant part	Reference
9,10-Dihydromoscatin [104]	<i>D. polyanthum</i>	Stem	Hu et al., 2009
9,10-Dihydrophenanthrene-2,4,7-triol [105]	<i>D. polyanthum</i>	Stem	Hu et al., 2009
4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [106]	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014
	<i>D. sinense</i>	Whole plant	Chen et al., 2014
4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene [107]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
	<i>D. devonianum</i>	Stem	Wu et al., 2019
4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene [108]	<i>D. nobile</i>	Stem	Ye and Zhao, 2002
4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene [109]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
	<i>D. devonianum</i>	Stem	Wu et al., 2019
Lusianthridin [110]	<i>D. brymerianum</i>	Whole plant	Klongkumnuankarn et al., 2015
	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007; Hwang et al., 2010
	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
	<i>D. plicatile</i>	Stem	Yamaki and Honda, 1996
	<i>D. venustum</i>	Whole plant	Sukphan et al., 2014
	<i>D. scabrilingue</i>	Whole plant	Sarakulwattana et al., 2018

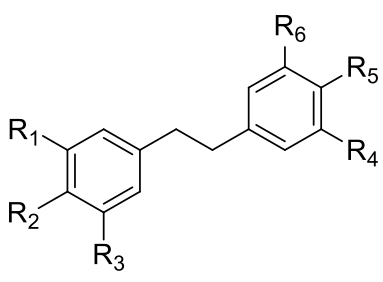
Stilbenoids	Plant	Plant part	Reference
	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019
2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene [111]	<i>D. rotundatum</i>	Whole plant	Majumder and Pal, 1992
2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [112]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene [113]	<i>D. sinense</i>	Whole plant	Chen et al., 2013
Ephemeranthol A [114]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007; Hwang et al., 2010
	<i>D. officinale</i>	Stem	Zhao et al., 2018
	<i>D. infundibulum</i>	Whole plant	Na Ranong et al., 2019
Ephemeranthol C [115]	<i>D. nobile</i>	Stem	Hwang et al., 2010
Erianthridin [116]	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
	<i>D. nobile</i>	Stem	Hwang et al., 2010; Yang, Sung and Kim, 2007
	<i>D. plicatile</i>	Stem	Yamaki and Honda, 1996
Flavanthridin [117]	<i>D. nobile</i>	Stem	Hwang et al., 2010
Hircinol [118]	<i>D. nobile</i>	Stem	Hwang et al., 2010
	<i>D. aphyllum</i>	Stem	Yang et al., 2015
	<i>D. draconis</i>	Stem	Sritularak, Anuwat and Likhitwitayawuid, 2011
	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017

Stilbenoids	Plant	Plant part	Reference
3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene [119]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
7-Hydroxy-2,3,4-trimethoxy-9,10-dihydrophenanthrene [120]	<i>D. hainanense</i>	Aerial part	Zhang et al., 2019
Dendroinfundin A [121]	<i>D. infundibulum</i>	Whole plant	Na Ranong et al., 2019
Dendroinfundin B [122]	<i>D. infundibulum</i>	Whole plant	Na Ranong et al., 2019
3,4-Dimethoxy-1-(methoxymethyl)-9,10-dihydrophenanthrene-2,7-diol [123]	<i>D. hainanense</i>	Aerial part	Zhang et al., 2019
2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene [124]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol [125]	<i>D. draconis</i>	Stem	Sritularak, Anuwat and Likhitwitayawuid, 2011
2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene [126]	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
Plicatol C [127]	<i>D. plicatile</i>	Stem	Honda and Yamaki, 2000
Rotundatin [128]	<i>D. rotundatum</i>	Whole plant	Majumder and Pal, 1992
2,5-Dihydroxy-3,4-dimethoxyphenanthrene [129]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007

Stilbenoids	Plant	Plant part	Reference
2,5-Dihydroxy-4,9-dimethoxyphenanthrene [130]	<i>D. nobile</i>	Stem	Zhang et al., 2008c
	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019
2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene [131]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
Epheranthol B [132]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
	<i>D. plicatile</i>	Stem	Yamaki and Honda, 1996
Fimbriol B [133]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007; Hwang et al., 2010
Flavanthrinin [134]	<i>D. brymerianum</i>	Whole plant	Klongkumnuankarn et al., 2015
	<i>D. nobile</i>	Stem	Zhang et al., 2008c
	<i>D. venustum</i>	Whole plant	Sukphan et al., 2014
	<i>D. parishii</i>	Whole plant	Kongkatitham et al., 2018
Loddigesiinol A [135]	<i>D. loddigesii</i>	Whole plant	Ito et al., 2010
Nudol [136]	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
	<i>D. rotundatum</i>	Whole plant	Majumder and Pal, 1992
Plicatol A [137]	<i>D. nobile</i>	Stem	Yang, Sung and Kim, 2007
	<i>D. plicatile</i>	Stem	Honda and Yamaki, 2000
Plicatol B [138]	<i>D. plicatile</i>	Stem	Honda and Yamaki, 2000
2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene [139]	<i>D. nobile</i>	Stem	Yang, Sung and Kim., 2007

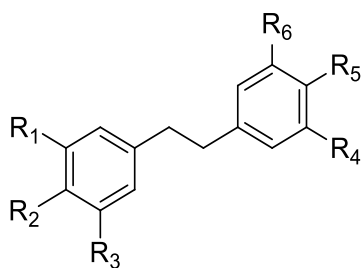
Stilbenoids	Plant	Plant part	Reference
3,4,8-Trimethoxy phenanthrene-2,5-diol [140]	<i>D. nobile</i>	Stem	Hwang et al., 2010
Aphyllone A [141]	<i>D. aphyllum</i>	Stem	Yang et al., 2015
2,4,5,9S-Tetrahydroxy-9,10-dihydro phenanthrene [142]	<i>D. fimbriatum</i>	Stem	Xu et al., 2014
1,5,7-Trimethoxy phenanthren-2-ol [143]	<i>D. nobile</i>	Stem	Kim et al., 2015
1,5-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [144]	<i>D. moniliforme</i>	Whole plant	Zhao et al., 2016
2,5,9S-Trihydroxy-9,10-dihydrophenanthrene-4-O- β -D-glucopyranoside [145]	<i>D. primulinum</i>	Whole plant	Ye et al., 2016
Loddigesiinol G [146]	<i>D. loddigesii</i>	Stem	Lu et al., 2014
Loddigesiinol H [147]	<i>D. loddigesii</i>	Stem	Lu et al., 2014
Loddigesiinol I [148]	<i>D. loddigesii</i>	Stem	Lu et al., 2014
Loddigesiinol J [149]	<i>D. loddigesii</i>	Stem	Lu et al., 2014
Dendrowillol A [150]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Dendrocandin P1 [151]	<i>D. officinale</i>	Stem	Zhao et al., 2018
Dendrocandin P2 [152]	<i>D. officinale</i>	Stem	Zhao et al., 2018
Orchinol [153]	<i>D. officinale</i>	Stem	Zhao et al., 2018
2,4,7-Trihydroxy-9,10-dihydrophenanthrene [154]	<i>D. officinale</i>	Stem	Zhao et al., 2018

Stilbenoids	Plant	Plant part	Reference
4-Methoxy-5,9 <i>R</i> -dihydroxy-9,10-dihydrophenanthrene-2- <i>O</i> - β -D-glucopyranoside [155]	<i>D. nobile</i>	Stem	Zhou et al., 2017
Dihydroresveratrol [156]	<i>D. aphyllum</i>	Stem	Yang et al., 2015
Aphyllone B [157]	<i>D. aphyllum</i>	Stem	Yang et al., 2015
Aphyllal C [158]	<i>D. aphyllum</i>	Stem	Yang et al., 2015
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
Aphyllal D [159]	<i>D. aphyllum</i>	Stem	Yang et al., 2015
Aphyllal E [160]	<i>D. aphyllum</i>	Stem	Yang et al., 2015
(-)-Dendroparishioid [161]	<i>D. parishii</i>	Whole plant	Kongkatitham et al., 2018
(<i>R</i>)-4,5,4'-Trihydroxy-3,3', α -trimethoxybibenzyl [162]	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
Dendrofindlaphenol A [163]	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
6"-De- <i>O</i> -methyl dendrofindlaphenol A [164]	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
Dendrofindlaphenol B [165]	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
Dendrofindlaphenol C [166]	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
Dendrodevonin A [167]	<i>D. devonianum</i>	Stem	Wu et al., 2019
Dendrodevonin B [168]	<i>D. devonianum</i>	Stem	Wu et al., 2019



	R ₁	R ₂	R ₃	R ₄	R ₅	R ₆
[1] Aloifol I	OMe	OH	OMe	OH	H	H
[2] Amoenylin	OMe	OH	OMe	H	OMe	H
[3] Batatasin	OMe	H	H	OH	H	OH
[4] Batatasin III	OH	H	OMe	H	H	OH
[5] Brittonin A	OMe	OMe	OMe	OMe	OMe	OMe
[6] Chrysotobibenzyl	OMe	OMe	OMe	OMe	OMe	H
[7] Chrysotoxine	OMe	OH	OMe	OMe	OMe	H
[8] Crepidatin	OMe	OMe	OMe	OMe	OH	H
[9] Cumulatin	OMe	OMe	OH	OH	OMe	OMe
[10] Dendrobin A	OH	OH	OMe	H	H	OMe
[11] 3,3'-Dihydroxy-4,5-dimethoxybibenzyl	OMe	OMe	OH	H	H	OH
[12] 3,4'-Dihydroxy-5-methoxybibenzyl	OH	H	OMe	H	OH	H
[13] 3,4'-Dihydroxy-5,5'-dimethoxydihydrostilbene	OH	H	OMe	OMe	OH	H

Figure 2 Structures of stilbenoids from *Dendrobium*



R₁ R₂ R₃ R₄ R₅ R₆

[14] 4,5-Dihydroxy-3,3'-dimethoxybibenzyl

OMe OH OH H H OMe

[15] Erianin

OMe OMe OMe H OMe OH

[16] Gigantol

OMe H H H OH OMe

[17] 4-Hydroxy-3,5,3'-trimethoxybibenzyl

OMe OH OMe H H OMe

[18] 5-Hydroxy-3,4,3',4',5'-pentamethoxybibenzyl

OMe OMe OH OMe OMe OMe

[19] Isoamoenylin

OMe OMe OMe H H OH

[20] Moniliformine

OH OH OMe H OMe H

[21] Moscatilin

OMe OH OMe H OH OMe

[22] 3,3',4-Trihydroxybibenzyl

OH OH H H H OH

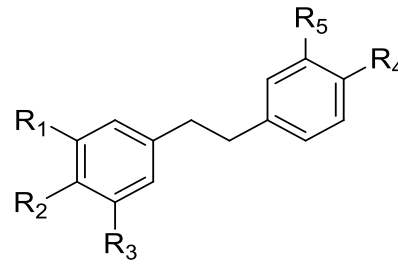
[23] 3,3',5-Trihydroxybibenzyl

OH H OH H H OH

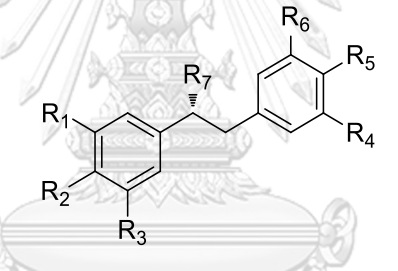
[24] 3,5,4'-Trihydroxybibenzyl

OH H OH H OH H

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)

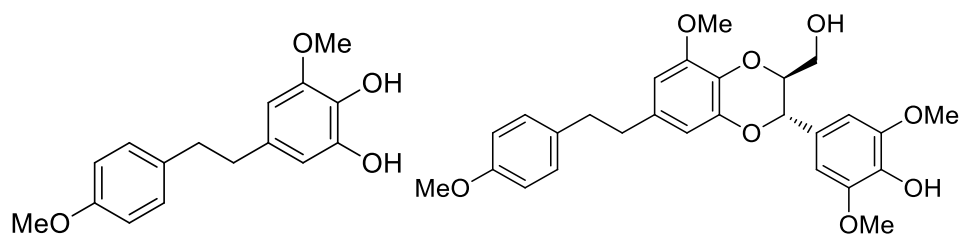


	R ₁	R ₂	R ₃	R ₄	R ₅
[25] 4,5,4'-Trihydroxy-3,3'-dimethoxybibenzyl	OMe	OH	OH	OH	OMe
[26] Tristin	OH	H	OH	OH	OMe
[27] Dendromonilside E	OGlc	OGlc	OMe	OMe	H
[28] 5,4'-Dihydroxy-3,4,3'-trimethoxybibenzyl	OH	OMe	OMe	OH	OMe
[29] 4,3',4'-Trihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	OH	OH



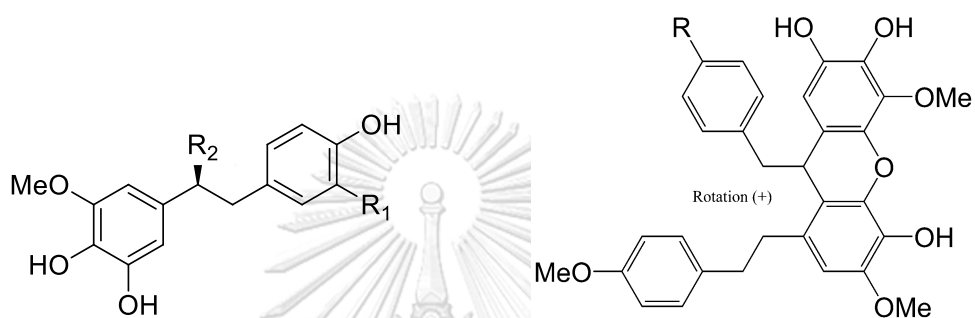
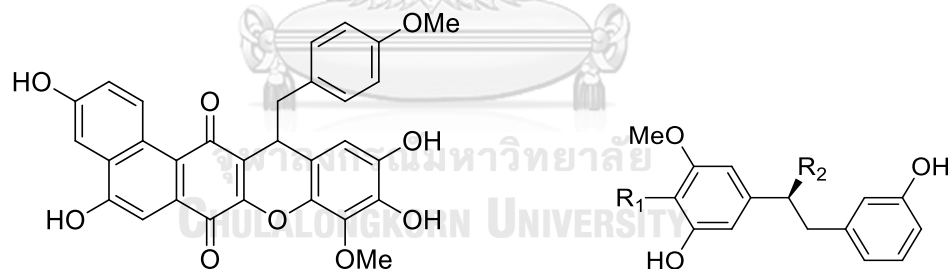
	R ₁	R ₂	R ₃	R ₄	R ₅	R ₆	R ₇
[30] Dendrophenol	OMe	OH	OMe	OH	OH	H	H
[31] 4,4'-Dihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	H	OH	H	H
[32] Loddigesinol C	OMe	OH	OMe	H	OH	OMe	OMe
[33] 3-O-Methylgigantol	OMe	H	OH	OMe	OMe	H	H

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



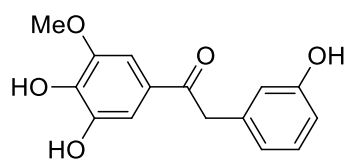
[34] Dendrocandin A

[35] Dendrocandin B

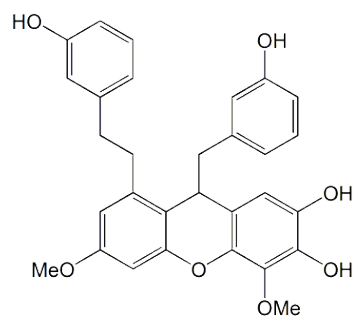
[36] Dendrocandin C $R_1 = H$ $R_2 = OMe$ [39] Dendrocandin F $R = OMe$ [37] Dendrocandin D $R_1 = H$ $R_2 = OEt$ [40] Dendrocandin G $R = OH$ [38] Dendrocandin E $R_1 = OH$ $R_2 = H$ 

[41] Dendrocandin H

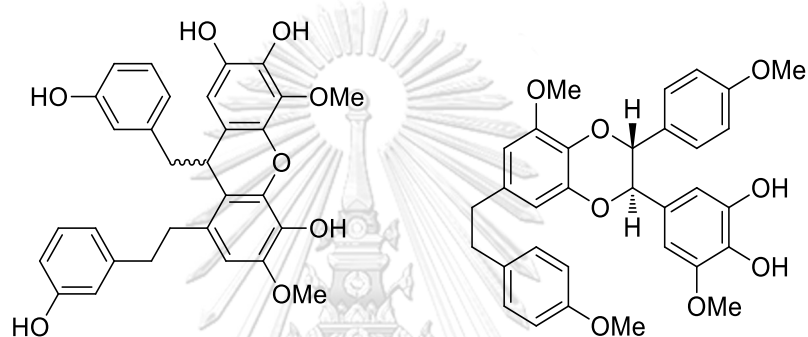
[42] Dendrosinen A $R_1 = OMe$ $R_2 = OH$ [43] Dendrosinen B $R_1 = OH$ $R_2 = H$ Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



[44] Dendrosinen C

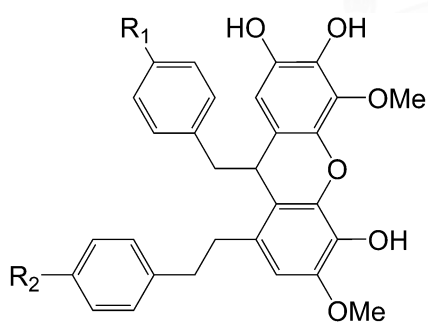


[45] Dendroscabrol B



[46] Dendrosinen D

[47] Dendrocandin I

R₁R₂

[48] Dendrocandin J

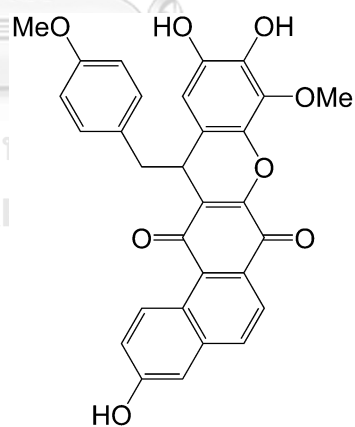
OMe

OH

[49] Dendrocandin K

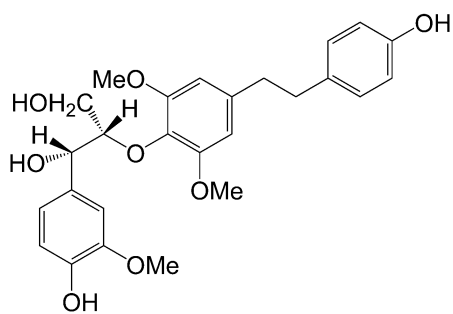
OH

OH

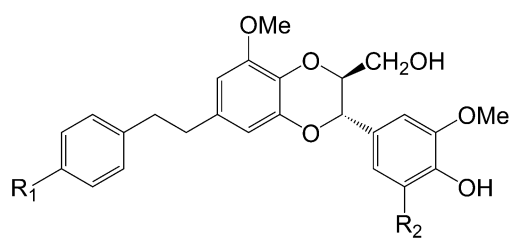


[50] Dendrocandin L

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



[51] Dendrocandin M



[52] Dendrocandin N

[53] Dendrocandin O

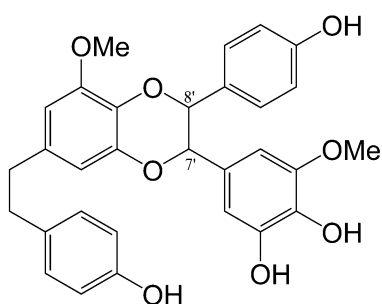
R₁R₂

OH

H

OH

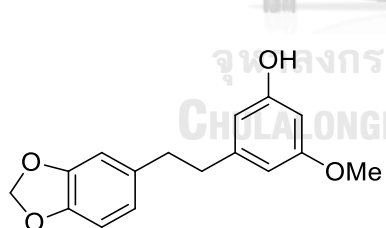
OH



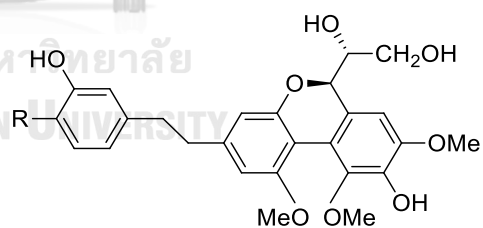
[54] Dendrocandin P

H-7', 8' *cis*

[55] Dendrocandin Q

H-7', 8' *trans*

[56] Densiflorol A



[57] Longicornuol A

R = H

[58] Trigonopol A

R = OMe

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)

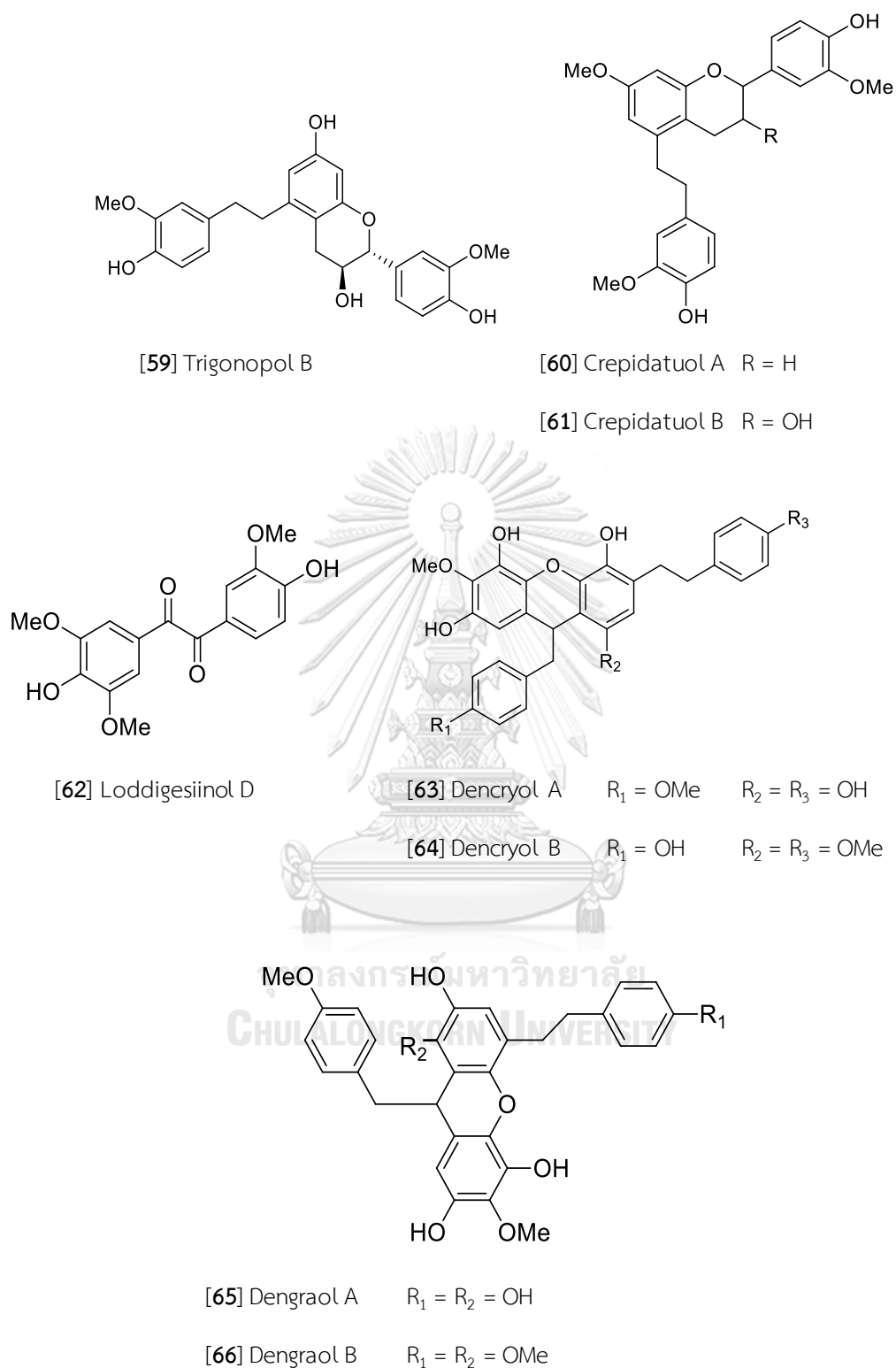
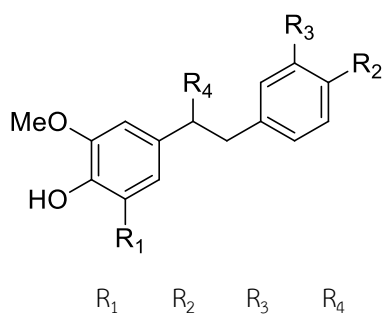


Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



[67] 4-[2-(3-Hydroxyphenyl)-1-methoxyethyl]-2,6-dimethoxyphenol

OMe H OH OMe

[68] Nobilin A

OH H OMe OMe

[69] Nobilin B

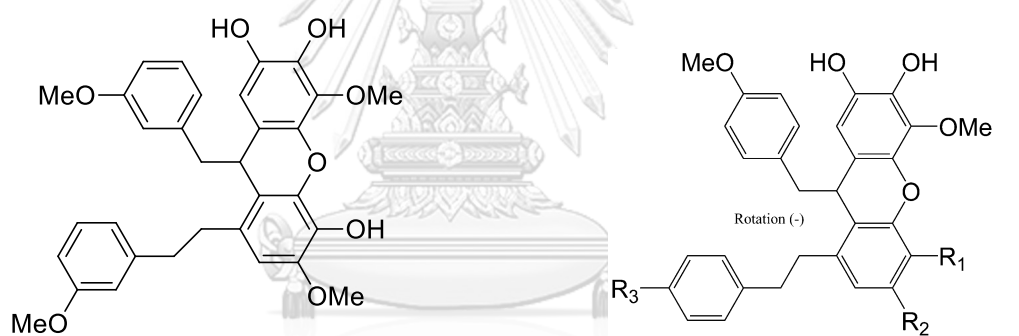
OMe OH OMe OMe

[70] Nobilin C

OMe OMe OMe OMe

[71] Nobilin D

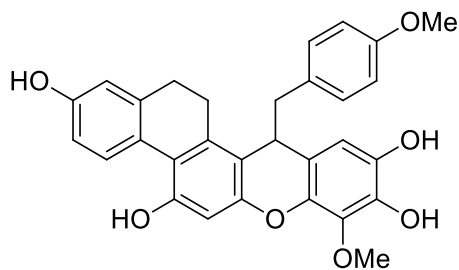
OMe OH OMe OH



[72] Nobilin E

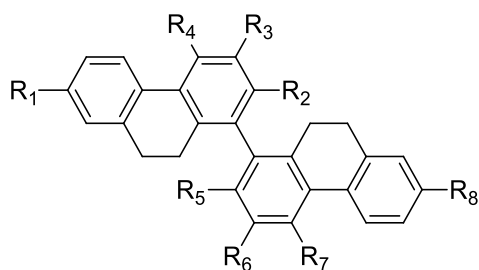
[73] Dendrofalconerol A R₁ = OH R₂ = R₃ = OMe

[74] Dendrofalconerol B R₁ = H R₂ = R₃ = OH



[75] Dendrosignatol

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



R₁ R₂ R₃ R₄ R₅ R₆ R₇ R₈

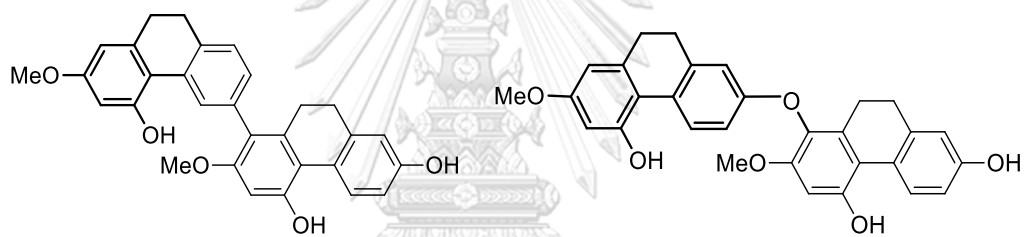
[76] 2,2'-Dihydroxy-3,3',4,4',7,7'-hexamethoxy-9,9',10,10'-tetrahydro-1,1'-biphenanthrene

OMe OH OMe OMe OH OMe OMe OMe

[77] 2,2'-Dimethoxy-4,4',7,7'-tetrahydroxy-9,9',10,10'-tetrahydro-1,1'-biphenanthrene

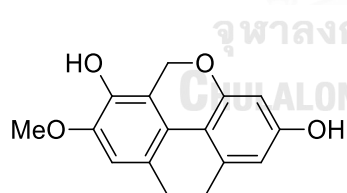
OH OMe H OH OMe H OH OH

[78] Flavanthrin OH OH H OMe OH H OMe OH

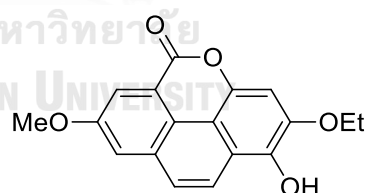


[79] Phoyunnanin C

[80] Phoyunnanin E

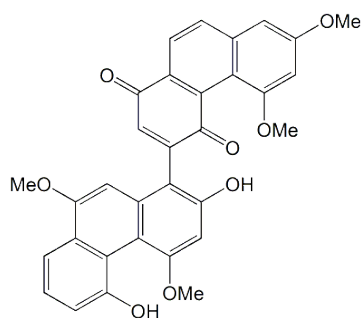


[81] Amoenumin

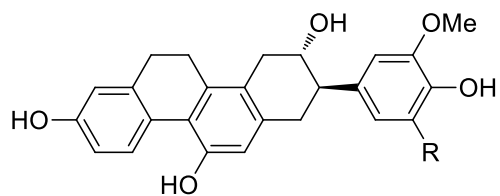


[82] Crystalltone

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)

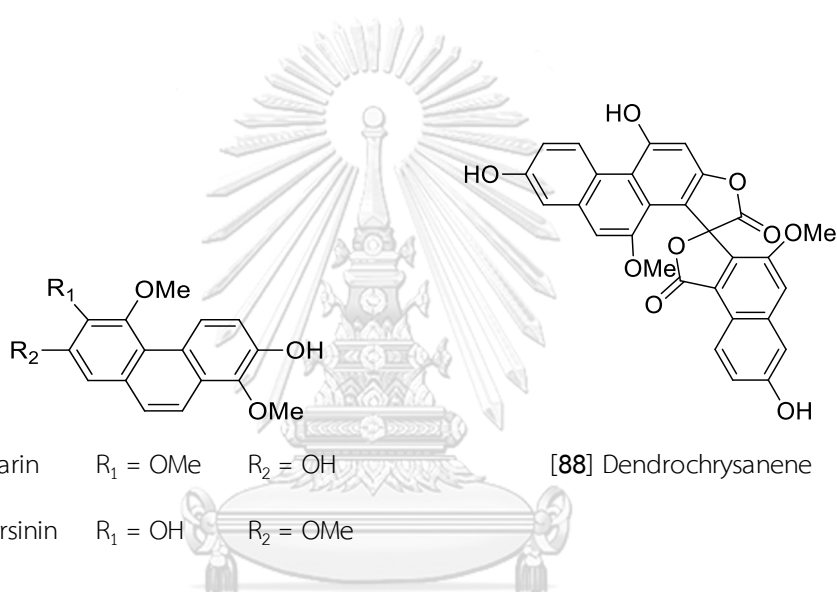


[83] Dendropalpebrone

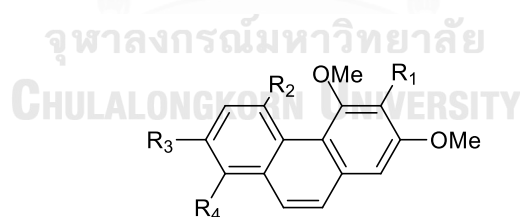


[84] Chrysotoxol A R = H

[85] Chrysotoxol B R = OMe

[86] Confusarin R₁ = OMe R₂ = OH[87] Denthysinin R₁ = OH R₂ = OMe

[88] Dendrochrysanene



[89] Bulbophyllanthrin

[90] 5-Hydroxy-2,4-dimethoxyphenanthrene

[91] 3-Hydroxy-2,4,7-trimethoxyphenanthrene

R ₁	R ₂	R ₃	R ₄
OH	OH	H	H
H	OH	H	H
OH	H	OMe	H

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)

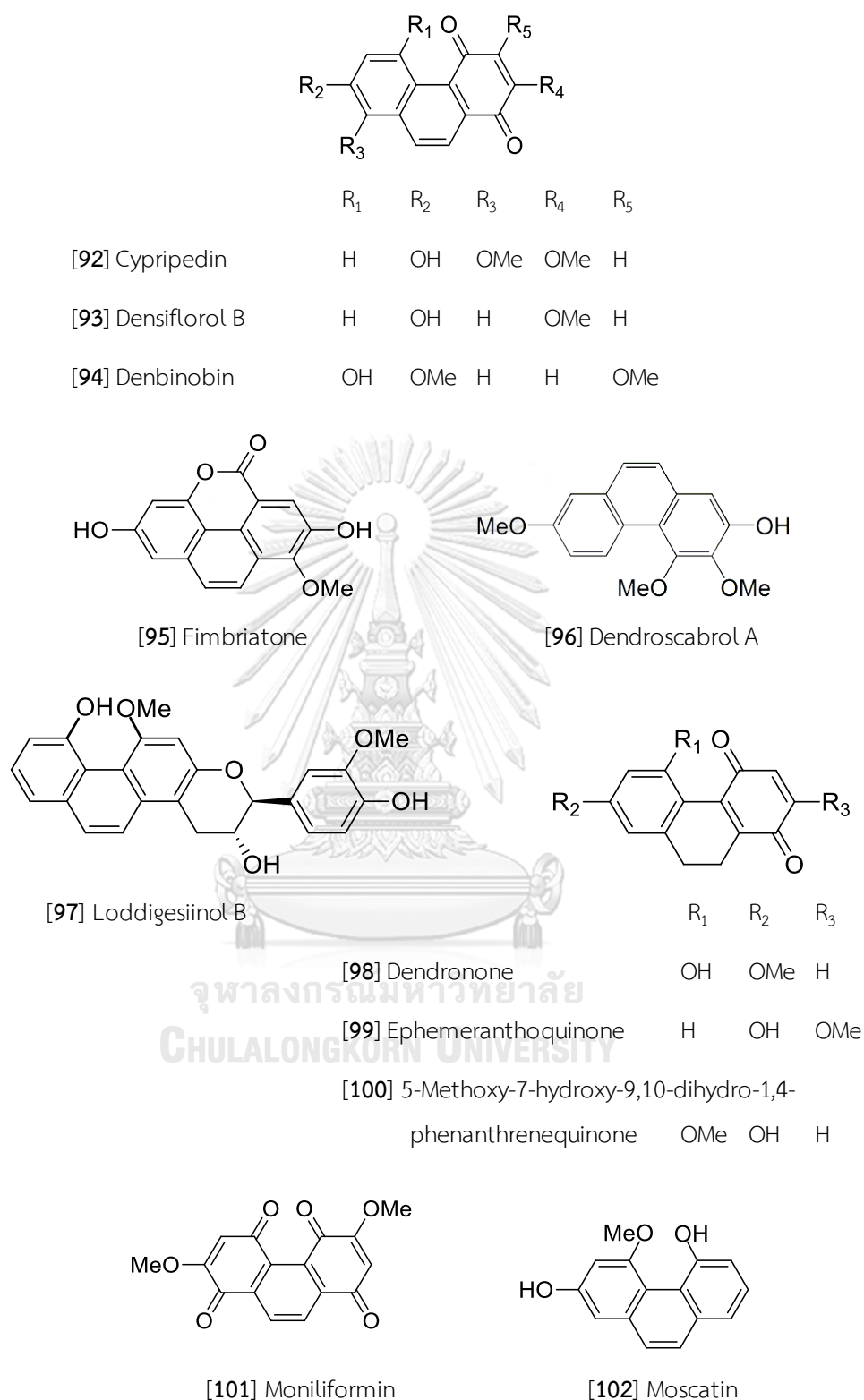
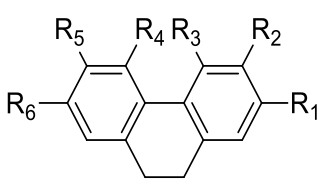
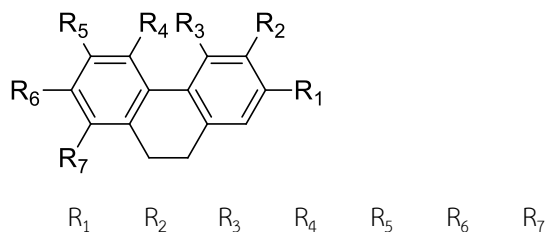


Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



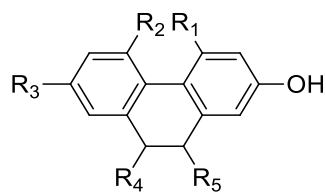
	R ₁	R ₂	R ₃	R ₄	R ₅	R ₆
[103] Coelonin	OH	H	OMe	H	H	OH
[104] 9,10-Dihydromoscatin	H	H	OH	OMe	H	OH
[105] 9,10-Dihydrophenanthrene-2,4,7-triol	OH	H	OH	H	H	OH
[106] 4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	OH	H	H
[107] 4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	OMe	H
[108] 4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene	H	OMe	OH	OH	H	OMe
[109] 4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	H	H
[110] Lusianthridin	OMe	H	OH	H	H	OH

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



[111]	2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene	OH	OMe	OMe	H	OMe	OH	H
[112]	2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene	OH	OMe	OMe	H	H	OMe	OH
[113]	4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	H	OMe	OH	H
[114]	Ephemeranthol A	OH	H	H	OH	OMe	OMe	H
[115]	Ephemeranthol C	OH	OH	OMe	OH	H	H	H
[116]	Erianthridin	OH	OMe	OMe	H	H	OH	H
[117]	Flavanthridin	OH	H	H	OMe	OH	OMe	H
[118]	Hircinol	OH	H	OMe	OH	H	H	H
[119]	3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene	OMe	OH	OMe	H	H	OMe	H
[120]	7-Hydroxy-2,3,4-trimethoxy-9,10-dihydrophenanthrene	OH	H	H	OMe	OMe	OMe	H
[121]	Dendroinfundin A	OMe	OMe	OH	H	H	OMe	H
[122]	Dendroinfundin B	OMe	OMe	OH	OH	H	H	OMe
[123]	3,4-Dimethoxy-1-(methoxymethyl)-9,10-dihydrophenanthrene-2,7-diol	OH	H	H	OMe	OMe	OH	-CH ₂ OMe

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



R₁ R₂ R₃ R₄ R₅

[124] 2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene

OMe H OMe H H

[125] 7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol

OH OH OMe H H

[126] 2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene

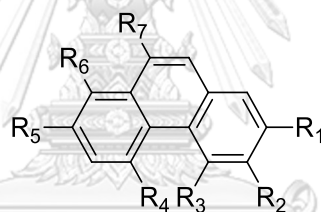
OMe OH OH H H

[127] Plicatol C

H OMe OH H OMe

[128] Rotundatin

H OMe OH H OH



R₁ R₂ R₃ R₄ R₅ R₆ R₇

[129] 2,5-Dihydroxy-3,4-dimethoxyphenanthrene

OH OMe OMe OH H H H

[130] 2,5-Dihydroxy-4,9-dimethoxyphenanthrene

OH H OMe OH H H OMe

[131] 2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene

OH OMe OMe H OMe OH H

[132] Epheranthol B

H H OMe OH OMe H H

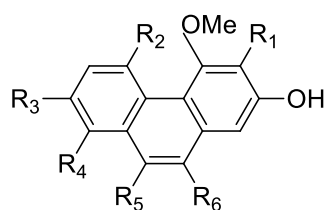
[133] Fimbriol B

OH OMe OH H H H H

[134] Flavanthrinin

OH H OMe H OH H H

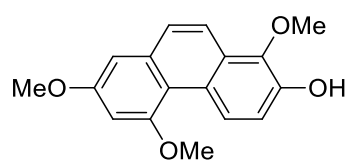
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



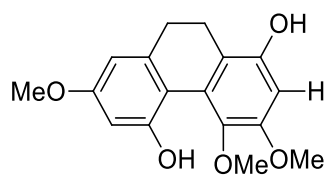
	R ₁	R ₂	R ₃	R ₄	R ₅	R ₆
[135] Loddigesinol A	H	OMe	H	H	OH	H
[136] Nudol	OMe	H	OH	H	H	H
[137] Plicatol A	H	OH	H	H	OMe	OMe
[138] Plicatol B	H	OH	H	H	H	H
[139] 2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene	OH	OH	H	H	OMe	H
[140] 3,4,8-Trimethoxyphenanthrene-2,5-diol	OMe	OH	H	OMe	H	H



[141] Aphyllone A [142] 2,4,5,9S-Tetrahydroxy-9,10-dihydrophenanthrene

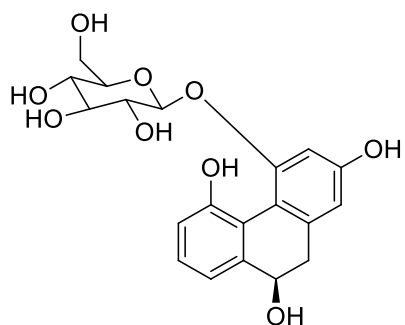


[143] 1,5,7-Trimethoxyphenanthren-2-ol

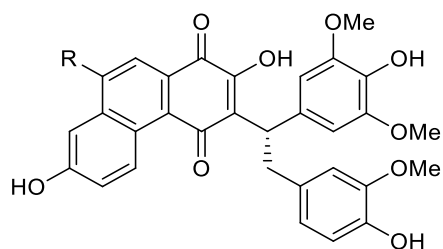


[144] 1,5-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene

Figure 2 Structures of stilbenoids from *Dendrobium* (continued)

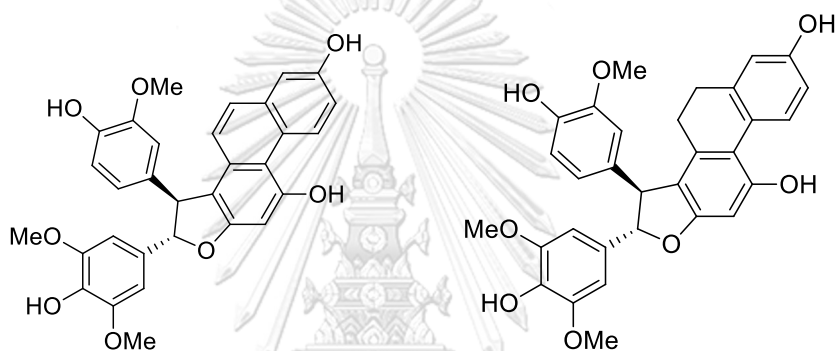


[145] 2,5,9S-Trihydroxy-9,10-dihydrophenanthrene
-4-O- β -D-glucopyranoside



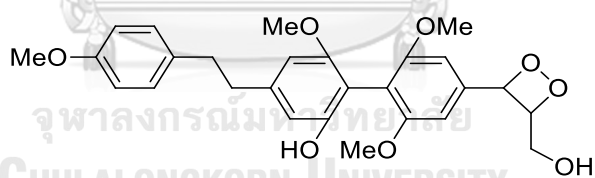
[146] Loddigesiinol G R = H

[147] Loddigesiinol H R = OH

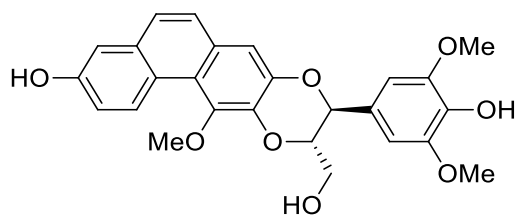


[148] Loddigesiinol I

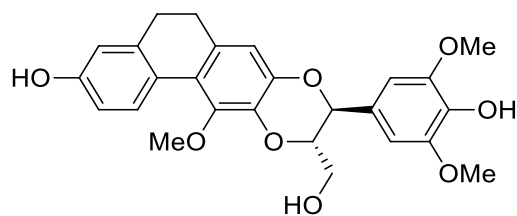
[149] Loddigesiinol J



[150] Dendrowillol A

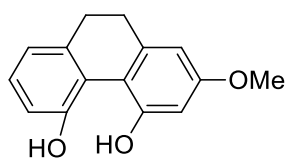


[151] Dendrocandin P1

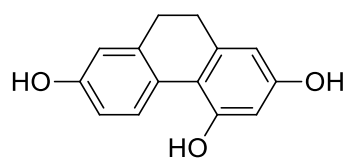


[152] Dendrocandin P2

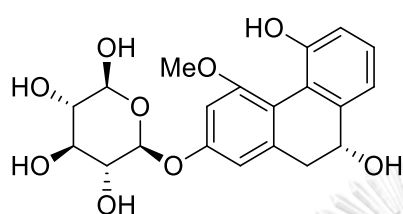
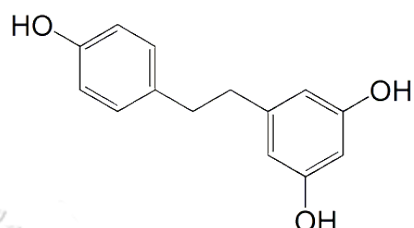
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



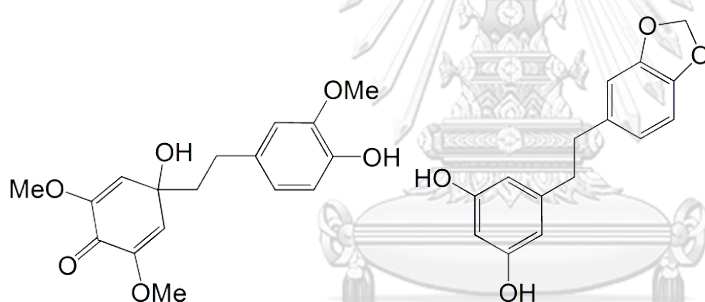
[153] Orchinol



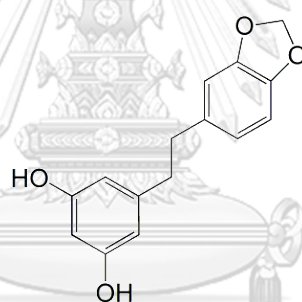
[154] 2,4,7-Trihydroxy-9,10-dihydrophenanthrene

[155] 4-Methoxy-5,9*R*-dihydroxy-9,10-dihydrophenanthrene-2-*O*- β -D-glucopyranoside

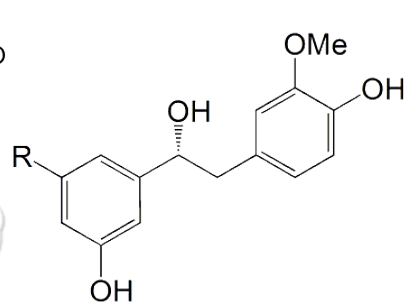
[156] Dihydroresveratrol



[157] Aphyllone B

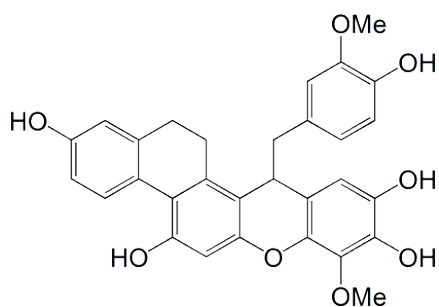


[158] Aphyllal C

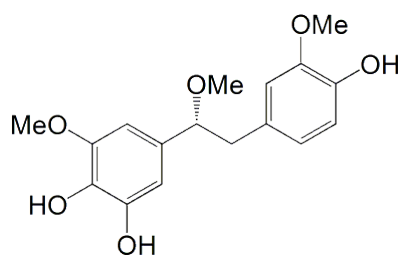


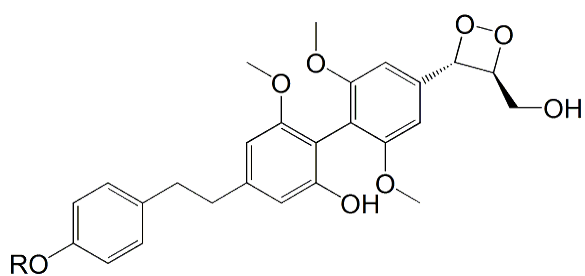
[159] Aphyllal D R = OH

[160] Aphyllal E R = OMe



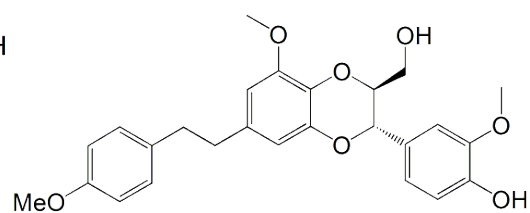
[161] (-)-Dendroparishioid

[162] (*R*)-4,5,4'-Trihydroxy-3,3', α -trimethoxybiphenylFigure 2 Structures of stilbenoids from *Dendrobium* (continued)



