สารที่มีฤทธิ์ต้านอนุมูลอิสระจากเอื้องครั่ง

นายวิรุฬห์ คงคติธรรม

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาเภสัชศาสตรมหาบัณฑิต
สาขาวิชาเภสัชเวท ภาควิชาเภสัชเวทและเภสัชพฤกษศาสตร์
คณะเภสัชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2560

FREE RADICAL SCAVENGING COMPOUNDS FROM *DENDROBIUM PARISHII*

Mr. Virunh Kongkatitham

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Pharmacy Program in Pharmacognosy
Department of Pharmacognosy and Pharmaceutical Botany
Faculty of Pharmaceutical Sciences
Chulalongkorn University
Academic Year 2017

Thesis Title	FREE RADICAL SCAVENGING COMPOUNDS FROM *DENDROBIUM PARISHII*
By	Mr. Virunh Kongkatitham
Field of Study	Pharmacognosy
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 Requirements for the Master's Degree

.....Dean of the Faculty of Pharmaceutical Sciences

(Assistant Professor Rungpetch Sakulbumrungsil, Ph.D.)

THESIS COMMITTEE

.....Chairman

(Associate Professor Rutt Suttisri, Ph.D.)

.....Thesis Advisor

(Associate Professor Boonchoo Sritularak, Ph.D.)

.....Thesis Co-Advisor

(Professor Kittisak Likhitwitayawuid, Ph.D.)

.....Examiner

(Assistant Professor Taksina Chuanasa, Ph.D.)

.....Examiner

(Chaisak Chansriniyom, Ph.D.)

.....External Examiner

(Duangpen Pattamadilok, Ph.D.)

วิรุฬห์ คงคติธรรม : สารที่มีฤทธิ์ต้านอนุมูลอิสระจากเอื้องครั่ง (FREE RADICAL SCAVENGING COMPOUNDS FROM *DENDROBIUM PARISHII*) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ภก. ดร. บุญชู ศรีตุลารักษ์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ศ. ภก. ดร. กิตติศักดิ์ ลิขิตวิทยาวุฒิ, หน้า.

การศึกษาทางพฤกษเคมีของสารสกัดหยาบด้วยเอทิลอะซีเตตจากเอื้องครั่ง สามารถแยกสารบริสุทธิ์ชนิดใหม่ได้ 2 ชนิด ได้แก่ 4,3′,4′-trihydroxy-3,5-dimethoxybibenzyl ซึ่งเป็นอนุพันธ์ของสารในกลุ่ม bibenzylและ (–)-dendroparishiol ซึ่งเป็นอนุพันธ์ของสารในกลุ่ม bibenzyl-dihydrophenanthrene และยังพบสารที่เคยมีการรายงานไว้แล้วอีก 5 ชนิด ซึ่งประกอบด้วย flavanthrinin, moscatilin, 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl, dendrocandin E และ asiatic acid โดยสารทุกชนิดจะถูกพิสูจน์โครงสร้างทางเคมีด้วยวิธีการทางสเปกโตรสโคปี (NMR and HR-ESI-MS) และจะถูกนำไปทดสอบฤทธิ์ต้านอนุมูลอิสระด้วยการทดสอบต่าง ๆ ได้แก่ DPPH free radical scavenging assay, oxygen radical absorbance capacity assay และ deoxyribose degradation assay จากผลการทดสอบพบว่า สาร (–)-dendroparishiol มีฤทธิ์ยับยั้งอนุมูลอิสระได้ดีที่สุดในทุกการทดสอบ และสารดังกล่าวจึงถูกเลือกเพื่อใช้ในการทดสอบฤทธิ์ต้านอนุมูลอิสระในเซลล์ murine macrophage RAW264.7 ซึ่งถูกเหนี่ยวนำโดย H_2O_2 ให้เกิดภาวะ oxidative stress โดยการทดสอบดังกล่าวพบว่าสาร (–)-dendroparishiol สามารถลดการสร้างอนุมูลอิสระในเซลล์ RAW264.7 ได้มากขึ้นตามขนาด dose ที่เพิ่มขึ้น และเพิ่มการทำงานของเอนไซม์ที่ยับยั้งอนุมูลอิสระ (SOD, GPx and CAT) ได้มากขึ้นตามขนาด dose ที่เพิ่มขึ้นเช่นเดียวกัน จากผลการทดสอบทั้งหมดนี้แสดงว่า สาร (–)-dendroparishiol มีศักยภาพที่จะสามารถพัฒนาต่อเป็นสารต้านอนุมูลอิสระที่ใช้ประโยชน์ได้ต่อไป

ภาควิชา	เภสัชเวทและเภสัชพฤกษศาสตร์	ลายมือชื่อนิสิต .....
สาขาวิชา	เภสัชเวท	ลายมือชื่อ อ.ที่ปรึกษาหลัก .....
ปีการศึกษา	2560	ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

6076117033 : MAJOR PHARMACOGNOSY

KEYWORDS: DENDROBIUM PARISHII / FREE RADICALS / ORCHIDACEAE / BIBENZYLS / PHENANTHRENES / DIHYDROPHENANTHRENES

VIRUNH KONGKATITHAM: FREE RADICAL SCAVENGING COMPOUNDS FROM *DENDROBIUM PARISHII*. ADVISOR: ASSOC. PROF. BOONCHOO SRITULARAK, Ph.D., CO-ADVISOR: PROF. KITTISAK LIKHITWITAYAWUID, Ph.D., pp.

In this study, the EtOAc extract of *Dendrobium parishii* Rchb. f. was separated to obtain two new compounds including a bibenzyl derivative, 4,3′,4′-trihydroxy-3,5-dimethoxybibenzyl, and a bibenzyl-dihydrophenanthrene derivative, (–)-dendroparishiol, and five known compounds including flavanthrinin, moscatilin, 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl, dendrocandin E and asiatic acid. The structures of all of the isolated compounds were determined by analysis of spectroscopic data (NMR and HR-ESI-MS). They were then evaluated for antioxidant activities using DPPH free radical scavenging activity, deoxyribose degradation and oxygen radical absorbance capacity assays. Among the tested compounds, (–)-dendroparishiol showed the strongest free radicals reduction and was further investigated for antioxidant activity in H_2O_2-induced oxidative stress in RAW264.7 murine macrophage cells. (–)-Dendroparishiol could decrease ROS production in RAW264.7 cells in a dose-dependent manner and enhanced the activities of cellular anti-oxidative enzymes (SOD, GPx and CAT). These results indicate that compound (–)-dendroparishiol has the potential to be developed as a useful antioxidant agent.

Department:	Pharmacognosy and Pharmaceutical Botany	Student's Signature .....
		Advisor's Signature .....
Field of Study:	Pharmacognosy	Co-Advisor's Signature .....
Academic Year:	2017	

ACKNOWLEDGEMENTS

I wish to express my appreciation to my thesis advisor, Associate Professor Dr. Boonchoo Sritularak and my co-advisor, Professor Dr. Kittisak Likhitwitayawuid, for their valuable guidance, endless support and encouragement throughout this thesis. I would not have succeeded my thesis research without all the advice, kindness and helps that I have always received from them.

I am grateful for all assistance and beneficial advice from the members of my thesis committee and all staff members of the Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University, especially Mr. Napat Kyokong, for all their assistance and help.

I would like to thank Associate Professor Dr. Pornchai Rojsitthisak, Mr. Chawanphat Muangnoi and Mr. Wuttinont Thaweesest from the Department of Food and Pharmaceutical Chemistry, Faculty of Pharmaceutical Sciences, Chulalongkorn University for their helps and support.

In addition, I would like to thankfully acknowledge Chulalongkorn University Graduate Scholarship to Commemorate the 72nd Anniversary of His Majesty King Bhumibol Adulyadej for supporting my research.

Finally, I want to express my special gratitude to my family and friends for their love, support and encouragement.

CONTENTS

Page

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF SCHEMES

ABBREVIATIONS & SYMBOLS

AAPH	=	2,2-Azobis (2-amidinopropane) dihydrochloride
Acetone-d_6	=	Deuterated acetone
Ara	=	Arabinose
α	=	Alpha
β	=	Beta
br s	=	Broad singlet (for NMR spectra)
br d	=	Broad doublet (for NMR spectra)
°C	=	Degree Celsius
CAT	=	Catalase
CC	=	Column chromatography
$CDCl_3$	=	Deuterated chloroform
CD_3OD	=	Deuterated methanol
CH_2Cl_2	=	Dichloromethane
cm	=	Centimeter
^{13}C-NMR	=	Carbon-13 Nuclear Magnetic Resonance
1-D NMR	=	One-dimensional Nuclear Magnetic Resonance
2-D NMR	=	Two-dimensional Nuclear Magnetic Resonance
d	=	Doublet (for NMR spectra)
dd	=	Doublet of doublets (for NMR spectra)
δ	=	Chemical shift
DCFH	=	2′,7′-Dichlorofluorescein
DCFH-DA	=	2′,7′-Dichlorofluorescein diacetate

DEPT	=	Distortionless Enhancement by Polarization Transfer
DMEM	=	Dulbecco's modified eagle's medium
DMSO	=	Dimethyl sulfoxide
DPPH	=	2,2-Diphenyl-1-picrylhydrazyl
ε	=	Molar absorptivity
EDTA	=	Ethylene diamine tetra-acetic acid
ESI-MS	=	Electrospray Ionization Mass Spectrometry
EtOAc	=	Ethyl acetate
FBS	=	Fetal bovine serum
FCC	=	Flash Column Chromatography
FL	=	Fluorescein
g	=	Gram
GF	=	Gel Filtration
Glc	=	Glucose
GPx	=	Glutathione peroxidase
GR	=	Glutathione reductase
GST	=	Glutathione-S-transferase
HMBC	=	^{1}H-detected Heteronuclear Multiple Bond Correlation
HR-ESI-MS	=	High Resolution Electrospray Ionization Mass Spectrometry
^{1}H-NMR	=	Proton Nuclear Magnetic Resonance
HSQC	=	^{1}H-detected Heteronuclear Single Quantum Coherence
Hz	=	Hertz
IC_{50}	=	Concentration exhibiting 50% inhibition

IR	=	Infrared
J	=	Coupling constant
Kg	=	Kilogram
L	=	Liter
λ_{max}	=	Wavelength at maximal absorption
$[M+Na]^+$	=	Sodium-adduct molecular ion
m	=	Multiplet (for NMR spectra)
MDA	=	Malondialdehyde
MeOH	=	Methanol
mg	=	Milligram
min	=	Minute
mL	=	Milliliter
mm	=	Millimeter
mM	=	Millimolar
MS	=	Mass spectrum
MW	=	Molecular weight
m/z	=	Mass to charge ratio
µg	=	Microgram
µL	=	Microliter
µM	=	Micromolar
nm	=	Nanometer
NMR	=	Nuclear Magnetic Resonance
NOESY	=	Nuclear Overhauser Effect Spectroscopy
NOS	=	Nitric oxide synthase

ν_{max}	=	Wave number at maximal absorption
OEt	=	Ethoxy group
OMe	=	Methoxy group
ORAC	=	Oxygen radical absorbance capacity
ppm	=	Part per million
PRX	=	Peroxiredoxins
Rha	=	Rhamnose
ROS	=	Reactive oxygen species
s	=	Singlet (for NMR spectra)
SOD	=	Superoxide dismutase
t	=	Triplet (for NMR spectra)
TBA	=	Thiobarbituric acid
TCA	=	Trichloroacetic Acid
TCM	=	Traditional Chinese medicine
TE	=	Trolox® equivalent
TLC	=	Thin Layer Chromatography
TRX	=	Thioredoxins
UV-VIS	=	Ultraviolet and Visible spectrophotometry
VLC	=	Vacuum Liquid Column Chromatography
Xyl	=	Xylose

CHAPTER I
INTRODUCTION

Free radicals are atoms or molecules that contain unpair electrons. They are highly reactive, very short lived, unstable and can donate electrons to or receive electrons from many molecules (Mohammed *et al*., 2015). Researchers have found that free radicals are involved in many human diseases such as aging (Devasagayam *et al*., 2004). In general, free radicals can be divided into 2 types by atom of radicals; (1) oxygen containing molecules (reactive oxygen species, ROS) such as ozone (O_3), singlet oxygen ($^1O_2$), organic hydroperoxide (ROOH), peroxyl radical (ROO·), hydrogen peroxide (H_2O_2), hydroxyl radical (OH·) and superoxide ($O_2^{\cdot-}$) and (2) nitrogen containing molecules (reactive nitrogen species, RNS) such as nitric oxide (NO·), peroxy nitrite (ONOO·), peroxy nitrous acid (ONOOH) and nitrogen dioxide (NO_2) (Phaniendra *et al*., 2015). Free radicals can be generated from endogenous and exogenous sources. Examples of endogenous factors are electron transport chain in mitochondria, enzyme activities such as NADPH oxidase, xanthine oxidase, and nitric oxide synthase (NOS), stress and inflammatory cytokines. Exogenous factors are from environmental sources such as air, water, foods, chemicals, UV light, radiation, alcohol. They can produce both ROS and RNS (Lobo *et al*., 2010; Pham-Huy *et al*., 2008).

The situation in which the body has excessive levels of free radicals or very low levels of antioxidants, which can cause an imbalance between antioxidants and free radicals, is called oxidative stress (Thanan *et al*., 2014). Oxidative stress can cause many human diseases or damage to many target organs in the body such as cardiovascular diseases (hypertension, ischemia, atherosclerosis, heart failure), eyes (cataract, retinal disease), kidneys (chronic renal failure, glomerulonephritis), lungs (asthma, chronic bronchitis), joints inflammation (arthritis, rheumatism), brain diseases (Parkinson's disease, Alzheimer's disease, stroke) and multi-organs (cancer, aging, diabetes, inflammations, infections) (Pham-Huy *et al*., 2008). Moreover, oxidative stress can cause damage to proteins, which results in protein dysfunction. Lipid peroxidation and oxysterol formation are caused by oxidative reactions to lipids which affect

phospholipid functions. In addition, oxidative stress can alter oncogenes and tumor suppressor genes, resulting in mutations, epigenetic changes and genetic instability (Thanan *et al*., 2014).

Normally, humans have the system or substances called antioxidants which can protect many organs from oxidative damage or neutralize free radicals. Antioxidants are molecules which can counteract the effect of free radicals before they interact with the target organs. They can be endogenous compounds or exogenous compounds from foods or dietary supplements. Endogenous antioxidants, which are important for maintaining cellular function, are enzymes such as superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), glutathione reductase (GR), glutathione-S-transferase (GST), thioredoxins (TRX), peroxiredoxins (PRX) or substances such as melatonin or coenzyme Q10. We can obtain exogenous antioxidant compounds that could enhance the activity of endogenous antioxidants from external sources such as ascorbic acid (vitamin C), α-tocopherol (vitamin E), selenium, β-carotene (carotenoids), omega-3 or omega-6 fatty acids, and flavonoids (Fraunberger *et al*., 2016; Nimse and Pal, 2015). There are many antioxidant compounds from plants that have been used as dietary supplements. *Dendrobium* plants have been known to produce a large number of antioxidant compounds.

Dendrobium, which is the largest genus in the Orchidaceae family, contains more than 1,110 species (Teixeira da Silva *et al*., 2017a). *Dendrobium* plants are known in China as Shi hu and their distributions are in Asia and Australia (Wang *et al*., 2014). There are 74 species in China which are used traditionally for relieving the stomach, nourishing the kidney, promoting the body's immunity and prolonging life (Zhitao *et al*., 2017). The chemical constituents of *Dendrobium* have been isolated and classified as bibenzyls, alkaloids, fluorenones, phenanthrenes, coumarins, sesquiterpenoids, polysaccharides. They showed many biological activities including antioxidant, anti-inflammation, neuroprotective, immunomodulatory, anticancer, antimicrobial, antifungal and antiplatelet aggregating activities (Lam *et al*., 2015).