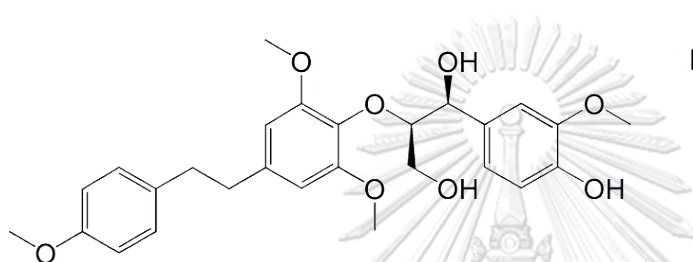
[163] Dendrofindlaphenol A

R = Me

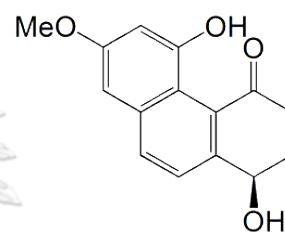


[165] Dendrofindlaphenol B

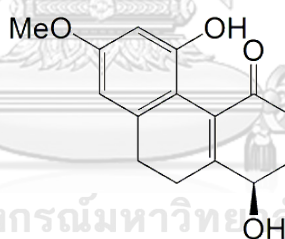
[164] 6''-De-O-methyldendrofindlaphenol A R = H



[166] Dendrofindlaphenol C



[167] Dendrodevonin A



[168] Dendrodevonin B

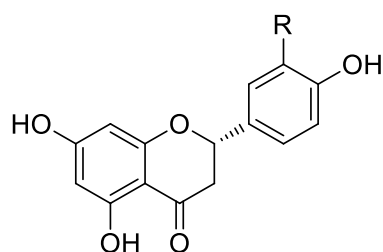
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)

Table 2 Flavonoids from *Dendrobium*

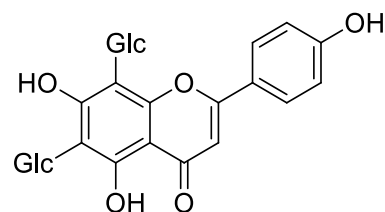
Flavonoids	Plant	Plant part	Reference
(2S)-Homoeriodictyol [169]	<i>D. densiflorum</i>	Stem	Fan et al., 2001
	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014
Naringenin [170]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang, Wang and Xu, 2006
	<i>D. densiflorum</i>	Stem	Fan et al., 2001
	<i>D. longicornu</i>	Stem	Hu et al., 2008a
(2S)-Eriodictyol [171]	<i>D. trigonopus</i>	Stem	Hu et al., 2008b
	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014
	<i>D. tortile</i>	Whole plant	Limpanit et al., 2016
Vicenin II [172]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Xiong et al., 2013
Apigenin [173]	<i>D. crystallinum</i>	Stem	Wang et al., 2009
	<i>D. williamsonii</i>	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid, 2014
5,6-Dihydroxy-4'-methoxyflavone [174]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
Chrysoeriol [175]	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014
Luteolin [176]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Whole plant	Liu et al., 2009b
	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014

Flavonoids	Plant	Plant part	Reference
6-C-(α -Arabinopyranosyl)-8-C-[(2-O- α -rhamnopyranosyl)- β -galactopyranosyl] apigenin [177]	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
6-C-(α -Arabinopyranosyl)-8-C-[(2-O- α -rhamnopyranosyl)- β -glucopyranosyl] apigenin [178]	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
6'''-Glucosyl-vitexin [179]	<i>D. crystallinum</i>	Stem	Wang et al., 2009
Isoschaftoside [180]	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
Isoviolanthin [181]	<i>D. crystallinum</i>	Stem	Wang et al., 2009
6-C-[(2-O- α -Rhamnopyranosyl)- β -glucopyranosyl]-8-C-(α -arabinopyranosyl) apigenin [182]	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
6-C-(β -Xylopyranosyl)-8-C-[(2-O- α -rhamnopyranosyl)- β -glucopyranosyl] apigenin [183]	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
Kaempferol [184]	<i>D. aurantiacum</i> <i>var. denneanum</i>	Stem	Yang, Wang and Xu, 2006
Kaempferol-3-O- α -L-rhamnopyranoside [185]	<i>D. secundum</i>	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012
Kaempferol-3,7-O-di- α -L-rhamnopyranoside [186]	<i>D. secundum</i>	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012

Flavonoids	Plant	Plant part	Reference
Kaempferol-3-O- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-glucopyranoside [187]	<i>D. capillipes</i>	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012
Kaempferol-3-O- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-xylopyranoside [188]	<i>D. capillipes</i>	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012
Quercetin-3-O- α -L-rhamnopyranoside [189]	<i>D. secundum</i>	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012
Quercetin-3-O- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-xylopyranoside [190]	<i>D. capillipes</i>	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012
5-Hydroxy-3-methoxyflavone-7-O-[[β -D-apiosyl-(1 \rightarrow 6)]- β -D-glucoside [191]	<i>D. devonianum</i>	Stem	Sun et al., 2014
Isorhamnetin-3-O- β -D-rutinoside [192]	<i>D. nobile</i>	Stem	Zhou et al., 2017
(S)-5,5',7-Trihydroxy-3',4'-dimethoxyflavanone [193]	<i>D. loddigesii</i>	Stem	Ma et al., 2019b

[169] (2*S*)-Homoeriodictyol R = OMe

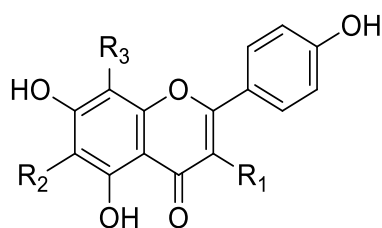
[170] Naringenin R = H

[171] (2*S*)-Eriodictyol R = OH

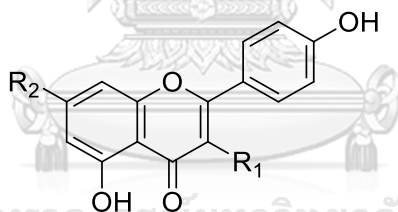
[172] Vicenin II

	R ₁	R ₂	R ₃	R ₄	R ₅
[173] Apigenin	H	OH	H	H	OH
[174] 5,6-Dihydroxy-4'-methoxyflavone	OH	H	H	H	OMe
[175] Chrysoeriol	H	OH	H	OMe	OH
[176] Luteolin	H	OH	H	OH	OH
[177] 6-C-(α -Arabinopyranosyl)-8-C-[(2-O- α -rhamnopyranosyl)- β -galactopyranosyl] apigenin	-Ara	OH	-Gal-Rha	H	OH
[178] 6-C-(α -Arabinopyranosyl)-8-C-[(2-O- α -rhamnopyranosyl)- β -glucopyranosyl] apigenin	-Ara	OH	-Glc-Rha	H	OH

Figure 3 Structures of flavonoids from *Dendrobium*

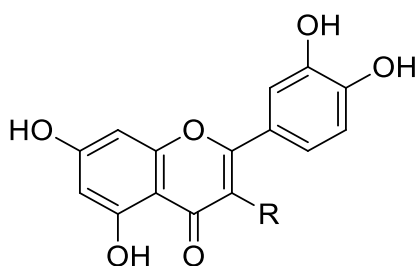


	R ₁	R ₂	R ₃
[179] 6'''-Glucosyl-vitexin	H	H	-Glc
[180] Isoschaftoside	H	-Ara	-Glc
[181] Isoviolanthin	H	-Rha	-Glc
[182] 6-C-[(2-O- α -Rhamnopyranosyl)- β -glucopyranosyl]-8-C-(α -arabinopyranosyl) apigenin	H	-Glc-Rha	-Ara
[183] 6-C-(β -Xylopyranosyl)-8-C-[(2-O- α -rhamnopyranosyl)- β -glucopyranosyl] apigenin	H	-Xyl	-Glc-Rha
[184] Kaempferol	OH	H	H



	R ₁	R ₂
[185] Kaempferol-3-O- α -L-rhamnopyranoside	O-Rha	OH
[186] Kaempferol-3,7-O-di- α -L-rhamnopyranoside	O-Rha	O-Rha
[187] Kaempferol-3-O- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-glucopyranoside	O-Glc-Rha	OH
[188] Kaempferol-3-O- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-xylopyranoside	O-Xyl-Rha	OH

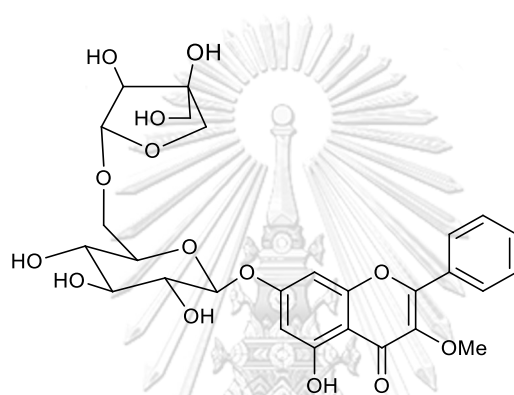
Figure 3 Structures of flavonoids from *Dendrobium* (continued)



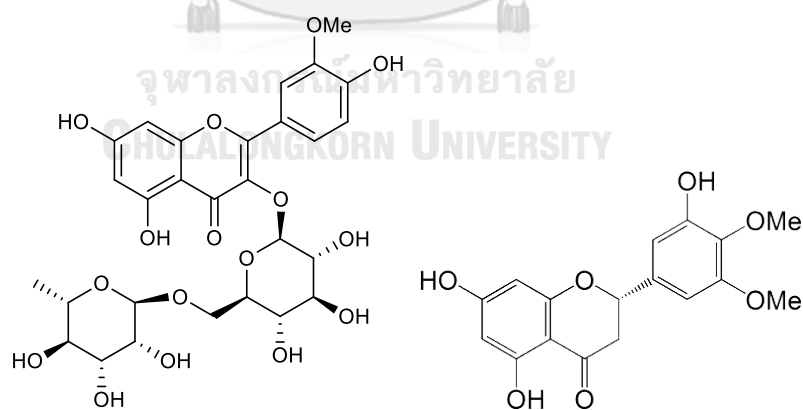
[189] Quercetin-3-O- α -L-rhamnopyranoside

R = O-Rha

[190] Quercetin-3-O- α -L-rhamnopyranosyl-(1 \rightarrow 2)- β -D-xylopyranoside R = O-Xyl-Rha



[191] 5-Hydroxy-3-methoxyflavone-7-O-[[β -D-aposyl-(1 \rightarrow 6)]- β -D-glucoside



[192] Isorhamnetin-3-O- β -D-rutinoside [193] (S)-5,5',7-Trihydroxy-3',4'-dimethoxyflavanone

Figure 3 Structures of flavonoids from *Dendrobium* (continued)

Table 3 Terpenoids from *Dendrobium*

Terpenoids	Plant	Plant part	Reference
Aduncin [194]	<i>D. aduncum</i>	Whole plant	Gawell and Leander, 1976
Amoenin [195]	<i>D. amoenum</i>	Whole plant	Dahmen and Leander, 1978; Majumder, Guha and Sen, 1999
Amotin [196]	<i>D. amoenum</i>	Whole plant	Majumder, Guha and Sen, 1999; Dahmen and Leander, 1978
α -Dihydropicrotoxinin [197]	<i>D. moniliforme</i>	Stem	Bi, Wang and Xu, 2004
Dendrobane A [198]	<i>D. nobile</i>	Stem	Zhang et al., 2007a
Dendronobilin A [199]	<i>D. nobile</i>	Stem	Zhang et al., 2007b
Dendronobilin B [200]	<i>D. nobile</i>	Stem	Zhang et al., 2007b
Dendronobilin C [201]	<i>D. nobile</i>	Stem	Zhang et al., 2007b
Dendronobilin D [202]	<i>D. nobile</i>	Stem	Zhang et al., 2007b
Dendronobilin E [203]	<i>D. nobile</i>	Stem	Zhang et al., 2007b
Dendronobilin F [204]	<i>D. nobile</i>	Stem	Zhang et al., 2007b
Dendronobilin G [205]	<i>D. nobile</i>	Stem	Zhang et al., 2007b
Dendronobilin H [206]	<i>D. nobile</i>	Stem	Zhang et al., 2007b
Dendronobilin I [207]	<i>D. nobile</i>	Stem	Zhang et al., 2007b
	<i>D. findlayanum</i>	Stem	Yang et al., 2019a
Dendronobilin J [208]	<i>D. nobile</i>	Stem	Zhang et al., 2007a
Dendronobilin K [209]	<i>D. nobile</i>	Stem	Zhang et al., 2008b
Dendronobilin L [210]	<i>D. nobile</i>	Stem	Zhang et al., 2008b
Dendronobilin M [211]	<i>D. nobile</i>	Stem	Zhang et al., 2008b
Dendronobilin N [212]	<i>D. nobile</i>	Stem	Zhang et al., 2008b
	<i>D. findlayanum</i>	Stem	Yang et al., 2019a

Terpenoids	Plant	Plant part	Reference
Dendrowardol A [213]	<i>D. wardianum</i>	Stem	Fan et al., 2013
Dendrowardol B [214]	<i>D. wardianum</i>	Stem	Fan et al., 2013
Dendrowardol C [215]	<i>D. wardianum</i>	Stem	Fan et al., 2013
Corchoionoside C [216]	<i>D. polyanthum</i>	Stem	Hu et al., 2009
Crystallinin [217]	<i>D. crystallinum</i>	Stem	Wang et al., 2009
	<i>D. findlayanum</i>	Whole plant	Qin et al., 2011
Findlayanin [218]	<i>D. findlayanum</i>	Whole plant	Qin et al., 2011
3-Hydroxy-2-oxodendrobine [219]	<i>D. nobile</i>	Stem	Wang, Zhao and Che, 1985
Dendrobine [220]	<i>D. nobile</i>	Stem	Wang, Zhao and Che, 1985
	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
2-Hydroxydendrobine [221]	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
Findlayine A [222]	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
Findlayine B [223]	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
Findlayine C [224]	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
Findlayine D [225]	<i>D. findlayanum</i>	Stem	Yang et al., 2018a
Dendromonilaside A [226]	<i>D. nobile</i>	Stem	Zhao et al., 2003
Dendromonilaside B [227]	<i>D. moniliforme</i>	Stem	Zhao et al., 2003
Dendromonilaside C [228]	<i>D. moniliforme</i>	Stem	Zhao et al., 2003
Dendromonilaside D [229]	<i>D. moniliforme</i>	Stem	Zhao et al., 2003
Dendronobiloside A [230]	<i>D. nobile</i>	Stem	Zhao et al., 2001
Dendronobiloside B [231]	<i>D. nobile</i>	Stem	Zhao et al., 2001
Dendronobiloside C [232]	<i>D. nobile</i>	Stem	Zhao et al., 2001; Ye and Zhao, 2002
Dendronobiloside D [233]	<i>D. nobile</i>	Stem	Zhao et al., 2001; Ye and Zhao, 2002

Terpenoids	Plant	Plant part	Reference
Dendronobiloside E [234]	<i>D. nobile</i>	Stem	Zhao et al., 2001; Ye and Zhao, 2002
Dendroside A [235]	<i>D. moniliforme</i>	Stem	Zhao et al., 2003
	<i>D. nobile</i>	Stem	Zhao et al., 2001
		Stem	Ye and Zhao, 2002
	<i>D. findlayanum</i>	Stem	Yang et al., 2019a
Dendroside B [236]	<i>D. nobile</i>	Stem	Ye and Zhao, 2002
Dendroside C [237]	<i>D. moniliforme</i>	Stem	Zhao et al., 2003
	<i>D. nobile</i>	Stem	Ye and Zhao, 2002
Dendroside D [238]	<i>D. nobile</i>	Stem	Ye and Zhao, 2002
Dendroside E [239]	<i>D. nobile</i>	Stem	Ye, Qin and Zhao, 2002
Dendroside F [240]	<i>D. moniliforme</i>	Stem	Ye, Qin and Zhao, 2002
Dendroside G [241]	<i>D. nobile</i>	Stem	Ye, Qin and Zhao, 2002
Dendrowillin A [242]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2019b
Dendrowillin B [243]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2019b
(-)-Picroton [244]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2019b
10 β ,12,14-Trihydroxyaromadendrane [245]	<i>D. findlayanum</i>	Stem	Yang et al., 2019a
10 β ,13,14-Trihydroxyaromadendrane [246]	<i>D. findlayanum</i>	Stem	Yang et al., 2019a
Dendrofindlayanoside A [247]	<i>D. findlayanum</i>	Stem	Yang et al., 2019a
Dendrofindlayanoside B [248]	<i>D. findlayanum</i>	Stem	Yang et al., 2019a
Dendrofindlayanoside C [249]	<i>D. findlayanum</i>	Stem	Yang et al., 2019a
Dendrofindlayanobilin [250]	<i>D. findlayanum</i>	Stem	Yang et al., 2019a

Terpenoids	Plant	Plant part	Reference
(+)-(1 <i>R</i> ,2 <i>S</i> ,3 <i>R</i> ,4 <i>S</i> ,5 <i>R</i> ,6 <i>S</i> ,9 <i>R</i>)-3,11,12-Trihydroxypicrotoxane-2(15)-lactone [251]	<i>D. nobile</i>	Stem	Ma et al., 2019a
(-)-(1 <i>S</i> ,2 <i>R</i> ,3 <i>S</i> ,4 <i>R</i> ,5 <i>S</i> ,6 <i>R</i> ,9 <i>S</i> ,12 <i>R</i>)-3,11,13-Trihydroxypicrotoxane-2(15)-lactone [252]	<i>D. nobile</i>	Stem	Ma et al., 2019a
(+)-(1 <i>R</i> ,5 <i>R</i> ,6 <i>S</i> ,8 <i>R</i> ,9 <i>R</i>)-8,12-Dihydroxycopacamphan-3-en-2-one [253]	<i>D. nobile</i>	Stem	Ma et al., 2019a
Dendroterpene A [254]	<i>D. nobile</i>	Stem	Wang et al., 2019
Dendroterpene B [255]	<i>D. nobile</i>	Stem	Wang et al., 2019
Dendroterpene C [256]	<i>D. nobile</i>	Stem	Wang et al., 2019
Dendroterpene D [257]	<i>D. nobile</i>	Stem	Wang et al., 2019

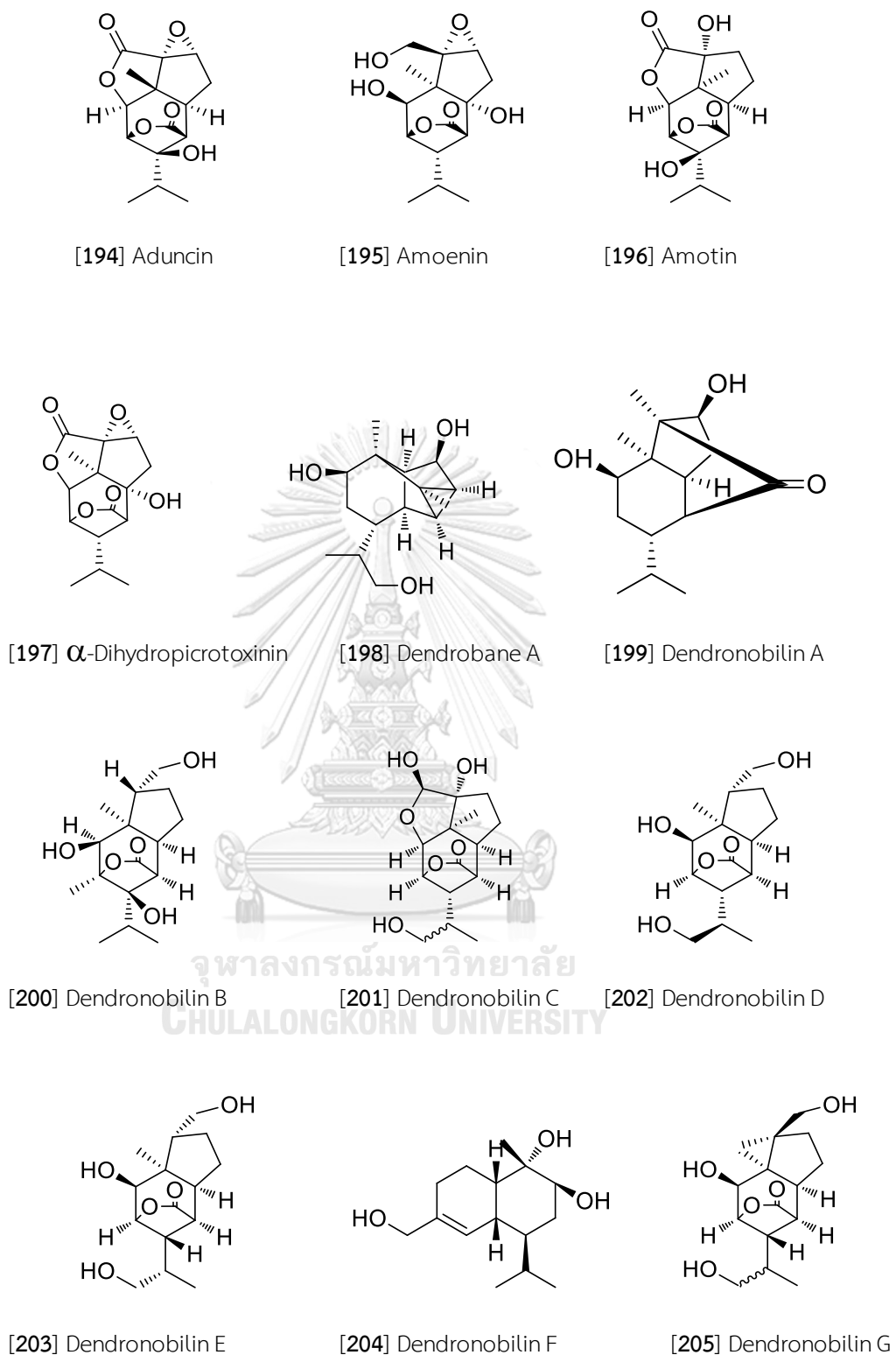
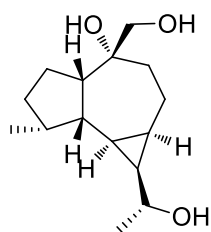
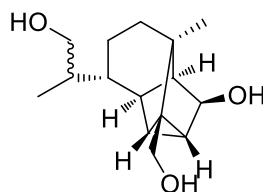


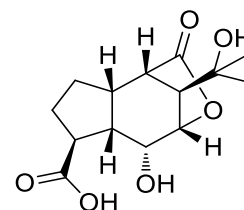
Figure 4 Structures of terpenoids from *Dendrobium*



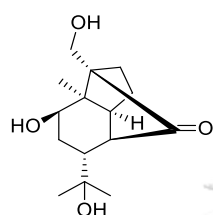
[206] Dendronobilin H



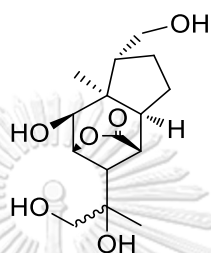
[207] Dendronobilin I



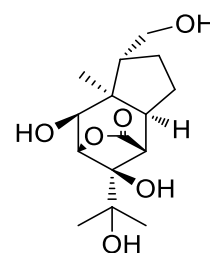
[208] Dendronobilin J



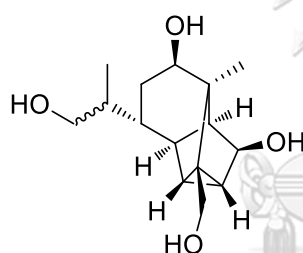
[209] Dendronobilin K



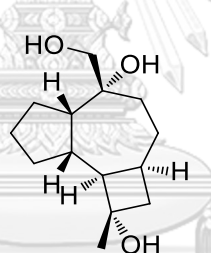
[210] Dendronobilin L



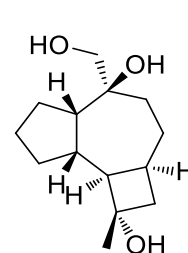
[211] Dendronobilin M



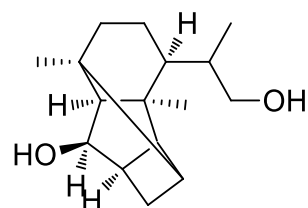
[212] Dendronobilin N



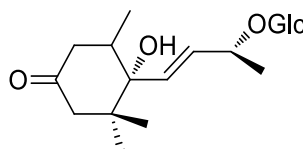
[213] Dendrowardol A



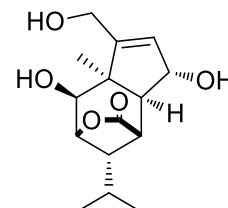
[214] Dendrowardol B



[215] Dendrowardol C



[216] Corchoionoside C



[217] Crystallinin

Figure 4 Structures of terpenoids from *Dendrobium* (continued)

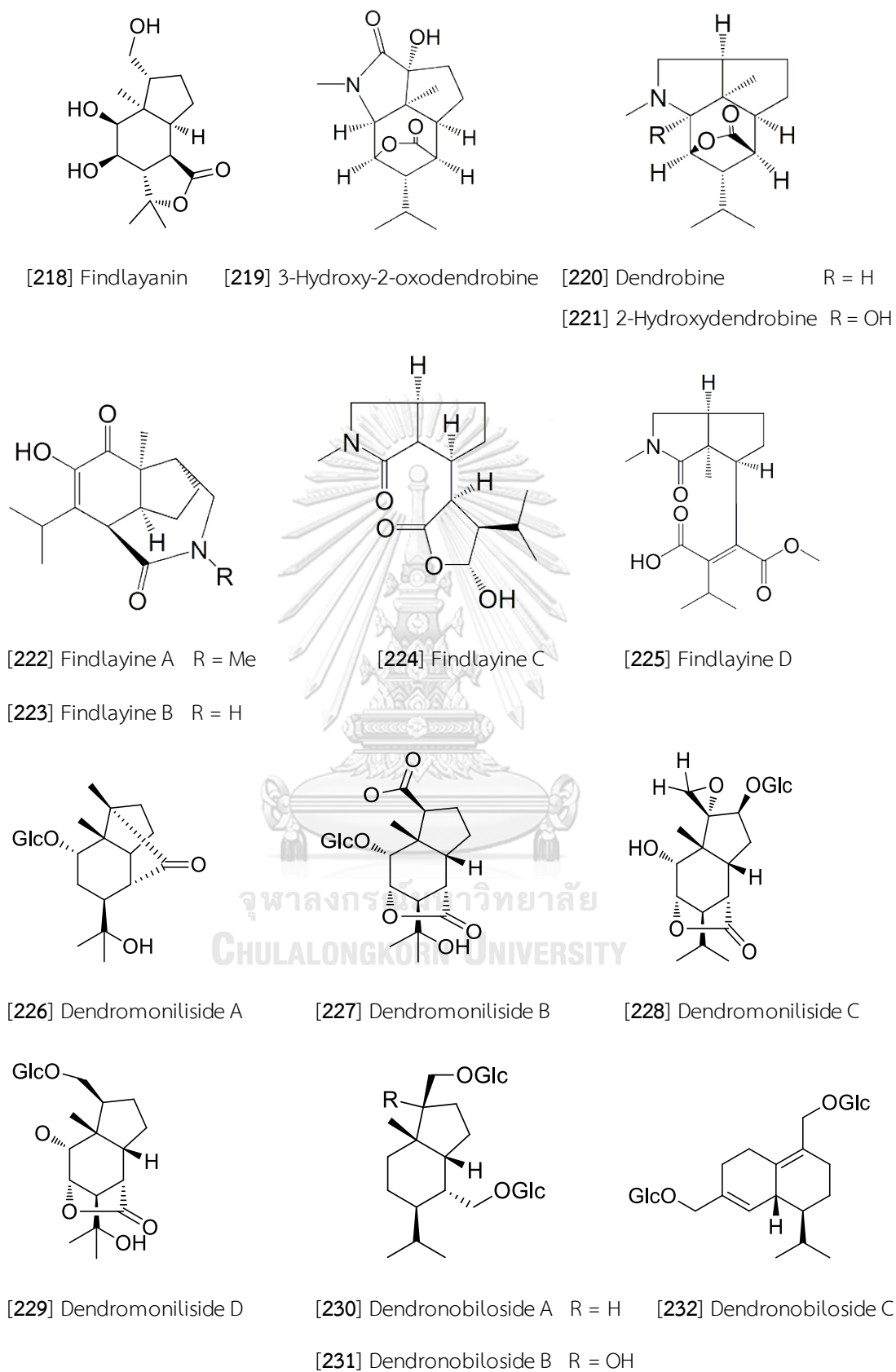
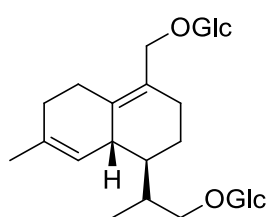
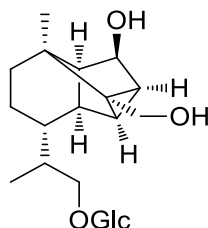


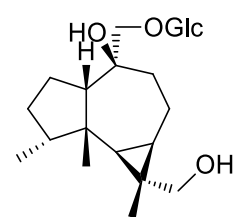
Figure 4 Structures of terpenoids from *Dendrobium* (continued)



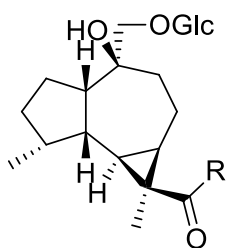
[233] Dendronobiloside D



[234] Dendronobiloside E

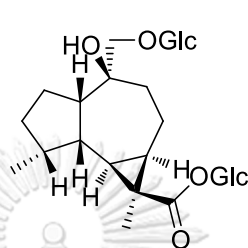


[235] Dendroside A

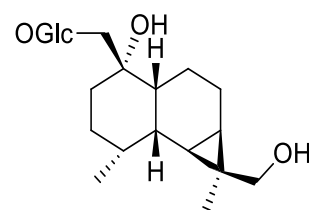


[236] Dendroside B R = OGlc

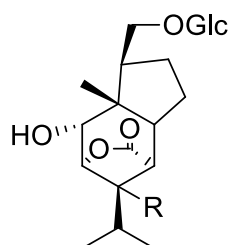
[237] Dendroside C R = OH



[238] Dendroside D

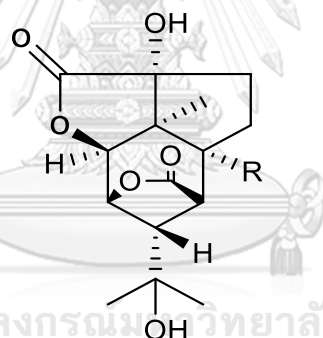


[239] Dendroside E



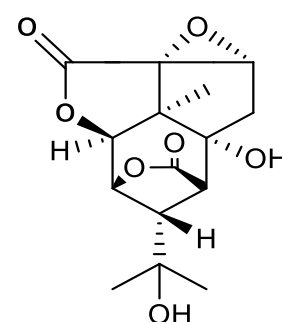
[240] Dendroside F R = H

[241] Dendroside G R = OH

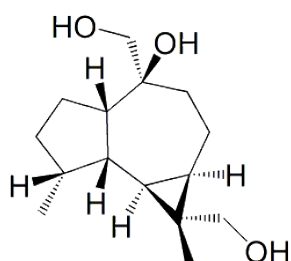
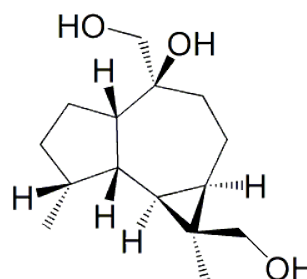


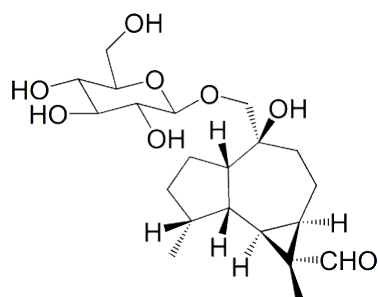
[242] Dendrowillin A R = OH

[243] Dendrowillin B R = H

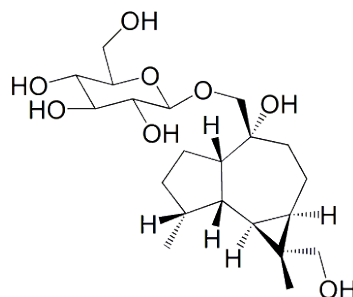


[244] (-)-Picrotin

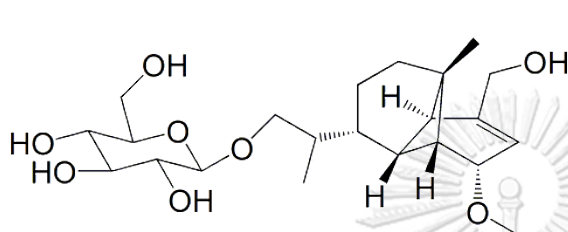
[245] 10 β ,12,14-Trihydroxyaromadendrane[246] 10 β ,13,14-TrihydroxyaromadendraneFigure 4 Structures of terpenoids from *Dendrobium* (continued)



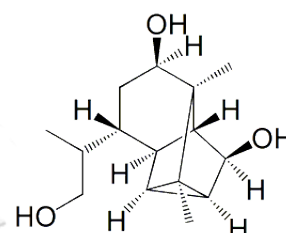
[247] Dendrofindlayanoside A



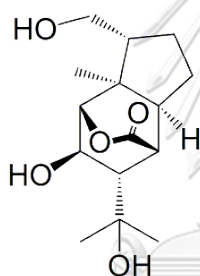
[248] Dendrofindlayanoside B



[249] Dendrofindlayanoside C

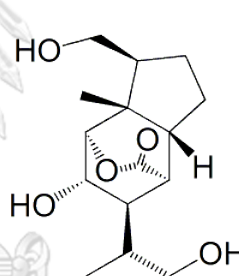


[250] Dendrofindlayanobilin



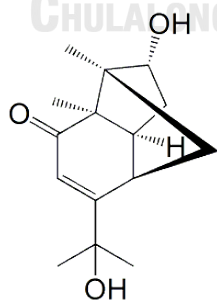
[251] (+)-(1R,2S,3R,4S,5R,6S,9R)-

3,11,12-Trihydroxypicrotoxane-2(15)-lactone



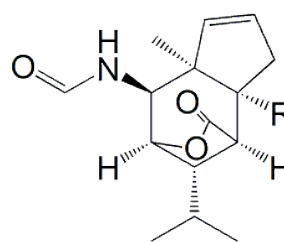
[252] (-)-(1S,2R,3S,4R,5S,6R,9S,12R)-

3,11,13-Trihydroxypicrotoxane-2(15)-lactone



[253] (+)-(1R,5R,6S,8R,9R)-

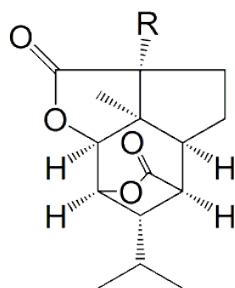
8,12-Dihydroxycopacamphan-3-en-2-one



[254] Dendroterpene A R = H

[255] Dendroterpene B R = OH

Figure 4 Structures of terpenoids from *Dendrobium* (continued)



[256] Dendroterpene C R = H

[257] Dendroterpene D R = OH



Figure 4 Structures of terpenoids from *Dendrobium* (continued)

Table 4 Miscellaneous compounds from *Dendrobium*

Categories and compounds	Plant	Plant part	Reference
Aliphatic acid derivatives			
Aliphatic acids [258]	<i>D. clavatum</i> var. <i>aurantiacum</i>	Stem	Chang, Lin and Chen, 2001
Aliphatic alcohols [259]	<i>D. clavatum</i> var. <i>aurantiacum</i>	Stem	Chang, Lin and Chen, 2001
Malic acid [260]	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
Dimethyl malate [261]	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
(-)-Shikimic acid [262]	<i>D. fuscescens</i>	Whole plant	Talapatra, Das and Talapatra, 1989
	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
	<i>D. longicornu</i>	Stem	Hu et al., 2008a
	<i>D. pulchellum</i>	Stem	Chanvorachote et al., 2013
Isopentyl butyrate [263]	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
Dendrodevonic acid A [264]	<i>D. devonianum</i>	Stem	Wu et al., 2019
Dendrodevonic acid B [265]	<i>D. devonianum</i>	Stem	Wu et al., 2019
Benzoic acid derivatives and phenolic compounds			
3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid [266]	<i>D. crystallinum</i>	Stem	Wang et al., 2009
Salicylic acid [267]	<i>D. huoshanense</i>	Aerial part	Chang et al., 2010
	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Vanilloloside [268]	<i>D. denneanum</i>	Stem	Pan et al., 2012
	<i>D. moniliforme</i>	Stem	Zhao et al., 2003
Gallic acid [269]	<i>D. longicornu</i>	Whole plant	Li et al., 2009a

Categories and compounds	Plant	Plant part	Reference
Syringic acid [270]	<i>D. crystallinum</i>	Stem	Wang et al., 2009
Vanillic acid [271]	<i>D. chrysotoxum</i>	Whole plant	Li et al., 2009d
	<i>D. williamsonii</i>	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid, 2014
Protocatechuic acid [272]	<i>D. nobile</i>	Stem	Ye and Zhao, 2002
Antiarol [273]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
Ethylhaematommate [274]	<i>D. longicornu</i>	Whole plant	Li et al., 2009a
<i>p</i> -Hydroxybenzaldehyde [275]	<i>D. devonianum</i>	Whole plant	Sun et al., 2014
	<i>D. falconeri</i>	Stem	Sritularak and Likhitwitayawuid, 2009
	<i>D. tortile</i>	Whole plant	Limpanit et al., 2016
	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Methyl β -orsellinate [276]	<i>D. longicornu</i>	Stem	Hu et al., 2008a
Tachioside [277]	<i>D. denneanum</i>	Stem	Pan et al., 2012
Alkyl 4'-hydroxy <i>trans</i> -cinnamates [278]	<i>D. clavatum</i> var. <i>aurantiacum</i>	Stem	Chang, Lin and Chen, 2001
Alkyl <i>trans</i> -ferulates [279]	<i>D. clavatum</i> var. <i>aurantiacum</i>	Stem	Chang, Lin and Chen, 2001
	<i>D. scabrilingue</i>	Whole plant	Sarakulwattana et al., 2018
Defuscin [280]	<i>D. fuscescens</i>	Whole plant	Talapatra, Das and Talapatra, 1989
	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang, Wang and Xu, 2006
<i>n</i> -Octacosyl ferulate [281]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang, Wang and Xu, 2006

Categories and compounds	Plant	Plant part	Reference
	<i>D. moniliforme</i>	Stem	Bi, Wang and Xu, 2004
<i>n</i> -Triacontyl- <i>p</i> -hydroxy <i>cis</i> -cinnamate [282]	<i>D. moniliforme</i>	Stem	Bi, Wang and Xu, 2004
Tetratriacontanyl <i>trans-p</i> -coumarate [283]	<i>D. williamsonii</i>	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid, 2014
<i>p</i> -Hydroxyphenethyl <i>trans</i> -ferulate [284]	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
<i>n</i> -Docosyl <i>trans</i> -ferulate [285]	<i>D. longicornu</i>	Whole plant	Li et al., 2009a
	<i>D. williamsonii</i>	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid, 2014
<i>trans</i> -Tetracosyl ferulate [286]	<i>D. tortile</i>	Whole plant	Limpanit et al., 2016
<i>cis</i> -Hexacosanoyl ferulate [287]	<i>D. tortile</i>	Whole plant	Limpanit et al., 2016
Ferulaldehyde [288]	<i>D. longicornu</i>	Whole plant	Li et al., 2009
Ferulic acid [289]	<i>D. secundum</i>	Stem	Sritularak, Duangrak and Likhitwitayawuid, 2011
2-(<i>p</i> -Hydroxyphenyl) ethyl <i>p</i> -coumarate [290]	<i>D. falconeri</i>	Stem	Sritularak and Likhitwitayawuid, 2009
Dihydroconiferyl dihydro- <i>p</i> -coumarate [291]	<i>D. formosum</i>	Whole plant	Inthongkaew et al., 2017
	<i>D. loddigesii</i>	Stem	Ma et al., 2019b
	<i>D. devonianum</i>	Stem	Wu et al., 2019
	<i>D. hainanense</i>	Aerial part	Zhang et al., 2019

Categories and compounds	Plant	Plant part	Reference
1-[4-(β -D-Glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone [292]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Xiong et al., 2013
3-Hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-1-propanone [293]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
2-Hydroxy-3-(4-hydroxy-3-methoxyphenyl)-3-methoxypropyl-3-(4-hydroxyphenyl)propanoate [294]	<i>D. hainanense</i>	Aerial part	Zhang et al., 2019
Coniferyl alcohol [295]	<i>D. trigonopus</i>	Stem	Hu et al., 2008b
(<i>E</i>)-Coniferyl aldehyde [296]	<i>D. hainanense</i>	Aerial part	Zhang et al., 2019
Sinapicaldehyde [297]	<i>D. hainanense</i>	Aerial part	Zhang et al., 2019
Decumbic acid A [298]	<i>D. nobile</i>	Stem	Zhou et al., 2016
Decumbic acid B [299]	<i>D. nobile</i>	Stem	Zhou et al., 2016
(-)-Decumbic acid [300]	<i>D. nobile</i>	Stem	Zhou et al., 2016
(+)-Dendrolactone [301]	<i>D. nobile</i>	Stem	Zhou et al., 2016
4-(3-Hydroxyphenyl)-2-butanone [302]	<i>D. nobile</i>	Stem	Zhou et al., 2016
3-Hydroxy-1-(3-methoxy-4-hydroxyphenyl)-propan-1-one [303]	<i>D. nobile</i>	Stem	Zhou et al., 2016
3',4',5'-Trimethoxy cinnamyl acetate [304]	<i>D. nobile</i>	Stem	Zhou et al., 2016
Alatusol A [305]	<i>D. hainanense</i>	Aerial part	Zhang et al., 2019

Categories and compounds	Plant	Plant part	Reference
<i>p</i> -Hydroxyphenyl propionic methyl ester [306]	<i>D. aphyllum</i>	Whole plant	Chen et al., 2008a
Phloretic acid [307]	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014
Dihydroconiferyl alcohol [308]	<i>D. longicornu</i>	Stem	Hu et al., 2008a
Salidrosol [309]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
Shashenoside I [310]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Xiong et al., 2013
Syringin [311]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Xiong et al., 2013
<i>cis</i> -Melilotoside [312]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang et al., 2007
<i>trans</i> -Melilotoside [313]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang et al., 2007
Dihydromelilotoside [314]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang et al., 2007
Tetracosyl (<i>Z</i>)- <i>p</i> -coumarate [315]	<i>D. falconeri</i>	Whole plant	Sritularak and Likhitwitayawuid, 2009
(7 <i>S</i> ,8 <i>R</i>)-Dehydrodiconiferyl alcohol 9'- β -D-glucopyranoside [316]	<i>D. nobile</i>	Stem	Zhou et al., 2017
Koaburaside [317]	<i>D. nobile</i>	Stem	Zhou et al., 2017
Juniperoside [318]	<i>D. nobile</i>	Stem	Zhou et al., 2017

Categories and compounds	Plant	Plant part	Reference
Dehydrodiconiferyl alcohol-4- β -D-glucoside [319]	<i>D. nobile</i>	Stem	Zhou et al., 2017
(3 <i>R</i> ,3' <i>S</i> ,4 <i>R</i> ,4' <i>S</i>)-3,3',4,4'-Tetrahydro-6,6'-dimethoxy[3,3'-bi-2 <i>H</i> -benzopyran]-4,4'-diol [320]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
<i>threo</i> -7- <i>O</i> -Ethyl-9- <i>O</i> -(4-hydroxyphenyl) propionyl-guaiacylglycerol [321]	<i>D. loddigesii</i>	Stem	Ma et al., 2019a
Coumarins			
Ayapin [322]	<i>D. densiflorum</i>	Stem	Fan et al., 2001
Coumarin [323]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang, Wang and Xu, 2006
	<i>D. clavatum</i> var. <i>aurantiacum</i>	Stem	Chang, Lin and Chen, 2001
Denthysin [324]	<i>D. thysiflorum</i>	Stem	Zhang et al., 2005
Scoparone [325]	<i>D. densiflorum</i>	Stem	Fan et al., 2001
	<i>D. thysiflorum</i>	Stem	Zhang et al., 2005
	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019
Scopoletin [326]	<i>D. densiflorum</i>	Stem	Fan et al., 2001
Lignans and neolignans			
Episyngaresinol [327]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
	<i>D. longicornu</i>	Stem	Hu et al., 2008a
	<i>D. nobile</i>	Stem	Zhang et al., 2008c

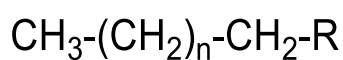
Categories and compounds	Plant	Plant part	Reference
Episingaresinol 4''-O- β -D-glucopyranoside [328]	<i>D. moniliforme</i>	Stem	Zhao et al., 2003
(-)-(7 <i>S</i> ,8 <i>R</i> ,7' <i>E</i>)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4'-oxyneolign-7'-ene-7,9'-bis-O- β -D-glucopyranoside [329]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Xiong et al., 2013
Lyoniresinol [330]	<i>D. chrysanthum</i>	Stem	Ye, Zhao and Qin, 2004
(-)-Syringaresinol-4,4'-bis-O- β -D-glucopyranoside [331]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Xiong et al., 2013
Syringaresinol-4-O-D-monoglucopyranoside [332]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Xiong et al., 2013
Dendrocoumarin [333]	<i>D. nobile</i>	Stem	Zhou et al., 2018
Itolide A [334]	<i>D. nobile</i>	Stem	Zhou et al., 2018
(-)-Medioresinol [335]	<i>D. loddigesii</i>	Whole plant	Ito et al., 2010
	<i>D. nobile</i>	Stem	Zhang et al., 2008c
(-)-Pinoresinol [336]	<i>D. loddigesii</i>	Whole plant	Ito et al., 2010
	<i>D. nobile</i>	Stem	Zhang et al., 2008c
(+)-Pinoresinol [337]	<i>D. devonianum</i>	Stem	Wu et al., 2019
erythro-1-(4-O- β -D-Glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol [338]	<i>D. longicornu</i>	Stem	Hu et al., 2008a
Syringaresinol [339]	<i>D. nobile</i>	Stem	Zhang et al., 2008c

Categories and compounds	Plant	Plant part	Reference
	<i>D. secundum</i>	Stem	Sritularak, Duangrak and Likhitwitayawuid, 2011
	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Acanthoside B [340]	<i>D. chrysanthum</i>	Stem	Ye, Zhao and Qin, 2004
Liriodendrin [341]	<i>D. brymerianum</i>	Whole plant	Chen, Yu and Liu, 2014
	<i>D. pulchellum</i>	Stem	Chanvorachote et al., 2013
(-)-(8 <i>R</i> ,7' <i>E</i>)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4'-oxyneolign-7'-ene-9,9'-diol 4,9-bis- <i>O</i> - β -D-glucopyranoside [342]	<i>D. auranticum</i> var. <i>denneanum</i>	Stem	Li et al., 2014a
(-)-(8 <i>S</i> ,7' <i>E</i>)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4'-oxyneolign-7'-ene-9,9'-diol 4,9-bis- <i>O</i> - β -D-glucopyranoside [343]	<i>D. auranticum</i> var. <i>denneanum</i>	Stem	Li et al., 2014a
(-)-(8 <i>R</i> ,7' <i>E</i>)-4-Hydroxy-3,3',5,5',9'-pentamethoxy-8,4'-oxyneolign-7'-ene-9-ol 4,9-bis- <i>O</i> - β -D-glucopyranoside [344]	<i>D. auranticum</i> var. <i>denneanum</i>	Stem	Li et al., 2014a
Fluorenonees			
Denchrysan B [345]	<i>D. brymerianum</i>	Whole plant	Klongkumnuankarn et al., 2015
	<i>D. chrysotoxum</i>	Whole plant	Li et al., 2009d
Denchrysan A [346]	<i>D. chrysotoxum</i>	Whole plant	Li et al., 2009d
Dendroflorin [347]	<i>D. aurantiacum</i> var. <i>denneanum</i>	Stem	Yang, Wang and Xu, 2006

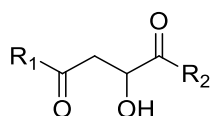
Categories and compounds	Plant	Plant part	Reference
	<i>D. brymerianum</i>	Whole plant	Klongkumnuankarn et al., 2015
	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019
Dengibsin [348]	<i>D. aurantiacum</i> <i>var. denneanum</i>	Stem	Yang, Wang and Xu, 2006b
	<i>D. chrysanthum</i>	Stem	Yang et al., 2006a
	<i>D. chrysotoxum</i>	Whole plant	Li et al., 2009d
Nobilone [349]	<i>D. brymerianum</i>	Whole plant	Klongkumnuankarn et al., 2015
	<i>D. nobile</i>	Stem	Zhang et al., 2007c
	<i>D. palpebrae</i>	Whole plant	Kyokong et al., 2019
1,4,5-Trihydroxy-7-methoxy-9H-fluoren-9-one [350]	<i>D. chrysotoxum</i>	Whole plant	Li et al., 2009d
2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone [351]	<i>D. chrysotoxum</i>	Stem	Yang et al., 2004
Others			
3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2H)-one [352]	<i>D. chrysotoxum</i>	Stem	Hu et al., 2012
Palmarumycin JC2 [353]	<i>D. crystallinum</i>	Stem	Wang et al., 2009
Dehydrovomifoliol [354]	<i>D. loddigesii</i>	Whole plant	Ito et al., 2010
2,6-Dimethoxybenzoquinone [355]	<i>D. chryseum</i>	Stem	Ma et al., 1998

Categories and compounds	Plant	Plant part	Reference
4-(2-Hydroxypropyl)-2(5H)-furanone [356]	<i>D. tortile</i>	Whole plant	Limpanit et al., 2016
5,7-Dihydroxychromen-4-one [357]	<i>D. ellipsophyllum</i>	Whole plant	Tanagornmeatar et al., 2014
Balanophonin [358]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Ergosta-8(9),22-diene-3,5,6,7-tetraol [359]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Stigmast-4-en-3 α ,6 β -diol [360]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
3 β -Hydroxy-5 α ,8 α -epidioxyergosta-6,9,22-triene [361]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Betulin [362]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
β -Sitosterol [363]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Daucosterol [364]	<i>D. williamsonii</i>	Whole plant	Yang et al., 2018b
Anosmine [365]	<i>D. parishii</i>	Whole plant	Hemscheidt and Spenser, 1991
Asiatic acid [366]	<i>D. parishii</i>	Whole plant	Klongkumnuankarn et al., 2015
Di- <i>p</i> -hydroxyphenylpropionic acid- <i>p</i> -coumaric acid lactone [367]	<i>D. chrysanthum</i>	Whole plant	Cai et al., 2018
RF-3192C [368]	<i>D. scabrilingue</i>	Whole plant	Sarakulwattana et al., 2018
Crepidatamine C [369]	<i>D. crepidatum</i>	Stem	Xu et al., 2019
Crepidatamine D [370]	<i>D. crepidatum</i>	Stem	Xu et al., 2019
Crepidine [371]	<i>D. crepidatum</i>	Stem	Xu et al., 2019

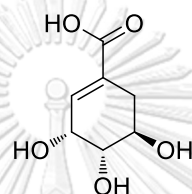
Categories and compounds	Plant	Plant part	Reference
Isocrepidamine [372]	<i>D. crepidatum</i>	Stem	Xu et al., 2019
Crepidamine [373]	<i>D. crepidatum</i>	Stem	Xu et al., 2019



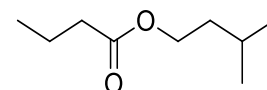
[258] Aliphatic acids R = COOH n = 19-31 [259] Aliphatic alcohols R = OH n = 22-32



[260] Malic acid R₁ = R₂ = OH

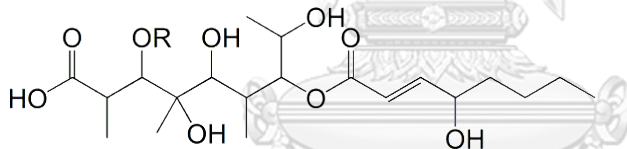


[262] (-)-Shikimic acid

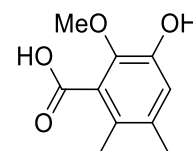


[263] Isopentyl butyrate

[261] Dimethyl malate R₁ = R₂ = OMe



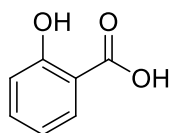
[264] Dendrodevonic acid A R = H



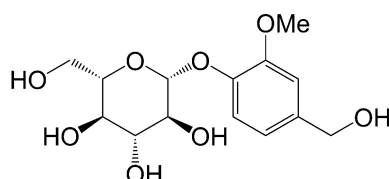
[266] 3-Hydroxy-2-methoxy-5,6-

[265] Dendrodevonic acid B R = acetyl

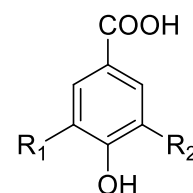
dimethylbenzoic acid



[267] Salicylic acid



[268] Vanilloloside



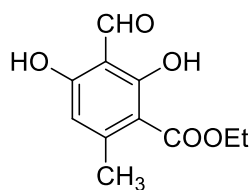
[269] Gallic acid R₁ = OH R₂ = OH

[270] Syringic acid R₁ = OMe R₂ = OMe

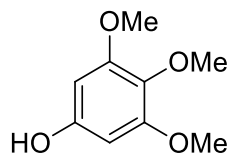
[271] Vanillic acid R₁ = H R₂ = OMe

[272] Protocatechuic acid R₁ = H R₂ = OH

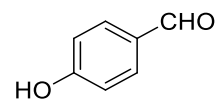
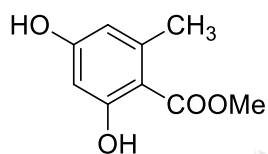
Figure 5 Structures of miscellaneous compounds from *Dendrobium*



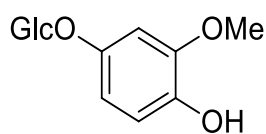
[273] Antiarol



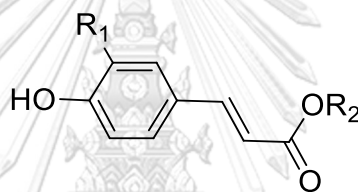
[274] Ethylhaematommate

[275] *p*-Hydroxybenzaldehyde

[276] Methyl β-orsellinate



[277] Tachioside



[278] Alkyl 4'-hydroxy *trans*-cinnamates $R_1 = \text{H}$ $R_2 = \text{C}_n\text{H}_{2n+1}$ $n = 22-32$

[279] Alkyl *trans*-ferulates $R_1 = \text{OMe}$, $R_2 = \text{C}_n\text{H}_{2n+1}$ $n = 18-28, 30$

[280] Defuscin $R_1 = \text{OMe}$ $R_2 = (\text{CH}_2)_{27}\text{CH}_3$

[281] *n*-Octacosyl ferulate $R_1 = \text{OMe}$ $R_2 = (\text{CH}_2)_{28}\text{CH}_3$

[282] *n*-Triacontyl-*p*-hydroxy *cis*-cinnamate $R_1 = \text{H}$ $R_2 = \text{C}_{30}\text{H}_{61}$

[283] Tetratriacontanyl *trans-p*-coumarate $R_1 = \text{H}$ $R_2 = (\text{CH}_2)_{33}\text{CH}_3$

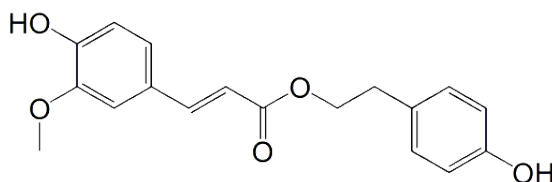
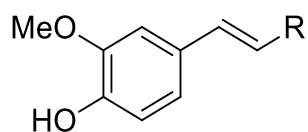
[284] *p*-Hydroxyphenethyl *trans*-ferulate

Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



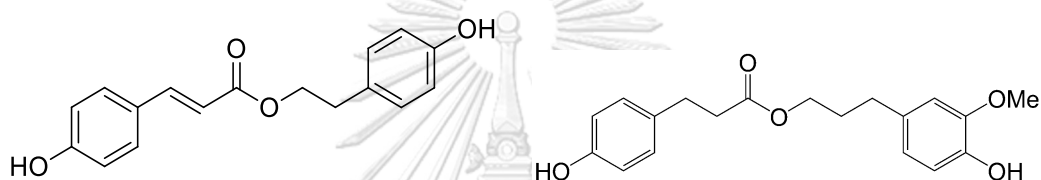
[285] *n*-Docosyl *trans*-ferulate: $R = \text{COOCH}_2(\text{CH}_2)_{20}\text{CH}_3$

[286] *trans*-Tetracosyl ferulate $R = \text{COOCH}_2(\text{CH}_2)_{22}\text{CH}_3$

[287] *cis*-Hexacosanoyl ferulate $R = \text{COOCH}_2(\text{CH}_2)_{24}\text{CH}_3$

[288] Ferulaldehyde $R = \text{CHO}$

[289] Ferulic acid $R = \text{COOH}$



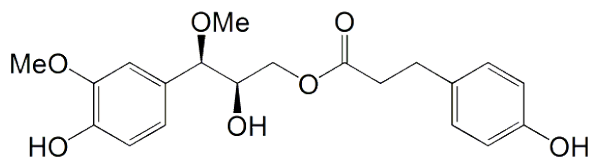
[290] 2-(*p*-Hydroxyphenyl) ethyl *p*-coumarate

[291] Dihydroconiferyl dihydro-*p*-coumarate



[292] 1-[4-(β -D-Glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone

[293] 3-Hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-1-propanone



[294] 2-Hydroxy-3-(4-hydroxy-3-methoxyphenyl)-3-methoxypropyl-3-(4-hydroxyphenyl) propanoate

Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)

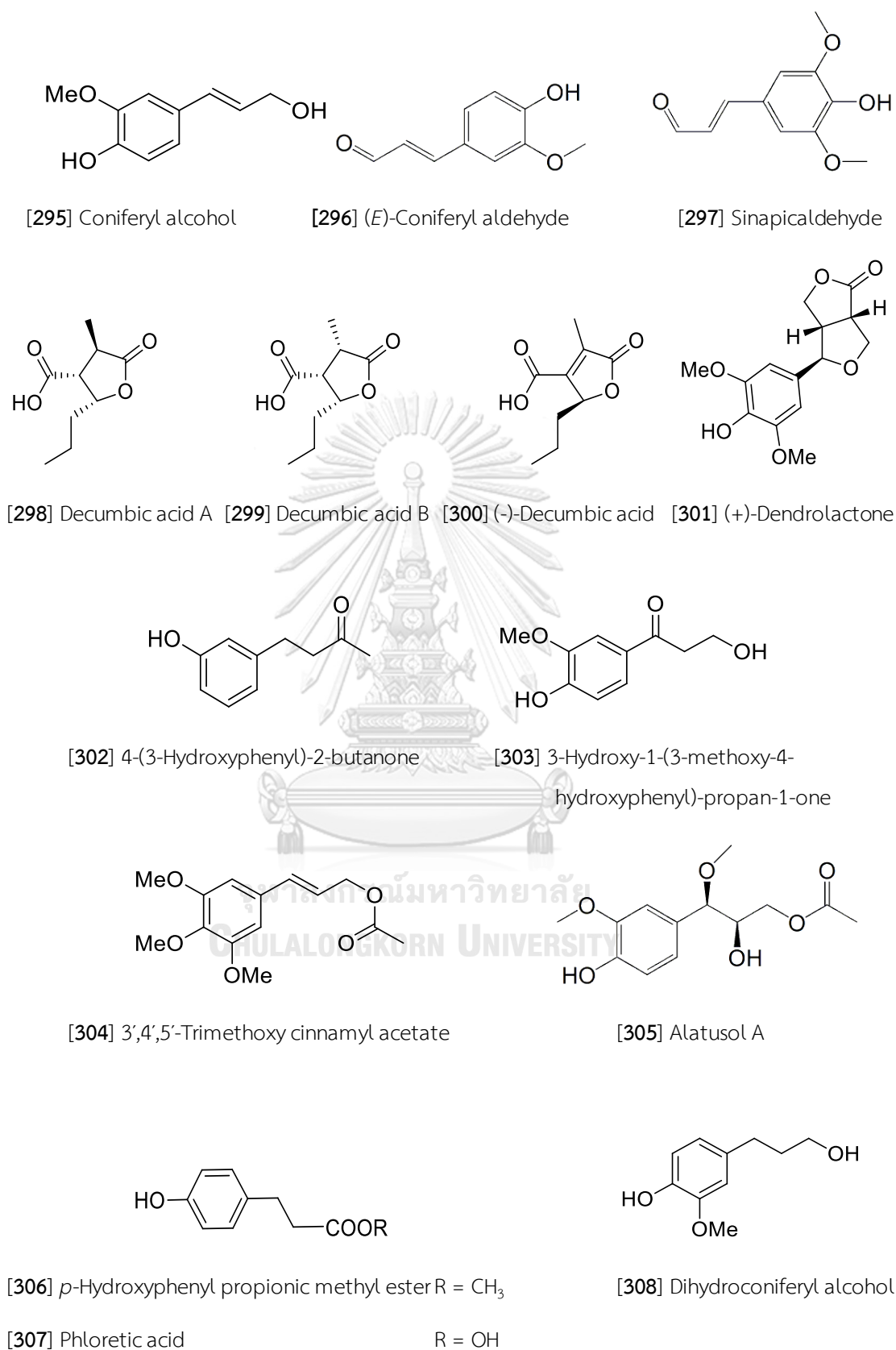


Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)

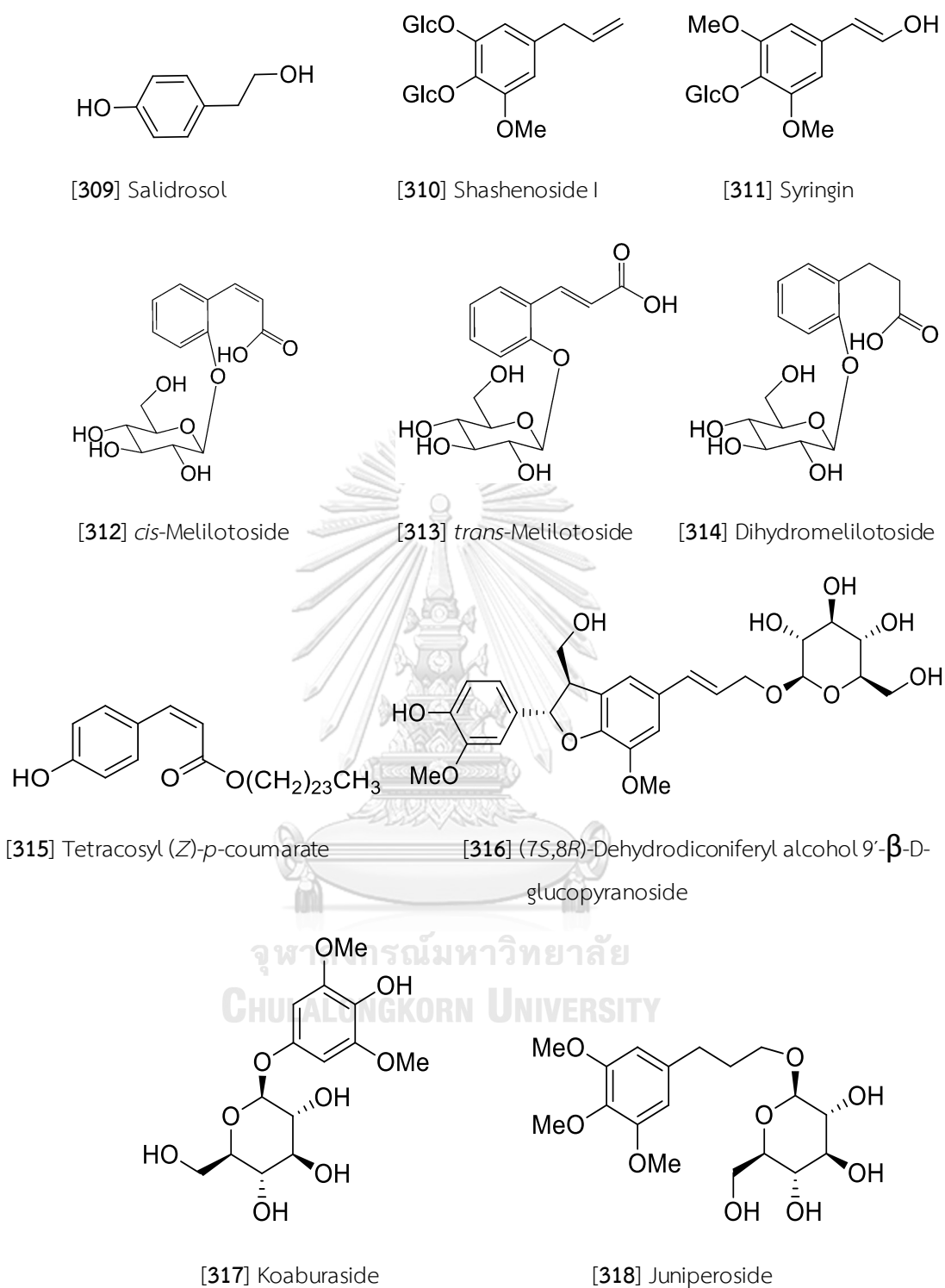
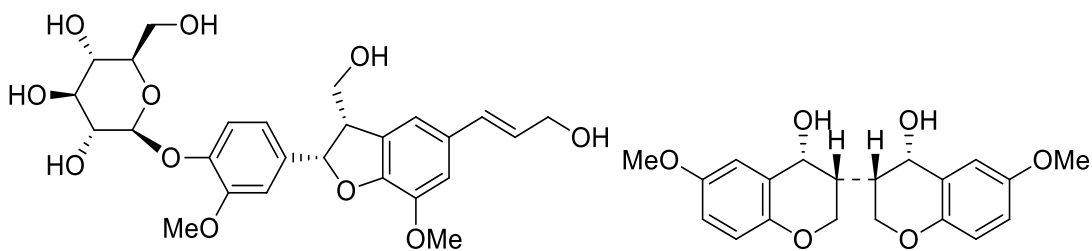
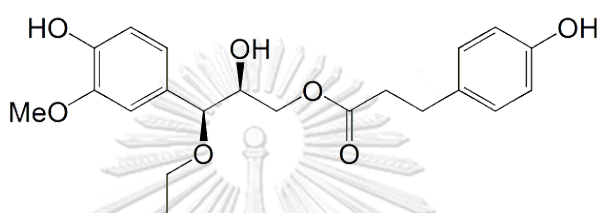
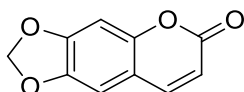
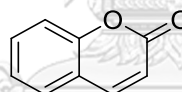


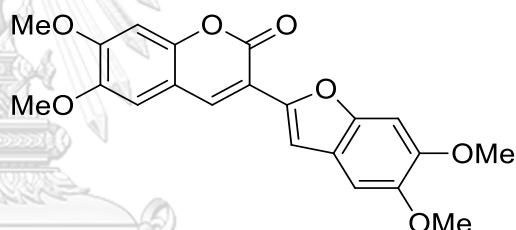
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)

[319] Dehydrodiconiferyl alcohol-4- β -D-glucoside[320] (3R,3'S,4R,4'S)-3,3',4,4'-
Tetrahydro-6,6'-dimethoxy[3,3'-
bi-2H-benzopyran]-4,4'-diol[321] *threo*-7-O-Ethyl-9-O-(4-hydroxyphenyl) propionyl-guaiacylglycerol

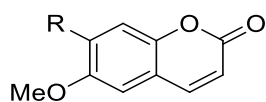
[322] Ayapin



[323] Coumarin

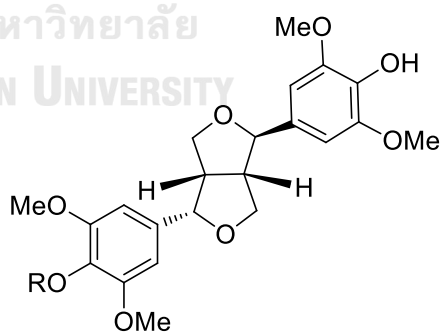


[324] Denthyrsin



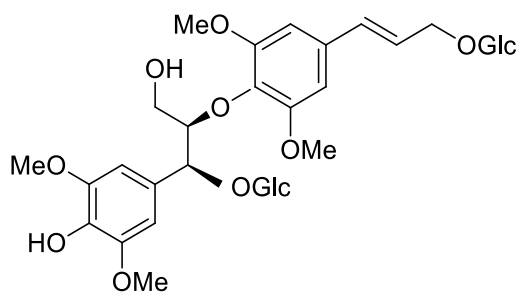
[325] Scoparone R = OMe

[326] Scopoletin R = OH

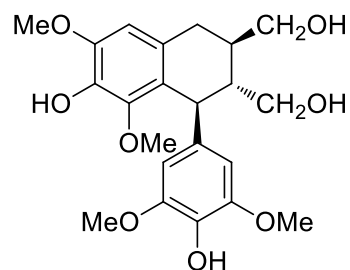


[327] Episingaresinol R = H

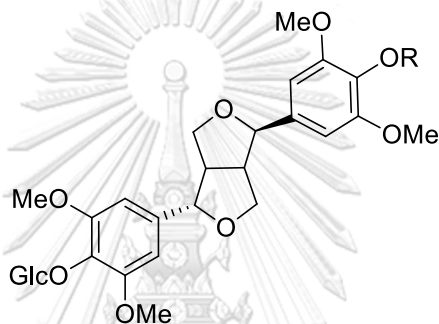
[328] Episingaresinol 4''-O- β -D-glucopyranoside
R = β -D-glucoseFigure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



[329] (-)-(7*S*,8*R*,7'*E*)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4'-oxyneolign-7'-ene-7,9'-bis-*O*- β -D-glucopyranoside

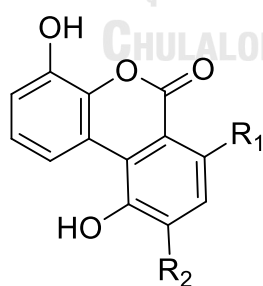


[330] Lyoniresinol



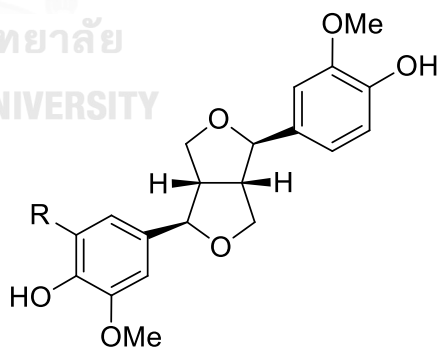
[331] (-)-Syringaresinol-4,4'-bis-*O*- β -D-glucopyranoside $R = \text{Glc}$

[332] Syringaresinol-4-*O*-D-monoglucopyranoside $R = \text{H}$



[333] Dendrocoumarin $R_1 = \text{H}$ $R_2 = \text{OH}$

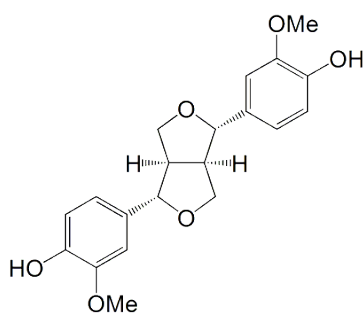
[334] Itolide A $R_1 = \text{OH}$ $R_2 = \text{H}$



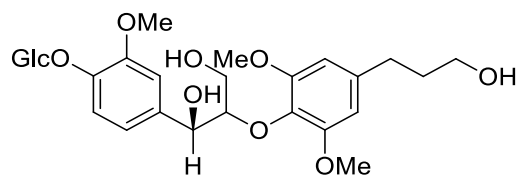
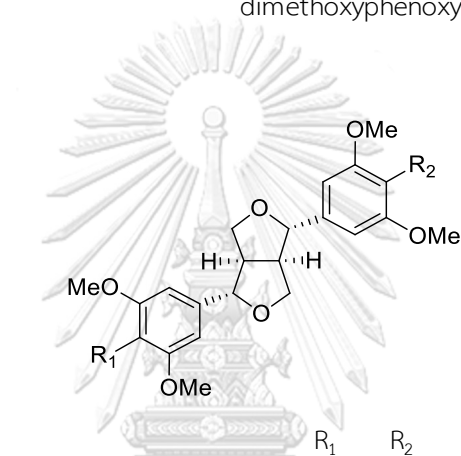
[335] (-)-Medioresinol $R = \text{OMe}$

[336] (-)-Pinoresinol $R = \text{H}$

Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



[337] (+)-Pinoresinol

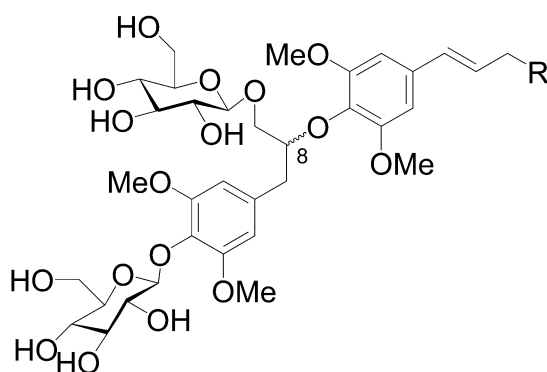
[338] *erythro*-1-(4-O- β -D-Glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol

[339] Syringaresinol

[340] Acanthoside B

[341] Liriodendrin

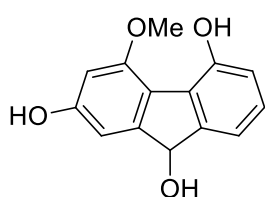
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



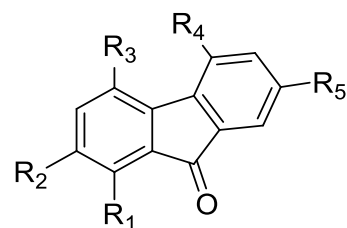
[342] (-)-(8*R*,7'*E*)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4'-oxyneolign-7'-ene-9,9'-diol 4,9-bis-*O*- β -D-glucopyranoside $R = \text{OH}; 8R$

[343] (-)-(8*S*,7'*E*)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4'-oxyneolign-7'-ene-9,9'-diol 4,9-bis-*O*- β -D-glucopyranoside $R = \text{OH}; 8S$

[344] (-)-(8*R*,7'*E*)-4-Hydroxy-3,3',5,5',9'-pentamethoxy-8,4'-oxyneolign-7'-ene-9-ol 4,9-bis-*O*- β -D-glucopyranoside $R = \text{OMe}; 8R$



[345] Denchrysan B



[346] Denchrysan A

[347] Dendroflorin

[348] Dengibsin

[349] Nobilone

[350] 1,4,5-Trihydroxy-7-methoxy-9*H*-fluoren-9-one

[351] 2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone

R_1	R_2	R_3	R_4	R_5
H	OH	OH	OMe	OH
OH	OH	H	OH	OMe
H	OH	OMe	OH	H
H	OH	H	OMe	OH
OH	H	OH	OH	OMe
OMe	OH	OH	OMe	OH

Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)

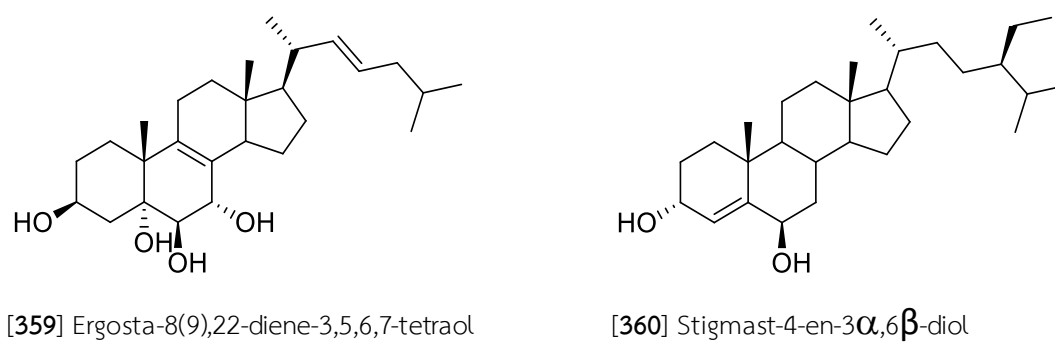
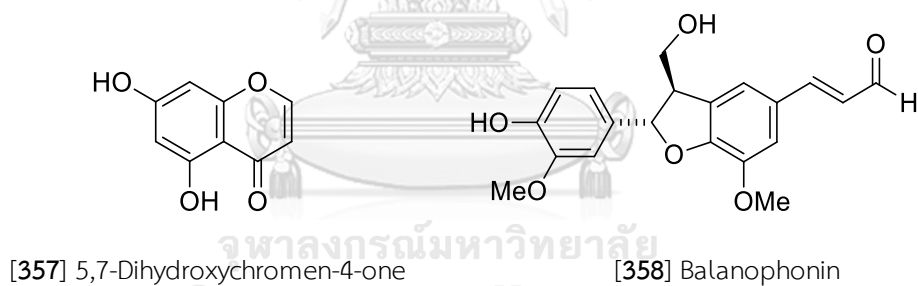
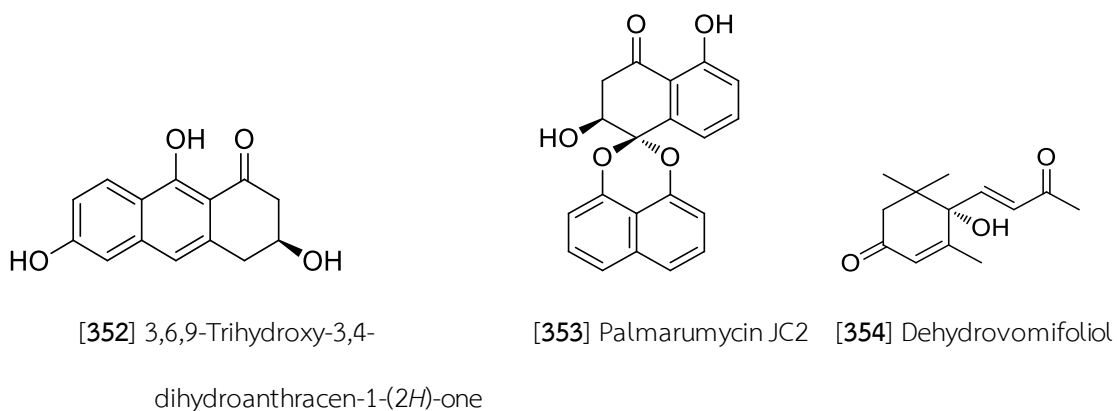
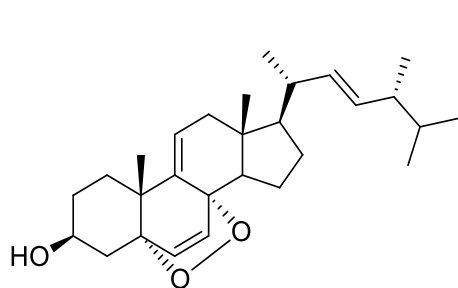
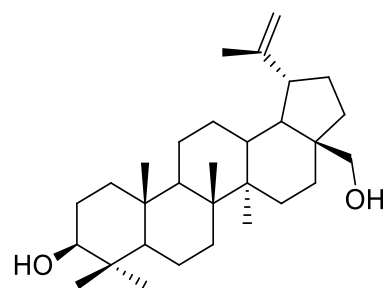


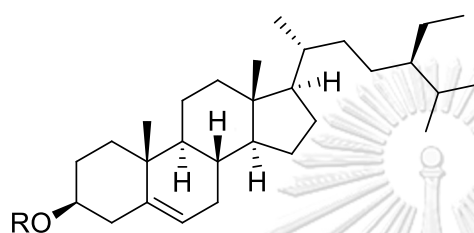
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



[361] 3β-Hydroxy-5α,8α-epidioxyergosta-6,9,22-triene

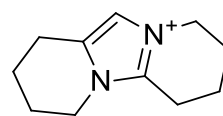


[362] Betulin

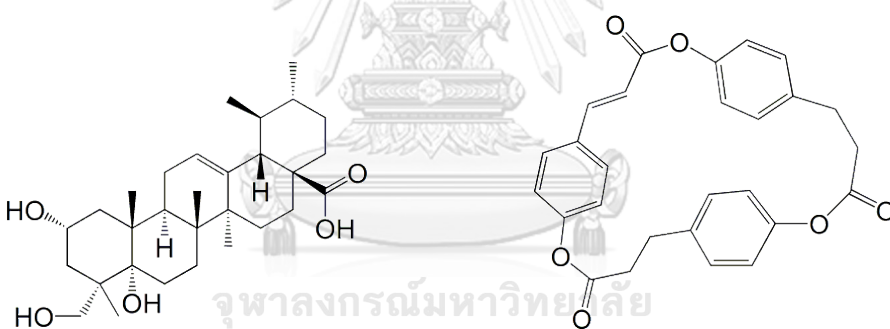


[363] β-Sitosterol R = H

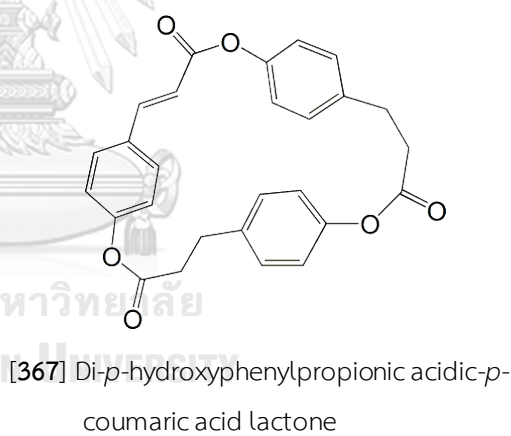
[364] Daucosterol R = Glc



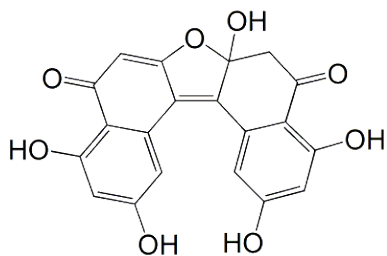
[365] Anosmine



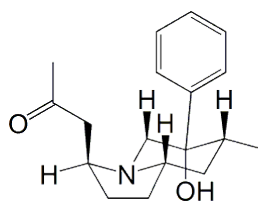
[366] Asiatic acid



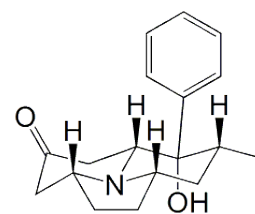
[367] Di-p-hydroxyphenylpropionic acid-p-coumaric acid lactone



[368] RF-3192C

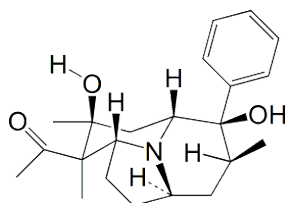


[369] Crepidatumine C

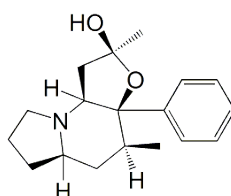


[370] Crepidatumine D

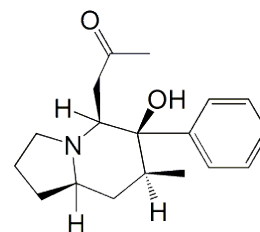
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



[371] Crepidine



[372] Isocrepidamine



[373] Crepidamine

Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)

2. Free radical scavenging activities of *Dendrobium* species

Various studies indicated that numerous *Dendrobium* species provided different compounds with free radical scavenging properties. The plants and their active constituents were summarized in Table 5.

To seek the radical scavengers from *D. aurantiacum* var. *denneanum*, a bio-guided fractionation strategy was applied in Yang et al. (2007). The *n*-butanol part manifested the highest DPPH radical scavenging activity. Subsequently, the *n*-butanol extract was further isolated by chromatographic procedures to give *cis*-melilotoside [312], *trans*-melilotoside [313], and dihydromelilotoside [314] with IC₅₀ of 280, 135, and 102 µg/mL for DPPH assay, respectively. In the preliminary study of Zhang et al. (2007c), EtOAc-soluble fraction, showed relevant DPPH scavenging activity, was separated to yield ten compounds. Of these, crepidatin [8], chrysotoxine [7], moscatilin [21], and dendroflorin [347] exhibited the activity higher than vitamin C in both DPPH and peroxy radical scavenging tests. New bibenzyl derivatives were isolated from *D. candidum* in the studies of Li et al. (2009b); Li et al. (2009c); Li et al. (2014b). Four of these were potent DPPH radical scavengers including dendrocandins E [38], H [41], I [47], and P [54] with IC₅₀ of 15.6, 19.8, 21.3, and 22.3 µM, respectively. *D. draconis*, which has been used as a blood tonic, was extracted, isolated, and studied for the antioxidant activity in Sritularak, Anuwat and Likhitwitayawuid (2011). The result showed the effective DPPH radical scavenging property of 7-methoxy-9,10-dihydrophenanthrene-2,4,5-triol [125] with IC₅₀ of 10.2 µM. Moscatilin [21], syringaresinol [339], 4,5,4'-trihydroxy-3,3'-dimethoxybibenzyl [25], and ferulic acid [289] isolated from *D. secundum* were reported as appreciable DPPH radical scavengers with IC₅₀ of 5.14, 11.38, 15.87, and 37.52 µM in Sritularak, Duangrak and Likhitwitayawuid (2011), respectively. To evaluate the efficacy of *D. aphyllum* in clinical use, Yang et al. (2015) examined chemical components from *D. aphyllum* and assessed their antioxidant activity. Out of the tested compounds, aphyllone B [157] significantly scavenged DPPH free radical by 87.97% at 100 µg/mL. Recently, the results of Ma et al. (2019b) indicated that crepidatin [8], moscatilin [21], 4,5,4'-trihydroxy-3,3'-dimethoxybibenzyl [25], gigantol [16], tristin [26], dihydroconiferyl dihydro-*p*-

coumarate [291], and *p*-hydroxyphenethyl *trans*-ferulate [284] possessed significant DPPH scavenging capacities with the inhibition percentage ranging from 89.411 to 94.278% at 100 µg/mL.

Table 5 Radical scavenging compounds from *Dendrobium*

Scientific name	Radical scavenging compound	Assay	Reference
<i>D. aurantiacum</i> var. <i>denneanum</i>	2-glucosyloxycinnamic acid derivatives (<i>cis</i> -melilotoside [312], <i>trans</i> - melilotoside [313], dihydromelilotoside [314])	DPPH assay*	Yang et al., 2007
<i>D. nobile</i>	nobilin D [71], nobilin E [72], crepidatin [8], chrysotoxine [7], moscatilin [21], dendroflorin [349]	DPPH assay*	Zhang et al., 2007c
<i>D. nobile</i>	nobilin D [72], nobilone [351], crepidatin [8], chrysotoxine [7], moscatilin [21], gigantol [16], dendroflorin [347]	ORAC assay**	Zhang et al., 2007c
<i>D. candidum</i>	bibenzyl derivatives (dendrocandins C [36], D [37], E [38], F [39], G [40], H [41], I [47])	DPPH assay*	Li et al., 2009a; Li et al., 2009b; Li et al., 2009c
<i>D. draconis</i>	stilbene derivatives (7-methoxy-9,10- dihydrophenanthrene-2,4,5-triol [125], hircinol [118], gigantol [16])	DPPH assay*	Sritularak, Anuwat and Likhitwitayawuid, 2011
<i>D. secundum</i>	4,5,4'-trihydroxy-3,3'- dimethoxybibenzyl [25], moscatilin [21], syringaresinol [339], ferulic acid [289]	DPPH assay*	Sritularak, Duangrak and Likhitwitayawuid, 2011
<i>D. candidum</i>	bibenzyl derivatives (dendrocandins J [48], K [49], L [50], M [51], N [52], O [53], P [54], Q [55])	DPPH assay*	Li et al., 2014b

Scientific name	Radical scavenging compound	Assay	Reference
<i>D. aphyllum</i>	phenanthrene derivative (aphyllone A [141]), bibenzyl derivatives (aphyllone B [157], aphyllal C [158])	DPPH assay*	Yang et al., 2015
<i>D. parishii</i>	asiatic acid [366], bibenzyl derivatives (4,3',4'-trihydroxy-3,5-dimethoxybibenzyl [29], moscatilin [21], 4,5,4'-trihydroxy-3,3'-dimethoxybibenzyl [25], dendrocandin E [38]), phenanthrene derivative (flavanthrinin [134]), bibenzyl-dihydrophenanthrene derivative ((-)-dendroparishioid [161])	DPPH assay*, ORAC assay**, deoxyribose assay	Kongkatitham et al., 2018
<i>D. parishii</i>	bibenzyl-dihydrophenanthrene derivative ((-)-dendroparishioid [161])	RAW264.7 cells***	Kongkatitham et al., 2018
<i>D. palpebrae</i>	fluorenone derivative (dendroflorin [347])	deoxyribose assay, RAW264.7 cells***	Kyokong et al., 2019
<i>D. loddigesii</i>	bibenzyl derivatives (crepidatin [8], moscatilin [21], 4,5,4'-trihydroxy-3,3'-dimethoxybibenzyl [25], gigantol [16], tristin [26]), dihydroconiferyl dihydro- <i>p</i> -coumarate [291], <i>p</i> -hydroxyphenethyl <i>trans</i> -ferulate [284], <i>threo</i> -7- <i>O</i> -ethyl-9- <i>O</i> -(4-hydroxyphenyl) propionyl-guaiacylglycerol [321]	DPPH assay*	Ma et al., 2019a

* 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, **oxygen radical absorbance capacity (ORAC) assay, ***significantly decreased ROS in H₂O₂-stimulated RAW264.7 cells and improved activity of antioxidant enzymes.

Furthermore, RAW264.7 cell, a mouse macrophage model, was utilized to evaluate isolated constituents from *D. parishii* and *D. palpebrae*. In research

conducted by Kongkatitham et al. (2018), (-)-dendroparishioid [161] showed the highest antioxidant activities against DPPH, peroxy, and hydroxyl radical. Then, it was further investigated using RAW264.7 cell induced with hydrogen peroxide (H_2O_2). Noticeably, they found that (-)-dendroparishioid [161] attenuated the level of intracellular ROS by 65% at 50 $\mu\text{g/mL}$. Similarly, dendroflorin [347] which exhibited the highest activities against hydroxyl radical among isolated compounds from *D. palpebrae* was tested with RAW264.7 cell under oxidative stress in the study of Kyokong et al. (2019). The tested compound decreased the formation of intracellular ROS by more than 50% at 50 $\mu\text{g/mL}$.



CHAPTER III

EXPERIMENTAL

1. Source of plant materials

Dendrobium lindleyi was purchased from the Chatuchak market, Bangkok, Thailand, and identified by Assoc. Prof. Boonchoo Sritularak from Faculty of Pharmaceutical Sciences, Chulalongkorn University, together with the botanical information from The Botanical Garden Organization (2016) and Vaddhanaphuti (2005). A voucher specimen (BS-DL-092552) has been deposited at the Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University.

2. Extraction and isolation

2.1 General techniques

2.1.1 Thin-layer chromatography (TLC)

Ascending one-dimensional TLC was performed using aluminium plate coated with silica gel 60 F254 (Merck, layer thickness 0.2 mm, developing distance 6.5 cm) at room temperature. The resulting plate was detected under ultraviolet light (UV) at wavelengths of 254 nm.

2.1.2 Adsorption column chromatography

Adsorption chromatography was proceeded using silica gel 60 (Merck, No. 9385, particle size 0.040-0.063 mm) as an adsorbent. The gel was suspended and equilibrated in selected organic solvents. The slurry was then poured into a column and left for the firm packing. The sample was dissolved in an appropriate solvent and mixed with the adsorbent as much as needed. It was then ground, dried, and placed on top of the packed column. Fractions received from the column were determined by TLC.

2.1.3 Size-exclusion chromatography

Size-exclusion chromatography was carried out using Sephadex LH-20 (GE Healthcare) as an adsorbent. Column packing was performed as the same

procedure of the adsorption column chromatography. The sample was dissolved in methanol and then filled on the top of the column. Methanol was used as a mobile phase. TLC was also used for the investigation of obtained fractions.

2.2 Extraction

The whole plant of *D. lindleyi* (1.2 kg) was dried and ground into fine powder. The powder was then macerated in methanol at room temperature for a week before collection of the extract. The maceration was repeated two times, all extracts were then mixed. The combined extract was filtered and evaporated under reduced pressure using rotary evaporator to give 97 g of methanol extract. The methanol extract was suspended in distilled water and partitioned with ethyl acetate (EtOAc) and *n*-butanol (*n*-BuOH), yielding 34 g of EtOAc extract, 24 g of *n*-BuOH extract, and 39 g of aqueous extract (Figure 6).

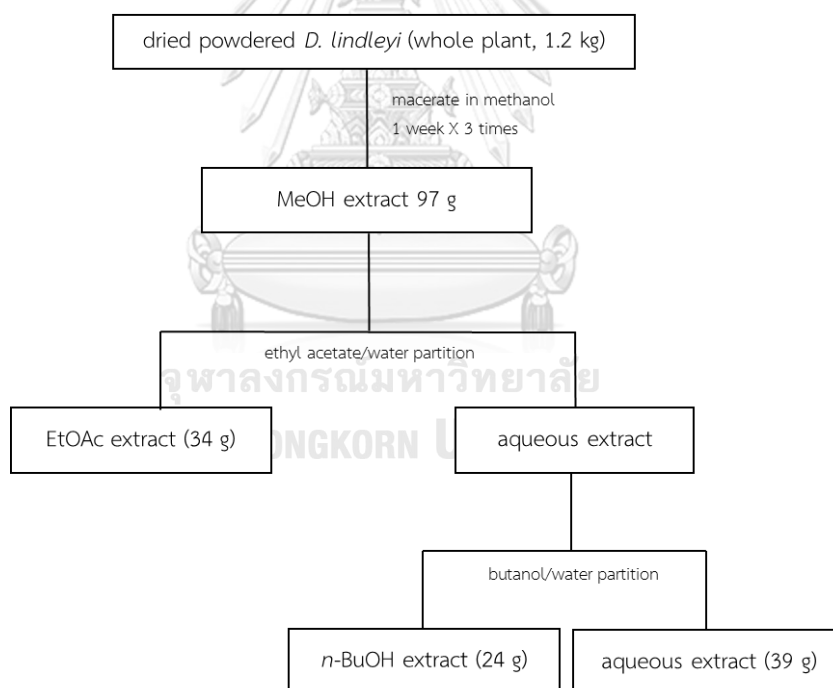


Figure 6 Extraction of *Dendrobium lindleyi*

2.3 Isolation

The EtOAc extract was fractionated by adsorption chromatography using a silica gel column (EtOAc-hexane, gradient) as described in section 2.1.2, yielding 10 fractions labeled as A-J (Figure 7).

2.3.1 Isolation of 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl

Adsorption chromatography (silica gel, EtOAc-hexane, gradient) was used to separate fraction G (2.6 g) to yield 8 fractions (GI-GVIII). GV (96 mg) was then separated by size-exclusion chromatography (see section 2.1.3) to give 47 mg of **compound 1** (Figure 7). This compound was identified as 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl.

2.3.2 Isolation of chrysotoxine, gigantol, and cypripedin

Fraction F (3.2 g) was divided into 13 fractions (FI-FXIII) by adsorption chromatography (silica gel, EtOAc-hexane, gradient). Fraction FVIII (140 mg) was fractionated by size-exclusion chromatography (see section 2.1.3) to yield **compound 2** (chrysotoxine, 90 mg), **compound 3** (gigantol, 20 mg) and **compound 4** (cypripedin, 25 mg) (Figure 7).

2.3.3 Isolation of moscatilin

Fraction FX (340 mg) obtained from the separation of fraction F (see section 2.3.2) was then separated by size-exclusion chromatography (see section 2.1.3) to give **compound 5** (90 mg). The compound was identified as moscatilin (Figure 7).

2.4 Solvents

Organic solvents used in the experiments were commercial grade. They were purified by distillation before use.