In Thailand, there are more than 100 species of *Dendrobium*, which have been reported and identified as follows (Forest herbarium, forest and plant conservation research office, department of national parks, wildlife and plant conservation, 2014).

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

D. chittimae Seidenf.	**เอื้องจิตติมา** Ueang chittima (General)
D. christyanum Rchb.f.	**เอื้องแซะภูกระดึง** Ueang sae phu kradueng (Loei)
D. chrysanthum Lindl.	**เอื้องสายมรกต** Ueang sai morakot (Bangkok)
D. chrysotoxum Lindl.	**เอื้องคำ** Ueang kham (Northern)
D. ciliatilabellum Seidenf.	**หวายเขาเขียว** Wai khao khiao (General)
D. clavator Ridl.	**N/A**
D. compactum Rolfe ex Hackett	**เอื้องข้าวตอก** Ueang khao tok (Northern)
D. compressum Lindl.	**หวายแบนตะนาวศรี** Wai baen tanao si (General)
D. concinnum Miq.	**หางเปีย** Hang pia (Narathiwat)
D. confinale Kerr	**N/A**
D. cowenii P. O'Byrne & J.J. Verm.	**N/A**
D. crepidatum Lindl. & Paxton	**เอื้องสายน้ำเขียว** Ueang sai nam khiao (General)
D. cretaceum Lindl.	**N/A**
D. crocatum Hook.f.	**เอื้องนางนวล** Ueang nang nuan (Peninsular)
D. cruentum Rchb.f.	**เอื้องนกแก้ว** Ueang nok kaeo (Bangkok)
D. crumenatum Sw.	**หวายตะมอย** Wai tamoi (Central, Peninsular)
D. crystallinum Rchb.f.	**เอื้องนางฟ่อน** Ueang nang fon (Chiang Mai)
D. cumulatum Lindl.	**เอื้องสายสี่ดอก** Ueang sai si dok (Northern, Southeastern)
D. curviflorum Rolfe	**N/A**
D. cuspidatum Lindl.	**เอื้องข้าวตอกปากแหลม**
D. dantaniense Guillaumin	**เอื้องเข็ม** Ueang khem (Chiang Mai)
D. delacourii Guillaumin	**เอื้องดอกมะขาม** Ueang dok ma kham (General)
D. deltatum Seidenf.	**N/A**

D. denneanum Kerr	N/A
D. densiflorum Lindl.	**เอื้องมอนไข่** Ueang mon khai (Northern)
D. denudans D. Don	**เอื้องสายจำปา** Ueang sai champa (General)
D. devonianum Paxton	**เอื้องเมี่ยง** Ueang miang (Chiang Mai)
D. dickasonii L. O. Williams	**เอื้องเคี้ยะ** Ueang khia (Chiang Mai)
D. dixanthum Rchb.f.	**เอื้องเทียน** Ueang thian (Northern)
D. dixonianum Rolfe ex Downie	**เอื้องข้าวตอกเหลือง**
D. draconis Rchb.f.	**เอื้องเงิน** Ueang ngoen (Northern)
D. elliottianum P. O'Byrne	**หวายเจดีย์** Wai chedi (Kanchanaburi)
D. ellipsophyllum Tang & Wang	**เอื้องทอง** Ueang thong (Genaeral)
D. erostelle Seidenf.	N/A
D. erosum (Blume) Lindl.	N/A
D. eserre Seidenf.	N/A
D. exile Schltr.	**เอื้องเสี้ยน** Ueang sian (General)
D. falconeri Hook.	**เอื้องสายวิสูตร** Ueang sai wisut (Bangkok)
D. farmeri Paxton	**เอื้องมัจฉาณุ** Ueang matchanu (Bangkok)
D. fimbriatum Hook.	**เอื้องคำน้อย** Ueang kham noi (Chiang Mai)
*D. findlayanu*m C.S.P. Parish & Rchb.f.	**พวงหยก** Phuang yok (Bangkok)
D. flexile Ridl.	N/A
D. formosum Roxb. ex Lindl.	**เอื้องเงินหลวง** Ueang ngoen luang (Chiang Mai)
D. friedericksianum Rchb.f.	**เอื้องเหลืองจันทบูร** Ueang lueang chantabun (Bangkok)
D. fuerstenbergianum Schltr.	**เอื้องแซะภูกระดึง** Ueang sae phukradueng (General)

D. fyychianum Bateman ex Rchb.f.	**หวายพม่า** Wai phama (General)
D. garrettii Seidenf.	**หวายการ์เร็ต** Wai karet (General)
D. gibsonii Paxton	**เอื้องคำสาย** Ueang kham sai (Northern)
D. grande Hook.f.	**เอื้องแผงใบใหญ่** Ueang pheang bai yai (Peninsular)
D. gratiotissimum Rchb.f.	**เอื้องกิ่งดำ** Ueang king dam (Bangkok)
D. gregulus Seidenf.	**เอื้องมะต่อม** Ueang ma tom (Chiang Mai)
D. griffithianum Lindl.	**เอื้องมัจฉาณุ** Ueang matchanu (Bangkok)
D. harveyanum Rchb.f.	**เอื้องคำฝอย** Ueang kham foi (Chiang Mai)
D. hendersonii Hawkes & Heller	**หวายตะมอยน้อย** Wai tamoi noi (Peninsular)
D. henryi Schltr.	**เอื้องสุริยัน** Ueang suriyan (Loei)
D. hercoglossum Rchb.f.	**เอื้องดอกมะเขือ** Ueang dok ma kuea (Bangkok)
D. heterocarpum Lindl.	**เอื้องสีตาล** Ueang si tan (Chiang Mai)
D. hymenanthum Rchb.f.	**เอื้องน้อยกลีบบาง** Ueang noi klip bang (Chiang Mai, Kanchanaburi)
D. hymenopterum Hook.f.	**N/A**
D. incurvum Lindl.	**N/A**
D. indivisum (Blume) Miq. var. *indivisum*	**ตานเสี้ยนไม้** Tan sian mai (Chumphon)
D. indivisum (Blume) Miq. var. *lampangense* Rolfe	**N/A**
D. indivisum (Blume) Miq. var. *pallidum* Seidenf.	**ก้างปลา** Kang pla (General)
D. indragiriense Schltr.	**N/A**
D. infundibulum Lindl.	**เอื้องตาเหิน** Ueang ta hoen (General)

D. intricatum Gagnep.	**เอื้องชมพู** Ueang chomphu (Chanthaburi)
D. jenkinsii Wall. ex Lindl.	**เอื้องผึ้งน้อย** Ueang phueng noi (Chiang Mai)
D. kanburiense Seidenf.	**หวายเมืองกาญจน์** Wai muang kan (Kanchanaburi)
D. keithii Ridl.	**หางเปีย** Hang pia (General)
D. kentrophyllum Hook.f.	**ก้างปลาใหญ่**
D. kontumense Gagnep.	**เอื้องเงินวิลาศ** Ueang ngoen wilat (Northeastern)
D. kratense Kerr	**N/A**
D. lagarum Seidenf.	**N/A**
D. lanpongense J.J.Sm.	**N/A**
D. lamyaiae Seidenf.	**N/A**
D. leonis (Lindl.) Rchb.f.	**เอื้องตะขาบใหญ่** Ueang ta khap yai (General)
D. lindleyi Steud.	**เอื้องผึ้ง** Ueang phueng (Northern)
D. linguella Rchb.f.	**N/A**
D. lituiflorum Lindl.	**เอื้องสายม่วง** Ueang sai muang (Northern, Bangkok)
D. lueckelianum Fessel & Wolff	**N/A**
D. mannii Ridl.	**เอื้องหางปลา** Ueang hang pla (General)
D. metachilinum Rchb.f.	**N/A**
D. monticola Hunt & Summerh	**N/A**
D. moschatum (Buch.-Ham.) Sw.	**เอื้องจำปา** Ueang champa (Northern)
D. mucronatum Seidenf.	**N/A**
D. nanocompactum Seidenf.	**N/A**
D. nathanielis Rchb.f.	**เกล็ดนิ่ม** Klet nim (Chantaburi)
D. ochreatum Lindl.	**เอื้องตะขาบ** Ueang ta khap (Chiang Mai)

D. oligophyllum Gagnep.	**ข้าวตอกปราจีน** Khao tok prachin (General)
D. pachyglossum Parish & Rchb.f	**เอื้องขนหมู** Ueang khon mu (Mae Hong Son)
D. pachyphyllum (Kuntze) Bakh.f.	**เอื้องน้อย** Ueang noi (General)
D. palpebrae Lindl.	**เอื้องมัจฉา** Ueang matcha (Bangkok)
D. pandaneti Ridl.	**N/A**
D. panduriferum Hook.f.	**N/A**
D. parciflorum Rchb.f. ex Lindl.	**เอื้องดอกขาวใบแบน** Ueang dok khao bai baen (General)
D. parcum Rchb.f.	**เอื้องก้านกิ่ว** Ueang kan kio (Bangkok)
D. parishii Rchb.f.	**เอื้องครั่ง** Ueang khrang (Northern)
D. parvum Seidenf.	**N/A**
D. peguanum Lindl.	**หวายเปกู** Wai peku (General)
D. pendulum Roxb.	**เอื้องไม้เท้าฤาษี** Ueang mai thao ruesi (Bangkok, Chiang Mai)
D. perpaulum Seidenf.	**เอื้องข้าวตอกอินทนนท์** Ueang khao tok inthanon (General)
D. planibulbe Lindl.	**N/A**
D. polyanthum Wall. ex Lindl.	**เอื้องสายประสาท** Ueang sai prasat (Bangkok)
D. porphyrochilum Lindl.	**เอื้องเฉวียน** Ueang chawian (General)
D. praecinctum Rchb.f.	**หวายภูหลวง** Wai phu luang (General)
D. proteranthum Seidenf.	**หวายน้อยภูหลวง** Wai noi phu luang (Loei)
D. pulchellum Roxb. ex Lindl.	**เอื้องคำตาควาย** Ueang kham ta khwai (Mae Hong Son)
D. pychnostachyum Lindl.	**เศวตสอดสี** Sawet sot si (Chiang Mai)
D. rhodostele Ridl.	**N/A**

D. salaccense (Blume) Lindl.	**เอื้องใบไผ่** Ueang bai phai (Chiang Mai)
D. sanguinolentum Lindl.	**N/A**
D. scabrilingue Lindl.	**เอื้องแซะ** Ueang sae (Mae Hong Son)
D. schilhaueri Ormerod & Pedersen	**N/A**
D. secundum (Blume) Lindl.	**เอื้องแปรงสีฟัน** Ueang preang si fan (Bangkok)
D. senile Parish & Rchb.f.	**เอื้องชะนี** Ueang chani (Bangkok)
D. setifolium Ridl.	**N/A**
D. signatum Rchb.f.	**เอื้องเค้ากิ่ว** Ueang khao kio (Northern)
D. singaporense Hawkes & Heller	**N/A**
D. sinuatum (Lindl.) Lindl. ex Rchb.f.	**N/A**
D. sociale J.J.Sm.	**N/A**
D. strongylanthum Rchb.f.	**เอื้องเย้าลม** Ueang yao lom (Northern)
D. stuposum Lindl.	**เอื้องสาย** Ueang sai (Chiang Mai)
D. subulatum (Blume) Lindl.	**N/A**
D. sukhakulii hort.	**หวายสุขะกุล** Wai sukhakun (General)
D. sulcatum Lindl.	**เอื้องจำปาน่าน** Ueang champa nan (Bangkok)
D. superbiens Rchb.f.	**หวายคิง** Wai khing (Bangkok)
D. sutepense Rolfe ex Downie	**เอื้องมะลิ** Ueang mali (Chiang Mai)
D. terminale Parish & Rchb.f	**เอื้องแผงโสภา** Ueang phaeng sopha (Peninsular)
D. thyrsiflorum Rchb.f	**เอื้องมอนไข่ใบมน** Ueang mon khai bai mon (Northern)
D. tortile Lindl.	**เอื้องไม้ตึง** Ueang mai tueng (Mae Hong Son)
D. trigonopus Rchb.f.	**เอื้องคำเหลี่ยม** Ueang kham liam (Chiang Mai)
D. trinervium Ridl.	**เทียนลิง** Thian ling (Chumphon)

D. truncatum Lindl.	**N/A**
D. umbonatum Seidenf.	**N/A**
D. unicum Seidenf.	**เอื้องครั่งแสด** Ueang krang saet (General)
D. uniflorum Griff.	**เอื้องทอง** Ueang thong (Pattani)
D. venustum Teijsm. & Binn	**ข้าวเหนียวลิง** Khao niao ling (Central)
D. villosulum Lindl.	**กล้วยหญ้านา** Kluai ya na (Bangkok)
D. viridulum Ridl.	**N/A**
D. wardianum R. Warner	**เอื้องมณีไตรรงค์** Ueang mani trairong (Northern)
D. wattii (Hook.f.) Rchb.f.	**เอื้องแซะ** Ueang sae (Northern)
D. williamsonii Day & Rchb.f.	**N/A**
D. xanthophlebium Lindl.	**เอื้องแซะภูลังกา**
D. ypsilon Seidenf.	**เอื้องแบนปากตัด** Ueang baen pak tat (General)

Dendrobium parishii Rchb. f. is known as “Ueang khrang” (เอื้องครั่ง) in Thai. Its stems are round, 15-30 cm in length. Leaves are 5-6 cm long, in alternate 2-ranked arrangement. It produces inflorescence of flower with red purple sepals and petals with purple lips (**Fig. 1**). The flowering period is during February to March. This orchid has been found in the north and northeast of Thailand (Sanga Sabhasri Research and Development Department, The Botanical Garden Organization, 2011).

At present, there has been only one report on the chemical constituents of *Dendrobium parishii* Rchb. f., describing an imidazole alkaloid named anosmine (Leander and Luning, 1968). No studies have been done on the biological activities of this plant. In a preliminary study, an ethyl acetate, butanol and aqueous extracts obtained from this plant were tested for DPPH radical scavenging activity. The ethyl acetate extract, at 100 µg/mL, showed 80% DPPH radical scavenging activity. The activity was not observed in the butanol and aqueous extracts. This study attempted

to find out the constituents and antioxidant activities of *D. parishii*, which might be useful for the development of drugs from natural sources.

The major objectives of this study were as follows.

1. To isolate and purify the constituents from *Dendrobium parishii* and analyze the chemical structure of each compound.

2. To investigate the antioxidant activities of the isolated compounds.

Figure 1 *Dendrobium parishii* Rchb. f.

CHAPTER II
HISTORICAL

1. Chemical constituents of *Dendrobium* species

Plants of the genus *Dendrobium* are known to produce several classes of secondary metabolites, which can be categorized as bibenzyls, flavonoids, terpenoids and miscellaneous compounds (**Fig. 2-5**).

Bibenzyls and their derivatives, as shown in **Table 1**, belong to the stilbene group. Stilbenoids are formed by a molecule of cinnamic acid with three malonyl- CoA units. First, cinnamic acid from the shikimic acid pathway is hydroxylated and activated to 4-coumaroyl-CoA. Three acetate units from malonyl-CoA are then added to this activated 4-coumaroyl-CoA using stilbene synthase enzyme. After cyclization, they form a tetraketide, an unstable intermediate which is transformed into either a chalcone or a stilbene (stilbenes, bibenzyls, phenanthrenes, 9,10-dihydro-phenanthrenes) (Tsopmo *et al*., 2013). Modifications to the chalcone structure including glycosylation, methylation and hydroxylation give various flavonoids (Dewick, 2002), as shown in **Table 2**.