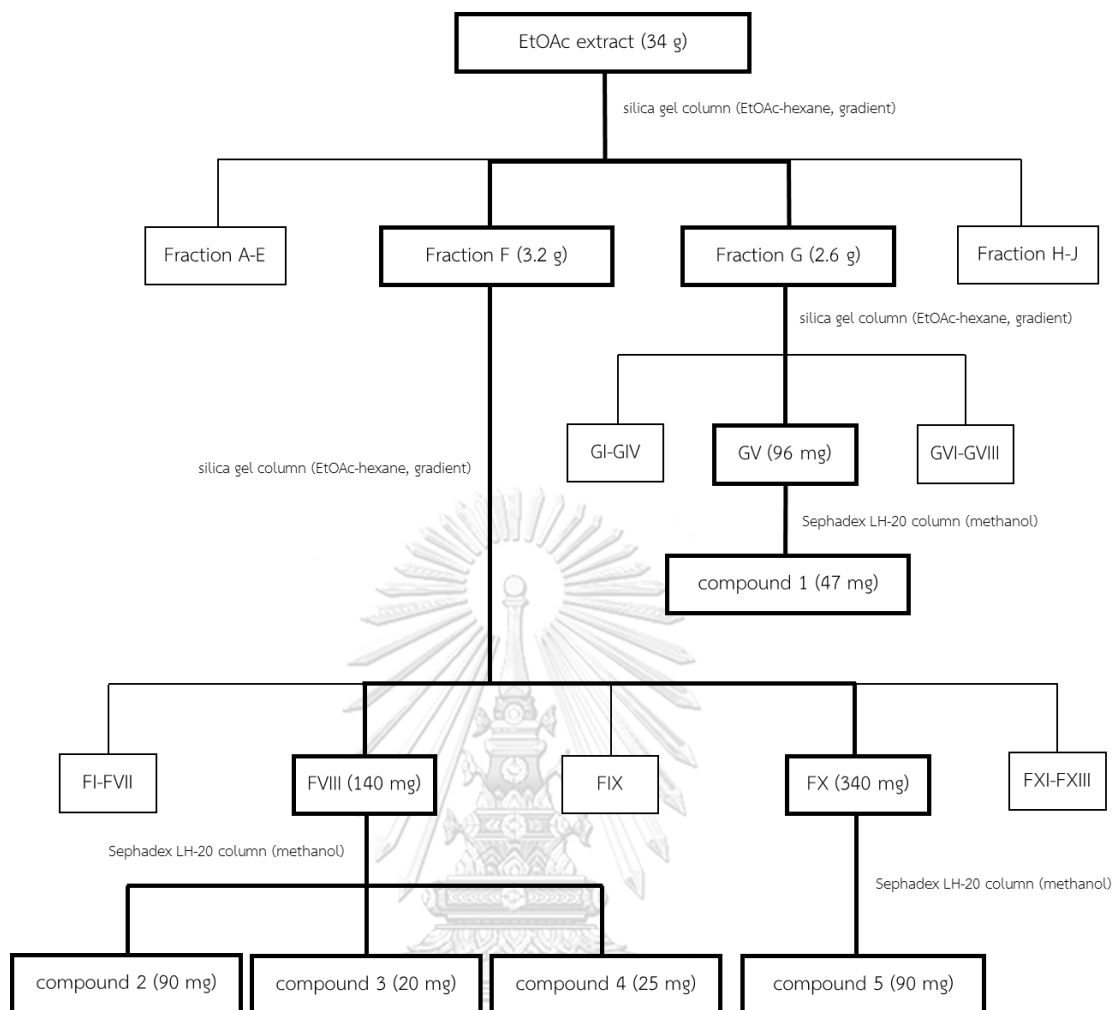


Figure 7 Isolation of the EtOAc extract from *Dendrobium lindleyi*

3. Identification of isolated compounds

3.1 General techniques

3.1.1 Mass spectrometry (MS)

Bruker micro TOF mass spectrometer (ESI-MS, Department of Chemistry, Faculty of Sciences, Mahidol University) was used for mass spectrometric analysis of isolated compounds.

3.1.2 Nuclear magnetic resonance (NMR) spectroscopy

One dimensional NMR (^1H NMR, 300 MHz and ^{13}C NMR, 75 MHz) and 2 dimensional NMR spectroscopy (NOESY, HSQC and HMBC) were performed using a Bruker Avance DPX 300 MHz FT-NMR spectrometer (Faculty of Pharmaceutical Sciences, Chulalongkorn University) or Bruker Avance III HD/OXFORD 500 MHz FT-NMR

spectrometer (Scientific and Technological Research Equipment Centre, Chulalongkorn University). Deuterated acetone (acetone- d_6) and deuterated chloroform ($CDCl_3$) were used as solvents. Chemical shifts were stated in ppm scale.

3.1.3 Ultraviolet (UV) spectroscopy

UV spectra were recorded by a Milton Roy Spectronic 3000 Array spectrophotometer (Pharmaceutical Research Instrument Center, Faculty of Pharmaceutical Sciences, Chulalongkorn University).

3.1.4 Infrared (IR) spectroscopy

A Perkin-Elmer FT-IR 1760X spectrophotometer (Scientific and Technology Research Equipment Center, Chulalongkorn University) was used for recording IR spectra.

3.2 Physical and spectral data

3.2.1 compound 1 (4,5-dihydroxy-3,3',4'-trimethoxybibenzyl)

Compound 1 was obtained as brown amorphous solid, soluble in methanol (47 mg, 0.0039% based on dried weight of whole plant).

HR-ESI-MS: m/z 327.1212 $[M+Na]^+$ (calcd for $C_{17}H_{20}O_5Na$, 327.1208) (see Appendix A.1).

IR (film): ν_{max} : 3428, 2924, 1724, 1629, 1605, 1515, 1453, 1263, 1093, 1027 cm^{-1} (see Appendix A.2)

UV (MeOH): λ_{max} (log ϵ) 220 (4.09), 229 (4.08), 285 (3.76) nm (see Appendix A.3)

1H NMR: see Appendices A.4-A.6

^{13}C NMR: see Appendix A.7

2D NMR (HSQC, HMBC, NOESY): see Appendices A.8-A.22

3.2.2 compound 2 (chrysotoxine)

Compound 2 was obtained as brown amorphous solid, soluble in methanol (90 mg, 0.0075% based on dried weight of whole plant).

HR-ESI-MS: m/z 341.1366 $[M+Na]^+$ (calcd for $C_{18}H_{22}O_5Na$, 341.1365).

(see Appendix B.1)

1H NMR: see Appendix B.2

^{13}C NMR: see Appendices B.3-B.4

2D NMR (HSQC, HMBC, NOESY): see Appendices B.5-B.8

3.2.3 compound 3 (*gigantol*)

Compound 3 was obtained as brown amorphous solid, soluble in methanol (20 mg, 0.0017% based on dried weight of whole plant).

HR-ESI-MS: m/z 297.1111 $[M+Na]^+$ (calcd for $C_{16}H_{18}O_4Na$, 297.1103).

(see Appendix C.1).

1H NMR: see Appendix C.2

^{13}C NMR: see Appendix C.3

2D NMR (HSQC, HMBC, NOESY): see Appendices C.4-C.8

3.2.4 compound 4 (*cypripedin*)

Compound 4 was obtained as red amorphous solid, soluble in methanol (25 mg, 0.0021% based on dried weight of whole plant).

HR-ESI-MS: m/z 307.0582 $[M+Na]^+$ (calcd. for $C_{16}H_{12}O_5Na$, 307.0582)

(see Appendix D.1).

1H NMR: see Appendix D.2

^{13}C NMR: see Appendix D.3

2D NMR (HSQC, HMBC, NOESY): see Appendices D.4-D.7

3.2.5 compound 5 (*moscatilin*)

Compound 5 was obtained as brown amorphous solid, soluble in methanol (90 mg, 0.0075% based on dried weight of whole plant).

HR-ESI-MS: m/z 327.1219 $[M+Na]^+$ (calcd for $C_{17}H_{20}O_5Na$, 327.1208)

(see Appendix E.1).

^1H NMR: see Appendix E.2

^{13}C NMR: see Appendix E.3

2D NMR (HSQC, HMBC, NOESY): see Appendices E.4-E.9

4. Free radical scavenging assay

4.1 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay

DPPH is a stable free radical molecule that has a violet color. The antioxidant reacts with DPPH by transferring its electron and hydrogen atom to DPPH radical and makes DPPH in the reduced form which has a yellow color (Figure 8). To investigate the antioxidant activity, the UV absorbance at 517 nm needs to be measured after the reaction (Alam, Bristi and Rafiquzzaman, 2013; Al-Temimi, 2013; Raghavendra et al., 2013). The larger absorbance value, the stronger the scavenging activity the compound has. The result can be reported as IC_{50} (half maximal inhibitory concentration) which is the sample concentration that can reduce DPPH by 50% (Antolovich et al., 2002). This method is one of the widely used assays for antioxidant activity determination because it is relatively fast but provides a precise result (Raghavendra et al., 2013). Furthermore, the procedure requires only simple reagents and instruments.

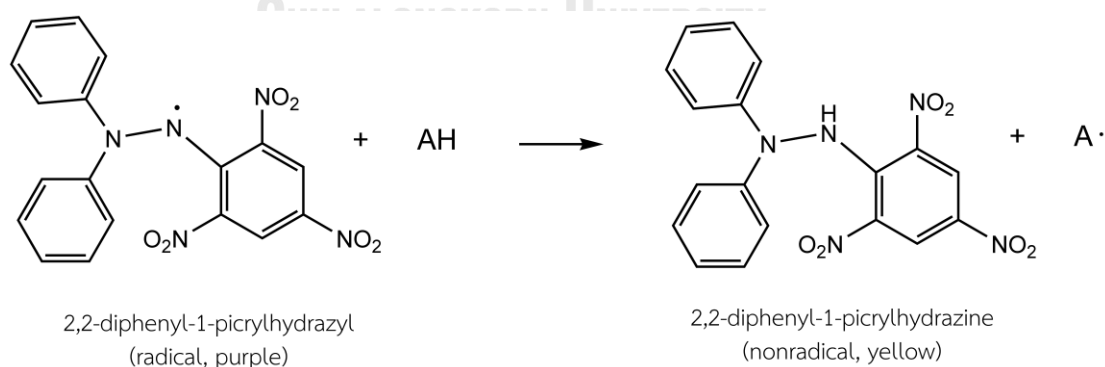


Figure 8 The reaction between DPPH and antioxidant (A)

4.1.1 Materials and instruments

DPPH, dimethyl sulfoxide (DMSO) and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) were purchased from Sigma-Aldrich (Missouri, USA). The experiment was performed using polystyrene 96-well microplates (SPL Life Sciences, Gyeonggi, Korea). Microplate reading was carried out on CLARIOstar® microplate reader (BMG Labtech, Ortenberg, Germany).

4.1.2 DPPH radical scavenging method

The assay was performed according to a procedure modified from the protocol of Allothman, Bhat and Karim (2009). Primarily, the samples were dissolved in 50% DMSO and diluted to give several concentrations. Each sample solution (20 µL) was added into a 96-well microplate followed by 180 µL of 150 µM DPPH in methanol. The experimental plate was kept in dark and incubated at room temperature for 30 minutes. The absorbance at 517 nm was then measured by a microplate reader. Methanol, 50% DMSO and Trolox were used as a blank, a negative control, and a positive control, respectively. The percentage of inhibition was calculated according to the equation 1. Finally, the graphs between the concentration of the sample and the calculated percentage of inhibition were plotted to determine the IC₅₀ value.

$$\% \text{ inhibition of DPPH radical} = \frac{(A_{\text{neg}} - A'_{\text{neg}}) - (A_{\text{sample}} - A'_{\text{sample}})}{(A_{\text{neg}} - A'_{\text{neg}})} \times 100 \quad (\text{equation 1})$$

Where A_{neg} and A_{sample} are the absorbance of negative control and sample, respectively.; A'_{neg} and A'_{sample} are the absorbance of blank for negative control and sample, respectively.

4.2 Superoxide radical scavenging activity assay

Although the superoxide radical ($\bullet\text{O}_2^-$) is a common and less reactive radical generated in mitochondria (Phaniendra, Jestadi and Periyasamy, 2015), it causes the more reactive and dangerous ROS including hydroxyl radical ($\bullet\text{OH}$) and singlet oxygen ($^1\text{O}_2$) (Alam, Bristi and Rafiquzzaman, 2013). In the assay, the riboflavin-light-NBT system was utilized (Beauchamp and Fridovich, 1971). In the presence of light, the riboflavin

is generally degraded to yield the superoxide radical ($\cdot\text{O}_2^-$) which then reacts to the NBT. Eventually, the purple-blue NBT formazan is produced. (Figure 9). The UV absorbance at 590 nm can be measured to determine the inhibition of formazan production which corresponds to the superoxide radical scavenging activity (Bagul et al., 2003).

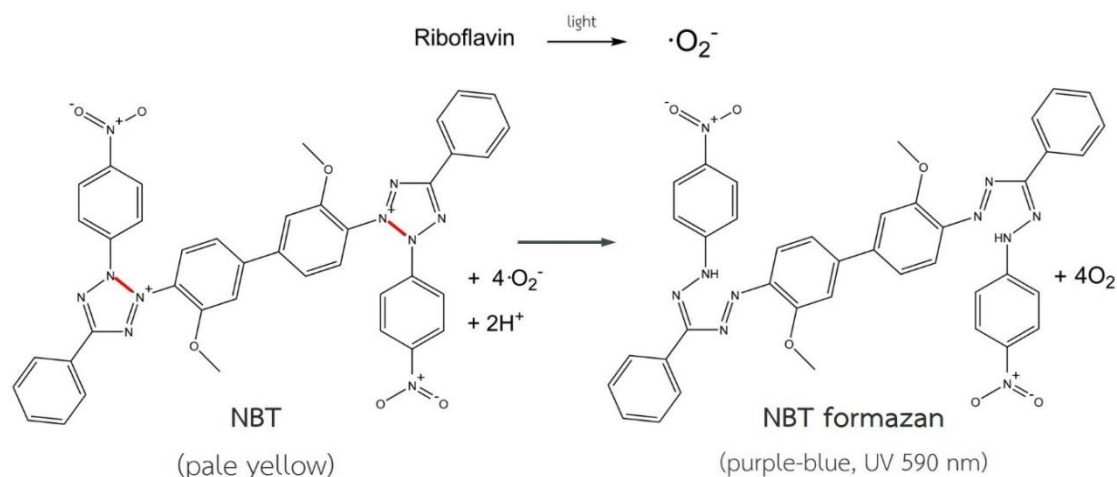


Figure 9 The reaction in riboflavin-light-NBT system

4.2.1 Materials and instruments

Methionine, riboflavin, nitro blue tetrazolium (NBT) and Trolox were purchased from Sigma-Aldrich (Missouri, USA). Ethylenediamine tetraacetic acid (EDTA) was purchased from Merck (Darmstadt, Germany). The experiment was proceeded using polystyrene 96-well microplates (SPL Life Sciences, Gyeonggi, Korea). Microplate reading was accomplished by CLARIOstar® microplate reader (BMG Labtech, Ortenberg, Germany). The light used to activate the reaction was from 18-watt fluorescent LED lamp.

4.2.2 Superoxide radical scavenging activity method

The assay was carried out according to a method modified from the protocol of Bagul et al. (2003) and Anandjiwala et al. (2008). Firstly, the samples were dissolved in 30% methanol in 50 mM potassium phosphate buffer (pH 7.6) and diluted

to yield solutions with different concentrations. Then, the diluted samples and reagents were added to 96-well microplate as summarized in Table 6.

Table 6 The reagents added in 96-well microplate for superoxide radical scavenging activity assay

Order	Reagent	Volume
1	50 mM potassium phosphate buffer (pH 7.6)	10 μ L
2	200 mM methionine	10 μ L
3	30 μ M riboflavin	100 μ L
4	100 mM EDTA	20 μ L
5	samples	40 μ L
6	400 μ M NBT	20 μ L
Total volume		200 μ L

For one sample, the two experimental plates were performed. One plate was exposed with the light from the 18-Watt fluorescent LED lamp for 20 seconds at room temperature to activate the reaction. The another was kept in dark and used as a blank. The absorbance at 590 nm was then measured by a microplate reader. The 30% MeOH in 50 mM potassium phosphate buffer (pH 7.6) was used as a negative control and Trolox was used as a positive control. The percentage of inhibition was calculated according to equation 2. The graphs between the concentration of the sample and the percentage of inhibition were plotted to investigate the IC₅₀ value.

$$\% \text{ inhibition of superoxide radical} = \frac{(A_{\text{neg}} - A'_{\text{neg}}) - (A_{\text{sample}} - A'_{\text{sample}})}{(A_{\text{neg}} - A'_{\text{neg}})} \times 100 \quad (\text{equation 2})$$

Where A_{neg} and A_{sample} are the absorbance of negative control and sample, respectively. A'_{neg} and A'_{sample} are the absorbance of blank for negative control and sample, respectively.

4.3 Oxygen radical absorbance capacity (ORAC) assay

Peroxyl radical is generally distributed throughout the body (Litescu et al., 2014). It relates to fatty acid peroxidation which is a major mechanism of cell death

caused by oxidative stress (Repetto, Semprine and Boveris, 2012). ORAC assay is the simulation of peroxy radical production by using 2,2'-azobis(2-amidinopropane) dihydrochloride (AAPH). In the presence of heat, AAPH can be degraded to C-centred radicals which then react with an oxygen molecule to give peroxy radical. This harmful radical can diminish fluorescent probes, for example, fluorescein (Figure 10). Hence, it has the potential to decrease the intensity and increase the degradation rate of fluorescence. In the condition that the antioxidant is present, the degradation rate is delayed (Litescu et al., 2014). This method is considerably sensitive because of the fluorescence measurement. Moreover, the result indicates both strength and time taken to inhibit the radical due to this assay eventually provides area under a curve (AUC) of fluorescence decay during a time (Cao and Prior, 1999).

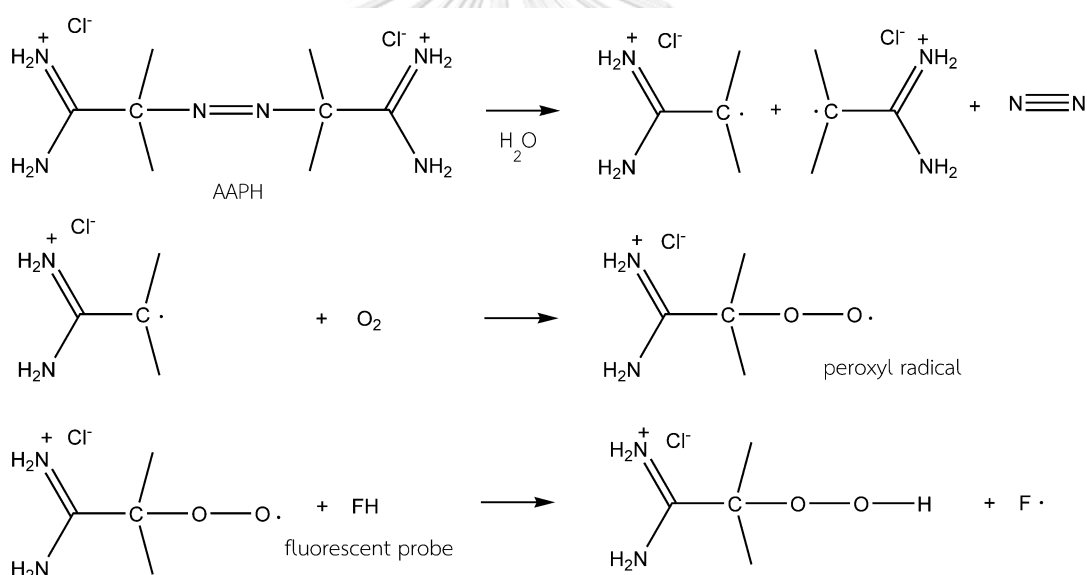


Figure 10 The production of peroxy radical from AAPH

4.3.1 Materials and instruments

AAPH and nitro blue tetrazolium (NBT) were purchased from Sigma-Aldrich (Missouri, USA). The experiment was conducted using black polystyrene 96-well microplates (SPL Life Sciences, Gyeonggi, Korea). Fluorescence intensity was recorded by CLARIOstar® microplate reader (BMG Labtech, Ortenberg, Germany).

4.3.2 ORAC method

The test was carried out according to a method modified from the protocol of Huang et al. (2002). The samples were dissolved and diluted in the solvent containing 0.5% DMSO, 0.5% distilled water, and 20% MeOH in potassium phosphate buffer (pH 7.4) to yield solutions with desired concentrations. Reagents and samples were added into a black 96-well microplate as defined in Table 7.

Table 7 The reagents added in black 96-well microplate for ORAC assay

Order	Reagent	Volume
1	Samples or Trolox	25 μ L
2	13.2 nM fluorescein (in potassium phosphate buffer pH 7.4)	150 μ L
The microplate was incubated at 37 °C for 10 minutes		
3	240 mM AAPH (in potassium phosphate buffer pH 7.4)	25 μ L
	total volume	200 μ L

The solvent containing 0.5% DMSO, 0.5% distilled water, and 20% MeOH in potassium phosphate buffer (pH 7.4) was used as blank. After the addition of 240 mM AAPH, the fluorescence intensity was immediately measured every 90 seconds for 4 hours by the microplate reader which its parameters were previously set according to Table 8. The AUC of the fluorescence decay curve was then computed by CLARIOstar[®] software version 5.70. In this method, different dilutions of Trolox (3.125-100 μ M) were also tested by the same operation to generate Trolox standard curve which was utilized for Trolox equivalent (TE) calculation (equation 3).

Table 8 The setting of microplate reader (CLARIOstar®) for ORAC assay

Parameter	Setting
Detection mode	fluorescence intensity
Method	plate mode kinetic, top optic
Optic settings	Ex-filter: excitation wavelength 483 nm Em-filter: emission wavelength 530 nm
Cycle time	90 seconds
Number of cycles	160 cycles
Temperature	37 °C

$$TE = \frac{\text{equivalent Trolox concentration (in } \mu\text{M)} \times MW}{\text{sample conc (in } \mu\text{g/mL)} \times 1000} \quad (\text{equation 3})$$

Where TE is Trolox equivalent (in mol Trolox/mol sample); equivalent Trolox concentration is the interpolated Trolox concentration (in μM) obtained from Trolox standard curve using the net AUC result (the different between the AUC of sample and blank); MW is molecular weight of sample (in g/mol); sample conc is tested sample concentration (in $\mu\text{g/mL}$).

CHAPTER IV

RESULTS AND DISCUSSION

The dried powdered whole plant of *Dendrobium lindleyi* was extracted with MeOH. The dried MeOH extract was suspended in water and partitioned with EtOAc and *n*-BuOH to give EtOAc, *n*-BuOH, and aqueous extracts after removal of the solvents. In the screening for DPPH radical scavenging activity, the EtOAc extract exhibited more than 70% inhibition at 100 µg/mL, whereas the other extracts did not show activity. Therefore, the EtOAc extract was selected for further detailed investigation. Through chromatographic separation, five compounds were isolated, and their structures were characterized by spectroscopic methods. These compounds were then evaluated for antioxidant potential in several models.

1. Identification of isolated compounds

1.1 Identification of compound 1 (4,5-dihydroxy-3,3',4'-trimethoxybibenzyl)

The positive HR-ESI-MS showed a sodium-adduct molecular ion $[M+Na]^+$ at m/z 327.1212 (calcd. for $C_{17}H_{20}O_5Na$, 327.1208), suggesting the molecular formula $C_{17}H_{20}O_5$ (Appendix A.1).

The IR spectrum exhibited absorption bands for hydroxyl (3428 cm^{-1}), aromatic ring ($2924, 1605\text{ cm}^{-1}$) and methylene (1453 cm^{-1}) groups (Appendix A.2).

The UV absorption peaks at 220, 229 and 285 nm (Appendix A.3). were indicative of a bibenzyl nucleus (Zhang et al., 2007c). The 1H NMR spectrum revealed the presence of five aromatic protons at δ_H 6.26-6.82 ppm and three methoxy groups at δ_H 3.85 (3H, s, MeO-3), 3.87 (3H, s, MeO-3') and 3.88 (3H, s, MeO-4'). The ^{13}C NMR spectrum displayed signals for twelve aromatic (δ_C 103.5-148.7), three methoxy (δ_C 56.1, 55.9, and 55.8) and two methylene (δ_C 37.6 and 38.0) carbons. In support of the bibenzyl skeleton, the HSQC spectrum showed cross peaks at δ_C 38.0/ δ_H 2.81 (C- α /H $_2$ - α) and δ_C 37.6/ δ_H 2.84 (C- α' / (H $_2$ - α')).

In the 1H NMR spectrum, two protons of the A ring appeared as doublets at δ_H 6.26 (1H, $J=2.0$ Hz, H-2) and 6.48 (1H, $J=2.0$ Hz, H-6), which were correlated to C-

α in the HMBC spectrum. The protons at δ_{H} 6.69 (1H, *d*, $J=2.0$ Hz) and 6.73 (1H, *dd*, $J=8.0, 2.0$ Hz) were assigned to H-2' and H-6' of ring B, respectively from their HMBC correlations with C- α '. The H-6' proton showed *ortho*-coupling with H-5' (δ_{H} 6.81, 1H *d*, $J = 8.0$ Hz). In order to locate the positions of the three methoxy substituents, a NOESY experiment was performed. The methoxy group at δ_{H} 3.85 ppm should be placed at C-3 of ring A according to its NOESY correlation with H-2. This was confirmed from the HMBC correlations from these methoxyl protons to C-3 and from H-2 to C-3. The methoxyl group at δ_{H} 3.87 should be located at C-3' of ring B based on its NOESY cross-peak with H-2'. The methoxyl group at δ_{H} 3.88 should be positioned at C-4' from its NOESY correlation with H-5', and this was confirmed by the HMBC connectivities from C-4' to MeO-4' protons' and H-6'.

The HBMC spectrum was further analyzed to obtain NMR assignments for the other quaternary carbons. For example, the peak at δ_{C} 133.7 was assigned to C-1 from its HMBC correlations to H₂- α (δ_{H} 2.81) and H₂- α' (δ_{H} 2.84). The carbon at δ_{C} 146.6 was assigned as C-3 from its HMBC 2-bond coupling with H-2 (δ_{H} 6.26) and 3-bond couplings with HO-4 (δ_{H} 5.25) and MeO-3 (δ_{H} 3.85) protons. All of the HMBC correlations of **1** are summarized in Table 9 and the key HMBC are shown in Figure 11.

From the above spectroscopic data, **compound 1** was characterized as a new compound and assigned to be 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl [**374**].

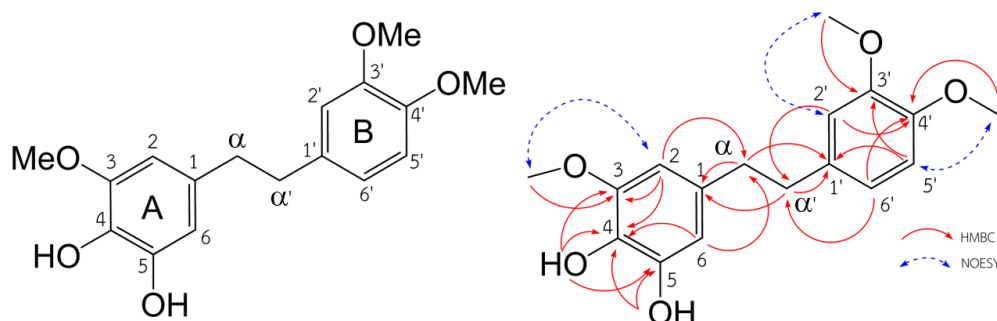


Figure 11 Chemical structure of **compound 1** [**374**] and key correlations of HMBC and NOESY

Table 9 ^1H NMR (500 MHz) and ^{13}C NMR (125 MHz) spectral data of compound 1 in CDCl_3

Position	^1H	^{13}C	HMBC (correlation with ^1H)
1	-	133.7	α^* , α'
2	6.26 (1H, <i>d</i> , <i>J</i> = 2.0 Hz)	103.5	6, α
3	-	146.6	3-OMe, 2*, 4-OH
4	-	130.5	2, 6, 4-OH*, 5-OH
5	-	143.7	6*, 4-OH, 5-OH*
6	6.48 (1H, <i>d</i> , <i>J</i> = 2.0 Hz)	108.6	2, α , 5-OH
1'	-	134.4	α , α^* , 5'
2'	6.69 (1H, <i>d</i> , <i>J</i> = 2.0 Hz)	111.9	6', α'
3'	-	148.7	5', 3'-OMe
4'	-	147.2	2', 6', 4'-OMe
5'	6.81 (1H, <i>d</i> , <i>J</i> = 8.0 Hz)	111.2	-
6'	6.73 (1H, <i>dd</i> , <i>J</i> = 8.0, 2.0 Hz)	120.3	2', α'
α	2.81 (2H, <i>m</i>)	38.0	α^* , 2, 6
α'	2.84 (2H, <i>m</i>)	37.6	α^* , 2', 6'
MeO-3	3.85 (3H, <i>s</i>)	56.1	-
MeO-3'	3.87 (3H, <i>s</i>)	55.9	-
MeO-4'	3.88 (3H, <i>s</i>)	55.8	-
HO-4	5.25 (1H, <i>s</i>)	-	-
HO-5	5.28 (1H, <i>s</i>)	-	-

*Two-bond coupling

1.2 Identification of compound 2 (chrysotoxine)

The positive HR-ESI-MS demonstrated a sodium-adduct molecular ion $[M+Na]^+$ at m/z 341.1366 (calcd. for $C_{18}H_{22}O_5Na$, 341.1365), suggesting the molecular formula $C_{18}H_{22}O_5$ (Appendix B.1).

The 1H NMR spectrum exhibited five aromatic protons at δ_H 6.48-6.83 ppm, four methylene protons at δ_H 2.81 ppm (4H, s, $H_2-\alpha$, $H_2-\alpha'$) and four methoxy groups at δ_H 3.75 ppm (6H, s) and 3.76 ppm (6H, s). Through comparison with the spectral data of **compound 1**, this isolated compound was suggested as one of the bibenzyls. In the HSQC spectrum, δ_C 38.8 ppm ($C-\alpha$) and 38.4 ppm ($C-\alpha'$) connected with $H_2-\alpha$ and $H_2-\alpha'$, respectively.

The HMBC spectrum presented the correlation of $C-\alpha$ and $C-\alpha'$ with four aromatic protons at δ_H 6.48 (2H, s, H-2, H-6), 6.71 (1H, *dd*, 1.8, 8.1, H-6'), and 6.80 (1H, *br s*, H-2'). The cross peaks of the methylene protons ($H_2-\alpha$, $H_2-\alpha'$) and the four aromatic protons from NOESY strengthened these positions. For H-6', the coupling constants implied the *meta*-coupling ($J=1.8$) of H-2' and the *ortho*-coupling ($J=8.1$) of H-5' (δ_H 6.82, *d*, 8.1).

According to NOESY spectrum, the first and the second methoxy groups were positioned at C-3 and C-5 due to the cross peaks of MeO-3 and MeO-5 (δ_H 3.76, 6H, s) with H-2 and H-6 (δ_H 6.48). While the third and the fourth methoxy groups were placed at C-3' and C-4' because MeO-3' and MeO-4' (δ_H 3.75, 6H, s,) correlated with H-2' (δ_H 6.80) and H-5' (δ_H 6.82). These findings led to the symmetry of ring A which was supported by a singlet peak of the two protons at δ_H 6.48 (2H, s, H-2, H-6).

The HSQC spectrum illustrated the correlative protons with C-2 and C-6 (δ_C 106.9), C-2' (δ_C 113.6), C-5' (δ_C 112.9), C-6' (δ_C 121.2), MeO-3 and MeO-5 (δ_C 56.6), 3'-OMe and 4'-OMe (δ_C 56.2 and 56.0).

The HMBC spectrum was also used to define the peaks of ^{13}C NMR spectrum. The peak at δ_C 133.1 was identified as C-1 because its relationships with H-

2, H-6 (δ_{H} 6.48), H- α , and H- α' (δ_{H} 2.81). The carbon at δ_{C} 148.5 was determined as C-3 and C-5 due to its correlations with H-2, H-6 (δ_{H} 6.48), MeO-3, and MeO-5 (δ_{H} 3.76). The peak at δ_{C} 135.1 was defined as C-4 because of its correlations with H-2 and H-6 (δ_{H} 6.48). The carbon at δ_{C} 135.5 was specified as H-1' due to its correlations with H-5' (δ_{H} 6.82), H-2' (δ_{H} 6.80), H- α , and H- α' (δ_{H} 2.81). The peak at δ_{C} 148.6 was determined as C-3' based on its relationships with MeO-3' (δ_{H} 3.75). The peak at δ_{C} 150.2 was identified as C-4' because it correlated with H-2' (δ_{H} 6.80), H-6' (δ_{H} 6.71), and MeO-4' (δ_{H} 3.75). These HMBC correlations were illustrated in Figure 12.

As per the spectroscopic evidence and the comparison of ^1H and ^{13}C NMR spectra with those of Ono et al. (1995) (Table 10), **compound 2** was defined as chrysotoxine [7], a bibenzyl compound, which was previously discovered from *Dendrobium* plants including *D. pulchellum* (Chanvorachote et al., 2013).

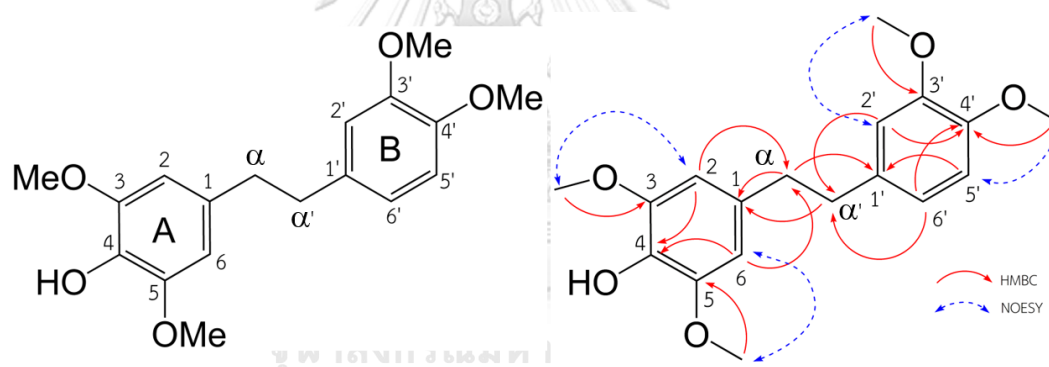


Figure 12 Chemical structure of **compound 2** [7] and key correlations of HMBC and NOESY

Table 10 ^1H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectral data of **compound 2** in acetone- d_6 and ^1H NMR (500 MHz) and ^{13}C NMR (100 MHz) of chrysotoxine in CDCl_3

Position	Compound 2		Chrysotoxine ^a	
	δ_{H} (mult., J in Hz)	δ_{C}	δ_{H} (mult., J in Hz)	δ_{C}
1	-	133.1	-	132.8
2, 6	6.48 (2H, s)	106.9	6.36 (2H, s)	105.2
3, 5	-	148.5	-	146.8
4	-	135.1	-	132.8
α	2.81 (4H, s)	38.4	2.83 (4H, s)	38.3***
α'	2.81 (4H, s)	38.8	2.83 (4H, s)	37.8***
1'	-	135.5	-	134.3
2'	6.80 (1H, br s)	113.6	6.66 (1H, d, 1.8)	111.9*
3'	-	148.6	-	147.2
4'	-	150.2	-	148.7
5'	6.82 (1H, d, 8.1)	112.9	6.79 (1H, d, 8.1)	111.2*
6'	6.71 (1H, dd, 1.8, 8.1)	121.2	6.70 (1H, dd, 1.8, 8.1)	120.4
MeO-3, MeO-5	3.76 (6H, s)	56.6	3.84 (6H, s)*	56.2
MeO-3'	3.75 (3H, s)	56.2*	3.85 (3H, s)*	55.9**
MeO-4'	3.75 (3H, s)	56.0*	3.84 (3H, s)*	55.8**

^a (Ono et al., 1995), *, **, *** Value in the same column are interchangeable

1.3 Identification of compound 3 (gigantol)

The positive HR-ESI-MS showed a sodium-adduct molecular ion $[M+Na]^+$ at m/z 297.1111 (calcd. for $C_{16}H_{18}O_4Na$, 297.1103), suggesting the molecular formula $C_{16}H_{18}O_4$ (Appendix C.1).

The 1H NMR spectrum represented six protons in aromatic rings at δ_H 6.21-6.81 ppm, four methylene protons at δ_H 2.78 ppm (4H, s, $H_2-\alpha$ $H_2-\alpha'$) and two methoxy substitutions at δ_H 3.70 ppm (3H, s) and 3.798 ppm (3H, s). In comparison to the chemical structure of **compound 1**, bibenzyl skeleton was suggested as a core structure of **compound 3**.

In the HSQC spectral data, there is a correlation peak of methylene protons ($H_2-\alpha$ and $H_2-\alpha'$) and methylene carbons at δ_C 37.1 ppm ($C-\alpha'$) and 38.2 ppm ($C-\alpha$). The HMBC spectrum revealed the correlation of $C-\alpha$ and $C-\alpha'$ with four aromatic protons at δ_H 6.30 (1H, t, 2.1, H-2), δ_H 6.31 (1H, t, 2.1, H-6), 6.66 (1H, dd, 1.8, 8.1, H-6'), and 6.81 (1H, d, 1.8, H-2'). Furthermore, NOESY spectrum supported these positions by showing the cross peaks of the methylene protons ($H_2-\alpha$, $H_2-\alpha'$) and the aromatic protons (H-2, H-6, H-2', H-6'). For the position of H-6', the coupling constants presented the *meta*-coupling ($J=1.8$) of H-2' and the *ortho*-coupling ($J=8.1$) of H-5' (δ_H 6.73, d, 8.1, H-5'). At δ_H 6.24 (t, 2.1), the coupling constant indicated H-4 position due to two *meta*-couplings ($J=2.1$) of H-2 and H-6.

The NOESY displayed the relationship between the methoxyl protons at δ_H 3.71 (3H, s, MeO-3) with H-2 (δ_H 6.30) and H-4 (δ_H 6.31). Hence, the methoxy groups at δ_H 3.71 was positioned at C-3. In the same manner, the second methoxy group 3.80 (3H, s, MeO-3') was placed at C-3' due to its NOESY correlation with H-2' (δ_H 6.81).

The HSQC was used to define ^{13}C NMR peaks which indicated 3-OMe (δ_C 54.4), 3'-OMe (δ_C 55.3), C-4 (δ_C 98.8), C-6 (δ_C 105.4), C-2 (δ_C 108.0), C-2' (δ_C 112.0), C-5' (δ_C 114.7), and C-6' (δ_C 120.7).

The HMBC spectral data was applied to define ^{13}C NMR. The carbon at δ_{C} 144.7 was indicated as C-1 because of its correlations with $\text{H}_2\text{-}\alpha'$ (δ_{H} 2.78). The carbon at δ_{C} 161.0 was identified as C-3 due to its correlations with MeO-3 (δ_{H} 3.71), H-2 (δ_{H} 6.30), and H-4 (δ_{H} 6.24). The carbon at δ_{C} 158.4 was defined as C-5 because of its relationship with H-4 (δ_{H} 6.24). The carbon at δ_{C} 133.2 was specified as C-1' based on its correlations with H-5' (δ_{H} 6.73) and $\text{H}_2\text{-}\alpha$ (δ_{H} 2.78). The carbon at δ_{C} 147.2 was identified as C-3' because it related to MeO-3' (δ_{H} 3.80) and H-5' (δ_{H} 6.73). The peak at δ_{C} 144.3 was defined as C-4' due to its correlations with H-2' (δ_{H} 6.81) and H-6' (δ_{H} 6.66). These HMBC correlations were shown in Figure 13.

According to the spectroscopic information and the comparison of ^1H and ^{13}C NMR data with that of Klongkumnuankarn et al. (2015) (Table 11), **compound 3** was proposed as gigantol [16], a compound belongs to bibenzyl group, which was previously found in genus *Dendrobium*, for example, *D. draconis* (Sritularak, Anuwat and Likhitwitayawuid, 2011), *D. venustum* (Sukphan et al., 2014), *D. brymerianum* (Klongkumnuankarn et al., 2015), and *D. formosum* (Inthongkaew et al., 2017).

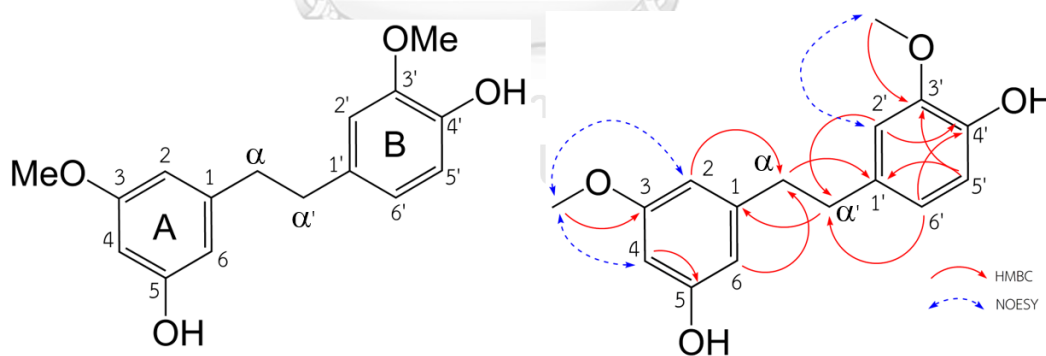


Figure 13 Chemical structure of **compound 3** [16], and key correlations of HMBC and NOESY

Table 11 ^1H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectral data of **compound 3** in acetone- d_6 and ^1H NMR (500 MHz) and ^{13}C NMR (125 MHz) of gigantol in acetone- d_6

Position	Compound 3		Gigantol ^a	
	δ_{H} (mult., J in Hz)	δ_{C}	δ_{H} (mult., J in Hz)	δ_{C}
1	-	144.7	-	145.4
2	6.30 (1H, t , 2.1)	108.0	6.22 (1H, t , 2.0)	108.8
3	-	161.0	-	159.1
4	6.24 (1H, t , 2.1)	98.8	6.28 (1H, t , 2.0)	99.6
5	-	158.4	-	161.7
6	6.31 (1H, t , 2.1)	105.4	6.30 (1H, t , 2.0)	106.2
α	2.78 (4H, s)	38.2	2.78 (4H, m)	39.0
α'	2.78 (4H, s)	37.1	2.78 (4H, m)	37.9
1'	-	133.2	-	134.0
2'	6.81 (1H, d , 1.8)	112.0	6.79 (1H, d , 1.5)	115.4
3'	-	147.2	-	147.9
4'	-	144.3	-	145.1
5'	6.73 (1H, d , 8.1)	114.7	6.69 (1H, d , 8.0)	112.8
6'	6.66 (1H, dd , 8.1, 1.8)	120.7	6.64 (1H, dd , 8.0, 1.5)	121.5
MeO-3	3.71 (3H, s)	54.4	3.69 (3H, s)	55.2
MeO-3'	3.80 (3H, s)	55.3	3.78 (3H, s)	56.0

^a (Klongkumnuankarn et al., 2015)

1.4 Identification of compound 4 (cypripedin)

The positive HR-ESI-MS displayed a sodium-adduct molecular ion $[M+Na]^+$ at m/z 307.0582 (calcd. for $C_{16}H_{12}O_5Na$, 307.0582), suggesting the molecular formula $C_{16}H_{12}O_5$ (Appendix D.1).

The 1H NMR spectrum exhibited five aromatic protons at δ_H 6.21-9.28 ppm, and two methoxyl groups at δ_H 3.93 ppm (3H, s) and 3.94 ppm (3H, s). Unlike the spectrum of **compound 1-3**, this spectrum did not show the peak of methylene proton. After calculation of degree of unsaturation which equal to 11, the two unsaturations belonged to two carbonyl carbons which appeared in the ^{13}C NMR spectrum at δ_C 181.2 (C-4) and 189.1 (C-1).

The other nine unsaturations were proposed as a phenanthrene ring containing three closed rings and six double bonds for an aromatic system. Thus, this compound was suggested as a phenanthrenequinone structure which was regularly found in *Dendrobium* species. These findings were confirmed by the presence of aromatic proton peaks at high chemical shift due to deshielding of a large anisotropic field produced from an extended aromatic system (Pavia et al., 2009).

The HMBC spectrum established the correlation of the carbonyl carbon C-1 (δ_C 181.2) with aromatic protons H-3 (δ_H 6.21, 1H, s) and H-10 (δ_H 8.097, 1H, d, 9.0). The NOESY spectrum exhibited the correlation of H-3 with methoxyl proton at δ_H 3.93 (2-OMe). Therefore, the first methoxy group was located at C-2. The 1H NMR indicated the H-9 position (δ_H 8.38, 1H, d, 9.0) which coupled with H-10 because of their similar coupling constants ($J=9.0$).

The second methoxy group (δ_H 3.94, MeO-8) was located at C-8 based on the HMBC correlations of C-8 (δ_C 141.1) with MeO (δ_H 3.94, MeO-8), H-9 (δ_H 8.38) and H-6 (δ_H 7.44).

Because of the absence of the cross peak of the methoxy group (δ_H 3.492, 3H, s, 8-OMe) with the other pair of protons in the NOESY spectrum, these aromatic protons were suggested to place at the position that was not adjacent to the methoxy.

Consequently, another couple of protons with the same coupling constant values ($J=9.6$) were positioned as H-5 (δ_{H} 9.28, 1H, *d*, 9.6) and H-6 (δ_{H} 7.44, 1H, *d*, 9.6, H-6).

The HSQC spectrum (Figure 60) presented the correlative protons with aromatic carbons at C-3 (δ_{C} 111.9), C-5 (δ_{C} 126.2), C-6 (δ_{C} 123.5), C-9 (δ_{C} 127.2), C-10 (δ_{C} 112.7), MeO-8 (δ_{C} 61.5), and MeO-2 (δ_{C} 56.7).

Lastly, the HMBC correlations were also used to identify the peaks of ^{13}C NMR. The peak at δ_{C} 159.6 was defined as C-2 due to its correlations with H-3 (δ_{H} 6.21) and MeO-2 (δ_{H} 3.93). The carbon at δ_{C} 128.3 was defined as C-4a because of its connections with H-10 (δ_{H} 8.10) and H-3 (δ_{H} 6.21). The carbon at δ_{C} 125.8 was indicated as C-4b because it correlated with H-6 (δ_{H} 7.44) and H-9 (δ_{H} 8.38). The peak at δ_{C} 149.5 was identified as C-7 due to its relationship with H-5 (δ_{H} 9.28) and H-6 (δ_{H} 7.44). The peak at δ_{C} 134.0 was defined as C-8a because of its cross peaks with H-10 (δ_{H} 8.10) and H-5 (δ_{H} 9.28). The carbon at δ_{C} 130.0 was determined as C-10a due to it correlated with H-9 (δ_{H} 8.38). These HMBC correlations were illustrated in Figure 14.

In accordance with the spectroscopic evidence and the comparison of ^1H and ^{13}C NMR spectra with those of Wattanathamsan et al. (2018) (Table 12), **compound 4** was identified as cypripedin [92], a phenanthrenequinone derivative, which was previously extracted from *Dendrobium* genus including *D. densiflorum* (Wattanathamsan et al., 2018; Fan et al., 2001) and *D. moniliforme* (Kim et al., 2018).

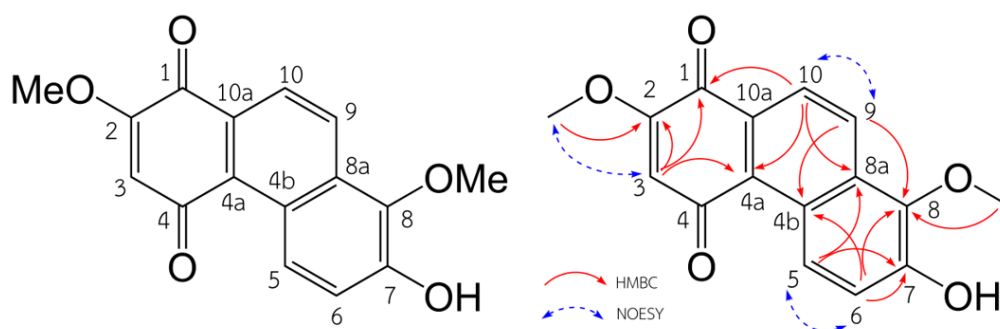


Figure 14 Chemical structure of **compound 4** [92] and key correlations of HMBC and NOESY

Table 12 ^1H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectral data of **compound 4** and cypripedin in acetone- d_6

Position	Compound 4		Cypripedin ^a	
	δ_{H} (mult., J in Hz)	δ_{C}	δ_{H} (mult., J in Hz)	δ_{C}
1	-	181.2	-	181.2
2	-	159.6	-	159.6
3	6.21 (1H, s)	111.9	6.20 (1H, s)	111.9
4	-	189.1	-	189.1
4a	-	128.3	-	128.3
4b	-	125.8	-	125.7
5	9.28 (1H, d , 9.6)	126.2	9.27 (1H, d , 9.6)	126.2
6	7.44 (1H, d , 9.6)	123.5	7.43 (1H, d , 9.6)	123.4
7	-	149.5	-	149.5
8	-	141.1	-	141.1
8a	-	134.0	-	134.0
9	8.38 (1H, d , 9.0)	127.2	8.37 (1H, d , 9.0)	127.2
10	8.10 (1H, d , 9.0)	122.7	8.09 (1H, d , 9.0)	122.7
10a	-	130.0	-	130.0
MeO-8	3.94 (3H, s)	61.5	3.94 (3H, s)	61.5
MeO-2	3.93 (3H, s)	56.7	3.93 (3H, s)	56.7

^a (Wattanathamsan et al., 2018)

1.5 Identification of compound 5 (moscatilin)

The positive HR-ESI-MS demonstrated a sodium-adduct molecular ion $[M+Na]^+$ at m/z 327.1219 (calcd. for $C_{17}H_{20}O_5Na$, 327.1208), suggesting the molecular formula $C_{17}H_{20}O_5$ (Appendix E.1).

The 1H NMR spectrum illustrated five aromatic protons at δ_H 6.49-6.79 ppm, four methylene protons at δ_H 2.80 ppm (4H, s, $H_2-\alpha$ $H_2-\alpha'$) and three methoxy groups at δ_H 3.77 ppm (6H, s) and 3.79 ppm (3H, s). These findings, along with the comparison with those of **compound 1**, were proposed as a bibenzyl derivative. In the HSQC spectrum, $H_2-\alpha$ and $H_2-\alpha'$ demonstrated correlation peaks with δ_C 37.6 ppm (C- α) and 38.2 ppm (C- α'), respectively.

The HMBC spectrum disclosed the correlation of C- α and C- α' with four aromatic protons including H-2, H-6 (δ_H 6.49, 2H, s), H-2' (δ_H 6.79, 1H, *d*, 1.8), and H-6' (δ_H 6.65, 1H, *dd*, 8.1, 1.8). These positions were also supported by the cross peaks of the methylene protons and the aromatic protons from NOESY. For H-6' position, the coupling constants indicated the *meta*-coupling ($J=1.8$) of H-2' and the *ortho*-coupling ($J=8.1$) of H-5' (δ_H 6.74, *d*, 8.1).

The NOESY spectral data exhibited the relationship of H-2 and H-6 (δ_H 6.49) with methoxyl protons at δ_H 3.77 (6H, MeO-3, MeO-5), therefore, the two methoxy groups were placed at C-3 and C-5. The data also showed the correlations of H-2' (δ_H 6.79) with methoxyl protons at δ_H 3.79 (3H, MeO-3'). As a result, the third methoxy group (δ_H 3.79, 3H, MeO-3') was placed at C-3'. These conclusions resulted in the symmetric structure of ring A which was encouraged by a singlet peak of the six methoxyl protons at δ_H 3.77.

The HSQC spectrum displayed the correlative protons with three methoxyl carbons at δ_C 55.3 (3'-OMe) and δ_C 55.7 (3-OMe, 5-OMe) and aromatic carbons at δ_C 106.0 (C-2 and C-6), 112.2 (C-2'), 114.7 (C-5') and 120.8 (C-6').

The HMBC was used to defined ^{13}C NMR. The carbon at δ_{C} 132.4 was specified as C-1 because of its correlations with H-2, H-6 (δ_{H} 6.49), and H₂- α' (δ_{H} 2.80). The carbon at δ_{C} 147.7 was defined as C-3 and C-5 due to the correlations with H-2, H-6 (δ_{H} 6.49), MeO-3, and MeO-5 (δ_{H} 3.77). The carbon at δ_{C} 134.1 was identified as C-4 because it correlated with H-2, and H-6 (δ_{H} 6.49). The carbon at δ_{C} 133.4 was determined as C-1' due to its relationships with H-5' (δ_{H} 6.74) and H₂- α (δ_{H} 2.80). The peak at δ_{C} 147.2 was defined as C-3' based on the correlations with MeO-3' (δ_{H} 3.79) and H-5' (δ_{H} 6.74). The peak at δ_{C} 144.7 was defined as C-4' because it correlated with H-2' (δ_{H} 6.79) and H-6' (δ_{H} 6.65). The key HMBC correlations were shown in Figure 15.

In accordance with the spectroscopic data and comparison of ^1H and ^{13}C NMR spectra with those in Klongkumnuankarn et al. (2015) (Table 13), **compound 5** was identified as moscatilin [21], a bibenzyl compound, which was previously isolated from several *Dendrobiums* including *D. moscatum* (Majumder and Sen, 1987), *D. nobile* (Miyazawa et al., 1999), *D. secundum* (Sritularak, Duangrak and Likhitwitayawuid, 2011), *D. pulchellum* (Chanvorachote et al., 2013), and *D. brymerianum* (Klongkumnuankarn et al., 2015).

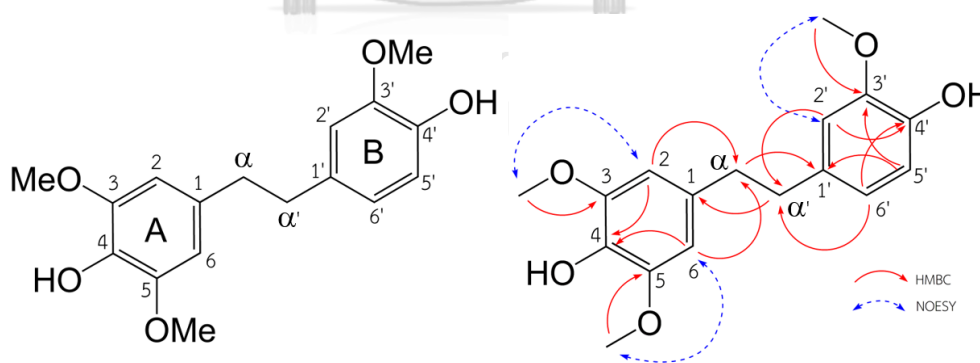


Figure 15 Chemical structure of **compound 5** [21] and key correlations of HMBC and NOESY

Table 13 ^1H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectral data of **compound 5** in acetone- d_6 and ^1H NMR (500 MHz) and ^{13}C NMR (125 MHz) of moscatilin in acetone- d_6

Position	Compound 5		Moscatilin ^a	
	δ_{H} (mult., J in Hz)	δ_{C}	δ_{H} (mult., J in Hz)	δ_{C}
1	-	132.4	-	133.1
2, 6	6.49 (2H, s)	106.0	6.48 (2H, s)	106.7
3, 5	-	147.7	-	148.3
4	-	134.1	-	134.8
α	2.80 (4H, s)	38.2	2.78 (4H, m)	38.3
α'	2.80 (4H, s)	37.6	2.78 (4H, m)	38.8
1'	-	133.4	-	134.1
2'	6.79 (1H, d, 1.8)	112.2	6.78 (1H, d, 2.0)	112.9
3'	-	147.2	-	147.9
4'	-	144.7	-	145.3
5'	6.74 (1H, d, 8.1)	114.7	6.75 (1H, d, 8.0)	115.4
6'	6.65 (1H, dd, 8.1, 1.8)	120.8	6.64 (1H, dd, 8.0, 2.0)	121.6
MeO-3, MeO-5	3.77 (6H, s)	55.7	3.75 (6H, s)	56.5
MeO-3'	3.79 (3H, s)	55.3	3.76 (3H, s)	56.1

^a (Klongkumnuankarn et al., 2015)

2. Free radical scavenging activities

Only ethyl acetate extract exhibited DPPH radical scavenging activity by more than 70% inhibition in the preliminary test. Then, the antioxidant activity of all isolated compounds from the extract was determined using three different methods comprising DPPH assay, superoxide radical scavenging activity assay, and ORAC assay.

In the DPPH assay, five dilutions of each sample were tested for IC_{50} calculation. According to Figure 16, the bar charts represent the inhibition percentages of each concentration. All compounds manifested concentration-dependent inhibition.

The IC_{50} values were stated in Table 14. Three known bibenzyls, chrysotoxine (**compound 2**, [7]), gigantol (**compound 3**, [16]), and moscatilin (**compound 5**, [21]), exhibited IC_{50} values of 35.40, 31.51, and 38.00 μ M, respectively. Chrysotoxine (**compound 2**, [7]) and gigantol (**compound 3**, [16]) were significantly stronger than Trolox. While the activity of moscatilin (**compound 5**, [21]) was equivalent to that of Trolox. These findings were consistent with the results of Song et al. (2010); Sritularak, Anuwat and Likhitwitayawuid (2011); Sritularak, Duangrak and Likhitwitayawuid (2011). The new compound (4,5-dihydroxy-3,3',4'-trimethoxybibenzyl, **compound 1**, [374]) showed the IC_{50} value of 91.28 μ M and cypripedin (**compound 4**, [92]), the only one phenanthrene, demonstrated the lowest inhibitory activity with the IC_{50} value of 340.49 μ M.

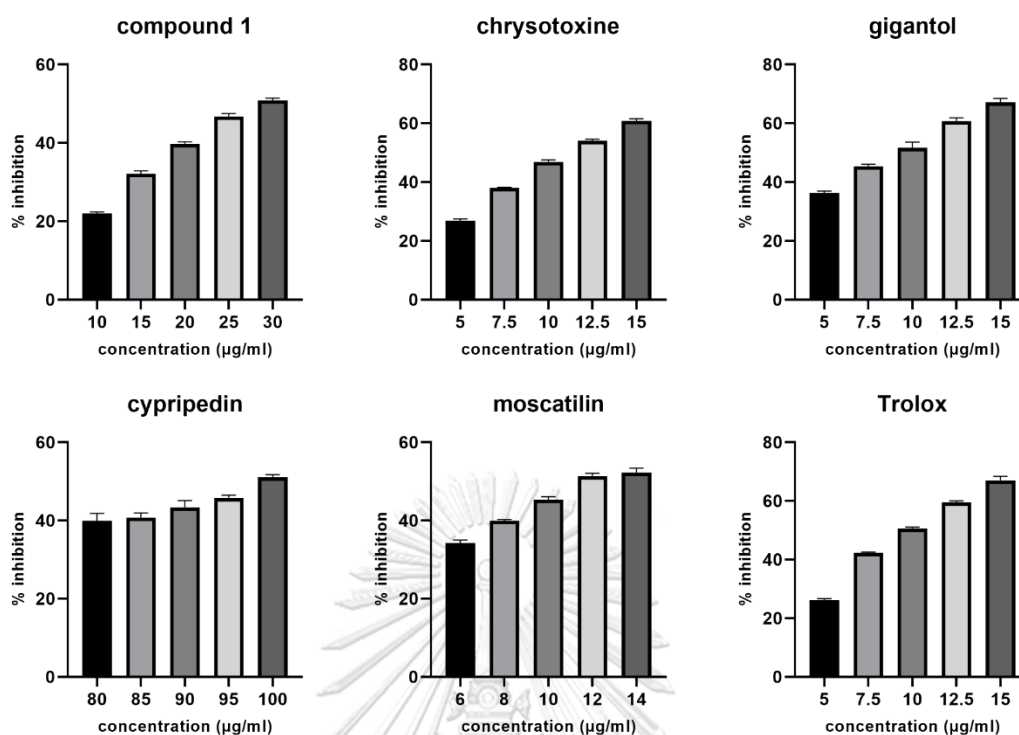


Figure 16 Concentration-dependent DPPH radical scavenging activity of **compound 1**, chrysotoxine, gigantol, cypripedin, moscatilin, and Trolox.

Table 14 IC_{50} values of DPPH radical scavenging activity

Compound	IC_{50} (μ M) \pm SD
4,5-dihydroxy-3,3',4'-trimethoxybibenzyl (compound 1 , [374])	91.28 ± 2.90
chrysotoxine (compound 2 , [7])	$35.40 \pm 0.71^*$
gigantol (compound 3 , [16])	$31.51 \pm 0.64^*$
cypripedin (compound 4 , [92])	340.49 ± 5.14
moscatilin (compound 5 , [21])	38.00 ± 0.31
Trolox	39.11 ± 0.48

*significantly stronger than Trolox ($p < 0.05$)

To evaluate the inhibitory activity against superoxide radicals, the assay of NBT formazan in the riboflavin-light-NBT system was used. Figure 17 displays % inhibition

values of each dilution and Table 15 presents the IC_{50} values. Among the isolated agents, cypripedin (**compound 4**, [92]), which inhibited only 39.64% of superoxide radical at 351.79 μ M, is the least competent antioxidant. Expectedly, the other four substances inhibited the radical in a concentration dependent manner. Gigantol (**compound 3**, [16]) revealed a considerable effect with an IC_{50} value of 162.44 μ M. Interestingly, 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl (**compound 1**, [374]), chrysotoxine (**compound 2**, [7]), and moscatilin (**compound 5**, [21]) were approximately 3-fold more potent than Trolox (IC_{50} 285.56 μ M).

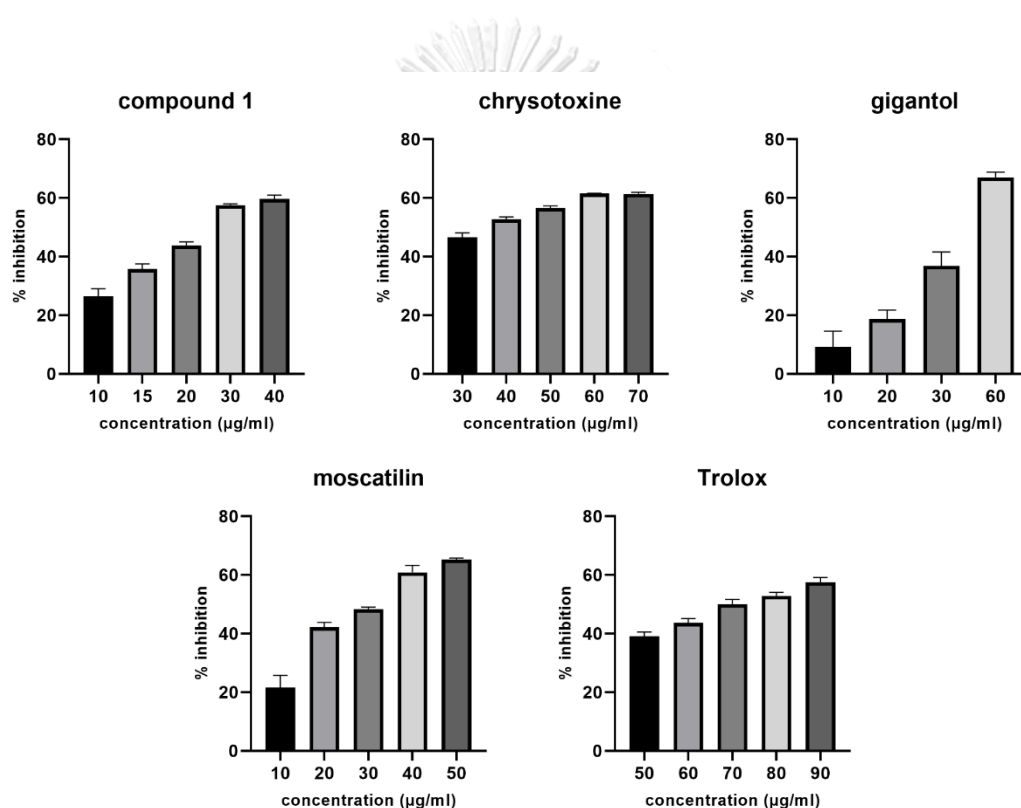


Figure 17 Concentration-dependent superoxide radical scavenging activity of **compound 1**, chrysotoxine, gigantol, moscatilin, and Trolox.

Table 15 IC₅₀ values of superoxide radical scavenging activity

Compound	IC ₅₀ (μM) ± SD
4,5-dihydroxy-3,3',4'-trimethoxybibenzyl (compound 1 , [374])	92.91 ± 9.68*
chrysotoxine (compound 2 , [7])	113.83 ± 4.91*
gigantol (compound 3 , [16])	162.44 ± 12.69*
cyprisedin (compound 4 , [92])	> 351.79 ^a
moscatilin (compound 5 , [21])	101.40 ± 5.14*
Trolox	285.56 ± 3.03

*significantly stronger than Trolox (p<0.05); ^acyprisedin (**compound 4**, [92]) at 351.79 μM (100 μg/mL) exhibits only 39.64% inhibition.

The radical absorbance capacity was measured by ORAC assay. The fluorescence signal curves of Trolox have shown in Figure 18A. The AUCs of 3.125-100 μM Trolox were plotted for the Trolox standard curve (Figure 18B). The fluorescence signal curves of isolated compounds have shown in Figure 19. The net AUC values (the different between the AUC of sample and blank) were shown as the dark areas. The activity was expressed in TE (mol Trolox equivalent/mol sample) (Table 16). Surprisingly, all five compounds were significantly more powerful than Trolox. Especially gigantol (**compound 3**, [16]), it manifested 14.26 times more potent than Trolox. While TE values of 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl, (**compound 1**, [374]), chrysotoxine (**compound 2**, [7]), and moscatilin (**compound 5**, [21]), were 2.89, 4.32, and 6.10 mol Trolox equivalent/mol sample, respectively. Similar to the DPPH tests, cyprisedin (**compound 4**, [92]), possessed the least potential with TE only 1.75 mol Trolox equivalent/mol sample.

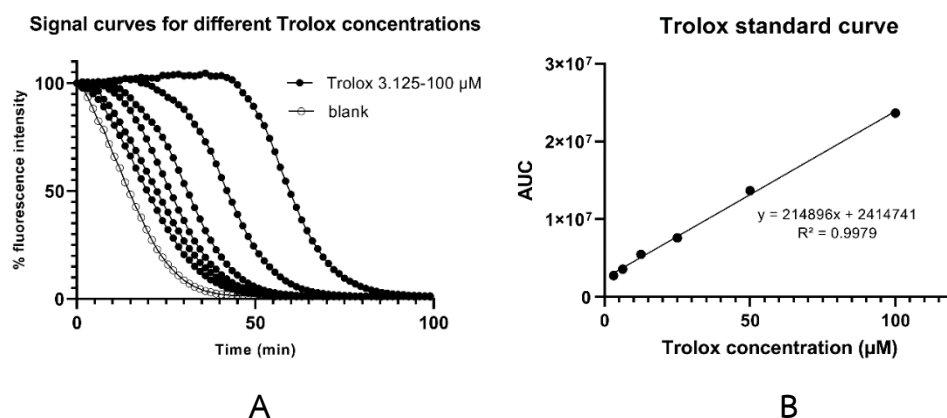


Figure 18 Signal curve for different Trolox concentrations (A) and Trolox standard curve (B)

Table 16 Trolox equivalent (TE) values of superoxide radical scavenging activity

Compound	TE (mol Trolox/mol sample) \pm SD
4,5-dihydroxy-3,3',4'-trimethoxybibenzyl (compound 1, [374])	$2.89 \pm 0.32^*$
chrysotoxine (compound 2, [7])	$4.32 \pm 0.24^*$
gigantol (compound 3, [16])	$14.26 \pm 0.27^*$
cypripedin (compound 4, [92])	$1.75 \pm 0.14^*$
moscatilin (compound 5, [21])	$6.10 \pm 0.28^*$
Trolox	1

*significantly stronger than Trolox ($p < 0.05$)

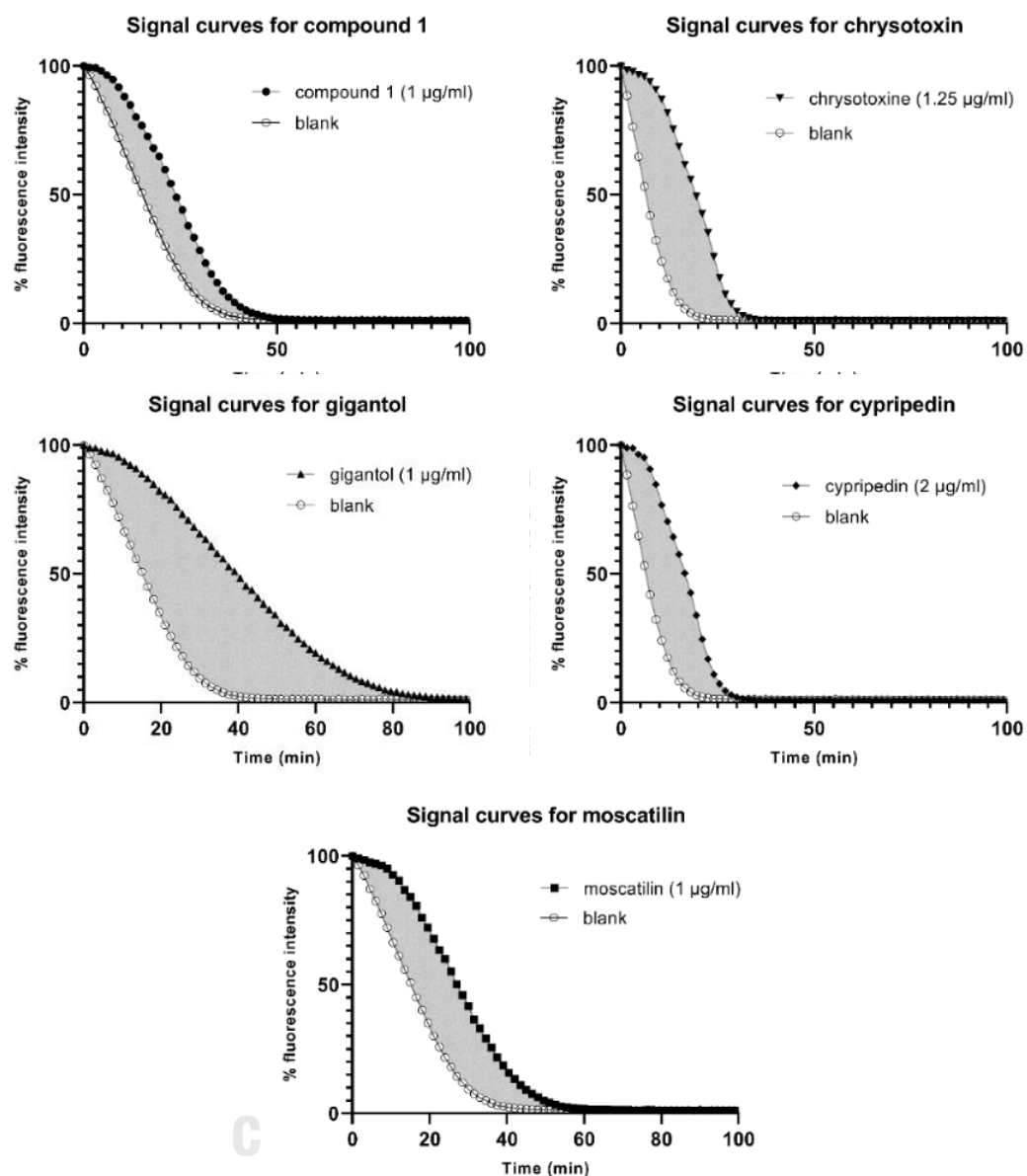


Figure 19 Signal curve for **compound 1**, chrysotoxine, gigantol, cypripedin, and moscatilin

Several reactive oxygen species are involved in oxidative stress and human diseases (Alam, Bristi and Rafiquzzaman, 2013; Kontoghiorghes and Kontoghiorghes, 2019). Accordingly, the evaluation of the antioxidant activity against the different reactive oxygen species strengthens the result and accomplishes the practical conclusion.

Overall tests, the phenanthrene derivative, cypripedin (**compound 4**, [92]), was unanimously defined as a poor radical scavenger, nevertheless, there was a report that

some phenanthrene exhibited considerable activity, for example, 2,4,8-trimethoxy-3,7-phenanthrenediol isolated from *Dioscorea communis* showed DPPH radical scavenging ability comparable to that of Trolox. In the same experiment, chrysotoxene (2,3,4,8-tetramethoxy-7-phenanthrenol), conversely, displayed poor scavenging activity because of the substitution of 3-methoxy instead of 3-hydroxy (Boudjada et al., 2019). The incompetence of chrysotoxene from *D. communis* and cypripedin (**compound 4**, [92]) from *D. lindleyi* might be explained by the hypothesis that the number of aromatic hydroxyl groups plays an essential role in the radical scavenging activity (Chen and Ho, 1997; Sroka and Cisowski, 2003; Zhang et al., 2007c). The bibenzyls, 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl (**compound 1**, [374]), chrysotoxine (**compound 2**, [7]), gigantol (**compound 3**, [16]), and moscatilin (**compound 5**, [21]) tended to exhibit greater radical scavenging activity than that of Trolox, however, there are some differences among the results of the three methods. Gigantol (**compound 3**, [16]) was superior to others in DPPH and ORAC tests but 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl (**compound 1**, [374]), chrysotoxine (**compound 2**, [7]), and moscatilin (**compound 5**, [21]) were prominent in the superoxide radical scavenging test. This dissimilarity was because their inhibitory mechanisms probably differed from each other (Villaño et al., 2005; Zhang et al., 2007c; Zhang et al., 2008c).

The discovery of the new bibenzyl derivative along with four known compounds from *D. lindleyi* would be an important extension for the phytochemistry of *Dendrobium*. Out of five compounds, four bibenzyls exerted notable radical scavenging activities. Chrysotoxine (**compound 2**, [7]) and moscatilin (**compound 5**, [21]), have been widely investigated for neuroprotective and anticancer properties, respectively (Cakova, Bonte and Lobstein, 2017). Interestingly, Song et al. (2010) found that chrysotoxine (**compound 2**, [7]) protected neuroblastoma model via suppression of neurotoxin-induced ROS, and Kowitdamrong et al. (2013) revealed that the cancer cell inhibitory effect of moscatilin (**compound 5**, [21]) was influenced by the alleviation of endogenous ROS. These encourage further studies of the four isolated bibenzyls for the treatment of diseases related to oxidative stress.

CHAPTER V

CONCLUSION

The components of EtOAc extract were the target of this study because the fraction possessed more than 70% radical inhibition in the preliminary test. Therefore, it was fractionated by both adsorption and size-exclusion chromatographic techniques. Eventually, the new bibenzyl 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl together with four known compounds including chrysotoxine, gigantol, moscatilin, and cypripedin were successfully isolated from *D. lindleyi*. All of them were tested for free radical scavenging activities by DPPH radical, superoxide radical, and ORAC assays. Chrysotoxine and gigantol exhibited DPPH radical inhibitory effect which is significantly stronger than that of Trolox. In the superoxide radical and ORAC assays, 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl, chrysotoxine, gigantol, and moscatilin showed superior activities than Trolox. These findings would fulfill the phytochemical study of *Dendrobium* and support further research of 4,5-dihydroxy-3,3',4'-trimethoxybibenzyl, chrysotoxine, gigantol, and moscatilin for clinical invention.

REFERENCES

- Al-Temimi, A. (2013). Determination of antioxidant activity in different kinds of plants *in vivo* and *in vitro* by using diverse technical methods. Journal of Nutrition and Food Sciences 3(1), 1-6.
- Alam, M. N., Bristi, N. J. and Rafiquzzaman, M. (2013). Review on *in vivo* and *in vitro* methods evaluation of antioxidant activity. Saudi Pharmaceutical Journal 21(2), 143-52.
- Allothman, M., Bhat, R. and Karim, A. A. (2009). Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. Food Chemistry 115(3), 785-788.
- Anandjiwala, S., Bagul, M. S., Parabia, M. and Rajani, M. (2008). Evaluation of free radical scavenging activity of an ayurvedic formulation, Panchvalkala. Indian Journal of Pharmaceutical Sciences 70(1), 31-35.
- Antolovich, M., Prenzler, P. D., Patsalides, E., McDonald, S. and Robards, K. (2002). Methods for testing antioxidant activity. The Analyst 127(1), 183-198.
- Bagul, M. S., Ravishankara, M. N., Padh, H. and Rajani, M. (2003). Phytochemical evaluation and free radical scavenging properties of rhizome of *Bergenia ciliata* (Haw.) Sternb. forma *ligulata* Yeo. Journal of Natural Remedies 3, 83-89.
- Beauchamp, C. and Fridovich, I. (1971). Superoxide dismutase: improved assays and an assay applicable to acrylamide gels. Analytical Biochemistry 44(1), 276-287.
- Bi, Z. M., Wang, Z. T. and Xu, L. S. (2004). Chemical constituents of *Dendrobium moniliforme*. Acta Botanica Sinica 46(1), 124-126.
- Boudjada, A., Touil, A., Bensouici, C., Bendif, H. and Rhouati, S. (2019). Phenanthrene and dihydrophenanthrene derivatives from *Dioscorea communis* with anticholinesterase, and antioxidant activities. Natural Product Research 33(22), 3278-3282.
- Brahmkshatriya, P. P. and Brahmkshatriya, P. S. (2013). Terpenes: chemistry, biological role, and therapeutic applications. In: Ramawat, K. G. and Merillon, J. M. (eds.)

- Natural products: phytochemistry, botany and metabolism of alkaloids, phenolics and terpenes. Heidelberg: Springer, 2665-2691
- Cai, J., Yang, C., Chen, T. and Zhao, L. (2018). Detection of new phenylpropanoids from *Dendrobium chrysanthum*. Natural Product Research 32(13), 1600-1604.
- Cakova, V., Bonte, F. and Lobstein, A. (2017). *Dendrobium*: sources of active ingredients to treat age-related pathologies. Aging and Disease 8(6), 827-849.
- Cao, G. and Prior, R. L. (1999). Measurement of oxygen radical absorbance capacity in biological samples. Methods in Enzymology 299, 50-62.
- Chang, C. C., Ku, A. F., Tseng, Y. Y., Yang, W. B., Fang, J. M. and Wong, C. H. (2010). 6,8-di-C-glycosyl flavonoids from *Dendrobium huoshanense*. Journal of Natural Products 73(2), 229-232.
- Chang, S. J., Lin, T. H. and Chen, C. C. (2001). Constituents from the stems of *Dendrobium clavatum* var. *aurantiacum*. Journal of Chinese Medicine 12(3), 211-218.
- Chanvorachote, P., Kowitdamrong, A., Ruanghirun, T., Sritularak, B., Mungmee, C. and Likhitwitayawuid, K. (2013). Anti-metastatic activities of bibenzyls from *Dendrobium pulchellum*. Natural Product Communications 8, 115-118.
- Chen, C. C., Wu, L. G., Ko, F. N. and Teng, C. M. (1994). Antiplatelet aggregation principles of *Dendrobium loddigesii*. Journal of Natural Products 57(9), 1271-1274.
- Chen, J. H. and Ho, C.-T. (1997). Antioxidant activities of caffeic acid and its related hydroxycinnamic acid compounds. Journal of Agricultural and Food Chemistry 45(7), 2374-2378.
- Chen, X. J., Mei, W. L., Cai, C. H., Guo, Z. K., Song, X. Q. and Dai, H. F. (2014). Four new bibenzyl derivatives from *Dendrobium sinense*. Phytochemistry Letters 9, 107-112.
- Chen, X. J., Mei, W. L., Zuo, W. J., Zeng, Y. B., Guo, Z. K., Song, X. Q. and Dai, H. F. (2013). A new antibacterial phenanthrenequinone from *Dendrobium sinense*. Journal of Asian Natural Products Research 15(1), 67-70.
- Chen, Y., Li, J., Wang, L. and Liu, Y. (2008a). Aromatic compounds from *Dendrobium aphyllum*. Biochemical Systematics and Ecology 36(5), 458-460.

- Chen, Y., Liu, Y., Jiang, J., Zhang, Y. and Yin, B. (2008b). Dendronone, a new phenanthrenequinone from *Dendrobium cariniferum*. Food Chemistry 111(1), 11-12.
- Chen, Y. G., Yu, H. and Liu, Y. (2014). Chemical constituents from *Dendrobium brymerianum* Rchb. f. Biochemical Systematics and Ecology 57, 175-177.
- Cheng, J., Dang, P. P., Zhao, Z., Yuan, L. C., Zhou, Z. H., Wolf, D. and Luo, Y. B. (2019). An assessment of the Chinese medicinal *Dendrobium* industry: supply, demand and sustainability. Journal of Ethnopharmacology 229, 81-88.
- Dahmen, J. and Leander, K. (1978). Amotin and amoenin, two sesquiterpenes of the picrotoxane group from *Dendrobium amoenum*. Phytochemistry 17(11), 1949-1952.
- Dewick, P. M. (2009). The shikimate pathway: aromatic amino acids and phenylpropanoids. In: Dewick, P. M. (ed.) *Medicinal natural products: a biosynthetic approach*. 3rd ed. New Jersey: John Wiley and Sons, Ltd., 137-186
- Fan, C., Wang, W., Wang, Y., Qin, G. and Zhao, W. (2001). Chemical constituents from *Dendrobium densiflorum*. Phytochemistry 57(8), 1255-1258.
- Fan, W. W., Xu, F. Q., Dong, F. W., Li, X. N., Li, Y., Liu, Y. Q., Zhou, J. and Hu, J. M. (2013). Dendrowardol C, a novel sesquiterpenoid from *Dendrobium wardianum* Warner. Natural Products and Bioprospecting 3(3), 89-92.
- Gawell, L. and Leander, K. (1976). The constitution of aduncin, a sesquiterpene related to picrotoxinin, found in *Dendrobium aduncum*. Phytochemistry 15(12), 1991-1992.
- Halliwell, B. (2006). Reactive species and antioxidants. redox biology is a fundamental theme of aerobic life. Journal of Plant Physiology 141(2), 312-322.
- Halliwell, B. (2011). Free radicals and antioxidants - quo vadis? Trends in Pharmacological Sciences 32(3), 125-130.
- Halliwell, B. (2012). Free radicals and antioxidants: updating a personal view. Nutrition Reviews 70(5), 257-265.
- Hemscheidt, T. and Spenser, I. D. (1991). Biosynthesis of anosmine, an imidazole alkaloid of the orchid *Dendrobium parishii*. Journal of the Chemical Society (7), 494-497.

- Honda, C. and Yamaki, M. (2000). Phenanthrenes from *Dendrobium plicatile*. Phytochemistry 53(8), 987-990.
- Hou, B., Luo, J., Zhang, Y., Niu, Z., Xue, Q. and Ding, X. (2017). Iteration expansion and regional evolution: phylogeography of *Dendrobium officinale* and four related taxa in southern China. Scientific Reports 7, 43525.
- Hu, J. M., Chen, J. J., Yu, H., Zhao, Y. X. and Zhou, J. (2008a). Five new compounds from *Dendrobium longicornu*. Planta Medica 74(5), 535-539.
- Hu, J. M., Chen, J. J., Yu, H., Zhao, Y. X. and Zhou, J. (2008b). Two novel bibenzyls from *Dendrobium trigonopus*. Journal of Asian Natural Products Research 10(7), 647-651.
- Hu, J. M., Fan, W. W., Dong, F. W., Miao, Z. H. and Zhou, J. (2012). Chemical components of *Dendrobium chrysotoxum*. Chinese Journal of Chemistry 30(6), 1327-1330.
- Hu, J. M., Zhao, Y. X., Miao, Z. H. and Zhou, J. (2009). Chemical components of *Dendrobium polyanthum*. Bulletin of the Korean Chemical Society 30(9), 2098-2100.
- Huang, D., Ou, B., Hampsch-Woodill, M., Flanagan, J. A. and Prior, R. L. (2002). High-throughput assay of oxygen radical absorbance capacity (ORAC) using a multichannel liquid handling system coupled with a microplate fluorescence reader in 96-well format. Journal of Agricultural and Food Chemistry 50(16), 4437-4444.
- Hwang, J. S., Lee, S. A., Hong, S. S., Han, X. H., Lee, C., Kang, S. J., Lee, D., Kim, Y., Hong, J. T., Lee, M. K. and Hwang, B. Y. (2010). Phenanthrenes from *Dendrobium nobile* and their inhibition of the LPS-induced production of nitric oxide in macrophage RAW 264.7 cells. Bioorganic and Medicinal Chemistry Letters 20(12), 3785-3787.
- Inthongkaew, P., Chatsumpun, N., Supasuteekul, C., Kitisripanya, T., Putalun, W., Likhitwitayawuid, K. and Sritularak, B. (2017). α -Glucosidase and pancreatic lipase inhibitory activities and glucose uptake stimulatory effect of phenolic

- compounds from *Dendrobium formosum*. Revista Brasileira de Farmacognosia 27(4), 480-487.
- Ito, M., Matsuzaki, K., Wang, J., Daikonya, A., Wang, N. L., Yao, X. S. and Kitanaka, S. (2010). New phenanthrenes and stilbenes from *Dendrobium loddigesii*. Chemical and Pharmaceutical Bulletin 58(5), 628-633.
- Jain, N. and Ramawat, K. G. (2013). Nutraceuticals and antioxidants in prevention of diseases. In: Ramawat, K. G. and Merillon, J. M. (eds.) Natural products. Heidelberg: Springer, 2559-2580
- Kim, E., Lee, W., Cho, S. S., Shim, J. H., Kim, S. N., Kim, H. J. and Yoon, G. (2018). Inhibitory effect of phenanthrenes and dihydrostilbenes from *Dendrobium moniliforme* on protein tyrosine phosphatase 1B. Bulletin of the Korean Chemical Society 39(12), 1467-1470.
- Kim, J. H., Oh, S. Y., Han, S. B., Uddin, G. M., Kim, C. Y. and Lee, J. K. (2015). Anti-inflammatory effects of *Dendrobium nobile* derived phenanthrenes in LPS-stimulated murine macrophages. Archives of Pharmacal Research 38(6), 1117-1126.
- Klongkumnuankarn, P., Busaranon, K., Chanvorachote, P., Sritularak, B., Jongbunprasert, V. and Likhitwitayawuid, K. (2015). Cytotoxic and antimigratory activities of phenolic compounds from *Dendrobium brymerianum*. Evidence-based Complementary and Alternative Medicine 2015, 1-9.
- Kongkatitham, V., Muangnoi, C., Kyokong, N., Thaweeseest, W., Likhitwitayawuid, K., Rojsitthisak, P. and Sritularak, B. (2018). Anti-oxidant and anti-inflammatory effects of new bibenzyl derivatives from *Dendrobium parishii* in hydrogen peroxide and lipopolysaccharide treated RAW264.7 cells. Phytochemistry Letters 24, 31-38.
- Kontoghiorghes, G. J. and Kontoghiorghes, C. N. (2019). Prospects for the introduction of targeted antioxidant drugs for the prevention and treatment of diseases related to free radical pathology. Expert Opinion on Investigational Drugs 28(7), 593-603.
- Kowitdamrong, A., Chanvorachote, P., Sritularak, B. and Pongrakhananon, V. (2013). Moscatilin inhibits lung cancer cell motility and invasion via suppression of

- endogenous reactive oxygen species. BioMed Research International 2013, 765894
- Kyokong, N., Muangnoi, C., Thaweesest, W., Kongkatitham, V., Likhitwitayawuid, K., Rojsitthisak, P. and Sritularak, B. (2019). A new phenanthrene dimer from *Dendrobium palpebrae*. Journal of Asian Natural Products Research 21(4), 391-397.
- Lam, Y., Ng, T. B., Yao, R. M., Shi, J., Xu, K., Sze, S. C. and Zhang, K. Y. (2015). Evaluation of chemical constituents and important mechanism of pharmacological biology in *Dendrobium* plants. Evidence-based Complementary and Alternative Medicine 2015, 841752.
- Li, C. B., Wang, C., Fan, W. W., Dong, F. W., Xu, F. Q., Wan, Q. L., Luo, H. R., Liu, Y. Q., Hu, J. M. and Zhou, J. (2013). Chemical components of *Dendrobium crepidatum* and their neurite outgrowth enhancing activities. Natural Products and Bioprospecting 3(2), 70-73.
- Li, J. T., Yin, B. L., Liu, Y., Wang, L. Q. and Chen, Y. G. (2009a). Mono-aromatic constituents of *Dendrobium longicornu*. Chemistry of Natural Compounds 45(2), 234-236.
- Li, X. H., Guo, L., Yang, L., Peng, C., He, C. J., Zhou, Q. M., Xiong, L., Liu, J. and Zhang, T. M. (2014a). Three new neolignan glucosides from the stems of *Dendrobium aurantiacum* var. *denneanum*. Phytochemistry Letters 937-940.
- Li, Y., Wang, C. L., Guo, S. X., Yang, J. S. and Xiao, P. G. (2008). Two new compounds from *Dendrobium candidum*. Chemical and Pharmaceutical Bulletin 56(10), 1477-1479.
- Li, Y., Wang, C. L., Wang, Y. J., Guo, S. X., Yang, J. S., Chen, X. M. and Xiao, P. G. (2009b). Three new bibenzyl derivatives from *Dendrobium candidum*. Chemical and Pharmaceutical Bulletin (Tokyo) 57(2), 218-219.
- Li, Y., Wang, C. L., Wang, Y. J., Wang, F. F., Guo, S. X., Yang, J. S. and Xiao, P. G. (2009c). Four new bibenzyl derivatives from *Dendrobium candidum*. Chemical and Pharmaceutical Bulletin (Tokyo) 57(9), 997-999.

- Li, Y., Wang, C. L., Zhao, H. J. and Guo, S. X. (2014b). Eight new bibenzyl derivatives from *Dendrobium candidum*. Journal of Asian Natural Products Research 16(11), 1035-1043.
- Li, Y. P., Qing, C., Fang, T. T., Liu, Y. and Chen, Y. G. (2009d). Chemical constituents of *Dendrobium chrysotoxum*. Chemistry of Natural Compounds 45(3), 414-416.
- Limpanit, R., Chuanasa, T., Likhitwitayawuid, K., Jongbunprasert, V. and Sritularak, B. (2016). α -Glucosidase inhibitors from *Dendrobium tortile*. Records of Natural Products 10(5), 609-616.
- Lin, T. H., Chang, S. J., Chen, C. C., Wang, J. P. and Tsao, L. T. (2001). Two phenanthraquinones from *Dendrobium moniliforme*. Journal of Natural Products 64(8), 1084-1086.
- Litescu, S. C., Eremia, S. V., Tache, A., Vasilescu, I. and Radu, G. L. (2014). The use of oxygen radical absorbance capacity (ORAC) and Trolox equivalent antioxidant capacity (TEAC) assays in the assessment of beverages' antioxidant properties. In: Preedy, V. R. (ed.) Processing and impact on antioxidants in beverages. 1st ed. Massachusetts: Academic Press.
- Liu, Y., Jiang, J. H., Yin, B. L. and Chen, Y. G. (2009a). Chemical constituents of *Dendrobium cariniferum*. Chemistry of Natural Compounds 45(2), 237-238.
- Liu, Y., Jiang, J. H., Zhang, Y. and Chen, Y. G. (2009b). Chemical constituents of *Dendrobium aurantiacum* var. *denneanum*. Chemistry of Natural Compounds 45(4), 525-527.
- Lu, Y., Kuang, M., Hu, G. P., Wu, R. B., Wang, J., Liu, L. and Lin, Y. C. (2014). Loddigesiinols G-J: α -glucosidase inhibitors from *Dendrobium loddigesii*. Molecules 19(6), 8544-8555.
- Ma, C., Meng, C. W., Zhou, Q. M., Peng, C., Liu, F., Zhang, J. W., Zhou, F. and Xiong, L. (2019a). New sesquiterpenoids from the stems of *Dendrobium nobile* and their neuroprotective activities. Fitoterapia 138, 104351.
- Ma, G. X., Wang, T. S., Yin, L., Pan, Y., Xu, G. J. and Xu, L. S. (1998). Studies on chemical constituents of *Dendrobium chryseum*. Journal of Chinese Pharmaceutical Sciences 7(1), 52-54.

- Ma, R. J., Yang, L., Bai, X., Li, J. Y., Yuan, M. Y., Wang, Y. Q., Xie, Y., Hu, J. M. and Zhou, J. (2019b). Phenolic constituents with antioxidative, tyrosinase inhibitory and anti-aging activities from *Dendrobium loddigesii* Rolfe. Natural Products and Bioprospecting 9(5), 329-336.
- Majumder, P. L. and Chatterjee, S. (1989). Crepidatin, a bibenzyl derivative from the orchid *Dendrobium crepidatum*. Phytochemistry 28(7), 1986-1989.
- Majumder, P. L., Guha, S. and Sen, S. (1999). Bibenzyl derivatives from the orchid *Dendrobium amoenum*. Phytochemistry 52(7), 1365-1369.
- Majumder, P. L. and Pal, S. (1992). Rotundatin, a new 9,10-dihydrophenanthrene derivative from *Dendrobium rotundatum*. Phytochemistry 31(9), 3225-3228.
- Majumder, P. L. and Pal, S. (1993). Cumulatin and tristin, two bibenzyl derivatives from the orchids *Dendrobium cumulatum* and *Bulbophyllum triste*. Phytochemistry 32(6), 1561-1565.
- Majumder, P. L. and Sen, R. C. (1987). Moscatilin, a bibenzyl derivative from the orchid *Dendrobium moscatum*. Phytochemistry 26(7), 2121-2124.
- Mittraphab, A., Muangnoi, C., Likhitwitayawuid, K., Rojsitthisak, P. and Sritularak, B. (2016). A new bibenzyl-phenanthrene derivative from *Dendrobium signatum* and its cytotoxic activity. Natural Product Communications 11(5), 657-659.
- Miyazawa, M., Shimamura, H., Nakamura, S., Sugiura, W., Kosaka, H. and Kameoka, H. (1999). Moscatilin from *Dendrobium nobile*, a naturally occurring bibenzyl compound with potential antimutagenic activity. Journal of Agricultural and Food Chemistry 47(5), 2163-2167.
- Na Ranong, S., Likhitwitayawuid, K., Mekboonsonglarp, W. and Sritularak, B. (2019). New dihydrophenanthrenes from *Dendrobium infundibulum*. Natural Product Research 33(3), 420-426.
- Ng, T. B., Liu, J., Wong, J. H., Ye, X., Wing Sze, S. C., Tong, Y. and Zhang, K. Y. (2012). Review of research on *Dendrobium*, a prized folk medicine. Applied Microbiology and Biotechnology 93(5), 1795-1803.
- Office of the Forest Herbarium (2014). Thai plant names Tem Smitinand revised edition. Bangkok: Office of the Forest Herbarium, Department of National Park, Wildlife and Plant Conservation.

- Ono, M., Ito, Y., Masuoka, C., Koga, H. and Nohara, T. (1995). Antioxidative constituents from *Dendrobii* Herba (Stems of *Dendrobium* spp.). Food Science and Technology International 1(2), 115-120.
- Pan, H. M., Chen, B., Li, F. and Wang, M. K. (2012). Chemical constituents of *Dendrobium denneanum*. Chinese Journal of Applied Environmental Biology 18(3), 378-380.
- Pavia, D. L., Lampman, G. M., Kriz, G. S. and Vyvyan, J. R. (2009). Chapter 3 nuclear magnetic resonance spectroscopy part one: basic concepts. In: Pavia, D. L., Lampman, G. M., Kriz, G. S. and Vyvyan, J. R. (eds.) Introduction to spectroscopy. 4th ed. California: Brooks/Cole.
- Phaniendra, A., Jestadi, D. B. and Periyasamy, L. (2015). Free radicals: properties, sources, targets, and their implication in various diseases. Indian Journal of Clinical Biochemistry 30(1), 11-26.
- Phechrmeekha, T., Sritularak, B. and Likhitwitayawuid, K. (2012). New phenolic compounds from *Dendrobium capillipes* and *Dendrobium secundum*. Journal of Asian Natural Products Research 14(8), 748-754.
- Prescott, C. and Bottle, S. E. (2017). Biological relevance of free radicals and nitroxides. Cell Biochemistry and Biophysics 75(2), 227-240.
- Qin, X. D., Qu, Y., Ning, L., Liu, J. K. and Fan, S. K. (2011). A new picrotoxane-type sesquiterpene from *Dendrobium findlayanum*. Journal of Asian Natural Products Research 13(11), 1047-1050.
- Raghavendra, M., Reddy, A. M., Yadav, P. R., Raju, A. S. and Kumar, L. S. (2013). Comparative studies on the *in vitro* antioxidant properties of methanolic leafy extracts from six edible leafy vegetables of India. Asian Journal of Pharmaceutical and Clinical Research 6(3), 96-9.
- Rahimi, B. V., Ghadiri, M., Ramezani, M. and Askari, V. R. (2020). Anti-inflammatory and anti-cancer activities of pomegranate and its constituent, ellagic acid: evidence from cellular, animal, and clinical studies. Phytotherapy Research 34, 685-720.
- Repetto, M., Semprine, J. and Boveris, A. (2012). Lipid peroxidation: chemical mechanism, biological implications and analytical determination. In: Catala, A. (ed.) Lipid peroxidation. Rijeka: InTech, 3-30.

- Rungwichaniwat, P., Sritularak, B. and Likhitwitayawuid, K. (2014). Chemical constituents of *Dendrobium williamsonii*. Pharmacognosy Journal 6(3), 36-41.
- Sarakulwattana, C., Mekboonsonglarp, W., Likhitwitayawuid, K., Rojsitthisak, P. and Sritularak, B. (2018). New bisbibenzyl and phenanthrene derivatives from *Dendrobium scabrilingue* and their alpha-glucosidase inhibitory activity. Natural Product Research 34(12), 1694-1701.
- Shang, Z., Li, X. and Xiao, S. (2020). Two new bibenzyl compounds from *Dendrobium lindleyi*. Records of Natural Products, 1-5.
- Song, J. X., Shaw, P. C., Sze, C. W., Tong, Y., Yao, X. S., Ng, T. B. and Zhang, Y. B. (2010). Chrysotoxine, a novel bibenzyl compound, inhibits 6-hydroxydopamine induced apoptosis in SH-SY5Y cells via mitochondria protection and NF-kappaB modulation. Neurochemistry International 57(6), 676-689.
- Sritularak, B., Anuwat, M. and Likhitwitayawuid, K. (2011). A new phenanthrenequinone from *Dendrobium draconis*. Journal of Asian Natural Products Research 13(3), 251-255.
- Sritularak, B., Duangrak, N. and Likhitwitayawuid, K. (2011). A new bibenzyl from *Dendrobium secundum*. Zeitschrift Fur Naturforschung. C, Journal of Biosciences 66(5-6), 205-208.
- Sritularak, B. and Likhitwitayawuid, K. (2009). New bisbibenzyls from *Dendrobium falconeri*. Helvetica Chimica Acta 92(4), 740-744.
- Sroka, Z. and Cisowski, W. (2003). Hydrogen peroxide scavenging, antioxidant and anti-radical activity of some phenolic acids. Food and Chemical Toxicology 41(6), 753-758.
- Sukphan, P., Sritularak, B., Mekboonsonglarp, W., Lipipun, V. and Likhitwitayawuid, K. (2014). Chemical constituents of *Dendrobium venustum* and their antimalarial and anti-herpetic properties. Natural Product Communications 9(6), 825-827.
- Sun, J., Zhang, F., Yang, M., Zhang, J., Chen, L., Zhan, R., Li, L. and Chen, Y. (2014). Isolation of alpha-glucosidase inhibitors including a new flavonol glycoside from *Dendrobium devonianum*. Natural Product Research 28(21), 1900-1905.