Terpenoids (**Table 3)** are synthesized from two pathways including the mevalonic acid pathway and the methylerythritol phosphate pathway. These two pathways provide the precursors for biosynthesis of isoprenes (C5), monoterpenes (C10), sesquiterpenes (C15), diterpenes (C20), sesterterpenes (C25), triterpenes (C30) and tetraterpenes (C40) (Schrader and Bohlmann, 2015).

Several minor compounds are grouped together and presented as miscellaneous compounds (**Table 4**) including aliphatic compounds, phenolic compounds, benzoic acid derivatives, lignans, neolignans, alkaloids, phenylpropanoids, fluorenones and coumarins.

Table 1 Bibenzyls and derivatives in the genus *Dendrobium*

Compounds	Plant	Plant part	Reference
Aloifol I [**1**]	*D. longicornu*	Stem	Hu *et al*., 2008a
	D. williamsonii	Whole plant	Yang *et al*., 2017b
Amoenylin [**2**]	*D. amoenum*	Whole plant	Majumder *et al*., 1999
	D. williamsonii	Whole plant	Yang *et al*., 2017b
Batatasin [**3**]	*D. longicornu*	Stem	Hu *et al*., 2008a
	D. plicatile	Stem	Yamaki and Honda, 1996
Batatasin III [**4**]	*D. aphyllum*	Whole plant	Chen *et al*., 2008a
		Stem	Yang *et al*., 2015
	D. cariniferum	Stem	Chen *et al*., 2008
	D. chrysotoxum	Whole plant	Li *et al*., 2009c
	D. draconis	Stem	Sritularak *et al*., 2011a
	D. formosum	Whole plant	Inthongkaew *et al*., 2017
	D. gratiosissimum	Stem	Zhang *et al*., 2008a
	D. loddigesii	Stem	Ito *et al*., 2010
	D. venustum	Whole plant	Sukphan *et al*., 2014
Brittonin A [**5**]	*D. secundum*	Stem	Sritularak *et al*., 2011b

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
Chrysotobibenzyl [**6**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al*., 2006b
	D. capillipes	Stem	Phechrmeekha *et al*., 2012
	D. chrysanthum	Stem	Yang *et al*., 2006a
	D. chryseum	Stem	Ma *et al*., 1998
	D. chrysotoxum	Stem	Hu *et al*., 2012
	D. nobile	Stem	Zhang *et al*., 2007b
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
Chrysotoxine [**7**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al*., 2006b
	D. chrysanthum	Stem	Yang *et al*., 2006a
	D. chryseum	Stem	Ma *et al*., 1998
	D. nobile	Stem	Zhang *et al*., 2007b
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
Crepidatin [**8**]	*D. aurantiacum* var. *denneanum*	Whole plant	Liu *et al*., 2009b
	D. capillipes	Stem	Phechrmeekha *et al*., 2012
	D. chrysanthum	Stem	Yang *et al*., 2006a

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Crepidatin [**8**]	*D. crepidatum*	Whole plant	Majumder and Chatterjee, 1989
	D. nobile	Stem	Zhang *et al*., 2007b
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
Cumulatin [**9**]	*D. cumulatum*	Whole plant	Majumder and Pal, 1993
Dendrobin A [**10**]	*D. nobile*	Stem	Wang and Zhao, 1985; Ye and Zhao, 2002b
3,3′-Dihydroxy-4,5-dimethoxybibenzyl [**11**]	*D. williamsonii*	Whole plant	Rungwichaniwat *et al*., 2014
3,4′-Dihydroxy-5-methoxybibenzyl [**12**]	*D. amoenum*	Whole plant	Majumder *et al*., 1999
3,4′-Dihydroxy-5,5′-dimethoxydihydro stilbene [**13**]	*D. nobile*	Stem	Hwang *et al*., 2010
4,5-Dihydroxy-3,3′-dimethoxybibenzyl [**14**]	*D. nobile*	Stem	Ye and Zhao, 2002b

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Erianin [**15**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Gigantol [**16**]	*D. aphyllum*	Whole plant	Chen *et al*., 2008a
	D. aurantiacum var. *denneanum*	Whole plant	Liu *et al*., 2009b
	D. brymerianum	Whole plant	Klongkumnuankarn *et al*., 2015
	D. densiflorum	Stem	Fan *et al*., 2001
	D. devonianum	Whole plant	Sun *et al*., 2014
	D. draconis	Stem	Sritularak *et al*., 2011a
	D. formosum	Whole plant	Inthongkaew *et al*., 2017
	D. gratiosissimum	Stem	Zhang *et al*., 2008a
	D. loddigesii	Whole plant	Ito *et al*., 2010
	D. longicornu	Stem	Hu *et al*., 2008a
	D. nobile	Stem	Zhang *et al*., 2007b
	D. officinale	Stem	Zhao *et al*., 2018
	D. polyanthum	Stem	Hu *et al*., 2009
	D. trigonopus	Stem	Hu *et al*., 2008b
	D. venustum	Whole plant	Sukphan *et al*., 2014

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
4-Hydroxy-3,5,3´-trimethoxybibenzyl [**17**]	*D. nobile*	Stem	Ye and Zhao, 2002b
5-Hydroxy-3,4,3´,4´,5´-pentamethoxybibenzyl [**18**]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Isoamoenylin [**19**]	*D. amoenum*	Whole plant	Majumder *et al*., 1999
Moniliformine [**20**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b
Moscatilin [**21**]	*D. amoenum*	Whole plant	Majumder *et al*., 1999
	D. aurantiacum var. *denneanum*	Stem	Yang *et al*., 2006b
	D. brymerianum	Whole plant	Klongkumnuankarn *et al*., 2015
	D. chrysanthum	Stem	Yang *et al*., 2006a
	D. densiflorum	Stem	Fan *et al*., 2001
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al*., 2014
	D. formosum	Whole plant	Inthongkaew *et al*., 2017
	D. gratiosissimum	Stem	Zhang *et al*., 2008a

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Moscatilin [**21**]	*D. loddigesii*	Whole plant	Chen *et al*., 1994; Ito *et al*., 2010
	D. longicornu	Stem	Hu *et al*., 2008a
	D. moscatum	Whole plant	Majumder and Sen, 1987
	D. nobile	Stem	Miyazawa *et al*., 1999
	D. polyanthum	Stem	Hu *et al*., 2009
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
	D. secundum	Stem	Sritularak *et al*., 2011b
	D. williamsonii	Whole plant	Yang *et al*., 2017b
3,3′,4-Trihydroxy bibenzyl [**22**]	*D. longicornu*	Stem	Hu *et al*., 2008a
3,3′,5-Trihydroxy bibenzyl [**23**]	*D. cariniferum*	Whole plant	Liu *et al*., 2009a
3,5,4′-Trihydroxy bibenzyl [**24**]	*D. gratiosissimum*	Stem	Zhang *et al*., 2008a

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl [**25**]	*D. secundum*	Stem	Sritularak *et al*., 2011b
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al*., 2014
Tristin [**26**]	*D. aphyllum*	Stem	Yang *et al*., 2015
	D. chrysotoxum	Stem	Hu *et al*., 2012
	D. densiflorum	Stem	Fan *et al*., 2001
	D. gratiosissimum	Stem	Zhang *et al*., 2008a
	D. longicornu	Stem	Hu *et al*., 2008a
	D. officinale	Stem	Zhao *et al*., 2018
	D. trigonopus	Stem	Hu *et al*., 2008b
Dendromoniliside E [**27**]	*D. nobile*	Stem	Miyazawa *et al*., 1999
Dendrophenol [**28**]	*D. candidum*	Stem	Li *et al*., 2008
3,4-Dihydroxy-5,4′-dimethoxybibenzyl [**29**]	*D. candidum*	Stem	Li *et al*., 2008
	D. signatum	Whole plant	Mittraphab *et al*., 2016
	D. tortile	Whole plant	Limpanit *et al*., 2016

Table 1 (continued)

Compounds	Plant	Plant part	Reference
4,4′-Dihydroxy-3,5-dimethoxybibenzyl [**30**]	*D. candidum*	Stem	Li *et al*., 2008
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al*., 2014
	D. williamsonii	Whole plant	Yang *et al*., 2017b
Loddigesiinol C [**31**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
3-*O*-Methylgigantol [**32**]	*D. candidum*	Stem	Li *et al*., 2008
	D. plicatile	Stem	Yamaki and Honda, 1996
Dendrocandin A [**33**]	*D. candidum*	Stem	Li *et al*., 2008
Dendrocandin B [**34**]	*D. candidum*	Stem	Li *et al*., 2008
	D. signatum	Whole plant	Mittraphab *et al*., 2016
Dendrocandin C [**35**]	*D. candidum*	Stem	Li *et al*., 2009b
Dendrocandin D [**36**]	*D. candidum*	Stem	Li *et al*., 2009b
Dendrocandin E [**37**]	*D. candidum*	Stem	Li *et al*., 2009b
Dendrocandin F [**38**]	*D. candidum*	Stem	Li *et al*., 2009b
Dendrocandin G [**39**]	*D. candidum*	Stem	Li *et al*., 2009b
Dendrocandin H [**40**]	*D. candidum*	Stem	Li *et al*., 2009b

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
Dendrosinen A [**41**]	*D. sinense*	Whole plant	Chen *et al*., 2014a
Dendrosinen B [**42**]	*D. sinense*	Whole plant	Chen *et al*., 2014a
Dendrosinen C [**43**]	*D. sinense*	Whole plant	Chen *et al*., 2014a
Dendrosinen D [**44**]	*D. sinense*	Whole plant	Chen *et al*., 2014a
Dendrocandin I [**45**]	*D. candidum*	Stem	Li *et al*., 2009b
	D. signatum	Whole plant	Mittraphab *et al*., 2016
Densiflorol A [**46**]	*D. densiflorum*	Stem	Fan *et al*., 2001
Longicornuol A [**47**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Trigonopol A [**48**]	*D. trigonopus*	Stem	Hu *et al*., 2008b
Trigonopol B [**49**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
	D. trigonopus	Stem	Hu *et al*., 2008b
Crepidatuol A [**50**]	*D. crepidatum*	Stem	Li *et al*., 2013
Crepidatuol B [**51**]	*D. crepidatum*	Stem	Li *et al*., 2013
Loddigesiinol D [**52**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
Dencryol A [**53**]	*D. crystallinum*	Stem	Wang *et al*., 2009
Dencryol B [**54**]	*D. crystallinum*	Stem	Wang *et al*., 2009

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Dengraol A [**55**]	*D. gratiosissimum*	Stem	Zhang *et al*., 2008a
Dengraol B [**56**]	*D. gratiosissimum*	Stem	Zhang *et al*., 2008a
4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxy phenol [**57**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Nobilin A [**58**]	*D. nobile*	Stem	Zhang *et al*., 2006
Nobilin B [**59**]	*D. nobile*	Stem	Zhang *et al*., 2006
Nobilin C [**60**]	*D. nobile*	Stem	Zhang *et al*., 2006
Nobilin D [**61**]	*D. nobile*	Stem	Zhang *et al*., 2007b
Nobilin E [**62**]	*D. nobile*	Stem	Zhang *et al*., 2007b
Dendrofalconerol A [**63**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
	D. signatum	Whole plant	Mittraphab *et al*., 2016
	D. tortile	Whole plant	Limpanit *et al*., 2016
Dendrofalconerol B [**64**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
Dendrosignatol [**65**]	*D. signatum*	Whole plant	Mittraphab *et al*., 2016

Table 1 (continued)

Compounds	Plant	Plant part	Reference
2,2′-Dihydroxy-3,3′,4,4′,7,7-hexamethoxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene [**66**]	*D. nobile*	Stem	Yang *et al*., 2007a
2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene [**67**]	*D. plicatile*	Stem	Yamaki and Honda, 1996
Flavanthrin [**68**]	*D. aphyllum*	Whole plant	Chen *et al*., 2008a
Phoyunnanin C [**69**]	*D. venustum*	Whole plant	Sukphan *et al*., 2014
Phoyunnanin E [**70**]	*D. venustum*	Whole plant	Sukphan *et al*., 2014
Amoenumin [**71**]	*D. amoenum*	Whole plant	Veerraju *et al*., 1989
Crystalltone [**72**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
	D. crystallinum	Stem	Wang *et al*., 2009
Chrysotoxol A [**73**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Chrysotoxol B [**74**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Confusarin [**75**]	*D. chryseum*	Stem	Ma *et al*., 1998
	D. chrysotoxum	Stem	Hu *et al*., 2012
	D. formosum	Whole plant	Inthongkaew *et al*., 2017
	D. nobile	Stem	Zhang *et al*., 2008c
	D. officinale	Stem	Zhao *et al*., 2018
2,6-Dihydroxy-1,5,7-trimethoxy-phenanthrene [**76**]	*D. densiflorum*	Stem	Fan *et al*., 2001
Dendrochrysanene [**77**]	*D. chrysanthum*	Stem	Yang *et al*., 2006a
Bulbophyllanthrin [**78**]	*D. nobile*	Stem	Yang *et al*., 2007a
Denthyrsinin [**79**]	*D. thyrsiforum*	Stem	Zhang *et al*., 2005
5-Hydroxy-2,4-dimethoxy-phenanthrene [**80**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
3-Hydroxy-2,4,7-trimethoxy-phenanthrene [**81**]	*D. nobile*	Stem	Yang *et al*., 2007a
Cypripedin [**82**]	*D. densiflorum*	Stem	Fan *et al*., 2001
Densiflorol B [**83**]	*D. densiflorum*	Stem	Fan *et al*., 2001
	D. venustum	Whole plant	Sukphan *et al*., 2014

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Denbinobin [**84**]	*D. moniliforme*	Stem	Lin *et al*., 2001
	D. nobile	Stem	Yang *et al*., 2007a
Fimbriatone [**85**]	*D. nobile*	Stem	Zhang *et al*., 2008c
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
Loddigesiinol B [**86**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
Dendronone [**87**]	*D. chrysanthum*	Stem	Yang *et al*., 2006a
	D. longicornu	Stem	Hu *et al*., 2008a
Ephemeranthoquinone [**88**]	*D. plicatile*	Stem	Yamaki and Honda, 1996
5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**]	*D. draconis*	Stem	Sritularak *et al*., 2011a
	D. formosum	Whole plant	Inthongkaew *et al*., 2017
Moniliformin [**90**]	*D. moniliforme*	Stem	Lin *et al*., 2001
Moscatin [**91**]	*D. aphyllum*	Whole plant	Chen *et al*., 2008a
	D. chrysanthum	Stem	Yang *et al*., 2006a
	D. chrysotoxum	Whole plant	Li *et al*., 2009c
	D. densiflorum	Stem	Fan *et al*., 2001
	D. polyanthum	Stem	Hu *et al*., 2009

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
Coelonin [**92**]	*D. aphyllum*	Whole plant	Chen *et al*., 2008a
	D. formosum	Whole plant	Inthongkaew *et al*., 2017
	D. nobile	Stem	Yang *et al*., 2007a
9,10-Dihydromoscatin [**93**]	*D. polyanthum*	Stem	Hu *et al*., 2009
9,10-Dihydrophenanthrene-2,4,7-triol [**94**]	*D. polyanthum*	Stem	Hu *et al*., 2009
4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [**95**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al*., 2014
	D. sinense	Whole plant	Chen *et al*., 2014a
4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene [**96**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene [**97**]	*D. nobile*	Stem	Ye and Zhao, 2002b