- Talapatra, B., Das, A. K. and Talapatra, S. K. (1989). Defuscin, a new phenolic ester from *Dendrobium fuscescens*: conformation of shikimic acid. Phytochemistry 28(1), 290-292.
- Tanagornmeatar, K., Chaotham, C., Sritularak, B., Likhitwitayawuid, K. and Chanvorachote, P. (2014). Cytotoxic and anti-metastatic activities of phenolic compounds from *Dendrobium ellipsophyllum*. Anticancer Research 34(11), 6573-6580.
- Tang, S. M., Deng, X. T., Zhou, J., Li, Q. P., Ge, X. X. and Miao, L. (2020). Pharmacological basis and new insights of quercetin action in respect to its anti-cancer effects. Biomedicine and Pharmacotherapy 121, 109604.
- The Botanical Garden Organization (2016). *Dendrobium lindleyi* Steud [Online]. Available at: <http://www.qsbg.org/Database/plantdb/herbarium/herbarium-specimen.asp?qsbgno=10033>. (Accessed: 28 Jun 2019)
- Tholl, D. (2015). Biosynthesis and biological functions of terpenoids in plants. In: Schrader, J. and Bohlmann, J. (eds.) *Biotechnology of isoprenoids*. Cham: Springer International Publishing Switzerland, 63–106
- Tsopmo, A., Awah, F. M. and Kuete, V. (2013). Lignans and stilbenes from African medicinal plants. In: Kuete, V. (ed.) *Medicinal plant research in Africa*. London: Elsevier Inc, 435-478.
- Vaddhanaphuti, N. (2005). *A field guide to the wild orchids of Thailand*. Chiang Mai: Silkworm Books.
- Veerraju, P., Rao, N. S. P., Rao, L. J., Rao, K. V. J. and Rao, P. R. M. (1989). Amoenumin, A 9,10-dihydro-5H-phenanthro-(4,5-b,c,d)-pyran from *Dendrobium amoenum*. Phytochemistry 28(3), 950-951.
- Villaño, D., Fernández-Pachón, M. S., Troncoso, A. M. and García-Parrilla, M. C. (2005). Comparison of antioxidant activity of wine phenolic compounds and metabolites *in vitro*. Analytica Chimica Acta 538(1-2), 391-398.
- Wang, H., Zhao, T. and Che, C. T. (1985). Dendrobine and 3-hydroxy-2-oxodendrobine from *Dendrobium nobile*. Journal of Natural Products 48(5), 796-801.

- Wang, L., Zhang, C. F., Wang, Z. T., Zhang, M. and Xu, L. S. (2009). Five new compounds from *Dendrobium crystallinum*. Journal of Asian Natural Products Research 11(11), 903-911.
- Wang, P., Chen, X., Wang, H., Huang, S., Cai, C., Yuan, J., Zhu, G., Xu, X., Mei, W. and Dai, H. (2019). Four new picrotoxane-type sesquiterpenes from *Dendrobium nobile* Lindl. Frontiers in Chemistry 7, 812.
- Wattanathamsan, O., Treesuwan, S., Sritularak, B. and Pongrakhananon, V. (2018). Cypripedin, a phenanthrenequinone from *Dendrobium densiflorum*, sensitizes non-small cell lung cancer H460 cells to cisplatin-mediated apoptosis. Journal of Natural Medicines 72(2), 503-513.
- Wu, L., Lu, Y., Ding, Y., Zhao, J., Xu, H. and Chou, G. (2019). Four new compounds from *Dendrobium devonianum*. Natural Product Research 33(15), 2160-2168.
- Xiong, L., Cao, Z. X., Peng, C., Li, X. H., Xie, X. F., Zhang, T. M., Zhou, Q. M., Yang, L. and Guo, L. (2013). Phenolic glucosides from *Dendrobium aurantiacum* var. *denneanum* and their bioactivities. Molecules 18(6), 6153-6160.
- Xu, F. Q., Xu, F. C., Hou, B., Fan, W. W., Zi, C. T., Li, Y., Dong, F. W., Liu, Y. Q., Sheng, J., Zuo, Z. L. and Hu, J. M. (2014). Cytotoxic bibenzyl dimers from the stems of *Dendrobium fimbriatum* Hook. Bioorganic and Medicinal Chemistry Letters 24(22), 5268-5273.
- Xu, X., Li, Z., Yang, R., Zhou, H., Bai, Y., Yu, M., Ding, G. and Li, B. (2019). Crepidatumines C and D, two new indolizidine alkaloids from *Dendrobium crepidatum* Lindl. ex Paxt. Molecules 24(17), 3071.
- Yamaki, M. and Honda, C. (1996). The stilbenoids from *Dendrobium plicatile*. Phytochemistry 43(1), 207-208.
- Yang, D., Cheng, Z. Q., Zi, C. T., Yang, L., Dong, F. W., Hu, J. M. and Zhou, J. (2019a). Four new sesquiterpene derivatives from *Dendrobium findlayanum*. Chinese Journal of Natural Medicines 17(12), 900-905.
- Yang, D., Cheng, Z. Q., Yang, L., Hou, B., Yang, J., Li, X. N., Zi, C. T., Dong, F. W., Liu, Z. H., Zhou, J., Ding, Z. T. and Hu, J. M. (2018a). Seco-dendrobine-type alkaloids and bioactive phenolics from *Dendrobium findlayanum*. The Natural Products Journal 81(2), 227-235.

- Yang, D., Liu, L. Y., Cheng, Z. Q., Xu, F. Q., Fan, W. W., Zi, C. T., Dong, F. W., Zhou, J., Ding, Z. T. and Hu, J. M. (2015). Five new phenolic compounds from *Dendrobium aphyllum*. Fitoterapia 100, 11-18.
- Yang, H., Chou, G. X., Wang, Z. T., Guo, Y. W., Hu, Z. B. and Xu, L. S. (2004). Two new compounds from *Dendrobium chrysotoxum*. Helvetica Chimica Acta 87(2), 394-399.
- Yang, H. K., Sung, S. H. and Kim, Y. C. (2007). Antifibrotic phenanthrenes of *Dendrobium nobile* stems. Journal of Natural Products 70(12), 1925-1929.
- Yang, L., Han, H., Nakamura, N., Hattori, M., Wang, Z. and Xu, L. (2007). Bio-guided isolation of antioxidants from the stems of *Dendrobium aurantiacum* var. *denneanum*. Phytotherapy Research 21(7), 696-698.
- Yang, L., Qin, L. H., Bligh, S. W., Bashall, A., Zhang, C. F., Zhang, M., Wang, Z. T. and Xu, L. S. (2006a). A new phenanthrene with a spirolactone from *Dendrobium chrysanthum* and its anti-inflammatory activities. Bioorganic and Medicinal Chemistry 14(10), 3496-3501.
- Yang, L., Wang, Z. T. and Xu, L. S. (2006b). Phenols and a triterpene from *Dendrobium aurantiacum* var. *denneanum* (Orchidaceae). Biochemical Systematics and Ecology 34(8), 658-660.
- Yang, M., Chen, L. J., Zhang, Y. and Chen, Y. G. (2019b). Two new picrotoxane-type sesquiterpenoid lactones from *Dendrobium williamsonii*. Journal of Asian Natural Products Research 21(2), 129-133.
- Yang, M., Zhang, Y., Chen, L. and Chen, Y. (2018b). A new (propylphenyl)bibenzyl derivative from *Dendrobium williamsonii*. Natural Product Research 32(14), 1-7.
- Ye, Q. H., Mei, Y., Yang, P. M., Cheng, L. and Kong, D. Y. (2016). A New 9,10-dihydrophenanthrene glycoside from *Dendrobium primulinum*. Chemistry of Natural Compounds 52(3), 381-383.
- Ye, Q. H., Qin, G. W. and Zhao, W. M. (2002). Immunomodulatory sesquiterpene glycosides from *Dendrobium nobile*. Phytochemistry 61(8), 885-890.
- Ye, Q. H. and Zhao, W. M. (2002). New alloaromadendrane, cadinene and cyclocopacamphane type sesquiterpene derivatives and bibenzyls from *Dendrobium nobile*. Planta Medica 68(8), 723-729.

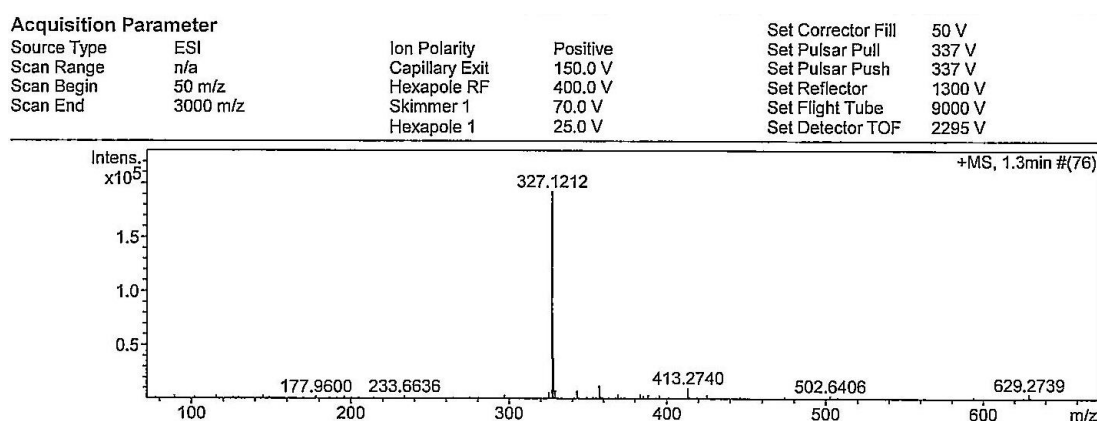
- Ye, Q. H., Zhao, W. M. and Qin, G. W. (2004). Lignans from *Dendrobium chrysanthum*. Journal of Asian Natural Products Research 6(1), 39-43.
- Zhang, C. F., Wang, M., Wang, L., Iinuma, M., Zhang, M., Xu, L. S. and Wang, Z. T. (2008a). Chemical constituents of *Dendrobium gratiosissimum* and their cytotoxic activities. Indian Journal of Chemistry 47B, 952-956.
- Zhang, G. N., Zhong, L. Y., Bligh, S. W., Guo, Y. L., Zhang, C. F., Zhang, M., Wang, Z. T. and Xu, L. S. (2005). Bi-bicyclic and bi-tricyclic compounds from *Dendrobium thyrsiflorum*. Phytochemistry 66(10), 1113-1120.
- Zhang, X., Gao, H., Han, H. Y., Liu, H., Wang, N. L., Yao, X. S. and Wang, Z. (2007a). Sesquiterpenes from *Dendrobium nobile*. Chinese Traditional and Herbal Drugs 38, 1771-1774.
- Zhang, X., Gao, H., Wang, N. L. and Yao, X. S. (2006). Three new bibenzyl derivatives from *Dendrobium nobile*. Journal of Asian Natural Products Research 8(1-2), 113-118.
- Zhang, X., Liu, H. W., Gao, H., Han, H. Y., Wang, N. L., Wu, H. M., Yao, X. S. and Wang, Z. (2007b). Nine New Sesquiterpenes from *Dendrobium nobile*. Helvetica Chimica Acta 90(12), 2386-2394.
- Zhang, X., Tu, F. J., Yu, H. Y., Wang, N. L., Wang, Z. and Yao, X. S. (2008b). Copacamphane, picrotoxane and cyclocopacamphane sesquiterpenes from *Dendrobium nobile*. Chemical and Pharmaceutical Bulletin 56(6), 854-857.
- Zhang, X., Xu, J. K., Wang, J., Wang, N. L., Kurihara, H., Kitanaka, S. and Yao, X. S. (2007c). Bioactive bibenzyl derivatives and fluorenones from *Dendrobium nobile*. The Natural Products Journal 70(1), 24-28.
- Zhang, X., Xu, J. K., Wang, N. L., Kurihara, H. and Yao, X. S. (2008c). Antioxidant phenanthrenes and lignans from *Dendrobium nobile*. Journal of Chinese Pharmaceutical Sciences 17, 314-318.
- Zhang, Y. Y., Wang, P., Song, X. Q., Zuo, W. J., Wang, H., Chen, L. L., Mei, W. L. and Dai, H. F. (2019). Chemical constituents from *Dendrobium hainanense*. Journal of Asian Natural Products Research 21(9), 873-880.
- Zhao, C. S., Liu, Q. F., Halaweish, F., Shao, B. P., Ye, Y. Q. and Zhao, W. M. (2003). Copacamphane, picrotoxane, and alloaromadendrane sesquiterpene glycosides

- and phenolic glycosides from *Dendrobium moniliforme*. Journal of Natural Products 66(8), 1140-1143.
- Zhao, G. Y., Deng, B. W., Zhang, C. Y., Cui, Y. D., Bi, J. Y. and Zhang, G. G. (2018). New phenanthrene and 9,10-dihydrophenanthrene derivatives from the stems of *Dendrobium officinale* with their cytotoxic activities. Journal of Natural Medicines 72(1), 246-251.
- Zhao, N., Yang, G., Zhang, Y., Chen, L. and Chen, Y. (2016). A new 9,10-dihydrophenanthrene from *Dendrobium moniliforme*. Natural Product Research 30(2), 174-179.
- Zhao, W. M., Ye, Q. H., Tan, X. J., Jiang, H. L., Li, X. Y., Chen, K. X. and Kinghorn, A. D. (2001). Three new sesquiterpene glycosides from *Dendrobium nobile* with immunomodulatory activity. Journal of Natural Products 64(9), 1196-1200.
- Zhou, X. M., Zhang, B., Chen, G. Y., Han, C. R., Jiang, K. C., Luo, M. Y., Meng, B. Z., Li, W. X. and Lin, S. D. (2018). Dendrocoumarin: a new benzocoumarin derivative from the stem of *Dendrobium nobile*. Natural Product Research 32(20), 1-4.
- Zhou, X. M., Zheng, C. J., Wu, J. T., Chen, G. Y., Chen, J. and Sun, C. G. (2016). Five new lactone derivatives from the stems of *Dendrobium nobile*. Fitoterapia 115, 96-100.
- Zhou, X. M., Zheng, C. J., Wu, J. T., Chen, G. Y., Zhang, B. and Sun, C. G. (2017). A new phenolic glycoside from the stem of *Dendrobium nobile*. Natural Product Research 31(9), 1042-1046.

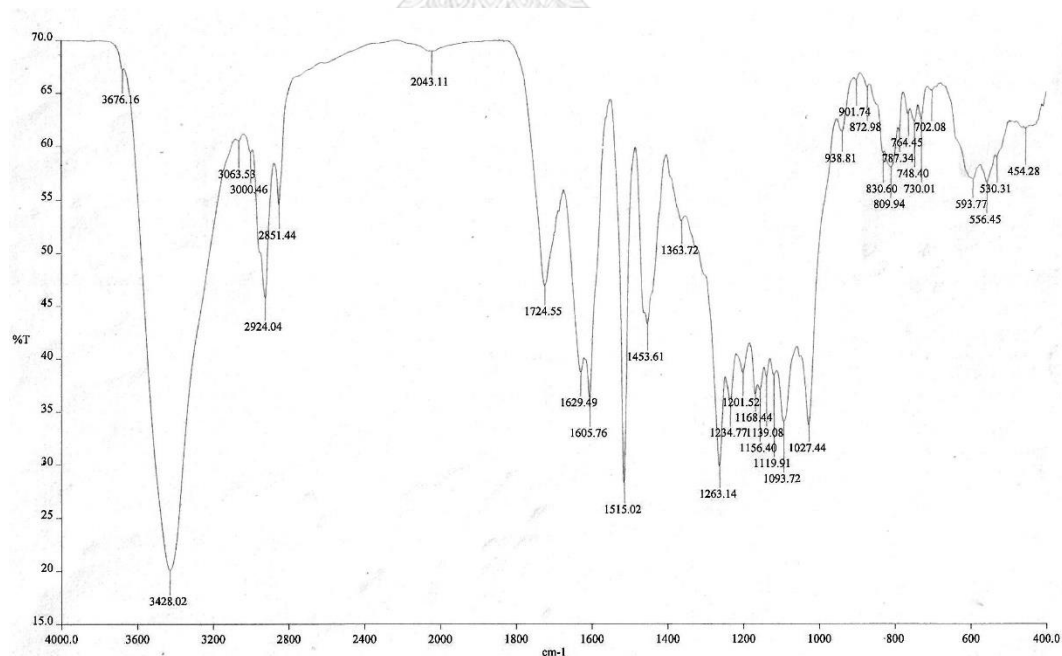
APPENDICES

Appendix A: The spectral data of compound 1

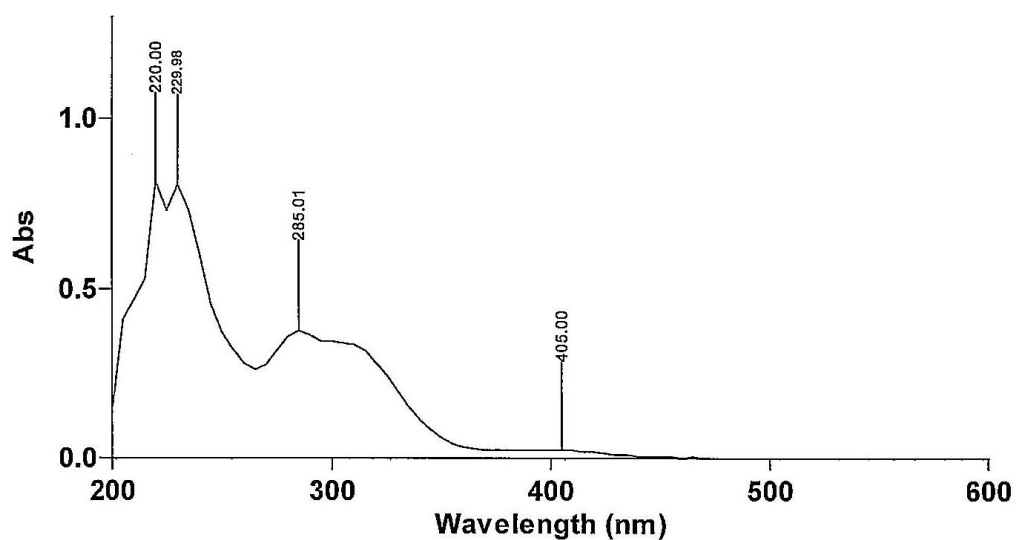
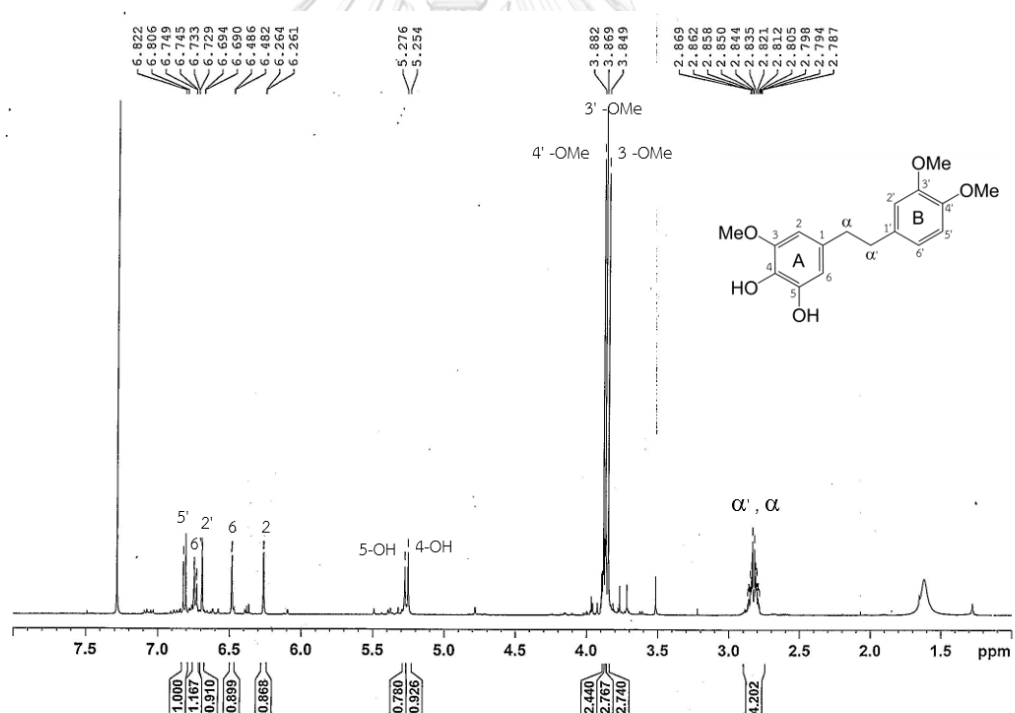
A.1 Mass spectrum of compound 1



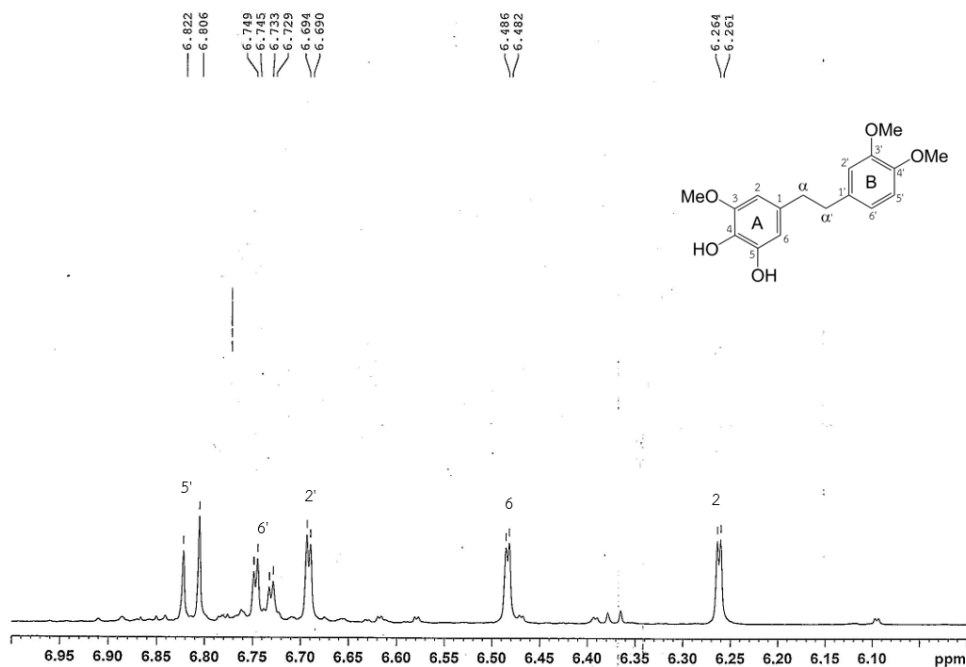
A.2 Infrared spectrum of compound 1



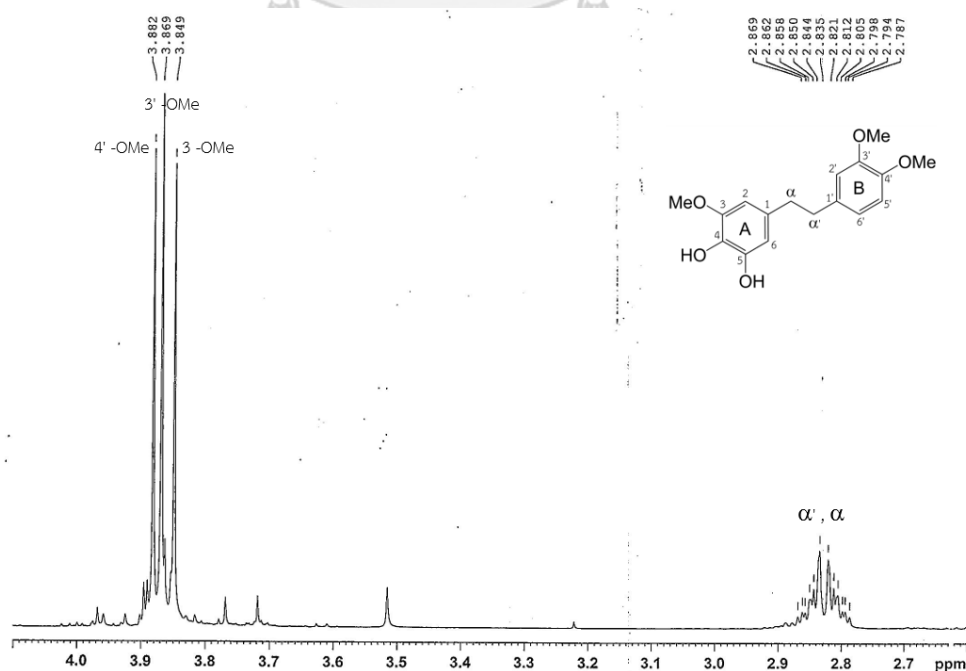
A.3 UV spectrum of compound 1

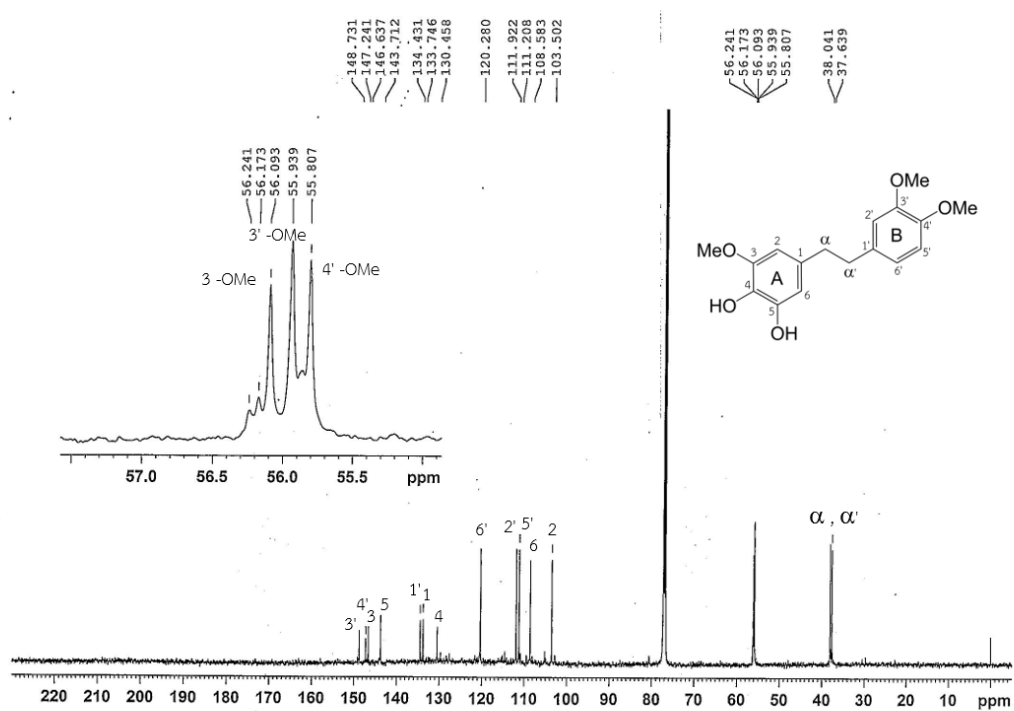
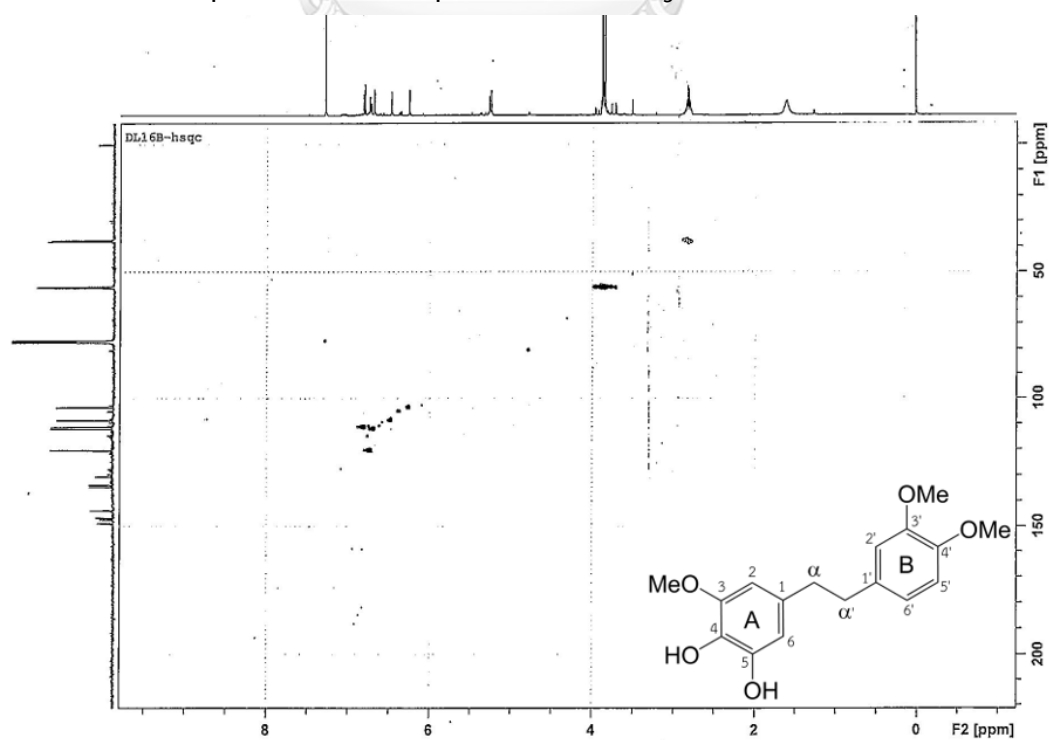
A.4 ^1H NMR (500 MHz) spectrum of compound 1 in CDCl_3 

A.5 ^1H NMR (500 MHz) spectrum of compound 1 in CDCl_3
(expansion from δ_{H} 6.00-7.00)



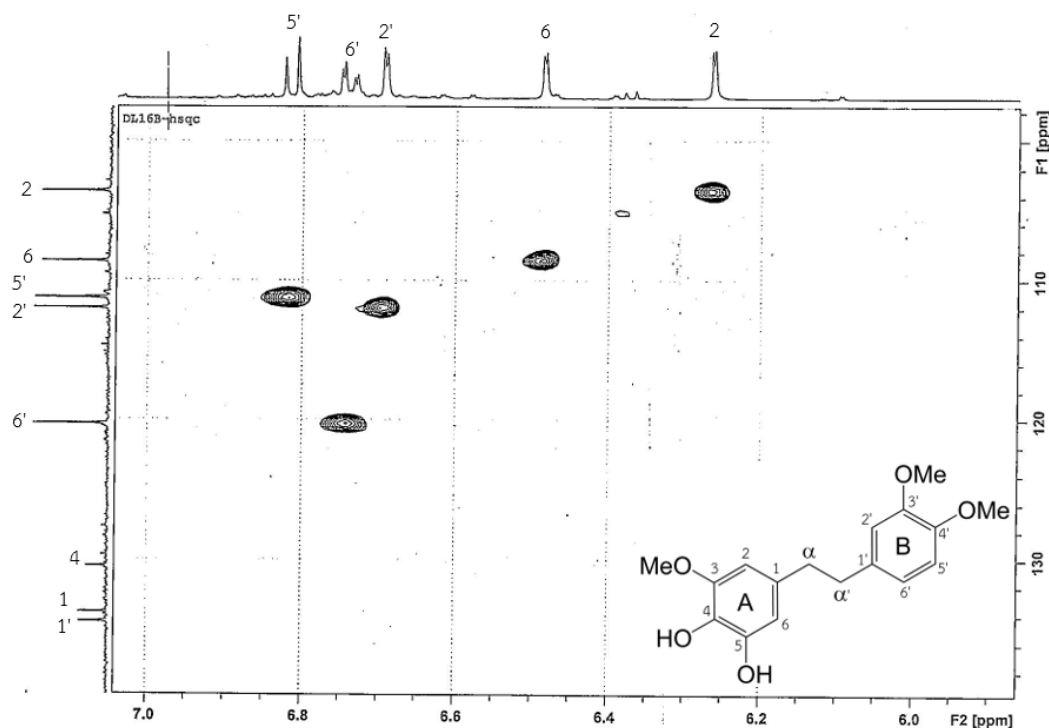
A.6 ^1H NMR (500 MHz) spectrum of compound 1 in CDCl_3
(expansion from δ_{H} 2.60-4.10)



A.7 ^{13}C NMR (125 MHz) spectrum of compound 1 in CDCl_3 A.8 HSQC spectrum of compound 1 in CDCl_3 

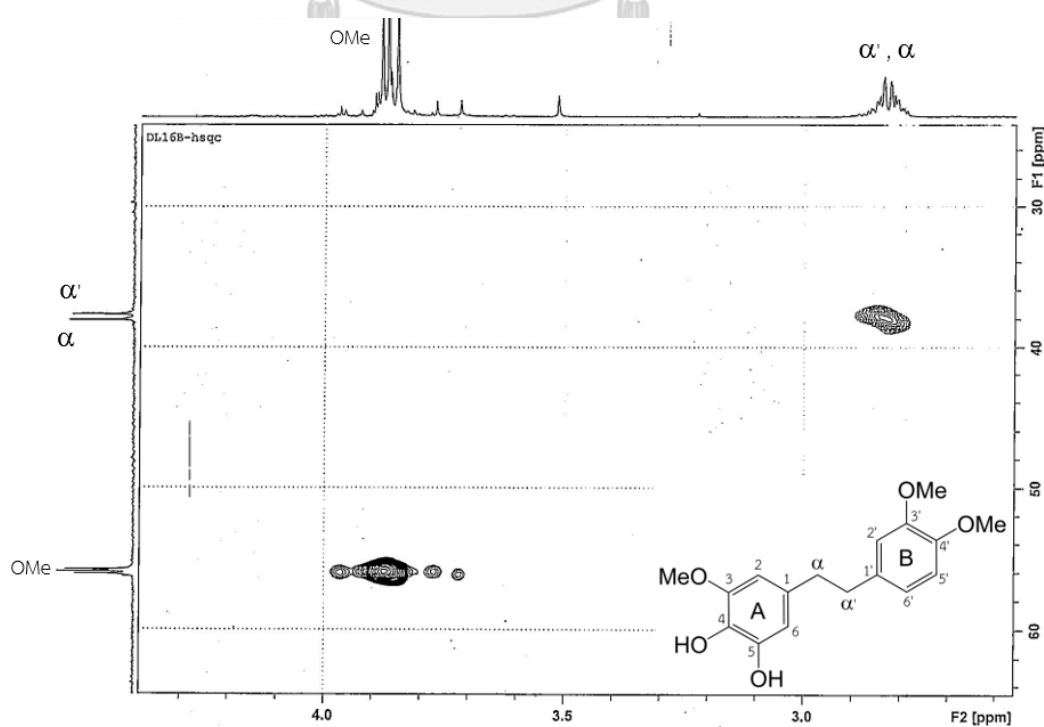
A.9 HSQC spectrum of compound 1 in CDCl_3

(expansion from δ_{C} 98.0-140.0 (F1) and δ_{H} 2.60-3.96 (F2))



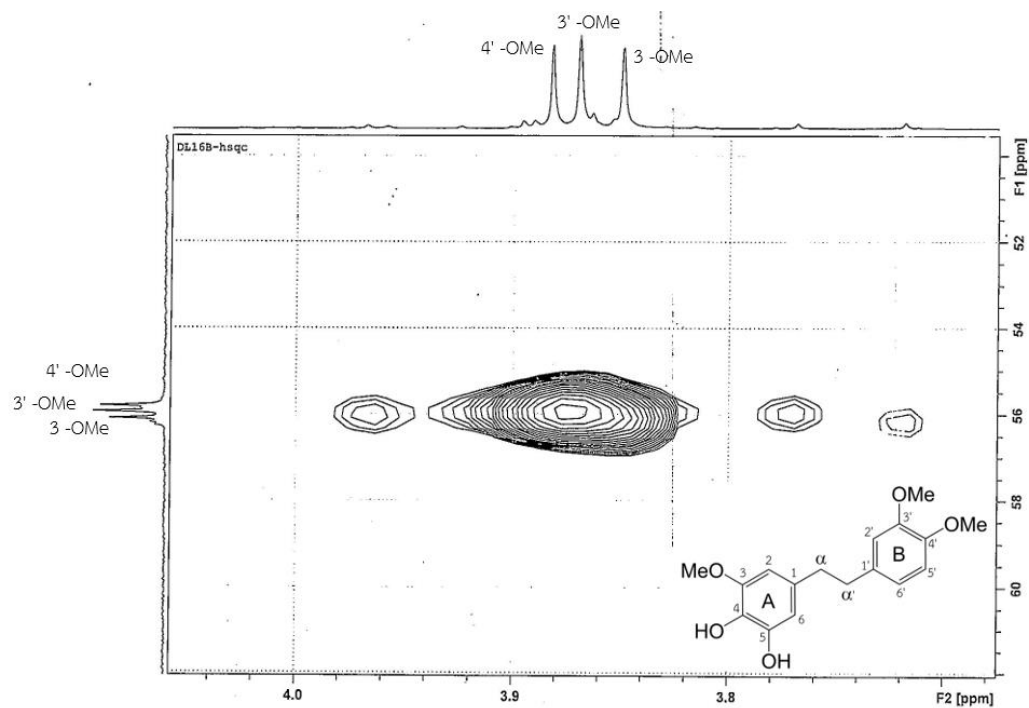
A.10 HSQC spectrum of compound 1 in CDCl_3

(expansion from δ_{C} 24.0-64.0 (F1) and δ_{H} 2.60-4.80 (F2))



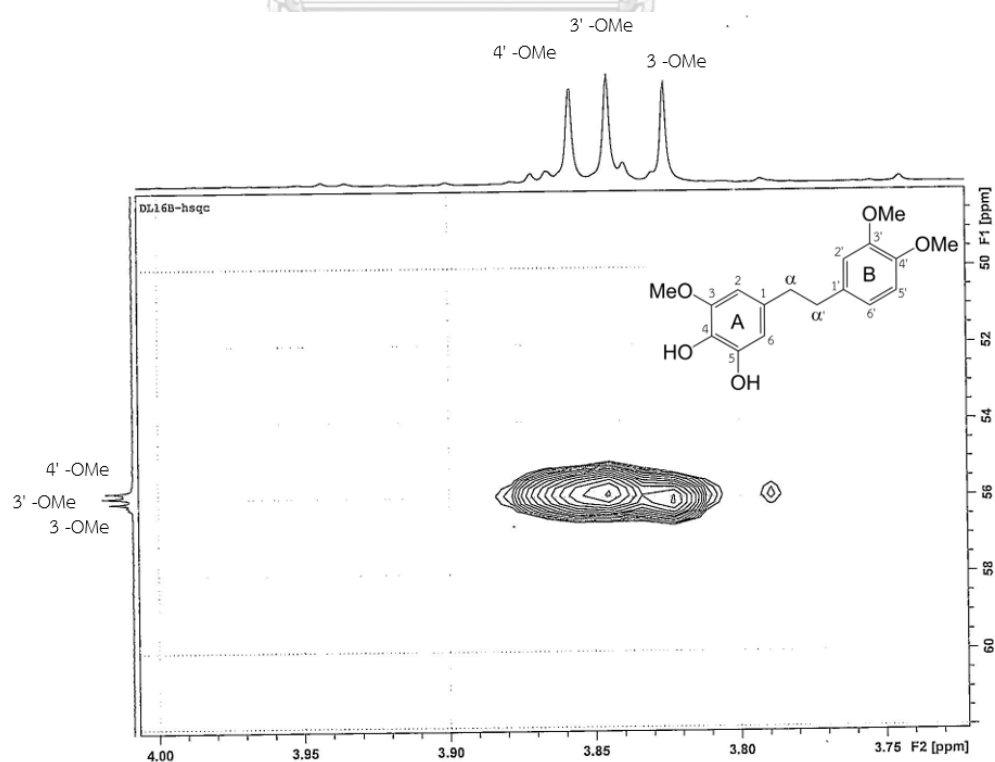
A.11 HSQC spectrum of compound 1 in CDCl_3

(expansion from δ_{C} 50.0-62.0 (F1) and δ_{H} 3.68-4.06 (F2))



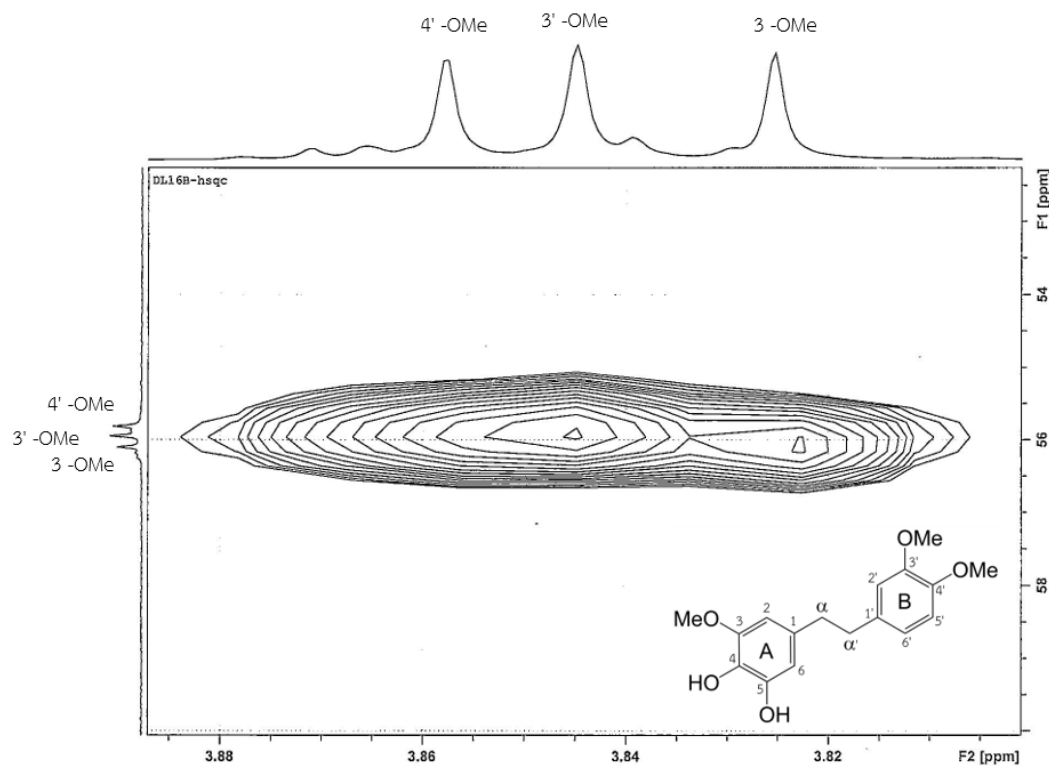
A.12 HSQC spectrum of compound 1 in CDCl_3

(expansion from δ_{C} 48.0-62.0 (F1) and δ_{H} 3.72-4.01 (F2))

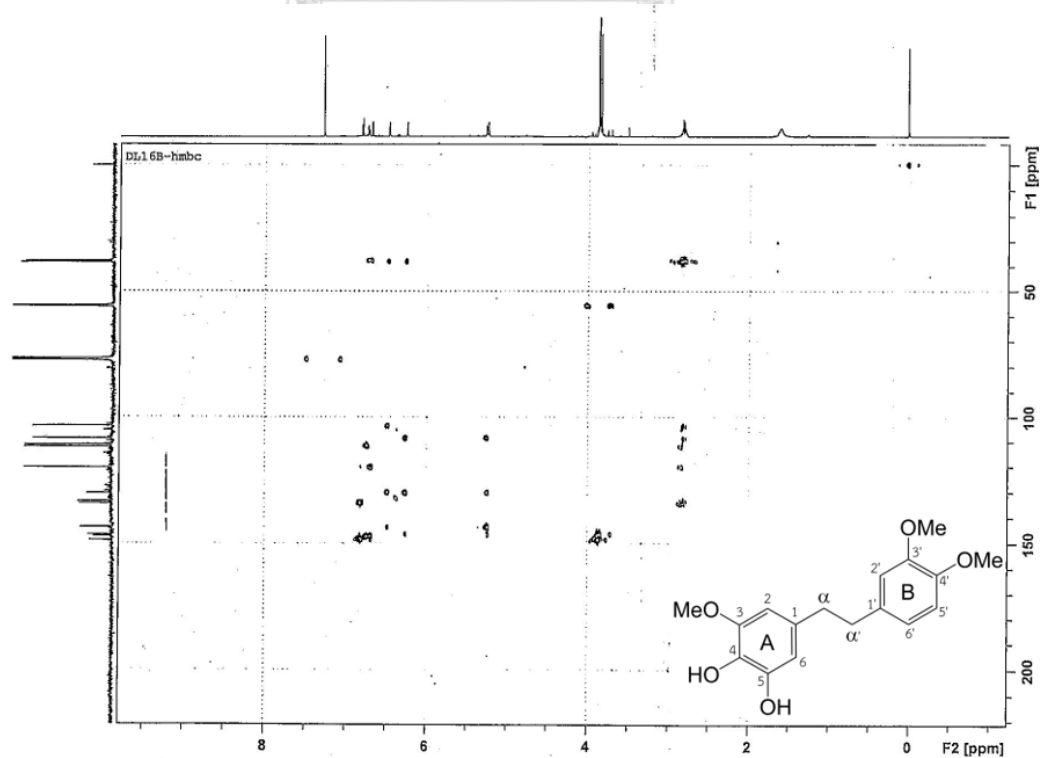


A.13 HSQC spectrum of compound 1 in CDCl₃

(expansion from δ_C 52.5-60.0 (F1) and δ_H 3.80-3.89 (F2))

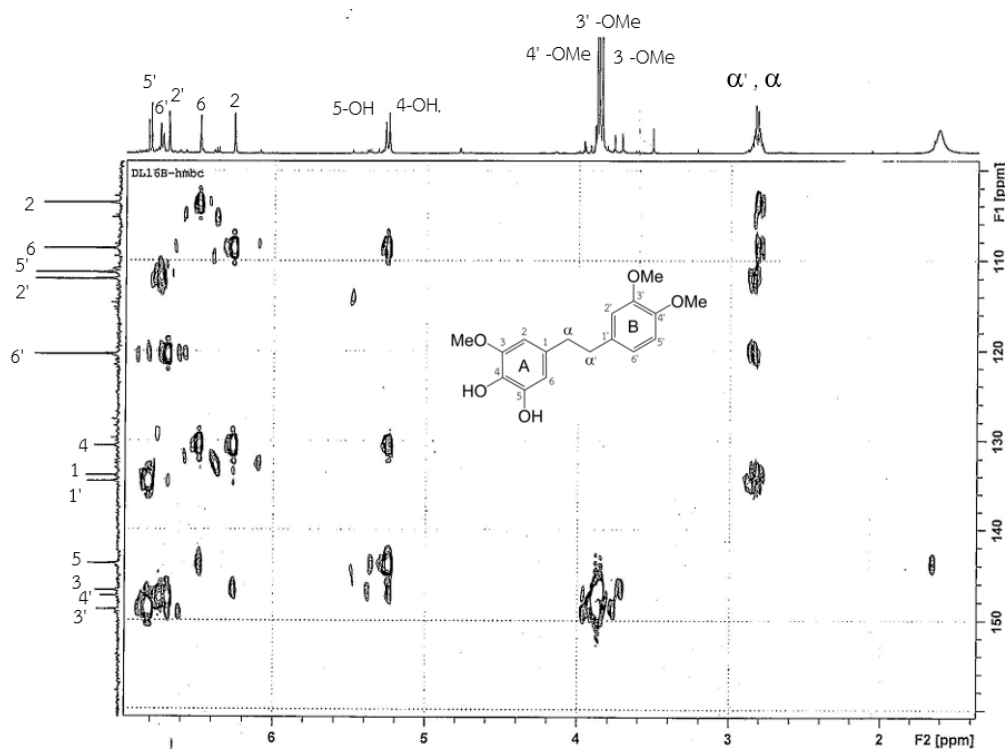


A.14 HMBC spectrum of compound 1 in CDCl₃



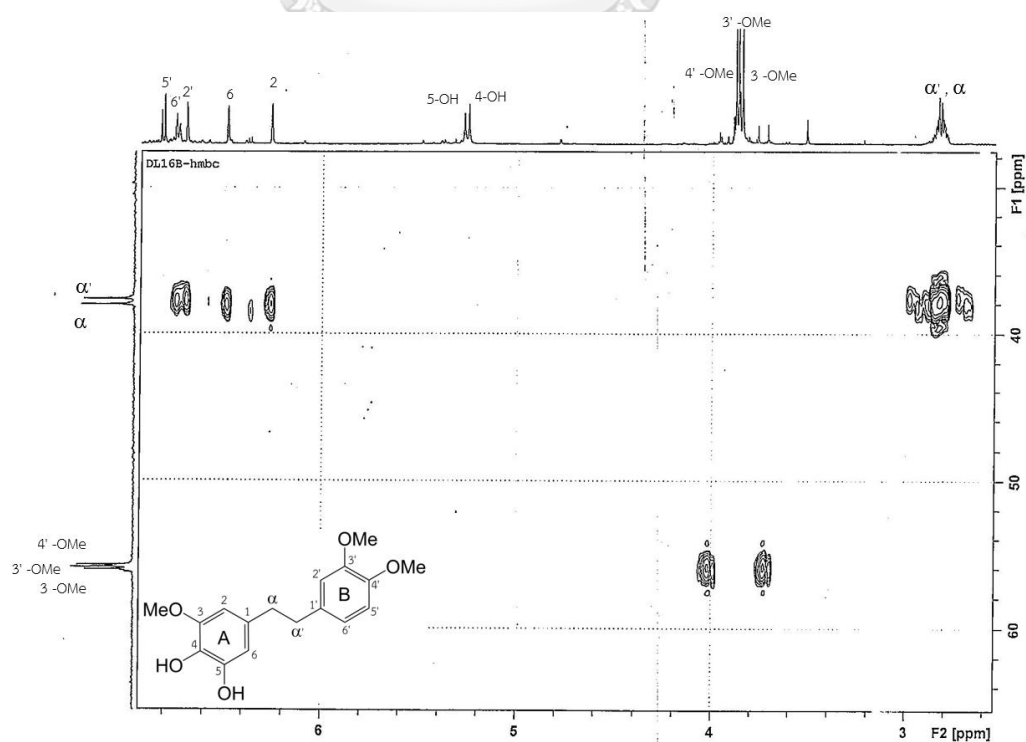
A.15 HMBC spectrum of compound 1 in CDCl_3