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene [**98**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Lusianthridin [**99**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al*., 2015
	D. formosum	Whole plant	Inthongkaew *et al*., 2017
	D. plicatile	Stem	Yamaki and Honda, 1996
	D. venustum	Whole plant	Sukphan *et al*., 2014
2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene [**100**]	*D. densiflorum*	Stem	Yang *et al*., 2007a
2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**101**]	*D. nobile*	Stem	Fan *et al*., 2001

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene [**102**]	*D. rotundatum*	Whole plant	Majumder and Pal, 1992
Ephemeranthol A [**103**]	*D. nobile*	Stem	Yang *et al*., 2007a Hwang *et al*., 2010
	D. officinale	Stem	Zhao *et al*., 2018
Ephemeranthol C [**104**]	*D. nobile*	Stem	Yang *et al*., 2007a Hwang *et al*., 2010
Erianthridin [**105**]	*D. formosum*	Whole plant	Inthongkaew *et al*., 2017
	D. nobile	Stem	Hwang *et al*., 2010
	D. plicatile	Stem	Yamaki and Honda, 1996
Flavanthridin [**106**]	*D. nobile*	Stem	Hwang *et al*., 2010
Hircinol [**107**]	*D. aphyllum*	Stem	Yang *et al*., 2015
	D. draconis	Stem	Sritularak *et al*., 2011a
	D. formosum	Whole plant	Inthongkaew *et al*., 2017

Table 1 (continued)

Compounds	Plant	Plant part	Reference
3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene [**108**]	*D. nobile*	Stem	Yang *et al*., 2007a
2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene [**109**]	*D. nobile*	Stem	Yang *et al*., 2007a
7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol [**110**]	*D. draconis*	Stem	Sritularak *et al*., 2011a
2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene [**111**]	*D. formosum*	Whole plant	Inthongkaew *et al*., 2017
	D. longicornu	Stem	Hu *et al*., 2008a
Plicatol C [**112**]	*D. plicatile*	Stem	Honda and Yamaki, 2000
Rotundatin [**113**]	*D. rotundatum*	Whole plant	Majumder and Pal, 1992

Table 1 (continued)

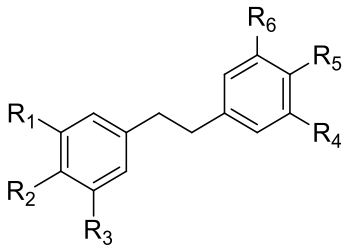
Compounds	**Plant**	**Plant part**	**Reference**
2,5-Dihydroxy-3,4 dimethoxyphenanthrene [**114**]	*D. nobile*	Stem	Yang *et al*., 2007a
2,5-Dihydroxy-4,9-dimethoxyphenanthrene [**115**]	*D. nobile*	Stem	Zhang *et al*., 2008a
2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene [**116**]	*D. nobile*	Stem	Yang *et al*., 2007a
Epheranthol B [**117**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
	D. plicatile	Stem	Yamaki and Honda, 1996
Fimbriol B [**118**]	*D. nobile*	Stem	Yang *et al*., 2007a; Hwang *et al*., 2010
Flavanthrinin [**119**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al*., 2015
	D. nobile	Stem	Zhang *et al*., 2008c
	D. venustum	Whole plant	Sukphan *et al*., 2014
Loddigesiinol A [**120**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Nudol [**121**]	*D. formosum*	Whole plant	Inthongkaew *et al*., 2017
	D. nobile	Stem	Yang *et al*., 2007a
	D. rotundatum	Whole plant	Majumder and Pal, 1992
Plicatol A [**122**]	*D. nobile*	Stem	Yang *et al*., 2007a
	D. plicatile	Stem	Honda and Yamaki, 2000
Plicatol B [**123**]	*D. plicatile*	Stem	Honda and Yamaki, 2000
2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene [**124**]	*D. nobile*	Stem	Yang *et al*., 2007a
3,4,8-Trimethoxy phenanthrene-2,5-diol [**125**]	*D. nobile*	Stem	Hwang *et al*., 2010
Aphyllone [**126**]	*D. nobile*	Stem	Hwang *et al*., 2010
(*S*)-2,4,5,9-Tetrahydroxy-9,10-dihydro phenanthrene [**127**]	*D. fimbriatum*	Stem	Xu *et al*., 2014
1,5,7-Trimethoxy phenanthren-2-ol [**128**]	*D. nobile*	Stem	Kim *et al*., 2015

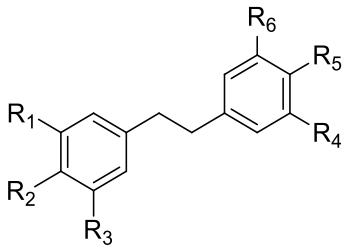
Table 1 (continued)

Compounds	Plant	Plant part	Reference
1,5-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**129**]	*D. moniliforme*	Whole plant	Zhao *et al*., 2016
2,5,9*S*-Trihydroxy-9,10-dihydro phenanthrene-4-*O*-β-D-glucopyranoside [**130**]	*D. primulinum*	Whole plant	Ye *et al*., 2016
Loddigesiinol G [**131**]	*D. loddigesii*	Stem	Lu *et al*., 2014
Loddigesiinol H [**132**]	*D. loddigesii*	Stem	Lu *et al*., 2014
Loddigesiinol I [**133**]	*D. loddigesii*	Stem	Lu *et al*., 2014
Loddigesiinol J [**134**]	*D. loddigesii*	Stem	Lu *et al*., 2014
Dendrowillol A [**135**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017a
Dendrocandin P1 [**136**]	*D. officinale*	Stem	Zhao *et al*., 2018
Dendrocandin P2 [**137**]	*D. officinale*	Stem	Zhao *et al*., 2018
Orchinol [**138**]	*D. officinale*	Stem	Zhao *et al*., 2018
2,4,7-Trihydroxy-9,10-dihydro-phenanthrene [**139**]	*D. officinale*	Stem	Zhao *et al*., 2018
4-Methoxy-5,9*R*-dihydroxy-9,10-dihydro phenanthrene 2-*O*-β-D-glucopyranoside [**140**]	*D. nobile*	Stem	Zhou *et al*., 2017



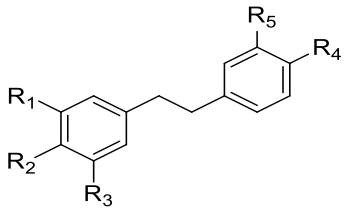
	R_1	R_2	R_3	R_4	R_5	R_6
[**1**] Aloifol I	OMe	OH	OMe	OH	H	H
[**2**] Amoenylin	OMe	OH	OMe	H	OMe	H
[**3**] Batatasin	OMe	H	H	OH	H	OH
[**4**] Batatasin III	OH	H	OMe	H	H	OH
[**5**] Brittonin A	OMe	OMe	OMe	OMe	OMe	OMe
[**6**] Chrysotobibenzyl	OMe	OMe	OMe	OMe	OMe	H
[**7**] Chrysotoxine	OMe	OH	OMe	OMe	OMe	H
[**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 bibenzyls and derivatives isolated from *Dendrobium* species

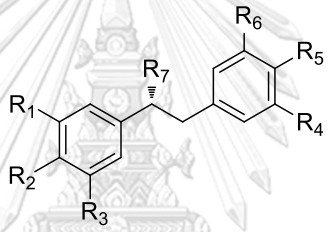


	R_1	R_2	R_3	R_4	R_5	R_6
[**14**] 4,5-Dihydroxy-3,3′-dimethoxybibenzyl	OMe	OH	OH	H	H	OMe
[**15**] Erianin	OMe	OMe	OMe	H	OMe	OH
[**16**] Gigantol	OMe	H	H	H	OH	OMe
[**17**] 4-Hydroxy-3,5,3′ trimethoxybibenzyl	OMe	OH	OMe	H	H	OMe
[**18**] 5-Hydroxy-3,4,3′,4′,5′ pentamethoxybibenzyl	OMe	OMe	OH	OMe	OMe	OMe
[**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 bibenzyls and derivatives isolated from *Dendrobium* species (continued)

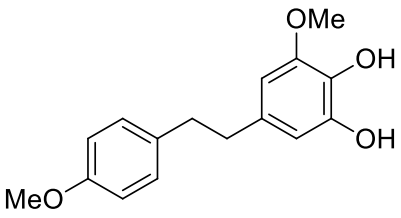


	R_1	R_2	R_3	R_4	R_5
[**25**] 4,5,4′-Trihydroxy-3-3′-dimethoxybibenzyl	OMe	OH	OH	OH	OMe
[**26**] Tristin	OH	H	OH	OH	OMe
[**27**] Dendromoniliside E	OGlc	OGlc	OMe	OMe	H

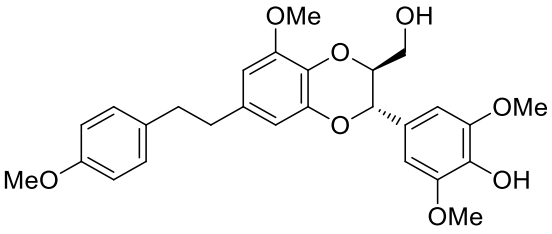


	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**28**] Dendrophenol	OMe	OH	OMe	OH	OH	H	H
[**29**] 3,4-Dihydroxy-5,4′-dimethoxybibenzyl	OH	OH	OMe	H	OMe	H	H
[**30**] 4,4′-Dihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	H	OH	H	H
[**31**] Loddigesiinol C	OMe	OH	OMe	H	OH	OMe	OMe
[**32**] 3-*O*-Methylgigantol	OMe	H	OH	OMe	OMe	H	H

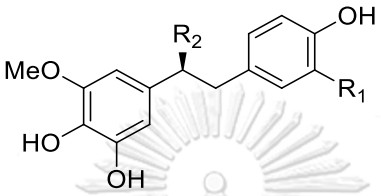
Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



[**33**] Dendrocandin A



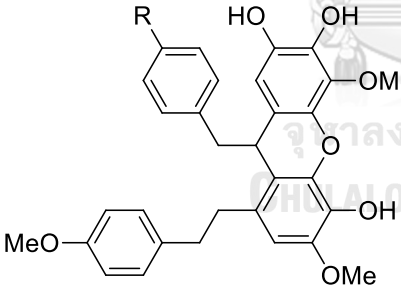
[**34**] Dendrocandin B



[**35**] Dendrocandin C: R_1 = H, R_2 = OMe

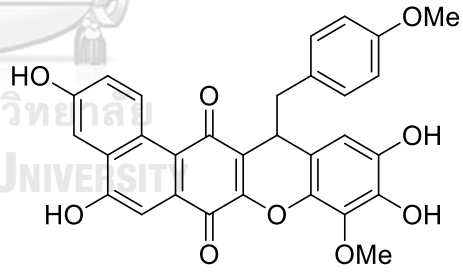
[**36**] Dendrocandin D: R_1 = H, R_2 = OEt

[**37**] Dendrocandin E: R_1 = OH, R_2 = H



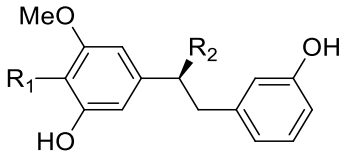
[**38**] Dendrocandin F: R = OMe

[**39**] Dendrocandin G: R = OH



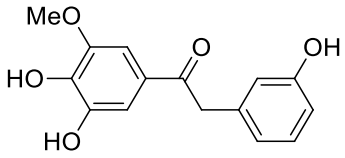
[**40**] Dendrocandin H

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)

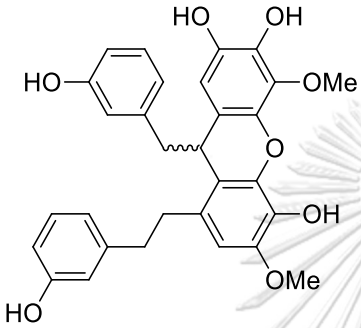


[**41**] Dendrosinen A R_1 = OMe, R_2 = OH

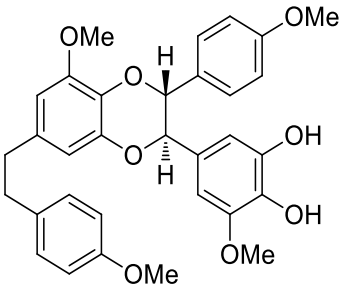
[**42**] Dendrosinen B R_1 = OH, R_2 = H



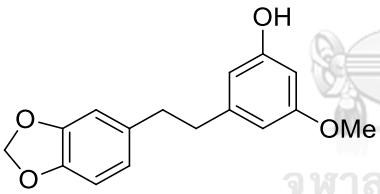
[**43**] Dendrosinen C



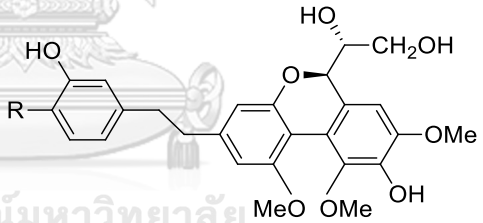
[**44**] Dendrosinen D



[**45**] Dendrocandin I

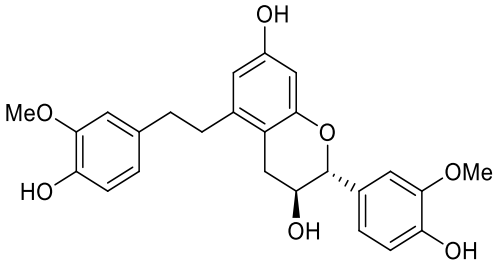


[**46**] Densiflorol A



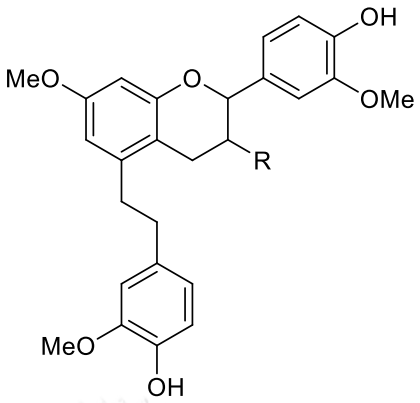
[**47**] Longicornuol A: R = H

[**48**] Trigonopol A: R = OMe



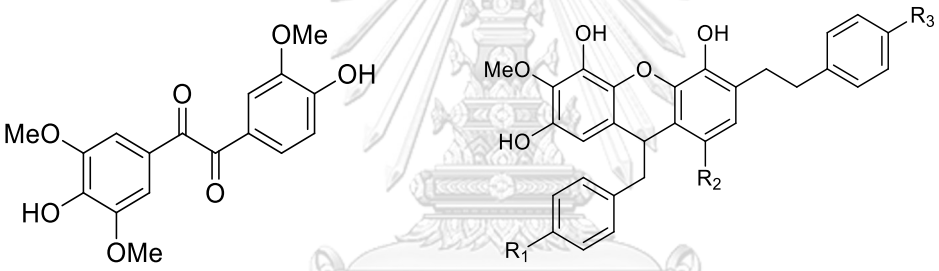
[**49**] Trigonopol B

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



[**50**] Crepidatuol A: R = H

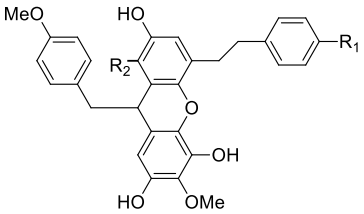
[**51**] Crepidatuol B: R = OH



[**52**] Loddigesiinol D

[**53**] Dencryol A: R_1 = OMe, R_2 = R_3 = OH

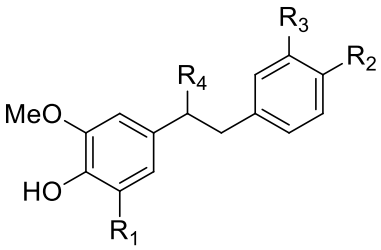
[**54**] Dencryol B: R_1 = OH, R_2 = R_3 = OMe



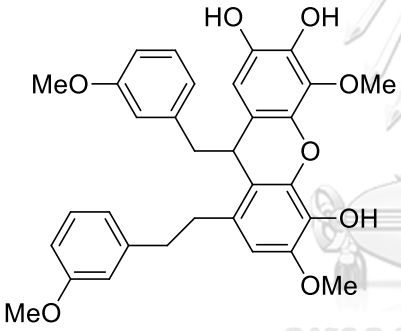
[**55**] Dengraol A: R_1 = R_2 = OH

[**56**] Dengraol B: R_1 = OMe, R_2 = OMe

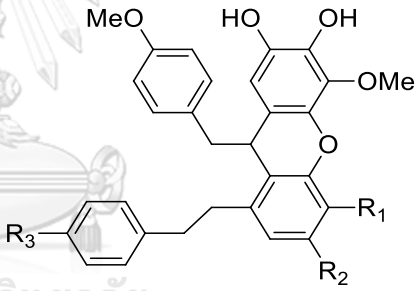
Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4
[**57**] 4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol	OMe	H	OH	OMe
[**58**] Nobilin A	OH	H	OMe	OMe
[**59**] Nobilin B	OMe	OH	OMe	OMe
[**60**] Nobilin C	OMe	OMe	OMe	OMe
[**61**] Nobilin D	OMe	OH	OMe	OH

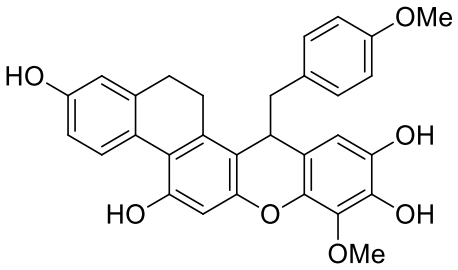


[**62**] Nobilin E



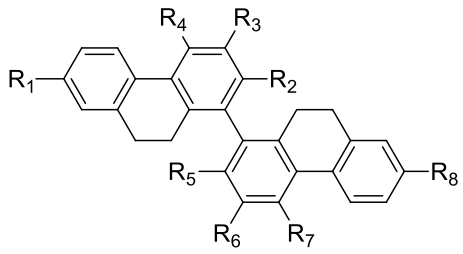
[**63**] Dendrofalconerol A: R_1 = OH, R_2 = R_3 = OMe

[**64**] Dendrofalconerol B: R_1 = H, R_2 = R_3 = OH

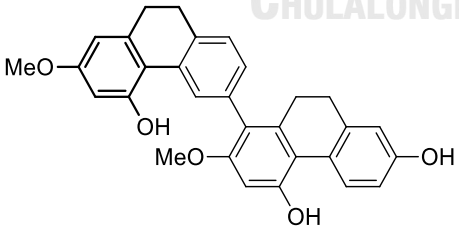


[**65**] Dendrosignatol

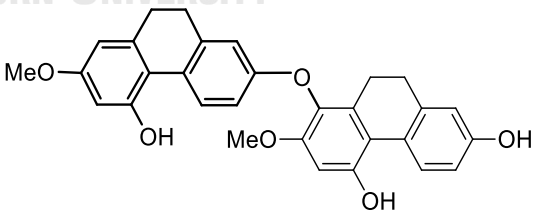
Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
[**66**] 2,2′-Dihydroxy-3,3′,4,4′,7,7′-hexa-methoxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OMe	OH	OMe	OMe	OH	OMe	OMe	OMe
[**67**] 2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OH	OMe	H	OH	OMe	H	OH	OH
[**68**] Flavanthrin	OH	OH	H	OMe	OH	H	OMe	OH

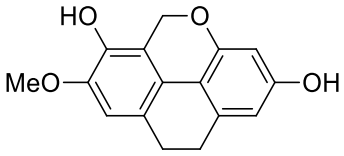


[**69**] Phoyunnanin C

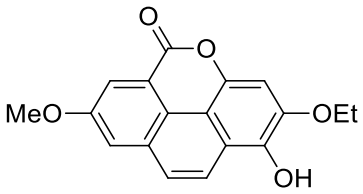


[**70**] Phoyunnanin E

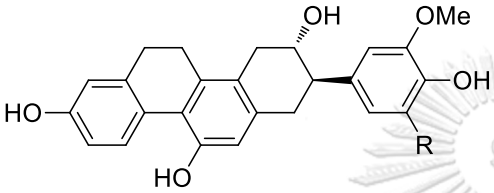
Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



[**71**] Amoenumin

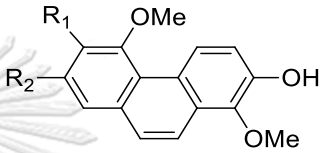


[**72**] Crystalltone



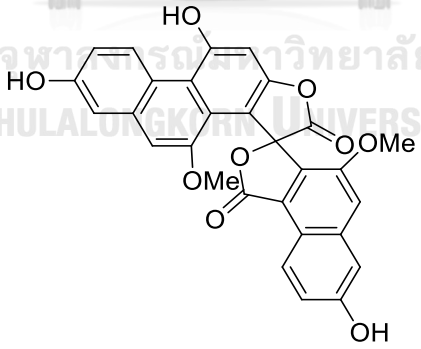
[**73**] Chrysotoxol A: R = H

[**74**] Chrysotoxol B: R = OMe



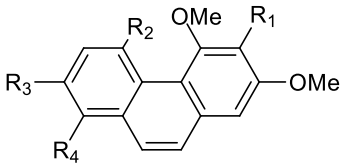
[**75**] Confusarin: R_1 = OMe, R_2 = OH

[**76**] 2,6-Dihydroxy-1,5,7 trimethoxyphenanthrene: R_1 = OH, R_2 = OMe

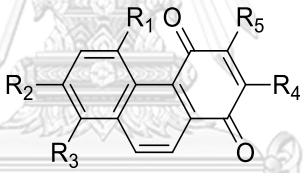


[**77**] Dendrochrysanene

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)

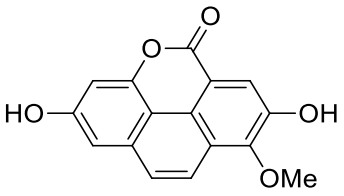


	R_1	R_2	R_3	R_4
[**78**] Bulbophyllanthrin	OH	OH	H	H
[**79**] Denthyrsinin	OH	H	OH	OMe
[**80**] 5-Hydroxy-2,4-dimethoxy-phenanthrene	H	OH	H	H
[**81**] 3-Hydroxy-2,4,7-trimethoxy-phenanthrene	OH	H	OMe	H

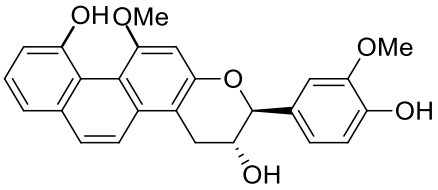


	R_1	R_2	R_3	R_4	R_5
[**82**] Cypripedin	H	OH	OMe	OMe	H
[**83**] Densiflorol B	H	OH	H	OMe	H
[**84**] Denbinobin	OH	OMe	H	H	OMe

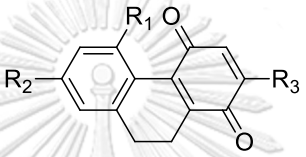
Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



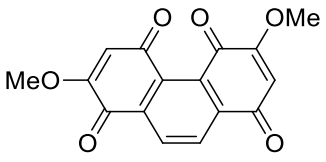
[**85**] Fimbriatone



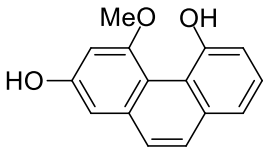
[**86**] Loddigesiinol B



	R_1	R_2	R_3
[**87**] Dendronone	OH	OMe	H
[**88**] Ephemeranthoquinone	H	OH	OMe
[**89**] 5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone	OMe	OH	H

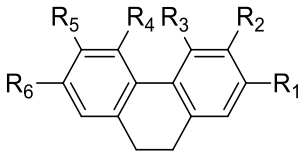


[**90**] Moniliformin



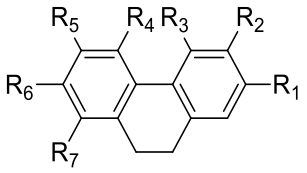
[**91**] Moscatin

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



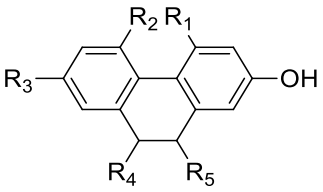
	R_1	R_2	R_3	R_4	R_5	R_6
[**92**] Coelonin	OH	H	OMe	H	H	OH
[**93**] 9,10-Dihydromoscatin	H	H	OH	OMe	H	OH
[**94**] 9,10-Dihydrophenanthrene-2,4,7-triol	OH	H	OH	H	H	OH
[**95**] 4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydro-phenanthrene	OMe	OMe	OH	OH	H	H
[**96**] 4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydro-phenanthrene	OMe	H	OH	OH	OMe	H
[**97**] 4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydro-phenanthrene	H	OMe	OH	OH	H	OMe
[**98**] 4,5-Dihydroxy-2-methoxy-9,10-dihydro-phenanthrene	OMe	H	OH	OH	H	H
[**99**] Lusianthridin	OMe	H	OH	H	H	OH

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



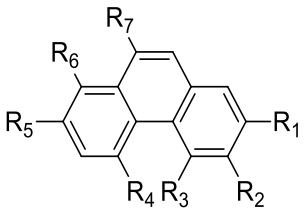
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**100**] 2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydro-phenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**101**] 2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydro-phenanthrene	OH	OMe	OMe	H	H	OMe	OH
[**102**] 4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydro-phenanthrene	OMe	OMe	OH	H	OMe	OH	H
[**103**] Ephemeranthol A	OH	H	H	OH	OMe	OMe	H
[**104**] Ephemeranthol C	OH	OH	OMe	OH	H	H	H
[**105**] Erianthridin	OH	OMe	OMe	H	H	OH	H
[**106**] Flavanthridin	OH	H	H	OMe	OH	OMe	H
[**107**] Hircinol	OH	H	OMe	OH	H	H	H
[**108**] 3-Hydroxy-2,4,7-trimethoxy-9,10-dihydro-phenanthrene	OMe	OH	OMe	H	H	OMe	H

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



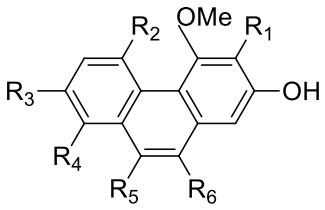
	R_1	R_2	R_3	R_4	R_5
[**109**] 2-Hydroxy-4,7-dimethoxy-9,10-dihydro-phenanthrene	OMe	H	OMe	H	H
[**110**] 7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol	OH	OH	OMe	H	H
[**111**] 2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene	OMe	OH	OH	H	H
[112] Plicatol C	H	OMe	OH	H	OMe
[**113**] Rotundatin	H	OMe	OH	H	OH

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



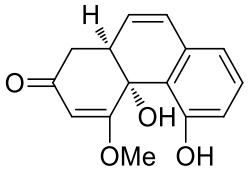
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**114**] 2,5-Dihydroxy-3,4-dimethoxyphenanthrene	OH	OMe	OMe	OH	H	H	H
[**115**] 2,5-Dihydroxy-4,9-dimethoxyphenanthrene	OH	H	OMe	OH	H	H	OMe
[**116**] 2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**117**] Epheranthol B	H	H	OMe	OH	OMe	H	H
[**118**] Fimbriol B	OH	OMe	OH	H	H	H	H
[**119**] Flavanthrinin	H	H	OMe	H	OH	H	H

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)

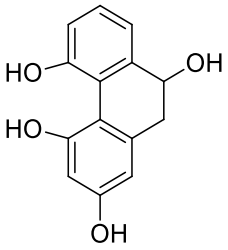


	R_1	R_2	R_3	R_4	R_5	R_6
[**120**] Loddigesiinol A	H	OMe	H	H	OH	H
[**121**] Nudol	OMe	H	OH	H	H	H
[**122**] Plicatol A	H	OH	H	H	OMe	OMe
[**123**] Plicatol B	H	OH	H	H	H	H
[**124**] 2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene	OH	OH	H	H	OMe	H
[**125**] 3,4,8-Trimethoxy phenanthrene-2,5-diol	OMe	OH	H	OMe	H	H

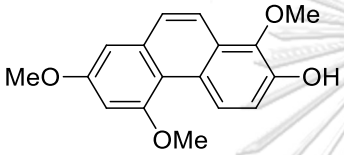
Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



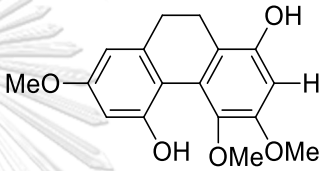
[**126**] Aphyllone



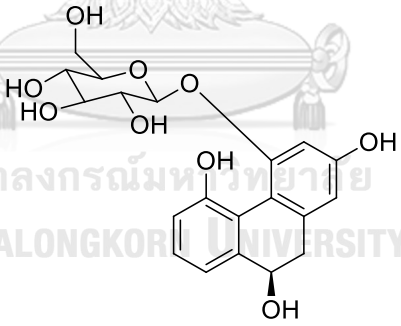
[**127**] 2,4,5,9*S*-Tetrahydroxy-9,10-dihydrophenanthrene



[**128**] 1,5,7-Trimethoxyphenanthren-2-ol

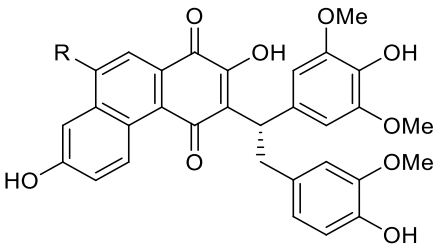


[**129**] 1,5-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene



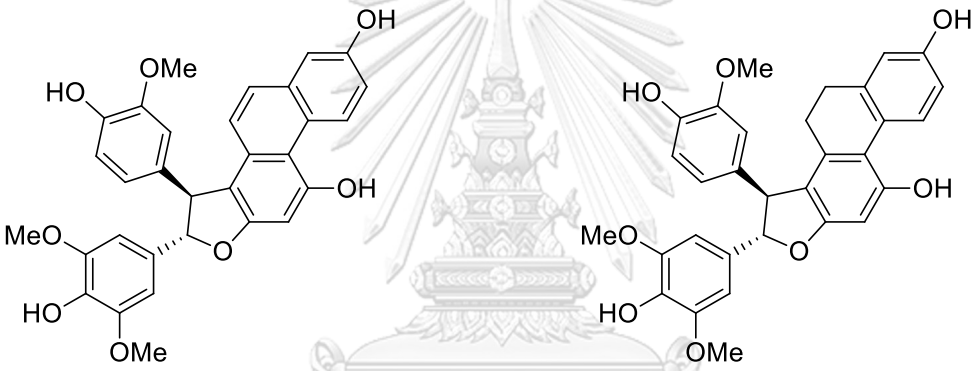
[**130**] 2,5,9*S*-Trihydroxy-9,10-dihydrophenanthrene 4-*O*-**β**-D-glucopyranoside

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)