(expansion from δ_{C} 100.0-160.0 (F1) and δ_{H} 1.40-7.00 (F2))



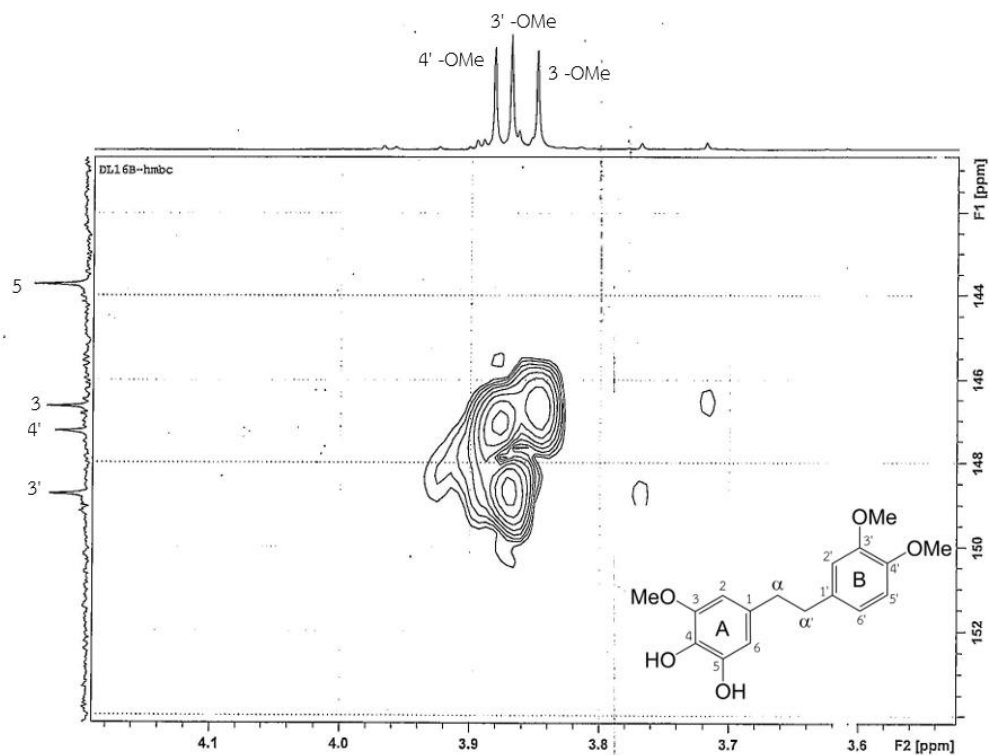
A.16 HMBC spectrum of compound 1 in CDCl_3

(expansion from δ_{C} 28.0-66.0 (F1) and δ_{H} 2.60-6.90 (F2))



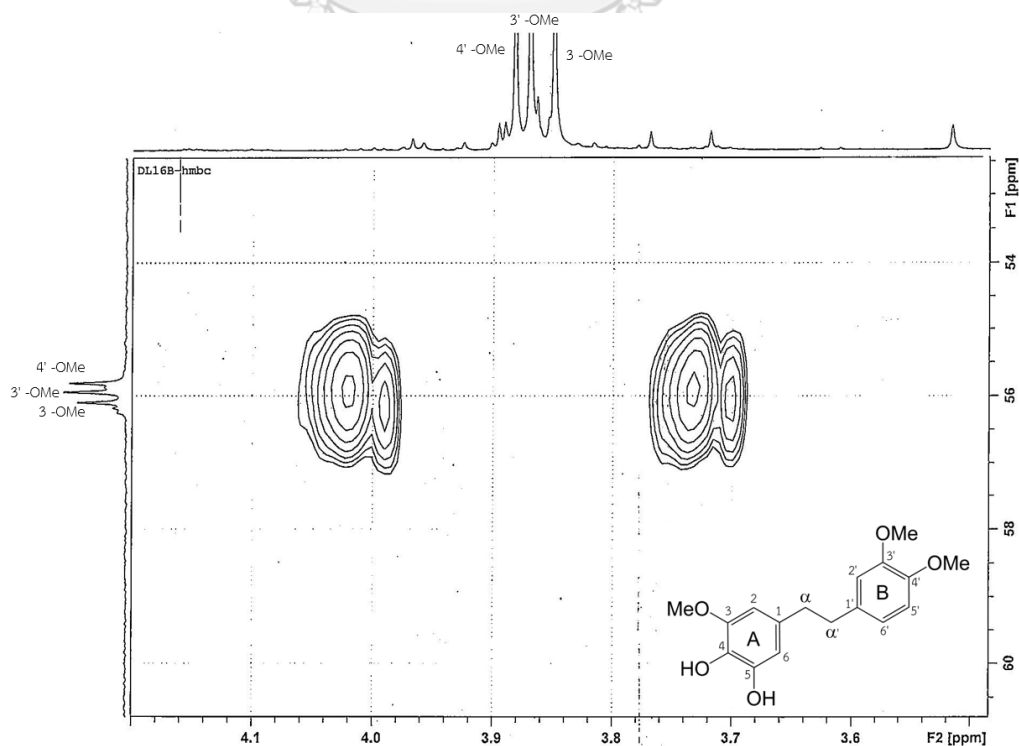
A.17 HMBC spectrum of compound 1 in CDCl_3

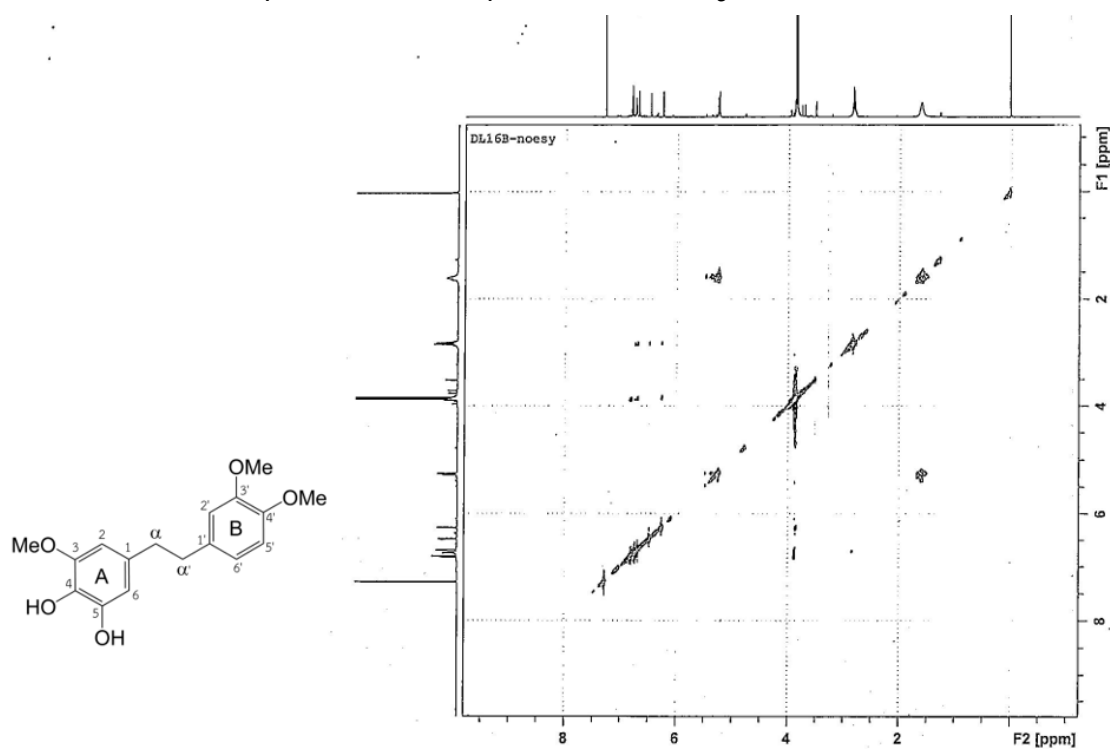
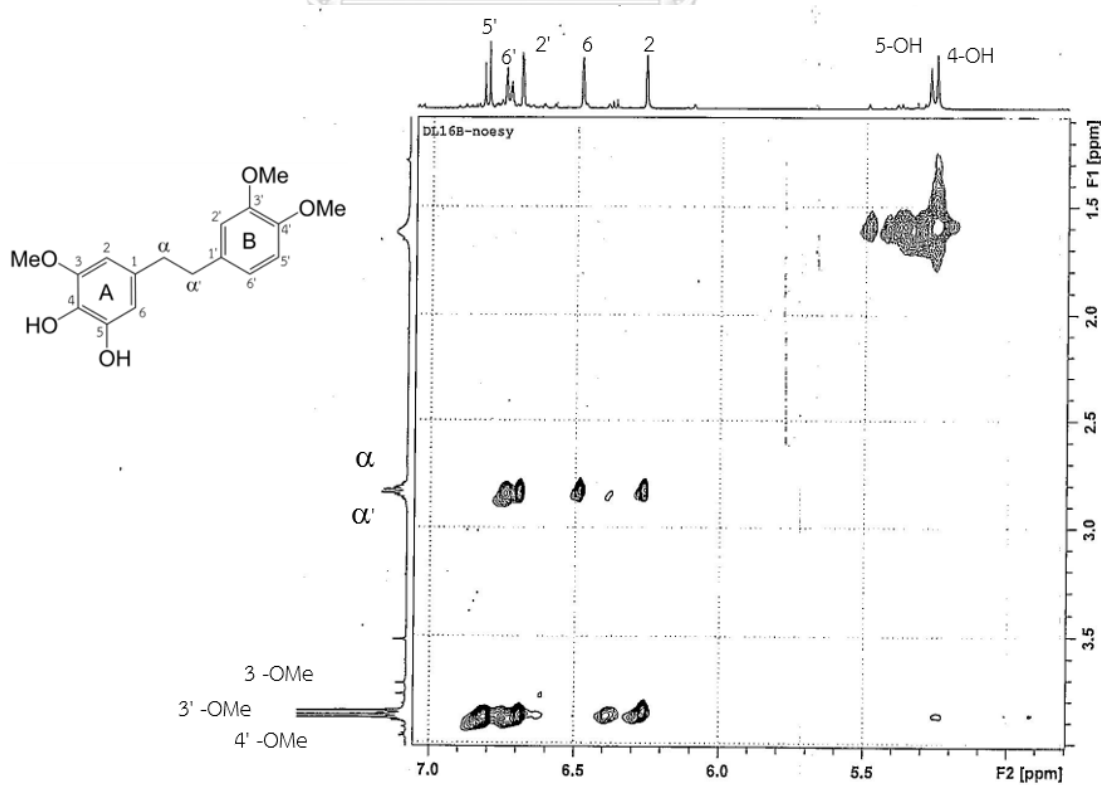
(expansion from δ_{C} 143.0-154.0 (F1) and δ_{H} 3.50-4.20 (F2))



A.18 HMBC spectrum of compound 1 in CDCl_3

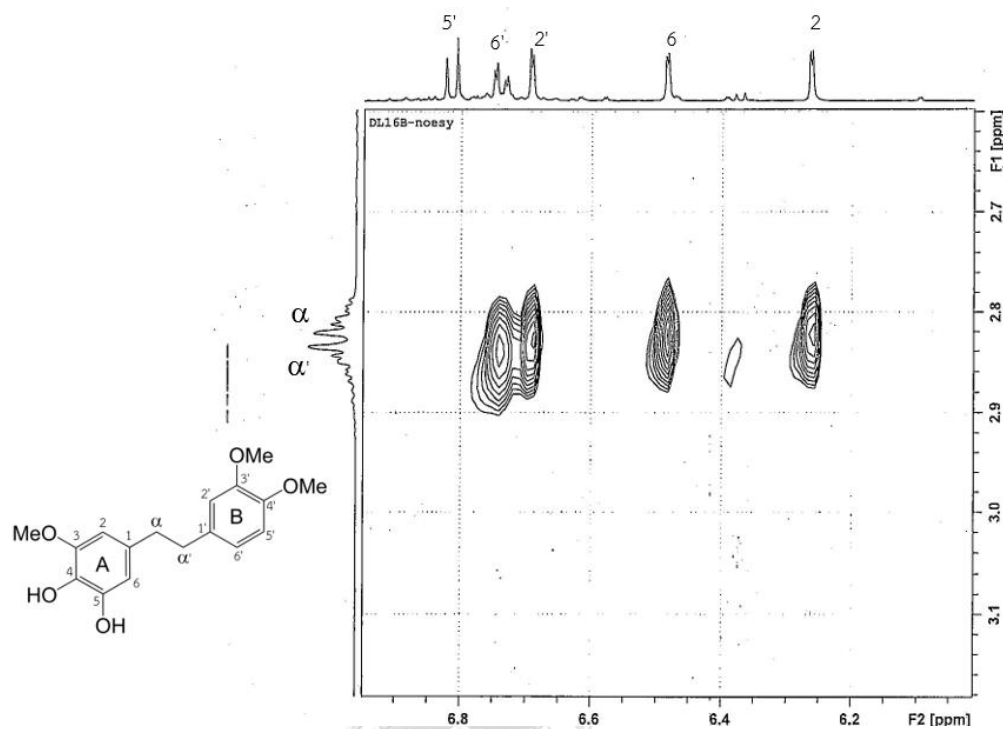
(expansion from δ_{C} 52.5-60.8 (F1) and δ_{H} 3.48-4.20 (F2))



A.19 NOESY spectrum of compound 1 in CDCl_3 A.20 NOESY spectrum of compound 1 in CDCl_3 (expansion from δ_{H} 1.10-4.00 (F1) and δ_{H} 4.80-7.05 (F2))

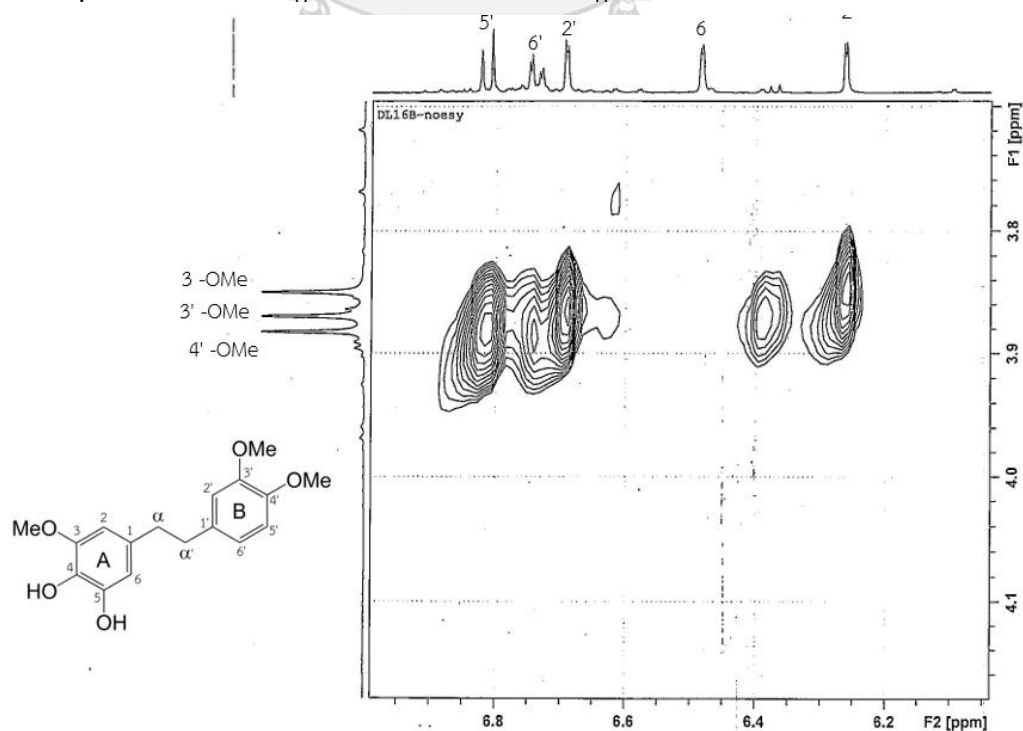
A.21 NOESY spectrum of compound 1 in CDCl_3

(expansion from δ_{H} 2.60-3.18 (F1) and δ_{H} 6.00-6.95 (F2))



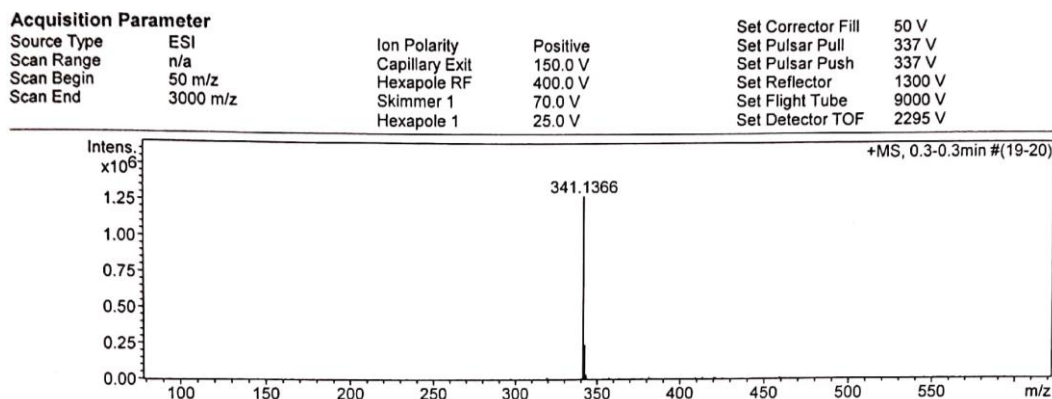
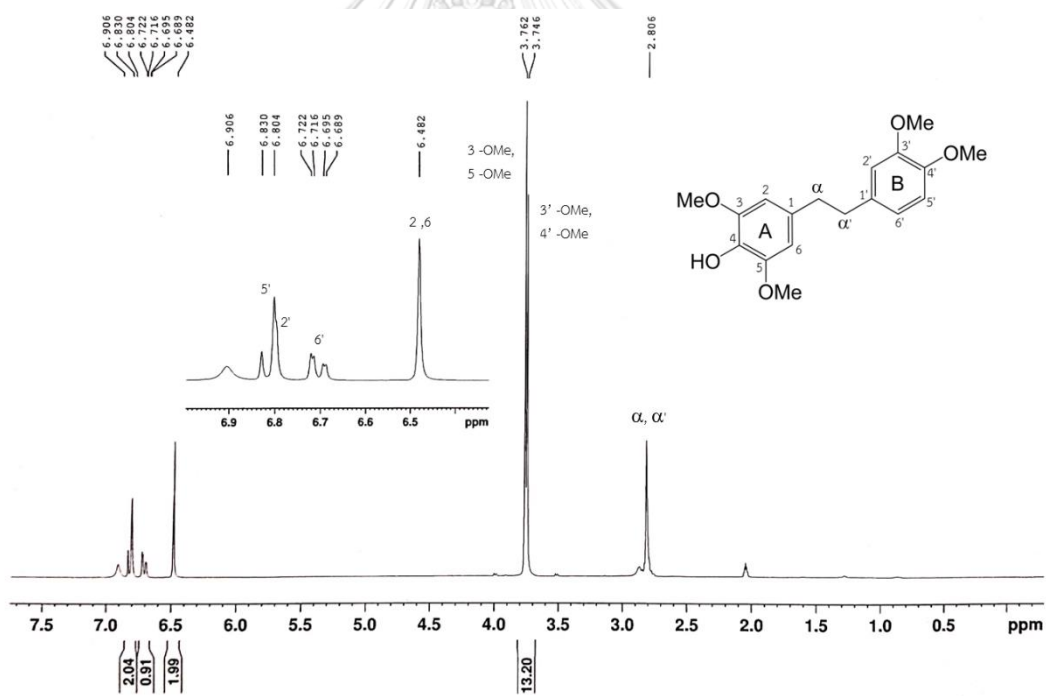
A.22 NOESY spectrum of compound 1 in CDCl_3

(expansion from δ_{H} 3.70-4.18 (F1) and δ_{H} 6.05-7.00 (F2))

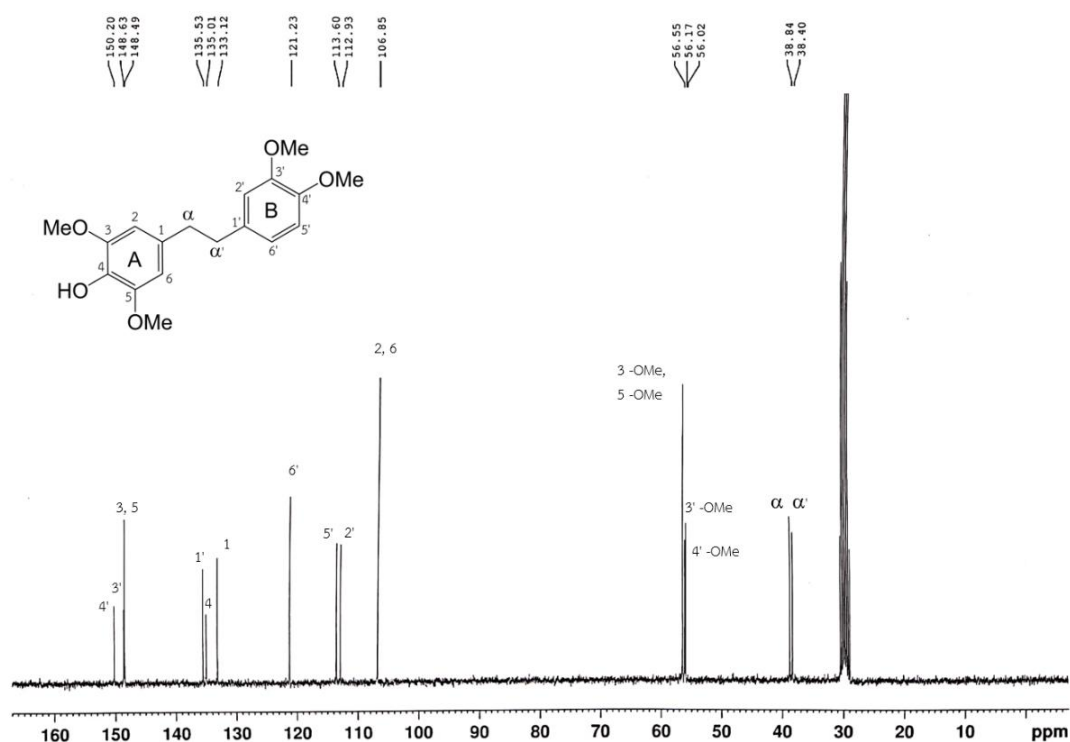


Appendix B: The spectral data of compound 2

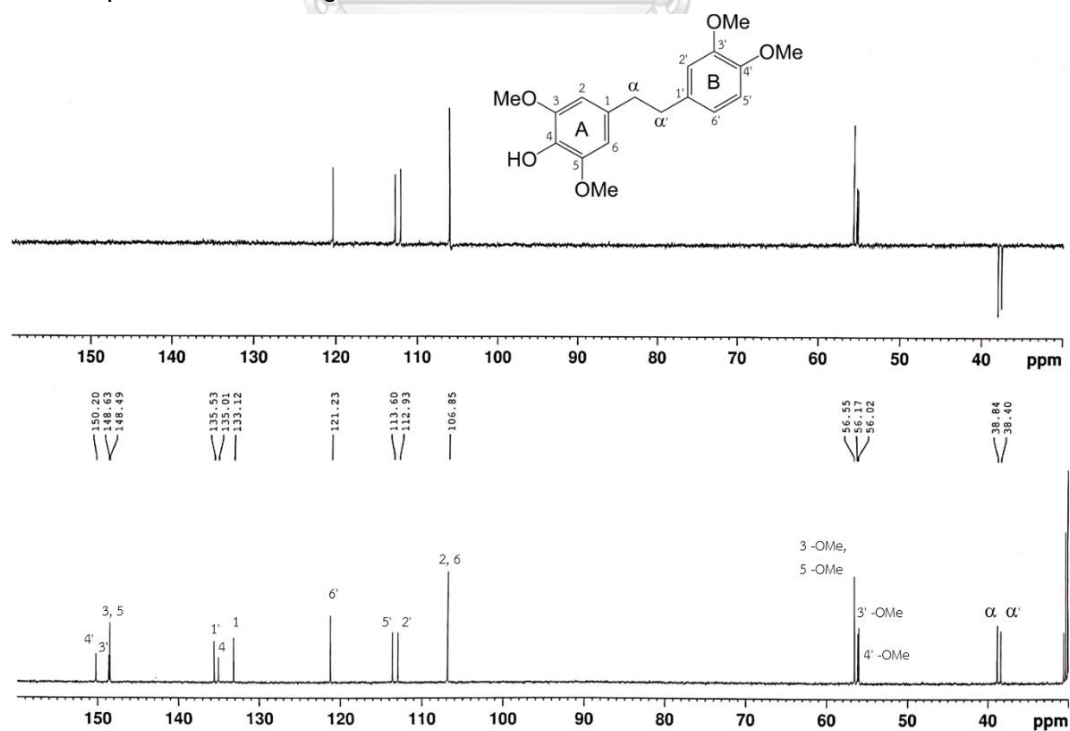
B.1 Mass spectrum of compound 2

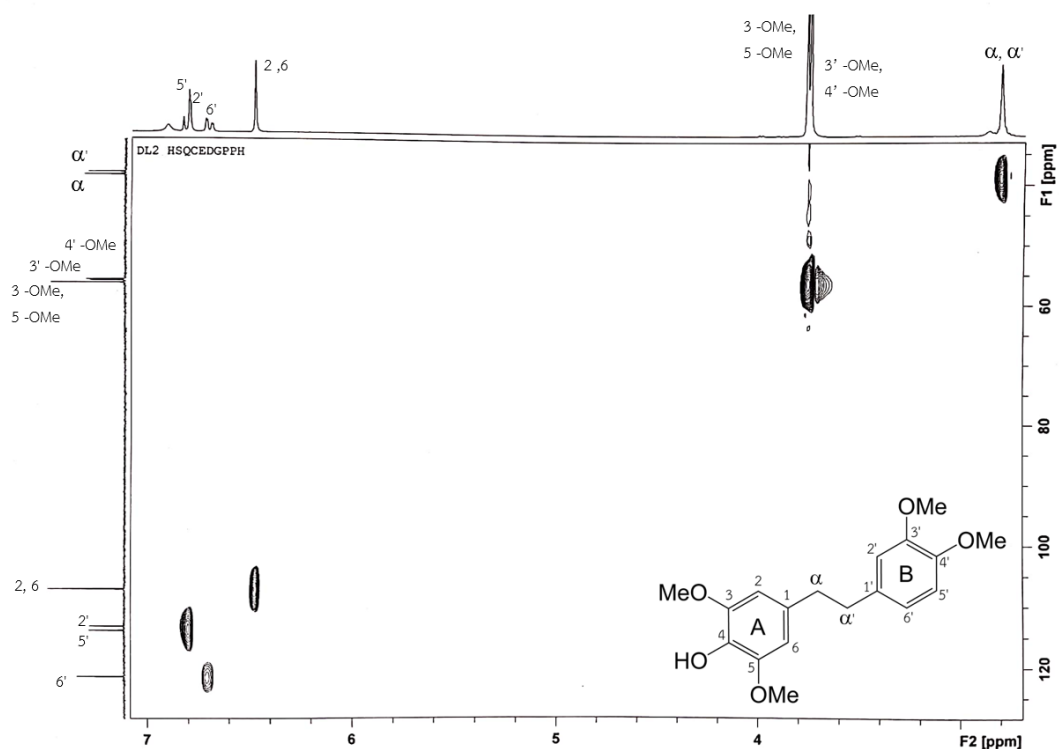
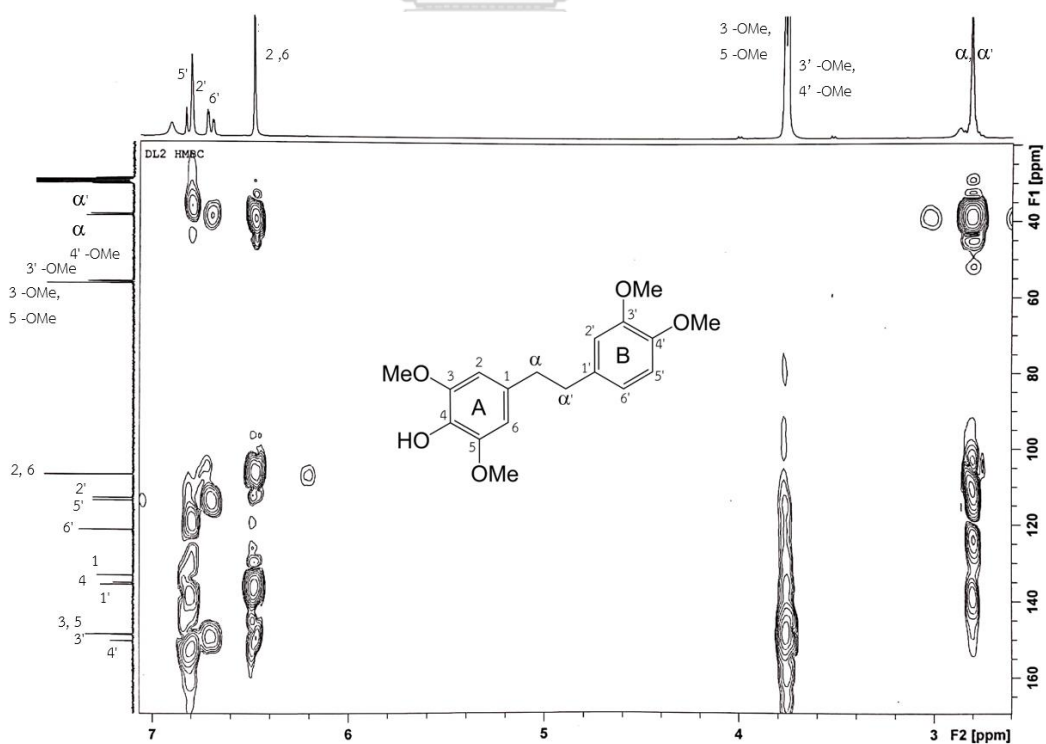
B.2 ^1H NMR (300 MHz) spectrum of compound 2 in acetone- d_6 

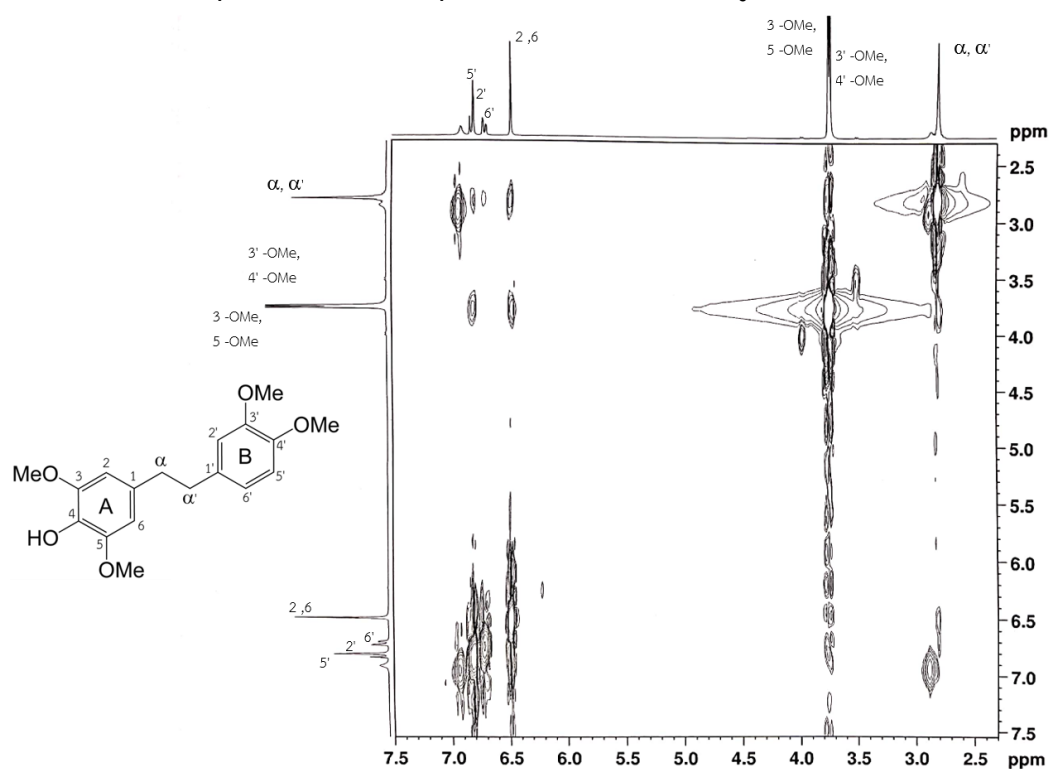
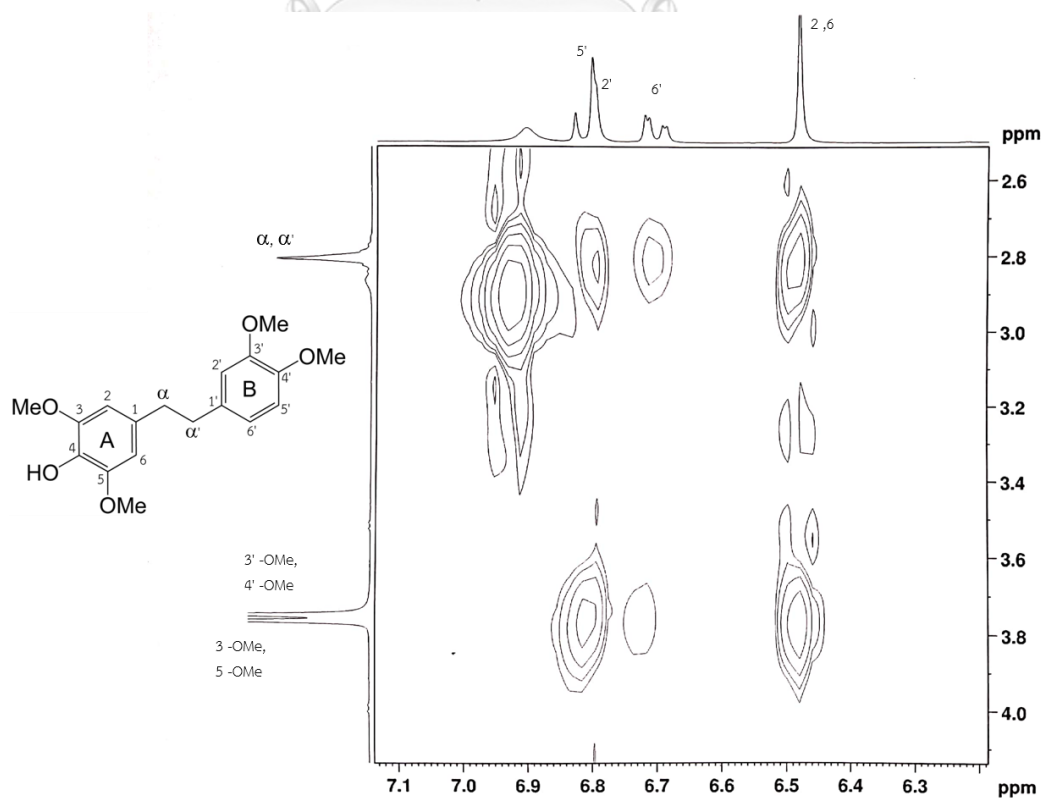
B.3 ^{13}C NMR (75 MHz) spectrum of compound 2 in acetone- d_6



B.4 ^{13}C NMR (75 MHz) spectrum of compound 2 in acetone- d_6
(expansion from δ_{C} 30.0-160.0)

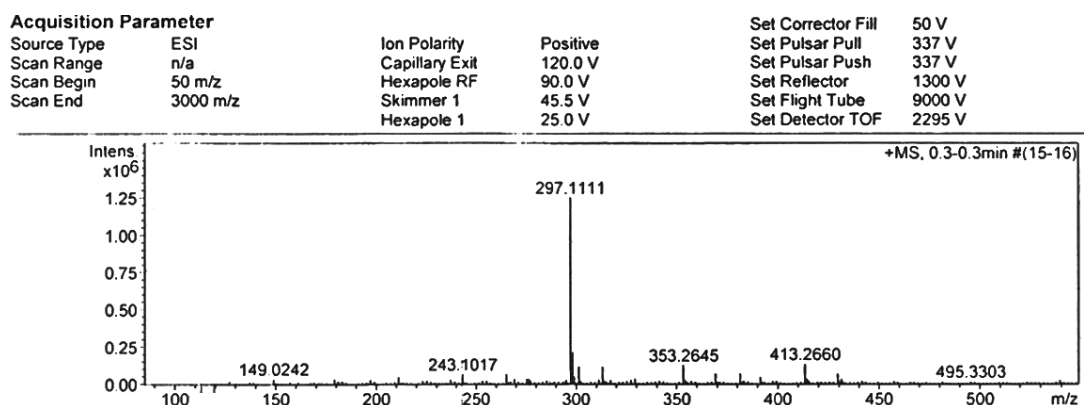
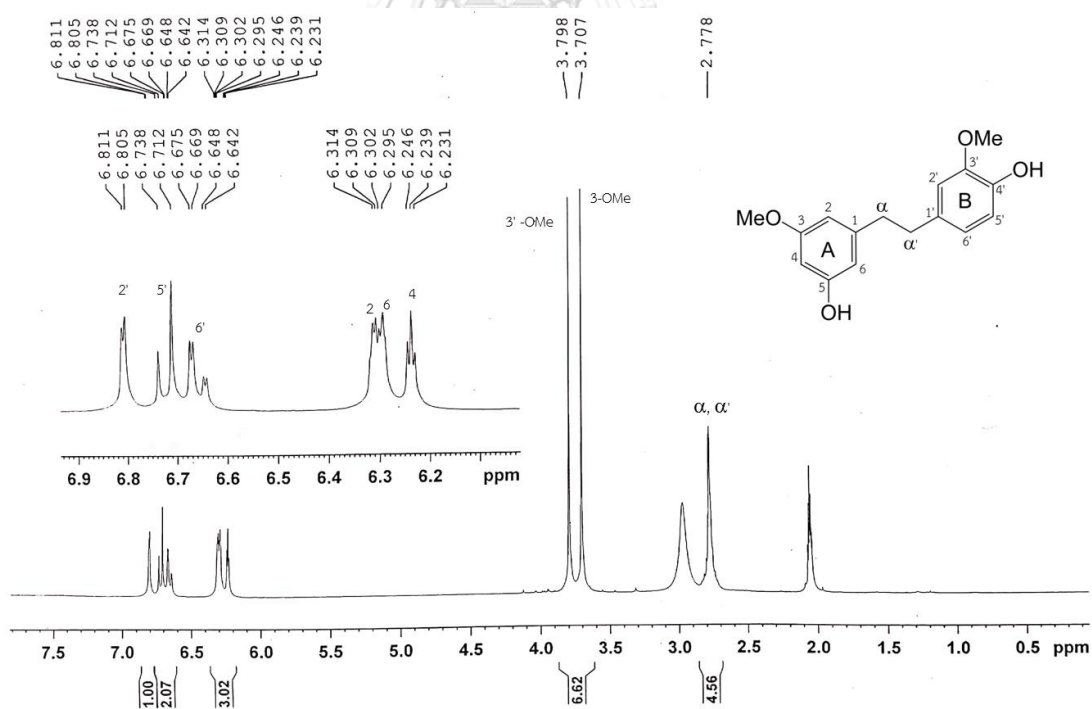


B.5 HSQC spectrum of compound 2 in acetone- d_6 B.6 HMBC spectrum of compound 2 in acetone- d_6 

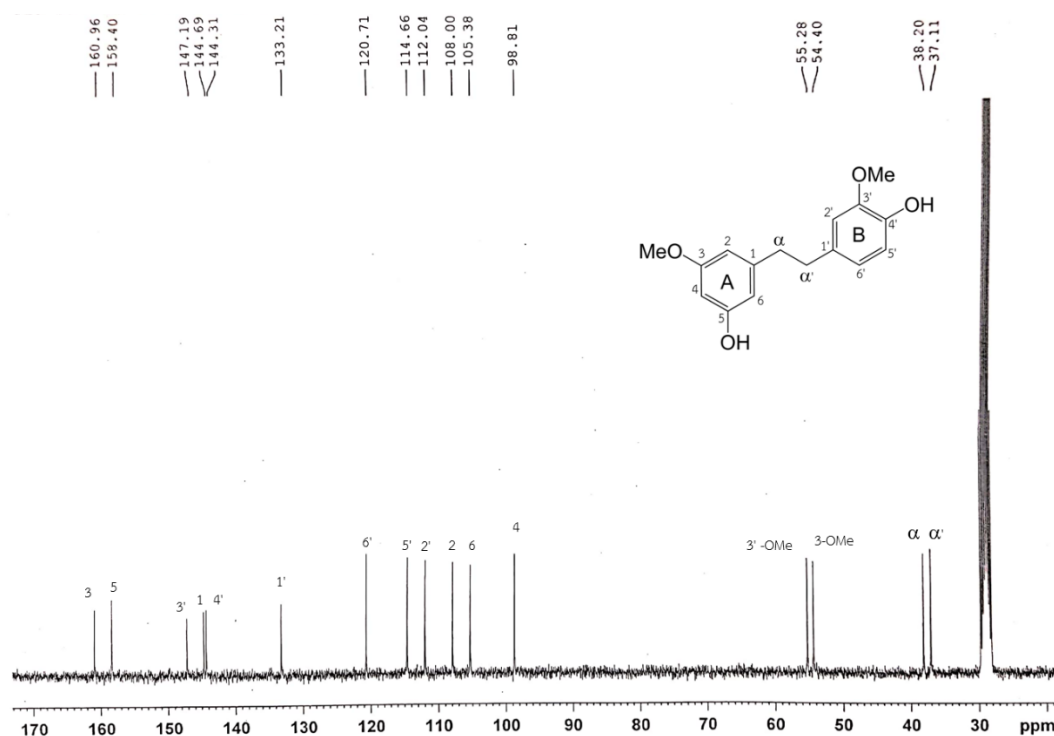
B.7 NOESY spectrum of compound 2 in acetone- d_6 B.8 NOESY spectrum of compound 2 in acetone- d_6 (expansion from δ_{H} 2.50-4.15 (F1) and δ_{H} 6.19-7.14 (F2))

Appendix C: The spectral data of compound 3

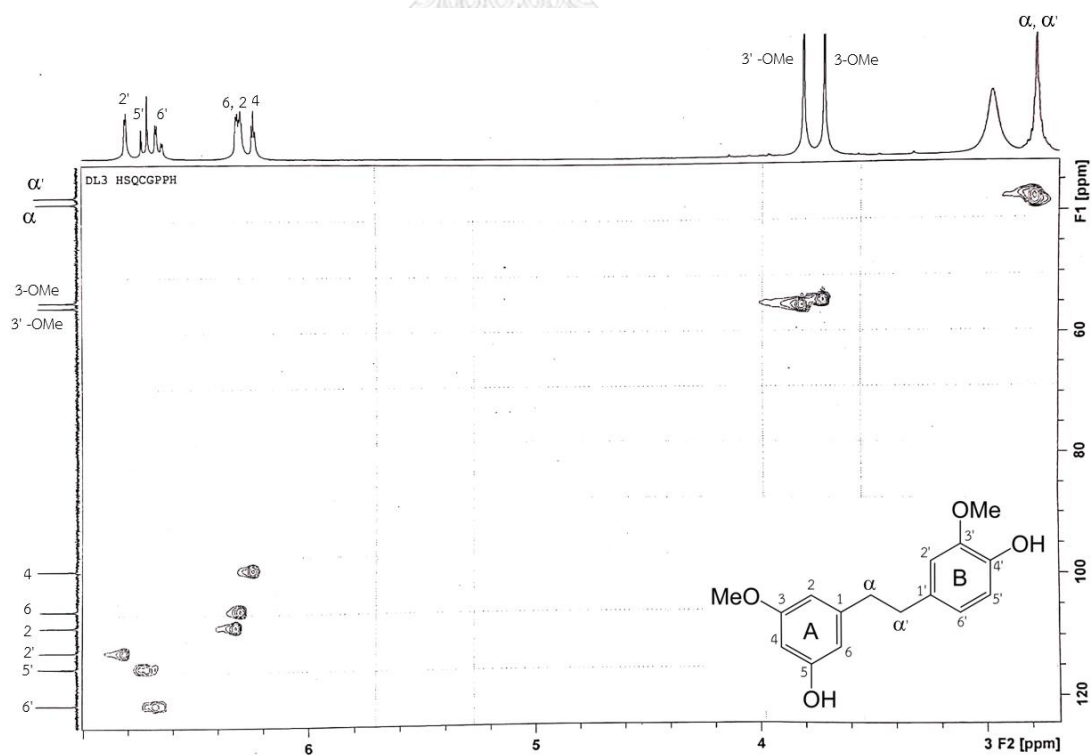
C.1 Mass spectrum of compound 3

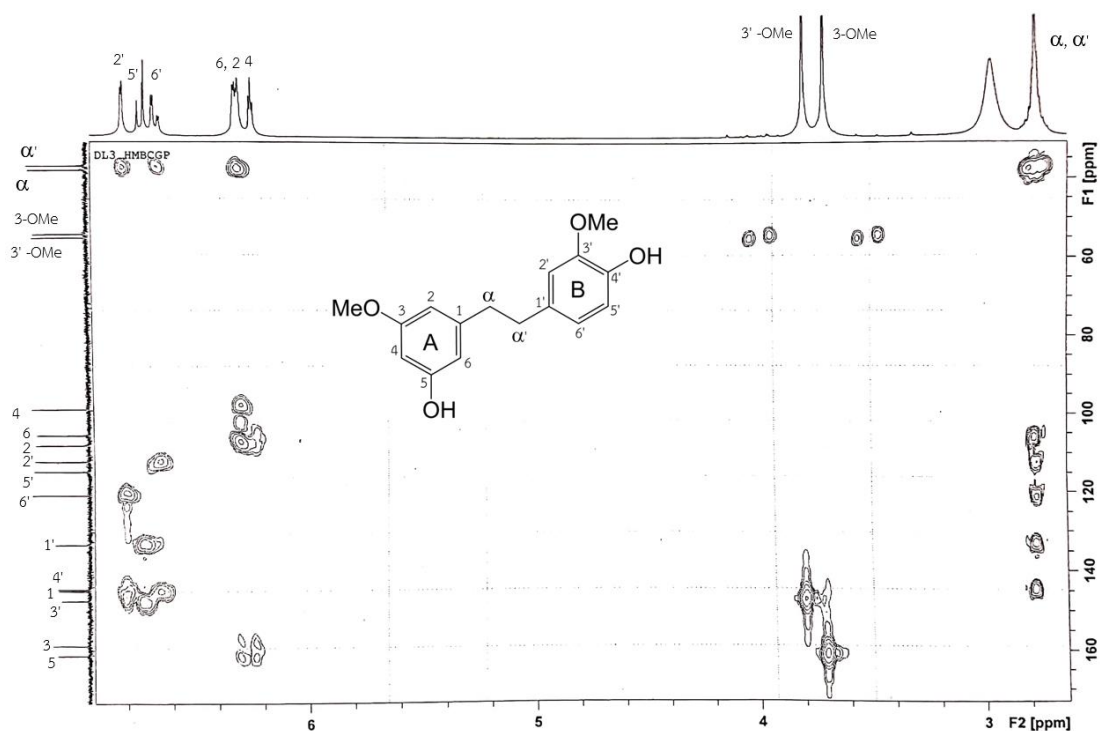
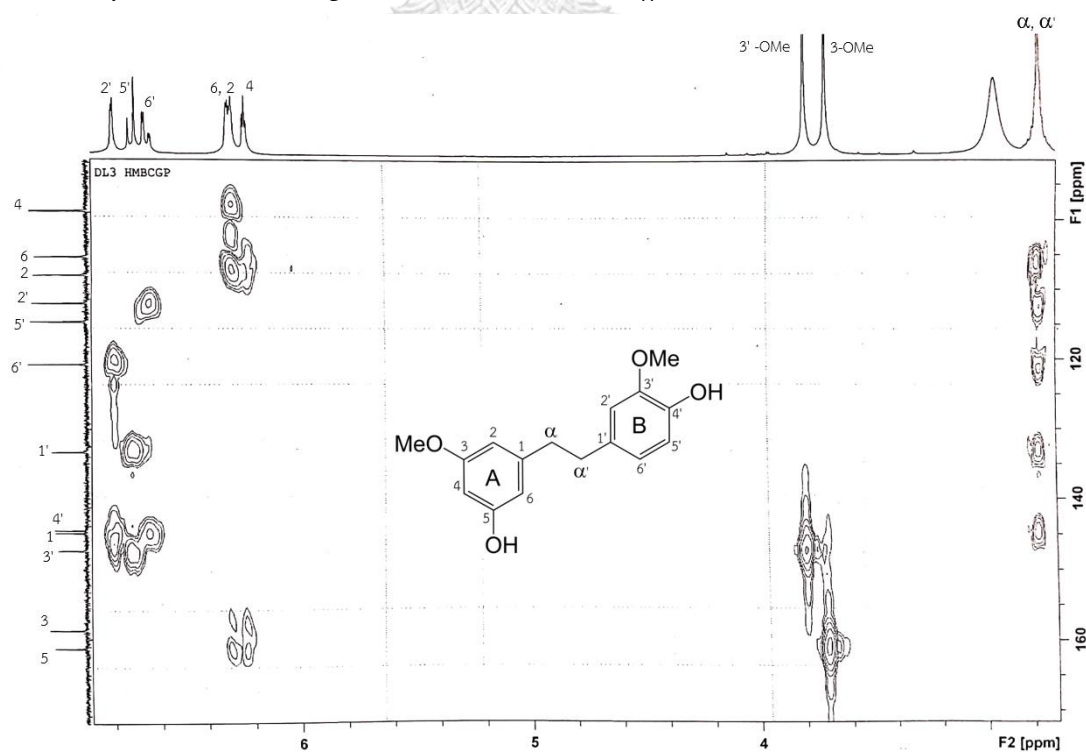
C.2 ^1H NMR (300 MHz) spectrum of compound 3 in acetone- d_6 