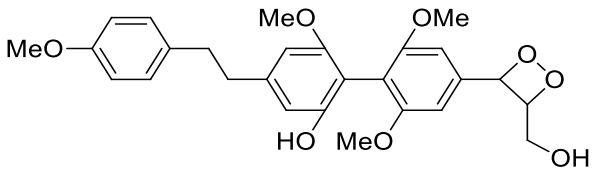


[**131**] Loddigesiinol G: R = H

[**132**] Loddigesiinol H: R = OH

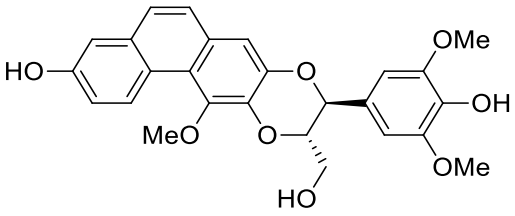


[**133**] Loddigesiinol I [**134**] Loddigesiinol J

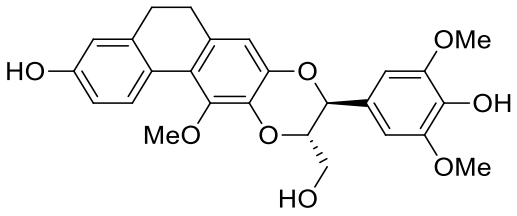


[**135**] Dendrowillol A

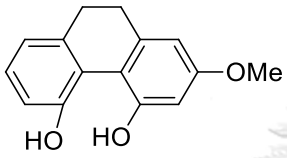
Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)



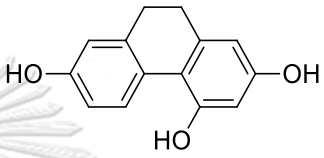
[**136**] Dendrocandin P1



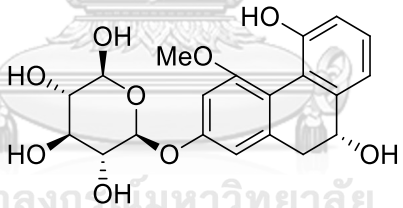
[**137**] Dendrocandin P2



[**138**] Orchinol



[**139**] 2,4,7-Trihydroxy-9,10-dihydrophenanthrene



[**140**] 4-Methoxy-5,9*R*-dihydroxy-9,10-dihydrophenanthrene 2-*O*-β-D-glucopyranoside

Figure 2 Structures of bibenzyls and derivatives isolated from *Dendrobium* species (continued)

Table 2 Flavonoids in the genus *Dendrobium*

Compounds	**Plant**	**Plant part**	**Reference**
(2*S*)-Homoeriodictyol [**141**]	*D. densiflorum*	Stem	Fan *et al*., 2001
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al*., 2014
Naringenin [**142**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al*., 2006b
	D. densiflorum	Stem	Fan *et al*., 2001
	D. longicornu	Stem	Hu *et al*., 2008a
(2*S*)-Eriodictyol [**143**]	*D. trigonopus*	Stem	Hu *et al*., 2008b
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al*., 2014
	D. tortile	Whole plant	Limpanit *et al*., 2016
Vicenin-2 [**144**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Apigenin [**145**]	*D. crystallinum*	Stem	Wang *et al*., 2009
	D. williamsonii	Whole plant	Rungwichaniwat *et al*., 2014
5,6-Dihydroxy-4′-methoxyflavone [**146**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Chrysoeriol [**147**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al*., 2014

Table 2 (continued)

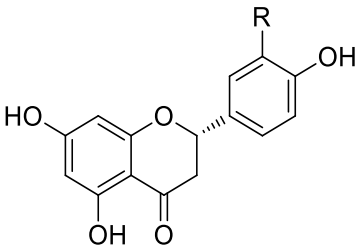
Compounds	**Plant**	**Plant part**	**Reference**
Luteolin [**148**]	*D. aurantiacum* var. *denneanum*	Whole plant	Liu *et al*., 2009b
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al*., 2014
6-*C*-(α-Arabino pyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-galactopyranosyl] apigenin [**149**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
6-*C*-(α-Arabino pyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-glucopyranosyl] apigenin [**150**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
6‴-Glucosyl-vitexin [**151**]	*D. crystallinum*	Stem	Wang *et al*., 2009
Isoschaftoside [**152**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Isoviolanthin [**153**]	*D. crystallinum*	Stem	Wang *et al*., 2009
6-*C*-[(2-*O*-α-Rhamno pyranosyl)-β-gluco pyranosyl]-8-*C*-(α-arabinopyranosyl) apigenin [**154**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010

Table 2 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
6-*C*-(β-Xylopyranosyl)-8-*C*-[(2-*O*-α-rhamno pyranosyl)-β-gluco pyranosyl]apigenin [**155**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Kaempferol [**156**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al*., 2006b
Kaempferol-3-*O*-α-L rhamnopyranoside [**157**]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside [**158**]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-gluco pyranoside [**159**]	*D. capillipes*	Stem	Phechrmeekha *et al*., 2012
Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylo pyranoside [**160**]	*D. capillipes*	Stem	Phechrmeekha *et al*., 2012
Quercetin-3-*O*-L-rhamnopyranoside [**161**]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012

Table 2 (continued)

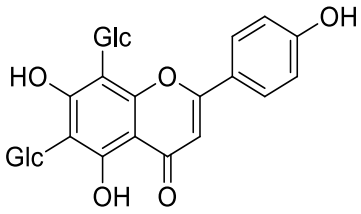
Compounds	**Plant**	**Plant part**	**Reference**
Quercetin-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside [**162**]	*D. capillipes*	Stem	Phechrmeekha *et al*., 2012
5-Hydroxy-3-methoxy-flavone-7-*O*-[β-D-apiosyl-(1⟶6)]-β-D-glucoside [**163**]	*D. devonianum*	Stem	Sun *et al*., 2014
Isorhamnetin-3-*O*-β-D-rutinoside [**164**]	*D. nobile*	Stem	Zhou *et al*., 2017



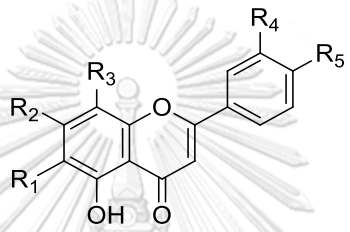
[**141**] (2*S*)-Homoeriodictyol: R = OMe

[**142**] Naringenin: R = H

[**143**] (2*S*)-Eriodictyol: R = OH

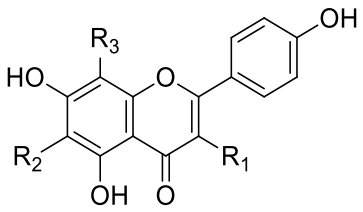


[**144**] Vicenin-2



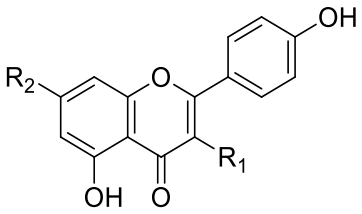
	R_1	R_2	R_3	R_4	R_5
[**145**] Apigenin	H	OH	H	H	OH
[**146**] 5,6-Dihydroxy-4′-methoxyflavone	OH	H	H	H	OMe
[**147**] Chrysoeriol	H	OH	H	OMe	OH
[**148**] Luteolin	H	OH	H	OH	OH
[**149**] 6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-galactopyranosyl]apigenin	-Ara	OH	-Gal-Rha	H	OH
[**150**] 6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-glucopyranosyl]apigenin	-Ara	OH	-Glc-Rha	H	OH

Figure 3 Structures of flavonoids isolated from *Dendrobium* species

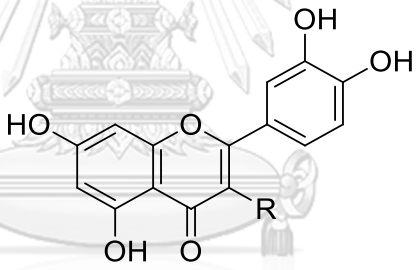


	R_1	R_2	R_3
[**151**] 6‴-Glucosyl-vitexin	H	H	-Glc
[**152**] Isoschaftoside	H	-Ara	-Glc
[**153**] Isoviolanthin	H	-Rha	-Glc
[**154**] 6-*C*-[(2-*O*-α-Rhamnopyranosyl)-β-glucopyranosyl]-8-*C*-(α-arabinopyranosyl)apigenin	H	-Glc-Rha	-Ara
[**155**] 6-*C*-(β-Xylopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-glucopyranosyl]apigenin	H	-Xyl	-Glc-Rha
[**156**] Kaempferol	OH	H	H

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

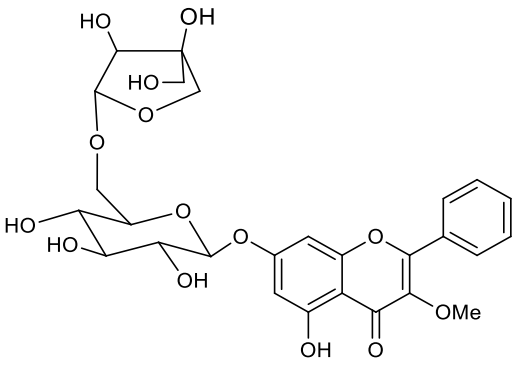


	R_1	R_2
[**157**] Kaempferol-3-*O*-α-L-rhamnopyranoside	O-Rha	OH
[**158**] Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside	O-Rha	O-Rha
[**159**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-glucopyranoside	O-Glc-Rha	OH
[**160**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside	O-Xyl-Rha	OH

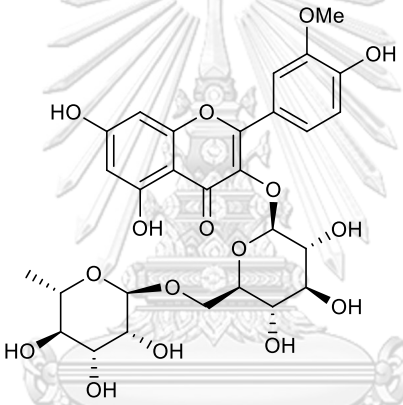


	R
[**161**] Quercetin-3-*O*-α-L-rhamnopyranoside	O-Rha
[**162**] Quercetin-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside	O-Xyl-Rha

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



[**163**] 5-Hydroxy-3-methoxy-flavone-7-*O*-[β-D-apiosyl-(1⟶6)]-β-D-glucoside



[**164**] Isorhamnetin-3-*O*-β-D-rutinoside

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

Table 3 Terpenoids in the genus *Dendrobium*

Compounds	**Plant**	**Plant part**	**Reference**
Aduncin [**165**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Amoenin [**166**]	*D. aduncum*	Whole plant	Dahmen and Leander, 1978
	D. williamsonii	Whole plant	Yang *et al*., 2017a
Amotin [**167**]	*D. amoenum*	Whole plant	Majumder *et al*., 1999
α-Dihydropicrotoxinin [**168**]	*D. amoenum*	Whole plant	Majumder *et al*., 1999
Dendrobane A [**169**]	*D. moniliforme*	Stem	Bi *et al*., 2004
Dendronobilin A [**170**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendronobilin B [**171**]	*D. wardianum*	Stem	Zhang *et al*., 2007a
Dendronobilin C [**172**]	*D. crystallium*	Stem	Wang *et al*., 2009
Dendronobilin D [**173**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendronobilin E [**174**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendronobilin F [**175**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendronobilin G [**176**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendronobilin H [**177**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendronobilin I [**178**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendronobilin J [**179**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendronobilin K [**180**]	*D. wardianum*	Stem	Fan *et al*., 2013
Dendronobilin L [**181**]	*D. nobile*	Stem	Zhang *et al*., 2007a

Table 3 (continued)

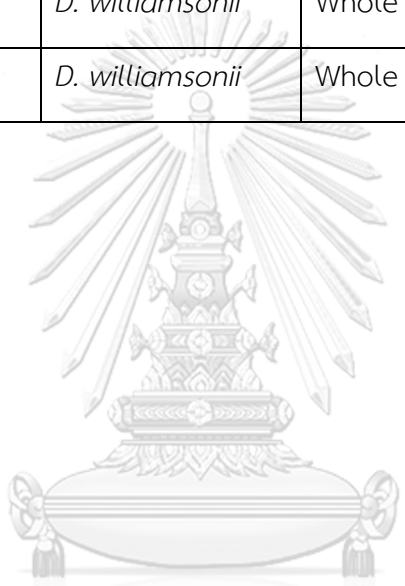
Compounds	Plant	Plant part	Reference
Dendronobilin M [**182**]	*D. nobile*	Stem	Zhang *et al*., 2008a
Dendronobilin N [**183**]	*D. nobile*	Stem	Zhang *et al*., 2008a
Dendrowardol A [**184**]	*D. nobile*	Stem	Zhang *et al*., 2008a
Dendrowardol B [**185**]	*D. nobile*	Stem	Zhang *et al*., 2008a
Dendrowardol C [**186**]	*D. wardianum*	Stem	Fan *et al*., 2013
Corchoionoside C [**187**]	*D. wardianum*	Stem	Fan *et al*., 2013
Crystallinin [**188**]	*D. wardianum*	Stem	Fan *et al*., 2013
Findlayanin [**189**]	*D. polyanthum*	Stem	Hu *et al*., 2009
3-Hydroxy-2-oxodendrobine [**190**]	*D. findlayanum*	Whole plant	Qin *et al*., 2011
Dendrobine [**191**]	*D. nobile*	Stem	Wang and Zhao, 1985
Dendromoniliside A [**192**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendromoniliside B [**193**]	*D. moniliforme*	Stem	Zhao *et al*., 2003
Dendromoniliside C [**194**]	*D. moniliforme*	Stem	Zhao *et al*., 2003
Dendromoniliside D [**195**]	*D. moniliforme*	Stem	Zhao *et al*., 2003
Dendronobiloside A [**196**]	*D. moniliforme*	Stem	Zhao *et al*., 2003
	D. nobile	Stem	Zhao *et al*., 2001; Ye and Zhao, 2002b

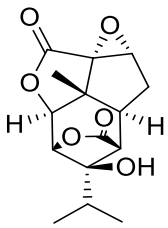
Table 3 (continued)

Compounds	Plant	Plant part	Reference
Dendronobiloside B [**197**]	*D. nobile*	Stem	Zhao *et al*., 2001; Ye and Zhao, 2002b
Dendronobiloside C [**198**]	*D. nobile*	Stem	Zhao *et al*., 2001; Ye and Zhao, 2002b
Dendronobiloside D [**199**]	*D. nobile*	Stem	Zhao *et al*., 2001; Ye and Zhao, 2002b
Dendronobiloside E [**200**]	*D. nobile*	Stem	Zhao *et al*., 2001; Ye and Zhao, 2002b
Dendroside A [**201**]	*D. moniliforme*	Stem	Zhao *et al*., 2003
	D. nobile	Stem	Zhao *et al*., 2001
		Stem	Ye and Zhao, 2002b
Dendroside B [**202**]	*D. nobile*	Stem	Ye and Zhao, 2002b
Dendroside C [**203**]	*D. moniliforme*	Stem	Zhao *et al*., 2003
	D. nobile	Stem	Ye and Zhao, 2002b
Dendroside D [**204**]	*D. nobile*	Stem	Ye and Zhao, 2002b

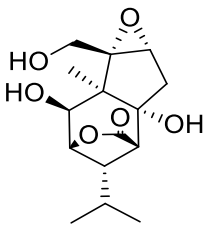
Table 3 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
Dendroside E [**205**]	*D. nobile*	Stem	Ye *et al*., 2002a
Dendroside F [**206**]	*D. moniliforme*	Stem	Zhao *et al*., 2003
Dendroside G [**207**]	*D. nobile*	Stem	Ye *et al*., 2002a
Dendrowillin A [**208**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017a
Dendrowillin B [**209**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017a
(–)-Picrotin [**210**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017a

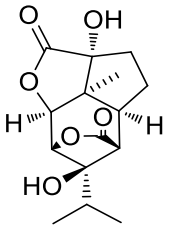




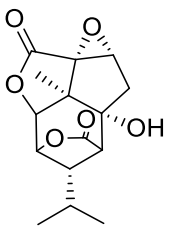
[**165**] Aduncin



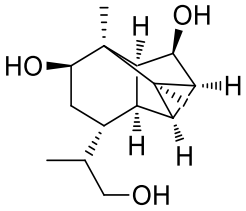
[**166**] Amoenin



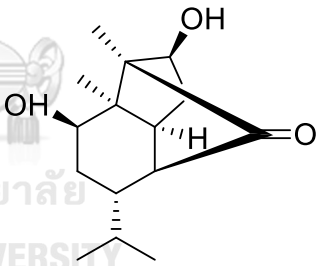
[**167**] Amotin



[**168**] α-Dihydropicrotoxinin

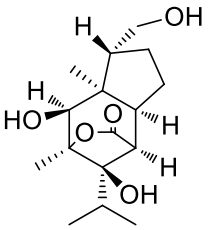


[**169**] Dendrobane A

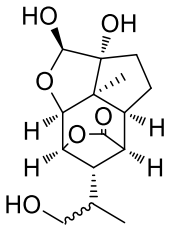


[**170**] Dendronobilin A

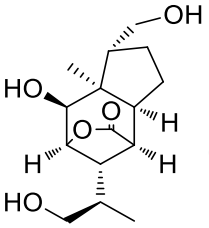
Figure 4 Structures of terpenoids isolated from *Dendrobium* species



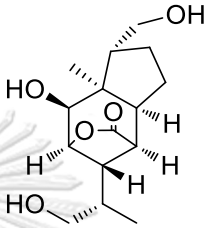
[**171**] Dendronobilin B



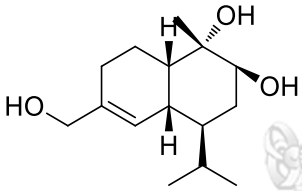
[**172**] Dendronobilin C



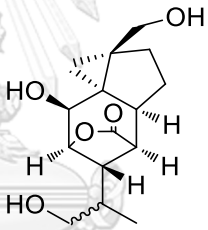
[**173**] Dendronobilin D



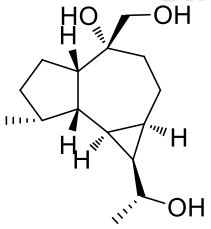
[**174**] Dendronobilin E



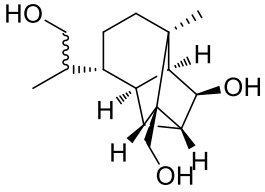
[**175**] Dendronobilin F



[**176**] Dendronobilin G

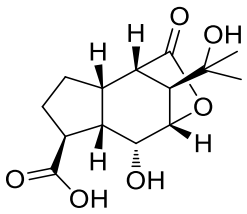


[**177**] Dendronobilin H

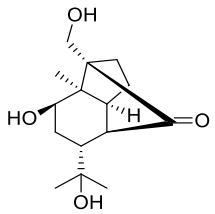


[**178**] Dendronobilin I

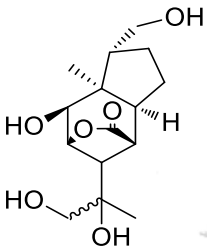
Figure 4 Structures of terpenoids isolated from *Dendrobium* species (continued)



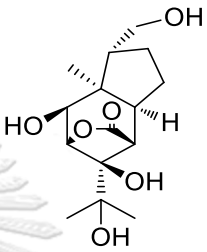
[**179**] Dendronobilin J



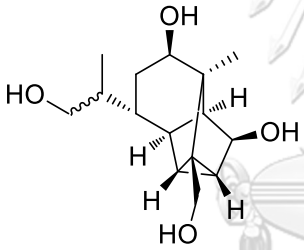
[**180**] Dendronobilin K



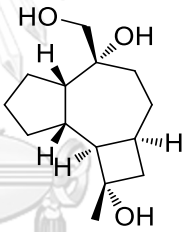
[**181**] Dendronobilin L



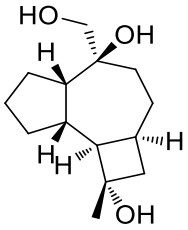
[**182**] Dendronobilin M



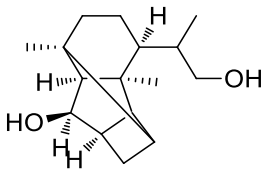
[**183**] Dendronobilin N



[**184**] Dendrowardol A

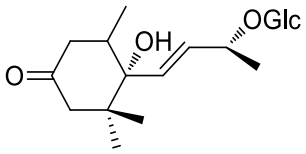


[**185**] Dendrowardol B

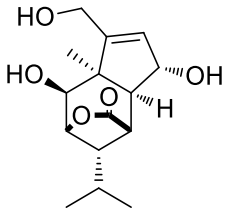


[**186**] Dendrowardol C

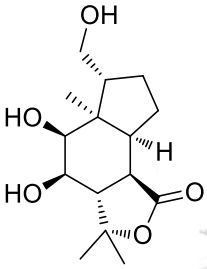
Figure 4 Structures of terpenoids isolated from *Dendrobium* species (continued)



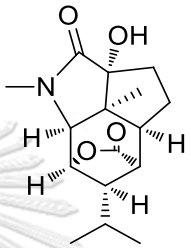
[**187**] Corchoionoside C



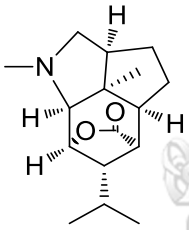
[**188**] Crystallinin



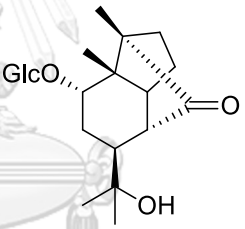
[**189**] Findlayanin



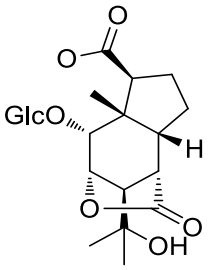
[**190**] 3-Hydroxy-2-oxodendrobine



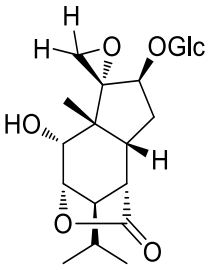
[**191**] Dendrobine



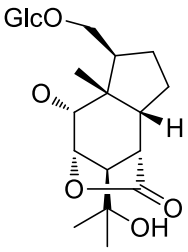
[**192**] Dendromoniliside A



[**193**] Dendromoniliside B

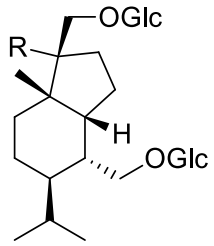


[**194**] Dendromoniliside C



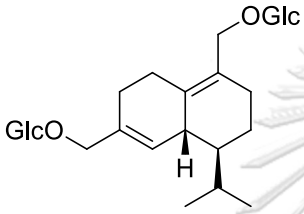
[**195**] Dendromoniliside D

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

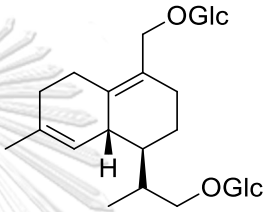


[**196**] Dendronobiloside A: R = H

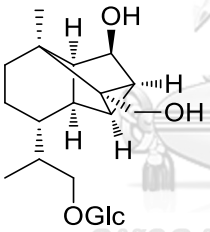
[**197**] Dendronobiloside B: R = OH



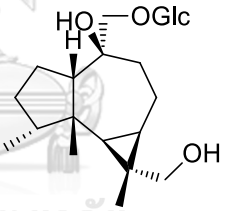
[**198**] Dendronobiloside C



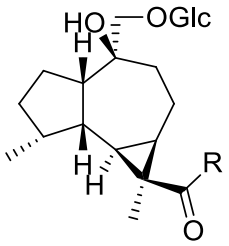
[**199**] Dendronobiloside D



[**200**] Dendronobiloside E



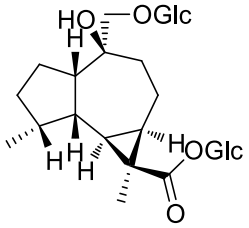
[**201**] Dendroside A



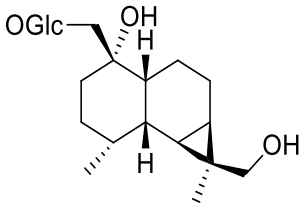
[**202**] Dendroside B: R = OGlc

[**203**] Dendroside C: R = OH

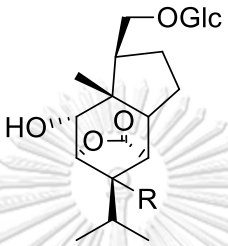
Figure 4 Structures of terpenoids isolated from *Dendrobium* species (continued)



[**204**] Dendroside D

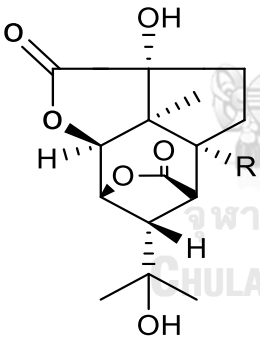


[**205**] Dendroside E



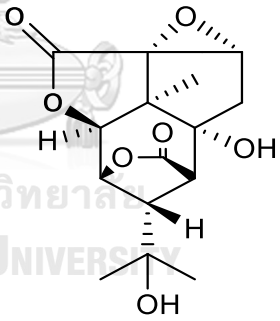
[**206**] Dendroside F: R = H

[**207**] Dendroside G: R = OH



[**208**] Dendrowillin A: R = OH

[**209**] Dendrowillin B: R = H



[**210**] (–)-Picrotin

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

Table 4 Miscellaneous compounds in the genus *Dendrobium*

Categories and compounds	**Plant**	**Plant part**	**Reference**
Aliphatic acid derivatives			
Aliphatic acids [**211**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al*., 2001
Aliphatic alcohols [**212**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al*., 2001
Malic acid [**213**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Dimethyl malate [**214**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
(-)-Shikimic acid [**215**]	*D. fuscescens*	Whole plant	Talapatra *et al*., 1989
	D. huoshanense	Aerial part	Chang *et al*., 2010
	D. longicornu	Stem	Hu *et al*., 2008a
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
Isopentyl butyrate [**216**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Benzoic acid derivatives and phenolic compounds			
3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid [**217**]	*D. crystallinum*	Stem	Wang *et al*., 2009
Salicylic acid [**218**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
	D. williamsonii	Whole plant	Yang *et al*., 2017b
Vanilloside [**219**]	*D. denneanum*	Stem	Pan *et al*., 2012

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Benzoic acid derivatives and phenolic compounds			
Gallic acid [**220**]	*D. longicornu*	Whole plant	Li *et al*., 2009a
Syringic acid [**221**]	*D. crystallinum*	Stem	Wang *et al*., 2009
Vanillic acid [**222**]	*D. crystallinum*	Stem	Wang *et al*., 2009
	D. williamsonii	Whole plant	Rungwichaniwat *et al*., 2014
Antiarol [**223**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Ethylhaematommate [**224**]	*D. longicornu*	Whole plant	Li *et al*., 2009a
p-Hydroxy-benzaldehyde [**225**]	*D. devonianum*	Whole plant	Sun *et al*., 2014
	D. falconeri	Stem	Sritularak and Likhitwitayawuid, 2009
	D. tortile	Whole plant	Limpanit *et al*., 2016
	D. williamsonii	Whole plant	Yang *et al*., 2017b
Methyl β-orsellinate [**226**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Protocatechuic acid [**227**]	*D. nobile*	Stem	Ye and Zhao, 2002b
Tachioside [**228**]	*D. denneanum*	Stem	Pan *et al*., 2012

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Benzoic acid derivatives and phenolic compounds			
Alkyl 4′-hydroxy-*trans*-cinnamates [**229**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al*., 2001
Alkyl *trans*-ferulate [**230**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al*., 2001
Defuscin [**231**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al*., 2006b
	D. moniliforme	Stem	Bi *et al*., 2004
n-Octacosyl ferulate [**232**]	*D. aurantiacum var. denneanum*	Stem	Yang *et al*., 2006b
	D. moniliforme	Stem	Bi *et al*., 2004
n-Triacontyl *p*-hydroxy-cis-cinnamate [**233**]	*D. moniliforme*	Stem	Bi *et al*., 2004
Tetratriacontanyl-*trans*-*p*-coumarate [**234**]	*D. williamsonii*	Whole plant	Rungwichaniwat *et al*., 2014
n-Docosyl *trans*-ferulate [**235**]	*D. longicornu*	Whole plant	Li *et al*., 2009a
	D. williamsonii	Whole plant	Rungwichaniwat *et al*., 2014
trans-Tetracosyl ferulate [**236**]	*D. tortile*	Whole plant	Limpanit *et al*., 2016

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Benzoic acid derivatives and phenolic compounds			
cis-Hexacosanoyl ferulate [**237**]	*D. tortile*	Whole plant	Limpanit *et al*., 2016
Ferulaldehyde [**238**]	*D. longicornu*	Whole plant	Li *et al*., 2009a
Ferulic acid [**239**]	*D. secundum*	Stem	Sritularak *et al*., 2011b
2-(*p*-Hydroxyphenyl) ethyl *p*-coumarate [**240**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
Dihydroconiferyl dihydro-*p*-coumarate [**241**]	*D. formosum*	Whole plant	Inthongkaew *et al*., 2017
	D. nobile	Stem	Zhang *et al*., 2006
1-[4-(**β**-D-Glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone [**242**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Benzoic acid derivatives and phenolic compounds			
3-Hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-1-propanone [**243**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b
Coniferyl alcohol [**244**]	*D. trigonopus*	Stem	Hu *et al*., 2008b
Decumbic acid A [**245**]	*D. nobile*	Stem	Zhou *et al*., 2016
Decumbic acid B [**246**]	*D. nobile*	Stem	Zhou *et al*., 2016
(–)-Decumbic acid [**247**]	*D. nobile*	Stem	Zhou *et al*., 2016
(+)-Dendrolactone [**248**]	*D. nobile*	Stem	Zhou *et al*., 2016
4-(3-Hydroxyphenyl)-2-butanone [**249**]	*D. nobile*	Stem	Zhou *et al*., 2016
3-Hydroxy-1(3-methoxy-4-hydroxyphenyl)-propan-1-one [**250**]	*D. nobile*	Stem	Zhou *et al*., 2016
3′,4′,5′-Trimethoxy cinnamyl acetate [**251**]	*D. nobile*	Stem	Zhou *et al*., 2016
p-Hydroxyphenyl propionic methyl ester [**252**]	*D. aphyllum*	Whole plant	Chen *et al*., 2008a

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Benzoic acid derivatives and phenolic compounds			
Phloretic acid [**253**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al*., 2014
Dihydroconiferyl alcohol [**254**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Salidrosol [**255**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Shashenoside I [**256**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Syringin [**257**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Tetracosyl(*Z*)-*p*-coumarate [**258**]	*D. falconeri*	Whole plant	Sritularak and Likhitwitayawuid, 2009
(7*S*,8*R*)-Dehydrodiconiferyl alcohol 9′-β-D-glucopyranoside [**259**]	*D. nobile*	Stem	Zhou *et al*., 2017
Koaburaside [**260**]	*D. nobile*	Stem	Zhou *et al*., 2017
Juniperoside [**261**]	*D. nobile*	Stem	Zhou *et al*., 2017
Dehydrodiconiferylalcohol-4-β-D-glucoside [**262**]	*D. nobile*	Stem	Zhou *et al*., 2017