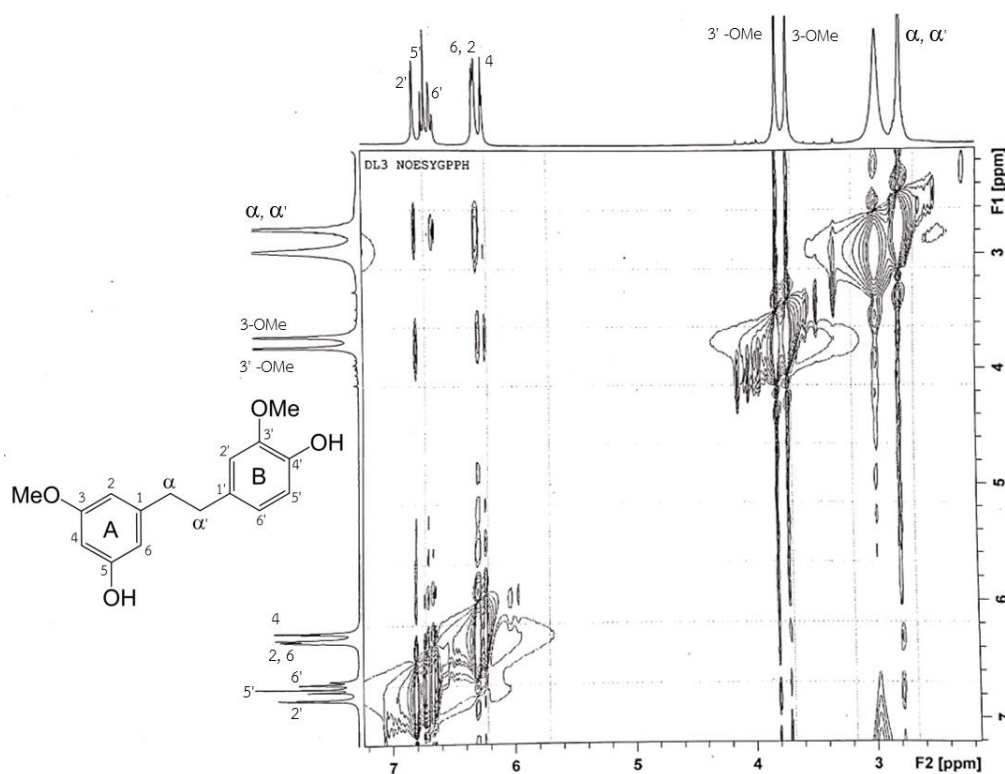
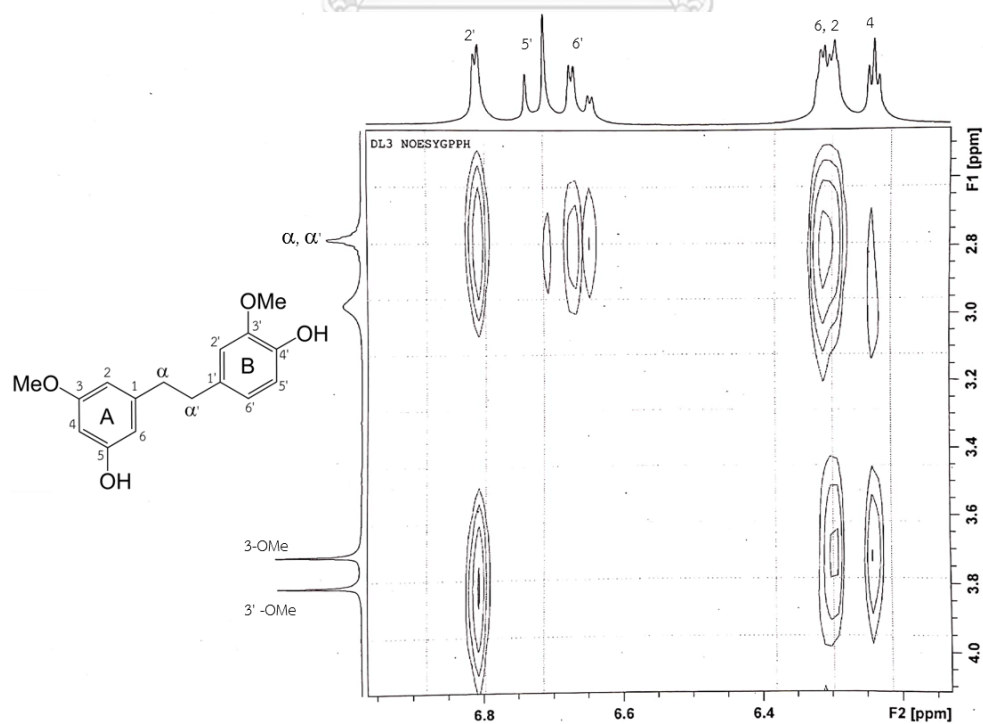
C.3 ^{13}C NMR (75 MHz) spectrum of compound 3 in acetone- d_6



C.4 HSQC spectrum of compound 3 in acetone- d_6

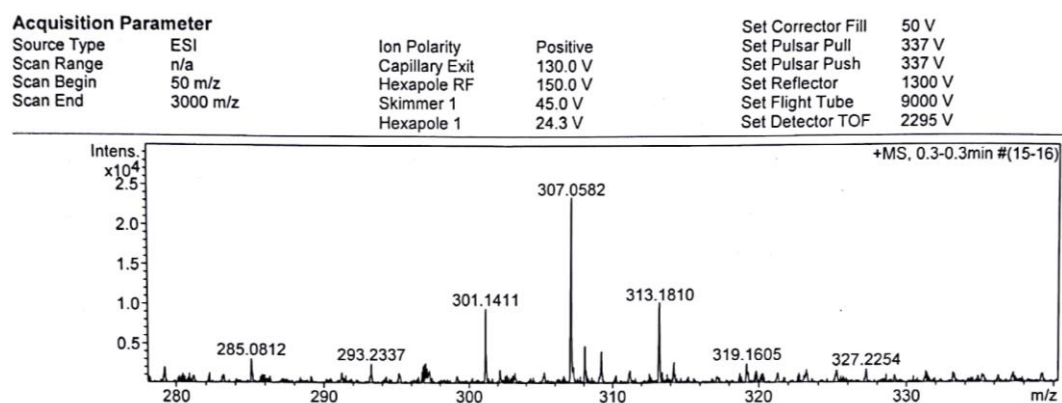
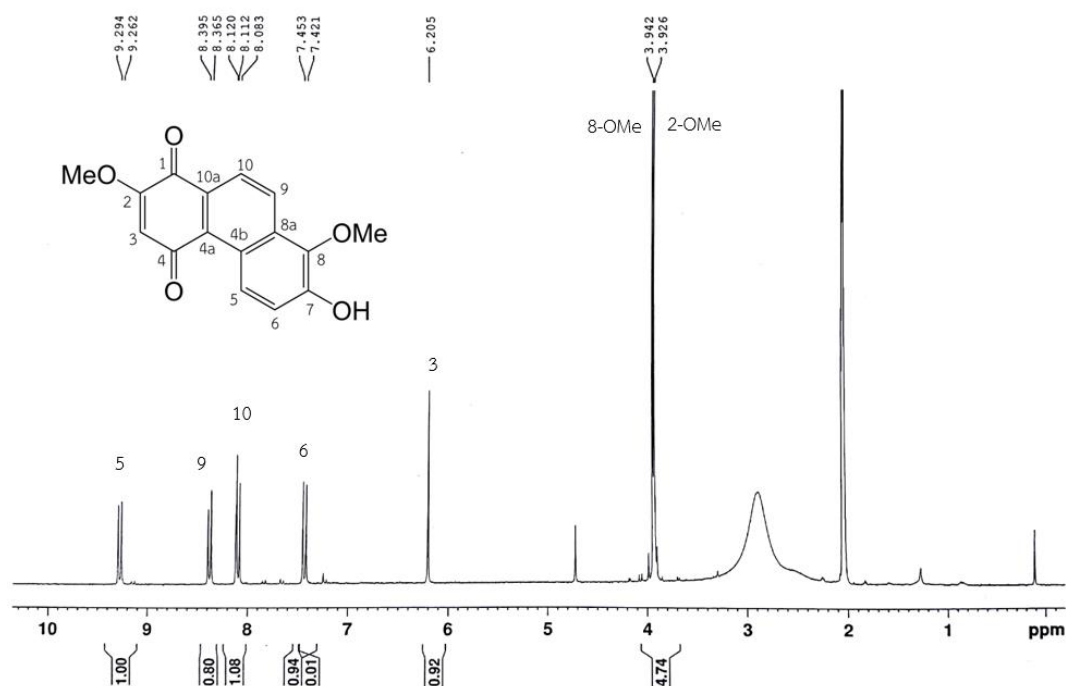


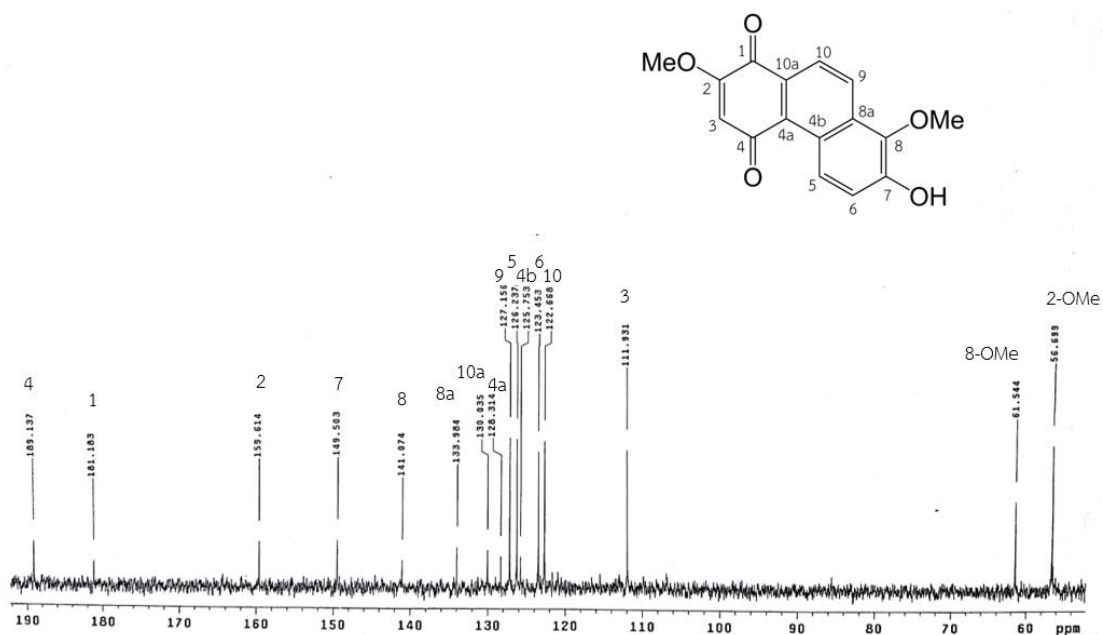
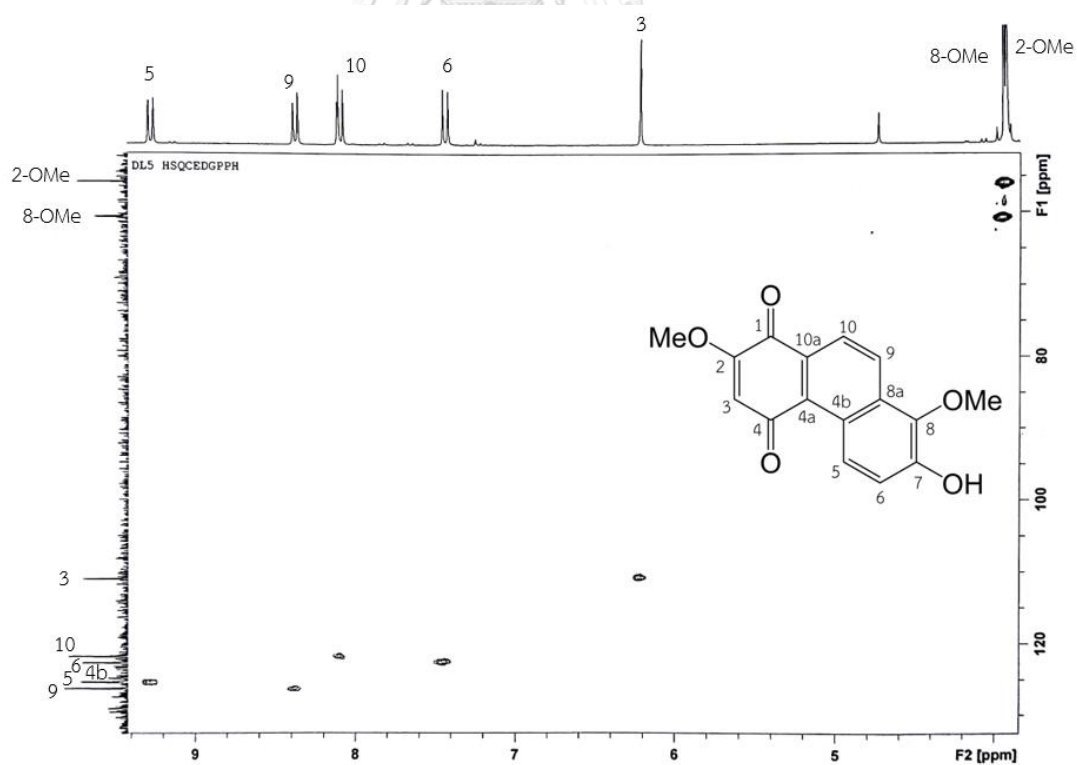
C.5 HMBC spectrum of compound 3 in acetone- d_6 C.6 HMBC spectrum of compound 3 in acetone- d_6 (expansion from δ_C 92.5-172.5 (F1) and δ_H 2.70-6.90 (F2))

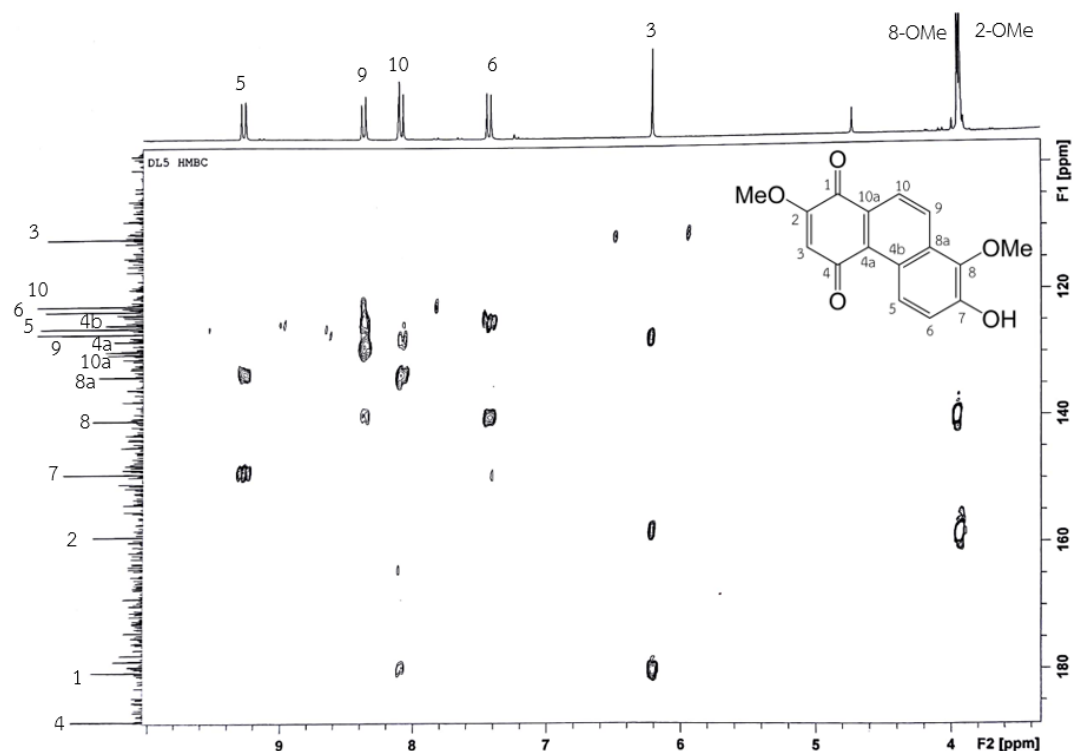
C.7 NOESY spectrum of compound 3 in acetone- d_6 C.8 NOESY spectrum of compound 3 in acetone- d_6 (expansion from δ_{H} 2.45-4.12 (F1) and δ_{H} 6.13-6.95 (F2))

Appendix D: The spectral data of compound 4

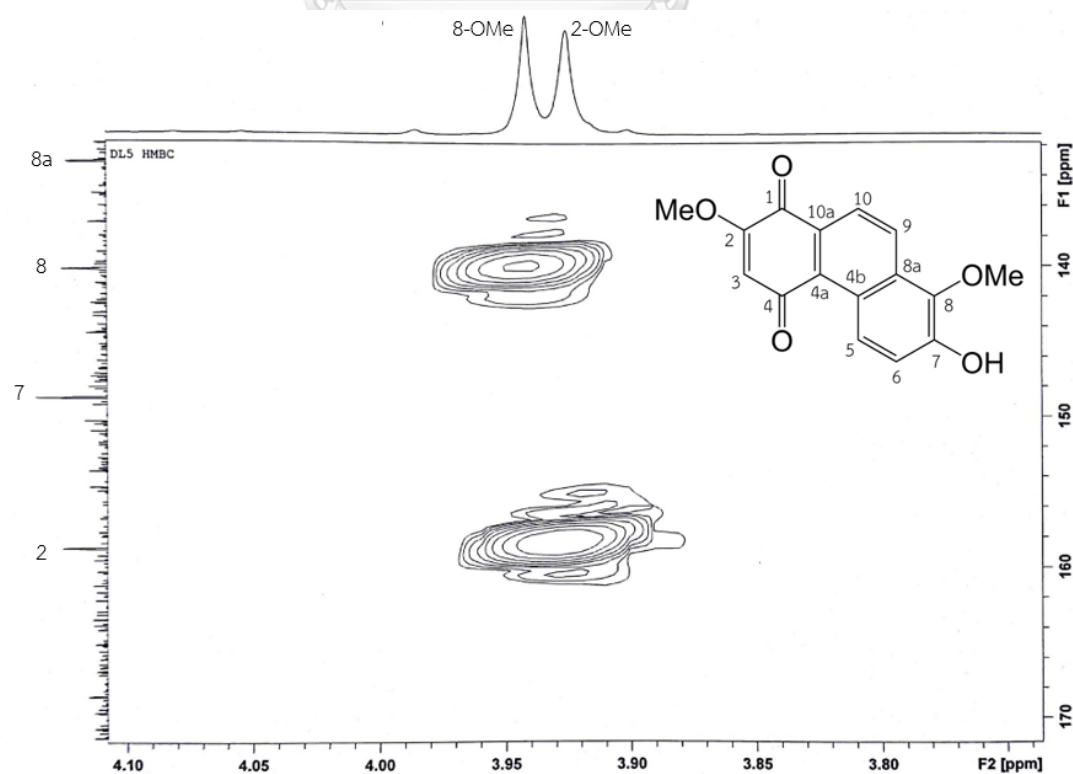
D.1 Mass spectrum of compound 4

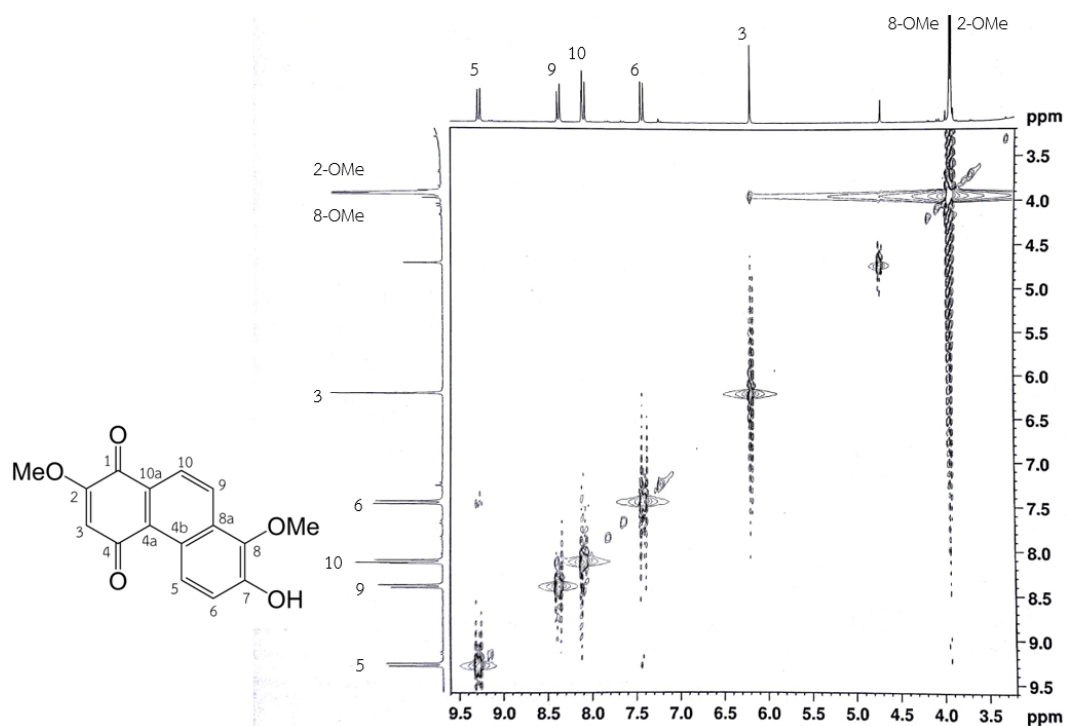
D.2 ^1H NMR (300 MHz) spectrum of compound 4 in acetone- d_6 

D.3 ^{13}C NMR (75 MHz) spectrum of compound 4 in acetone- d_6 D.4 HSQC spectrum of compound 4 in acetone- d_6 

D.5 HMBC spectrum of compound 4 in acetone- d_6 D.6 HMBC spectrum of compound 4 in acetone- d_6

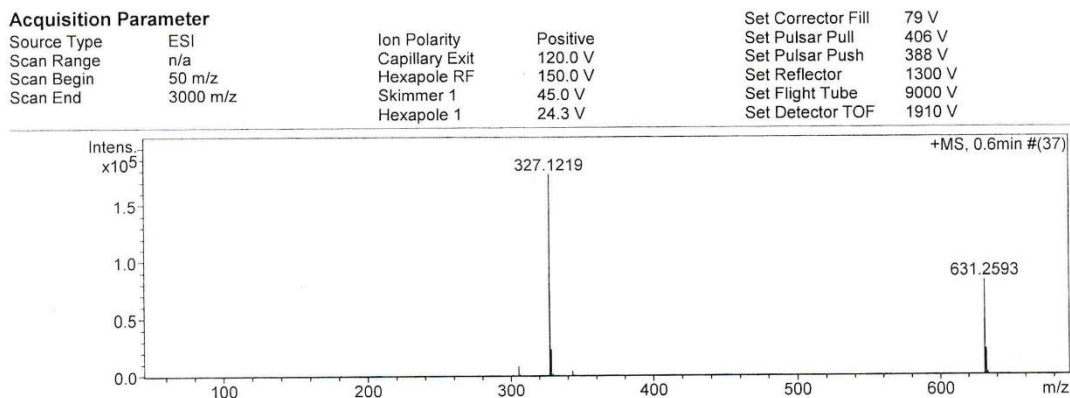
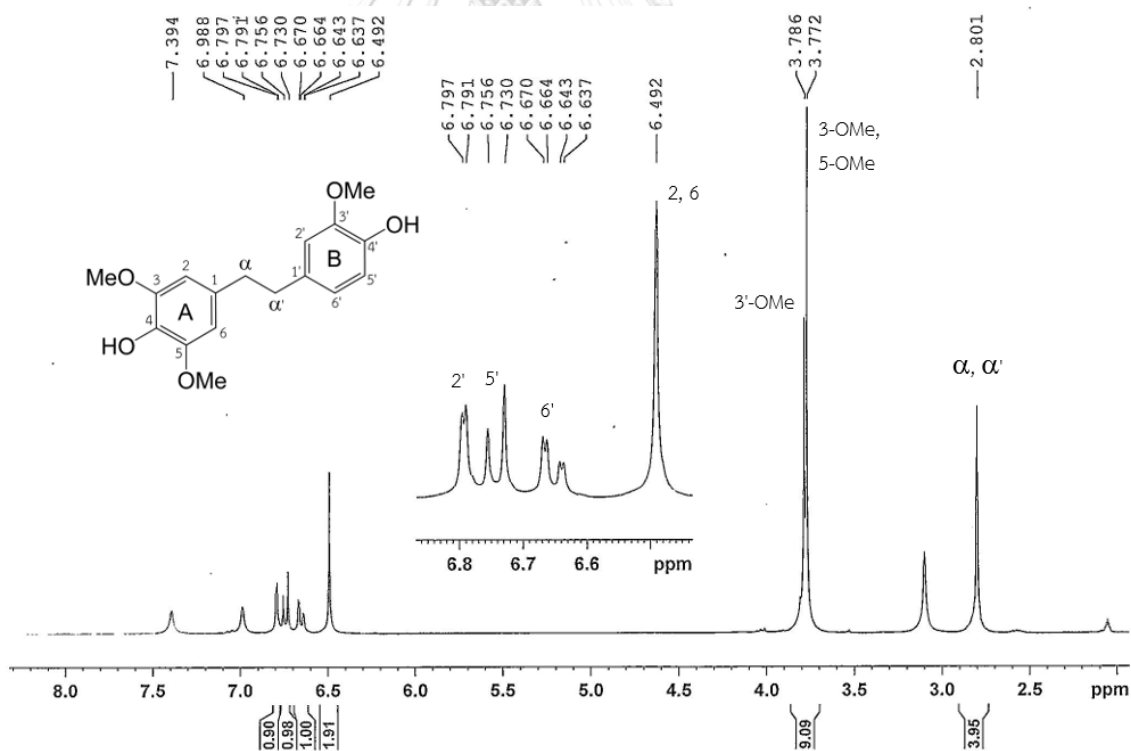
(expansion from δ_C 132.0-172.0 (F1) and δ_H 3.74-4.11 (F2))

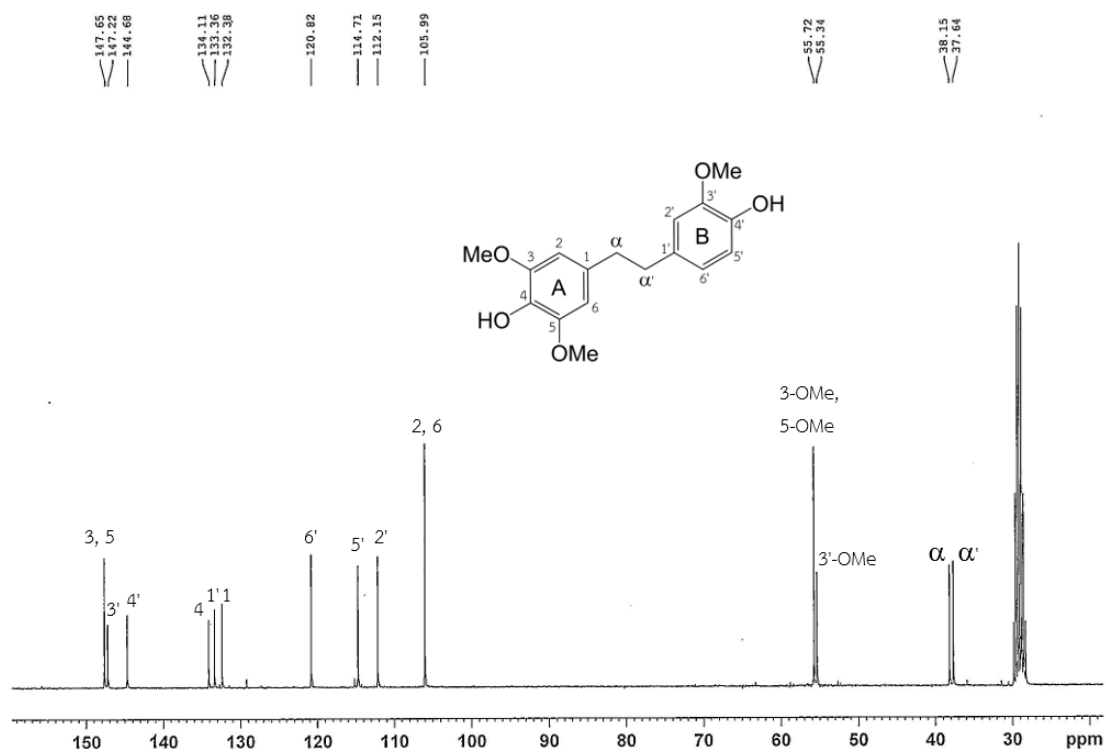
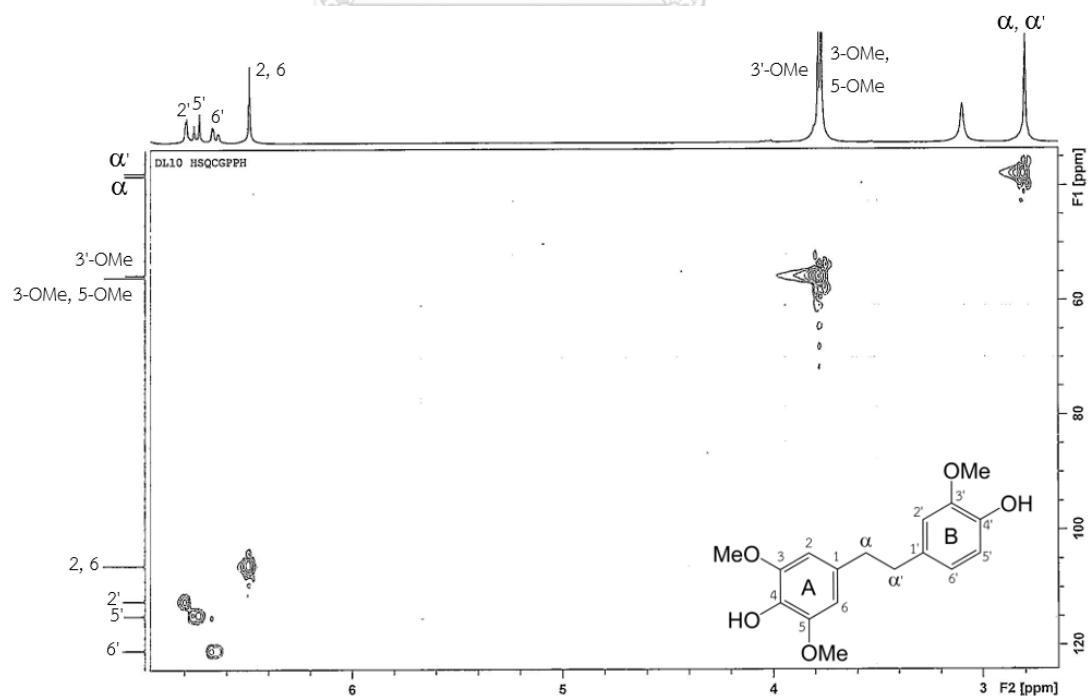


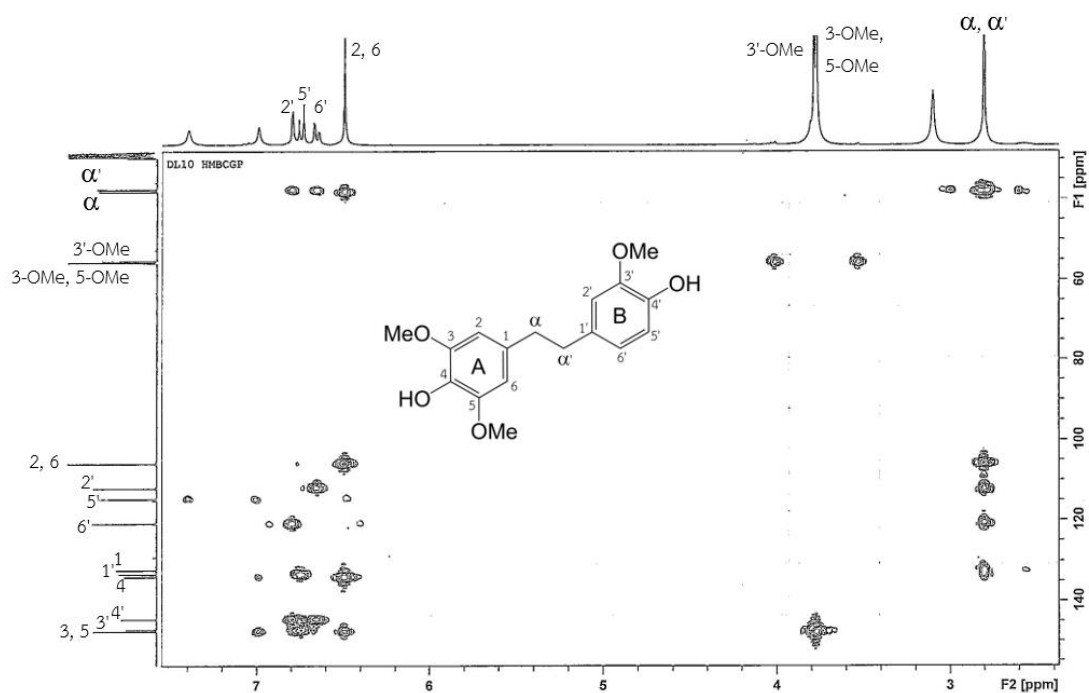
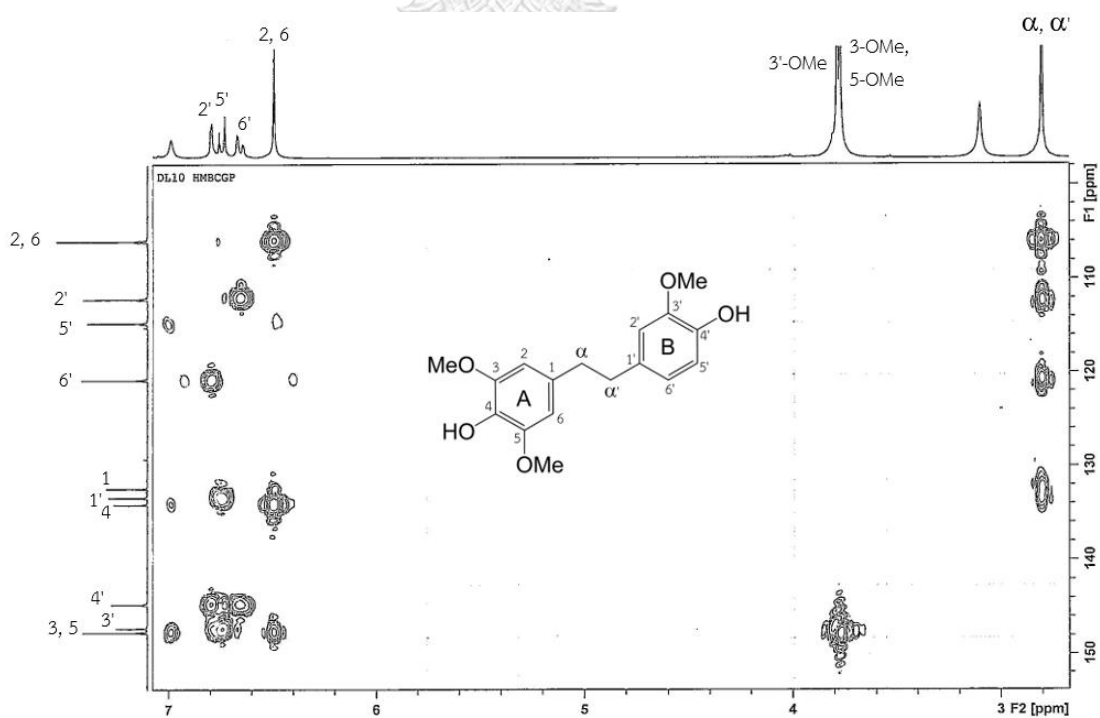
D.7 NOESY spectrum of compound 4 in acetone- d_6 

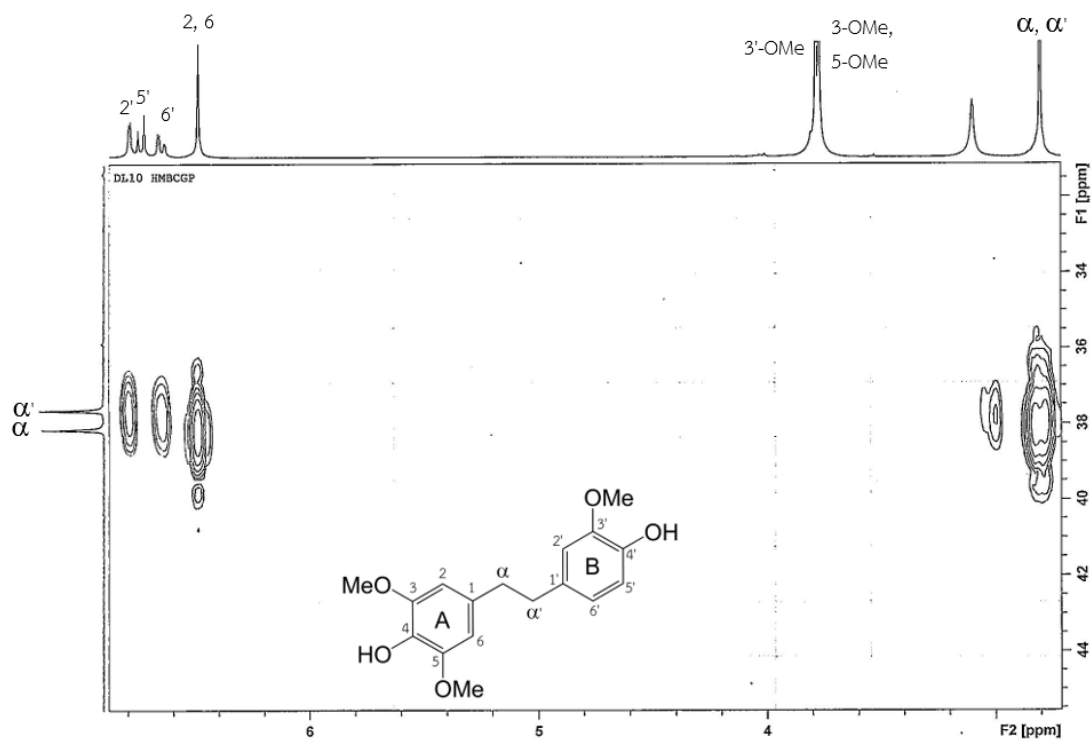
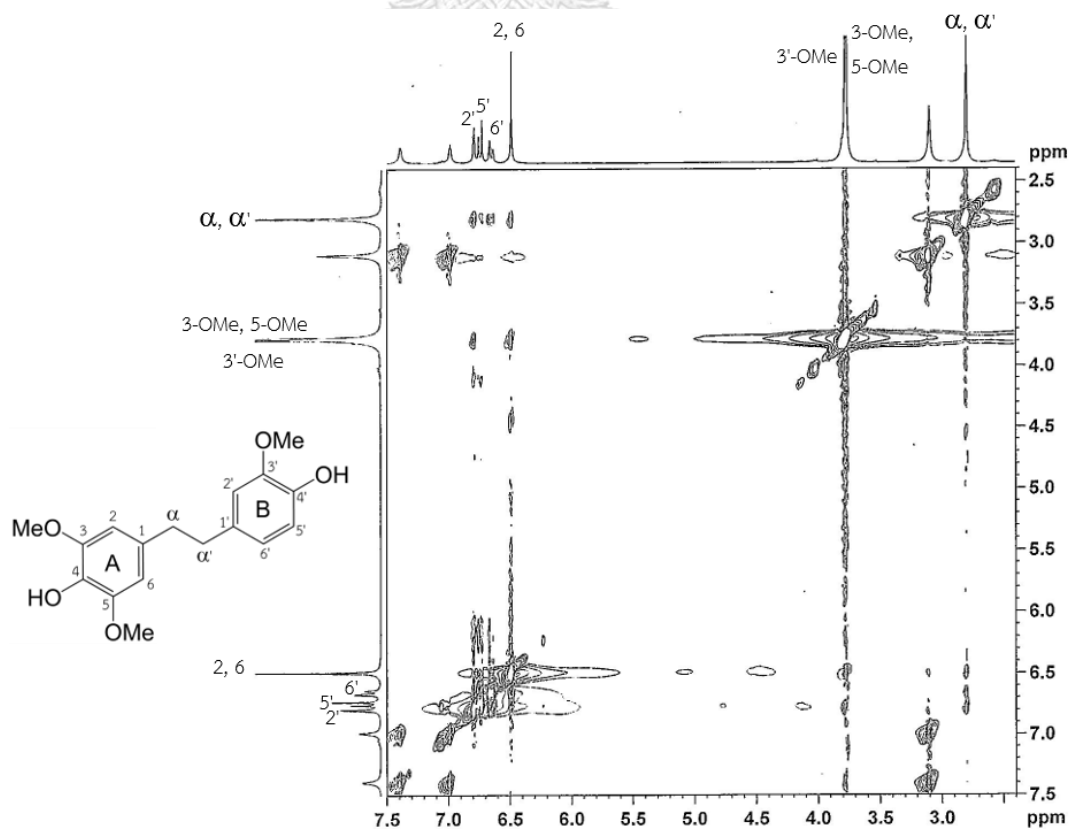
Appendix E: The spectral data of compound 5

E.1 Mass spectrum of compound 5

E.2 ^1H NMR (300 MHz) spectrum of compound 5 in acetone- d_6 

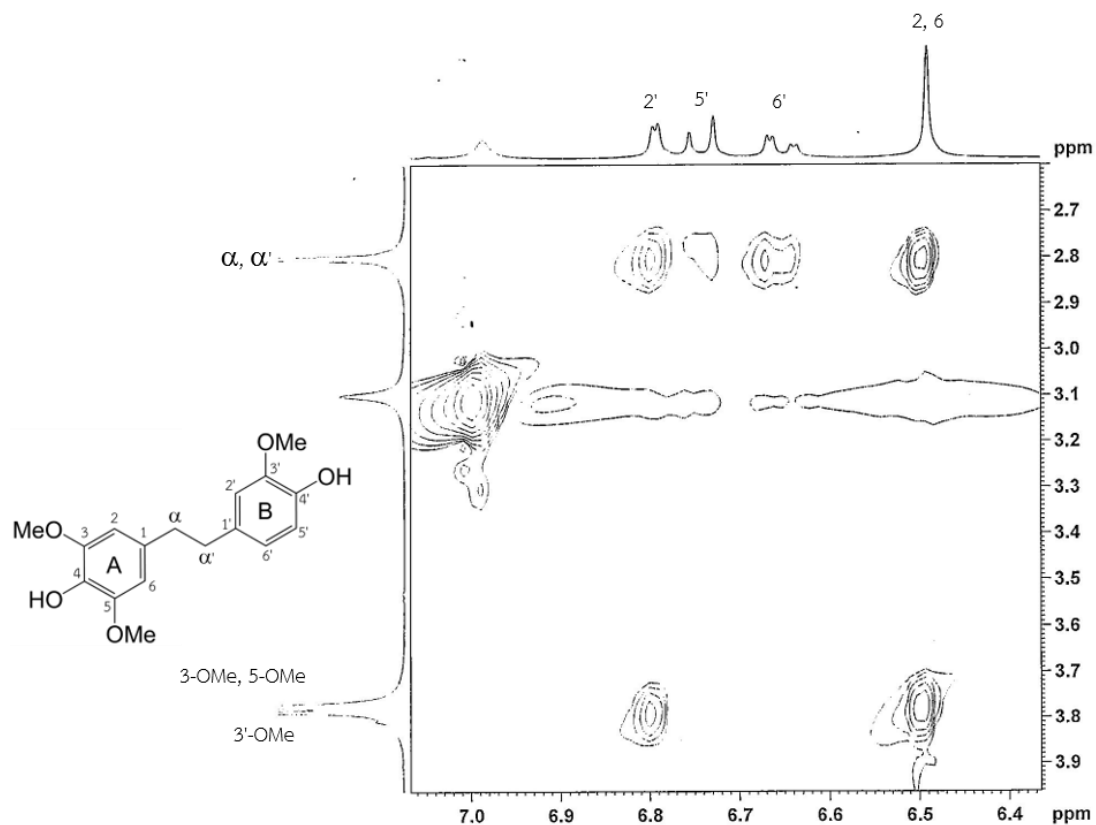
E.3 ^{13}C NMR (75 MHz) spectrum of compound 5 in acetone- d_6 E.4 HSQC spectrum of compound 5 in acetone- d_6 

E.5 HMBC spectrum of compound 5 in acetone- d_6 E.6 HMBC spectrum of compound 5 in acetone- d_6 (expansion from δ_{C} 98.0-151.0 (F1) and δ_{H} 2.70-7.10 (F2))

E.7 HMBC spectrum of compound 5 in acetone- d_6 (expansion from δ_C 31.3-45.5 (F1) and δ_H 2.70-6.90 (F2))E.8 NOESY spectrum of compound 5 in acetone- d_6 

E.9 NOESY spectrum of compound 5 in acetone- d_6

(expansion from δ_H 2.60-3.96 (F1) and δ_H 6.37-7.06 (F2))



VITA

NAME	PICHAYATRI KHOONRIT
DATE OF BIRTH	20 September 1994
PLACE OF BIRTH	Lopburi, Thailand
INSTITUTIONS ATTENDED	Faculty of Pharmaceutical Sciences, Chulalongkorn University
HOME ADDRESS	452/90 Ratchawithi Road, Thanon Phaya Thai, Ratchathewi Bangkok 10400
PUBLICATION	Chanpokaipaiboon, K., Khoonrit, P., Yusakul, G., Juengwatanatrakul, T., Putalun, W., Tanaka, H., Sakamoto, S. and Morimoto, S. A Recombinant Fab Antibody Against Kwakhurin as a Tool for Sensitive Indirect Competitive ELISA. Curr Pharm Biotechnol. 2018;19(14):1170-6.
AWARD RECEIVED	Chulalongkorn University Graduate Scholarship to Commemorate the 72nd Anniversary of His Majesty King Bhumibala Aduladeja.