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Benzoic acid derivatives and phenolic compounds			
(3*R*,3′*S*,4*R*,4′*S*)-3,3′,4,4′-Tetrahydro-6,6′-dimethoxy[3,3′-bi-2*H*-benzopyran]-4,4′-diol [**263**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b
Coumarins			
Ayapin [**264**]	*D. densiflorum*	Stem	Fan *et al*., 2001
Coumarin [**265**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al*., 2006b
	D. clavatum var. *aurantiacum*	Stem	Chang *et al*., 2001
Denthyrsin [**266**]	*D. thyrsiflorum*	Stem	Zhang *et al*., 2005
Scoparone [**267**]	*D. densiflorum*	Stem	Fan *et al*., 2001
	D. thyrsiflorum	Stem	Zhang *et al*., 2005
	D. williamsonii	Whole plant	Yang *et al*., 2017b
Scopoletin [**268**]	*D. densiflorum*	Stem	Fan *et al*., 2001

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Lignans and neolignans			
Episyringaresinol [**269**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
	D. longicornu	Stem	Hu *et al*., 2008a
	D. nobile	Stem	Zhang *et al*., 2008b
Episyringaresinol 4′′-*O*-β-D-glucopyranoside [**270**]	*D. moniliforme*	Stem	Zhao *et al*., 2003
(-)-(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 [**271**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Lyoniresinol [**272**]	*D. chrysanthum*	Stem	Ye *et al*., 2004
(-)-Syringaresinol-4,4′-bis-*O*-β–D-glucopyranoside [**273**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Dendrocoumarin [**274**]	*D. nobile*	Stem	Zhou *et al*., 2018
Itolide A [**275**]	*D. nobile*	Stem	Zhou *et al*., 2018

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Lignans and neolignans			
Syringaresinol-4-*O*-D-monoglucopyranoside [**276**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
(-)-Medioresinol [**277**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
(-)-Pinoresinol [**278**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
Syringaresinol [**279**]	*D. secundum*	Stem	Sritularak *et al*., 2011b
	D. williamsonii	Whole plant	Yang *et al*., 2017b
Erythro-1-(4-*O*-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol [**280**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Acanthoside B [**281**]	*D. chrysanthum*	Stem	Ye *et al*., 2004
Liriodendrin [**282**]	*D. brymerianum*	Whole plant	Chen *et al*., 2014b
	D. pulchellum	Stem	Chanvorachote *et al*., 2013

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Lignans and neolignans			
(-)-(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 [**283**]	*D. auranticum* var. *denneanum*	Stem	Li *et al*., 2014
(-)-(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 [**284**]	*D. auranticum* var. *denneanum*	Stem	Li *et al*., 2014
(-)-(8*R*,7′*E*)-4-Hydroxy-3,3′,5,5′,9′-penta methoxy-8,4′-oxyneolign-7′-ene-9-ol 4,9-bis-*O*-β-D-glucopyranoside [**285**]	*D. auranticum* var. *denneanum*	Stem	Li *et al*., 2014

Table 4 (continued)

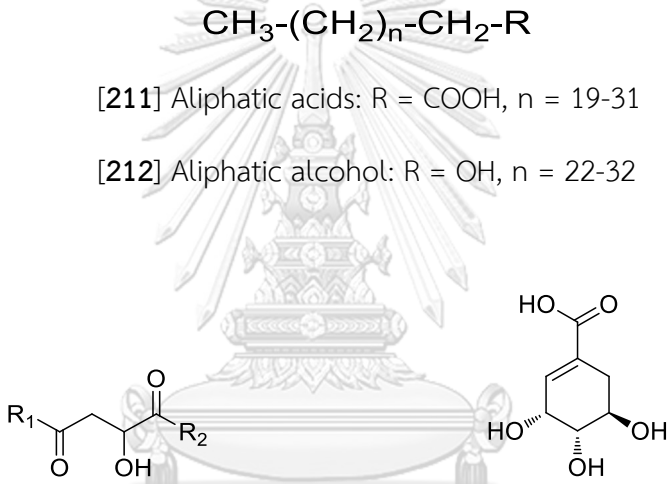
Categories and compounds	**Plant**	**Plant part**	**Reference**
Fluorenones			
Denchrysan A [**286**]	*D. chrysotoxum*	Whole plant	Li *et al*., 2009c
Denchrysan B [**287**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al*., 2015
	D. chrysotoxum	Whole plant	Li *et al*., 2009c
Dendroflorin [**288**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al*., 2006b
	D. brymerianum	Whole plant	Klongkumnuankarn *et al*., 2015
Dengibsin [**289**]	*D. aurantiacum var. denneanum*	Stem	Yang *et al*., 2006b
	D. chrysanthum	Stem	Yang *et al*., 2006a
	D. chrysotoxum	Whole plant	Li *et al*., 2009c
Nobilone [**290**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al*., 2015
	D. nobile	Stem	Zhang *et al*., 2007b
1,4,5-Trihydroxy-7-methoxy-9*H*-fluoren-9-one [**291**]	*D. chrysotoxum*	Whole plant	Li *et al*., 2009c
2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone [**292**]	*D. chrysotoxum*	Stem	Yang *et al*., 2004

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Others			
3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one [**293**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Palmarumycin JC2 [**294**]	*D. crystallinum*	Stem	Wang *et al*., 2009
Dehydrovomifoliol [**295**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
2,6-Dimethoxy Benzoquinone [**296**]	*D. chryseum*	Stem	Ma *et al*., 1998
4-(2-Hydroxypropyl)-2(5*H*)-furanone [**297**]	*D. tortile*	Whole plant	Limpanit *et al*., 2016
5,7-Dihydroxy-chromen-4-one [**298**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al*., 2014
Balanophonin [**299**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b
Ergosta-8(9),22-diene-3,5,6,7-tetraol [**300**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b
Stigmast-4-en-3α, 6β-diol [**301**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b
3β-Hydroxy-5α,8α-epidioxyergosta-6,9,22-triene [**302**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b
Betulin [**303**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b
β-Sitosterol [**304**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b

Table 4 (continued)

Categories and compounds	**Plant**	**Plant part**	**Reference**
Others			
Daucosterol [**305**]	*D. williamsonii*	Whole plant	Yang *et al*., 2017b
Anosmine [**306**]	*D. parishii*	Whole plant	Leander and Luning, 1968



[**211**] Aliphatic acids: R = COOH, n = 19-31

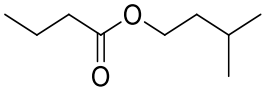
[**212**] Aliphatic alcohol: R = OH, n = 22-32

[**213**] Malic acid: R_1 = R_2 = OH

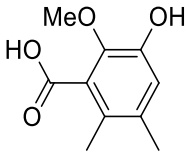
[**214**] Dimethyl malate: R_1 = R_2 = OMe

[**215**] (-)-Shikimic acid

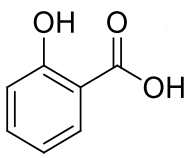
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species



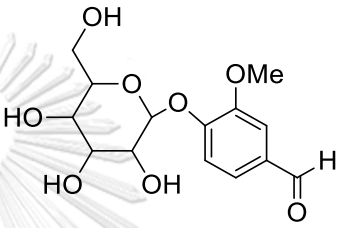
[**216**] Isopentyl butyrate



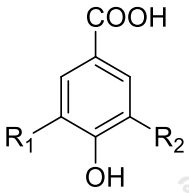
[**217**] 3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid

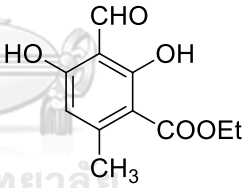


[**218**] Salicylic acid



[**219**] Vanilloside





[**220**] Gallic acid: R_1 = OH, R_2 = OH

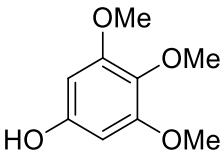
[**223**] Antiarol

[**221**] Syringic acid: R_1 = OMe, R_2 = OMe

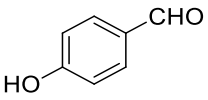
[**222**] Vanillic acid: R_1 = H, R_2 = OMe

[**227**] Protocatechuic acid: R_1 = H, R_2 = OH

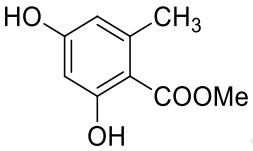
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



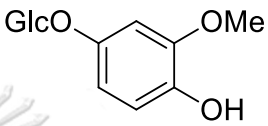
[**224**] Ethylhaematommate



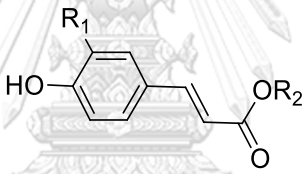
[**225**] *p*-Hydroxybenzaldehyde



[**226**] Methyl β-orsellinate



[**228**] Tachioside



[**229**] Alkyl 4′-hydroxy-*trans*-cinnamates: R_1 = H, R_2 = C_nH_{2n+1}, n =22-32

[**230**] Alkyl *trans*-ferulate: R_1 = OMe, R_2 = C_nH_{2n+1}, n = 18-28, 30

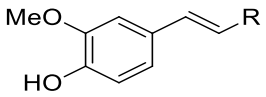
[**231**] Defuscin: R_1 = OMe, R_2 = $(CH_2)_{27}CH_3$

[**232**] *n*-Octacosyl ferulate: R_1 = OMe, R_2 = $(CH_2)_{28}CH_3$

[**233**] *n*-Triacontyl *p*-hydroxy-*cis*-cinnamate: R_1 = H, R_2 = $C_{30}H_{61}$

[**234**] Tetratriacontanyl-*trans*-*p*-coumarate: R_1 = H, R_2 = $(CH_2)_{33}CH_3$

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



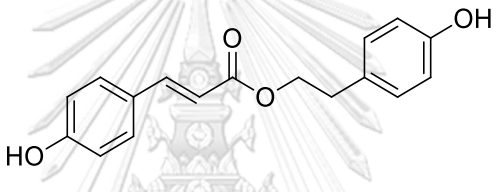
[**235**] *n*-Docosyl *trans*-ferulate: R = $COOCH_2(CH_2)_{20}CH_3$

[**236**] *trans*-Tetracosyl ferulate: R = $COOCH_2(CH_2)_{22}CH_3$

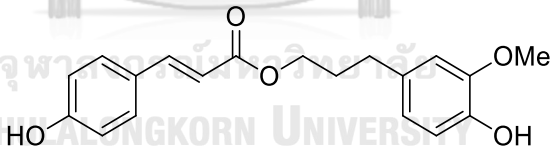
[**237**] *cis*-Hexacosanoyl ferulate: R = $COOCH_2(CH_2)_{24}CH_3$

[**238**] Ferulaldehyde: R = CHO

[**239**] Ferulic acid: R = COOH

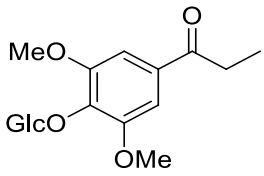


[**240**] 2-(*p*-Hydroxyphenyl) ethyl *p*-coumarate

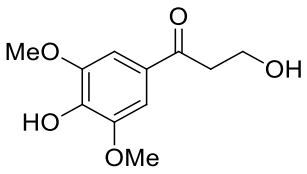


[**241**] Dihydroconiferyl dihydro-*p*-coumarate

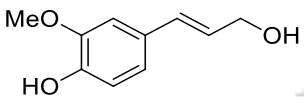
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



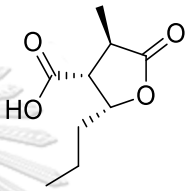
[**242**] 1-[4-(β-D-Glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone



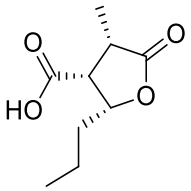
[**243**] 3-Hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-1-propanone



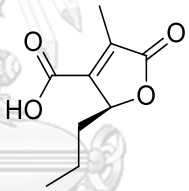
[**244**] Coniferyl alcohol



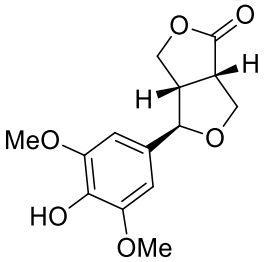
[**245**] Decumbic acid A



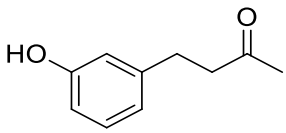
[**246**] Decumbic acid B



[**247**] (–)-Decumbic acid

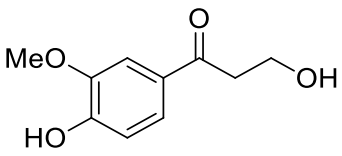


[**248**] (+)-Dendrolactone

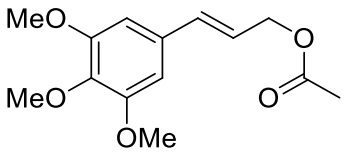


[**249**] 4-(3-Hydroxyphenyl)-2-butanone

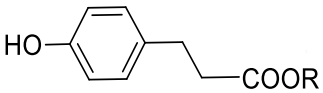
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



[**250**] 3-Hydroxy-1(3-methoxy-4-hydroxyphenyl)-propan-1-one

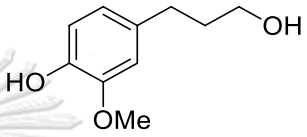


[**251**] 3′,4′,5′-Trimethoxy cinnamyl acetate

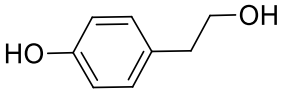


[**252**] *p*-Hydroxyphenyl propionic methyl ester: R = CH_3

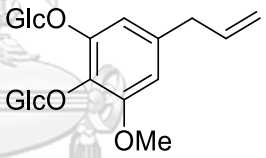
[**253**] Phloretic acid: R = OH



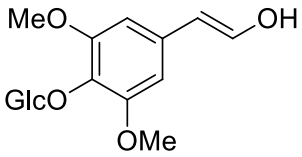
[**254**] Dihydroconiferyl alcohol



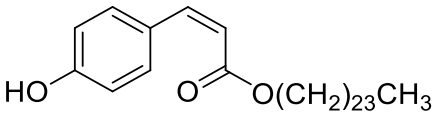
[**255**] Salidrosol



[**256**] Shashenoside I

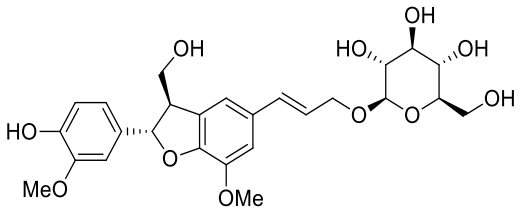


[**257**] Syringin

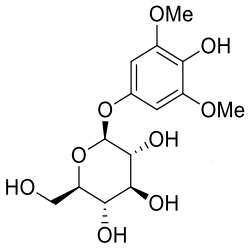


[**258**] Tetracosyl (*Z*)-*p*-coumarate

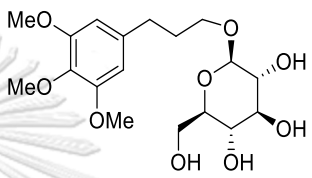
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



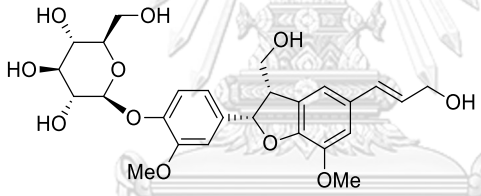
[**259**] (7*S*,8*R*)-Dehydrodiconiferyl alcohol 9′-β-D-glucopyranoside



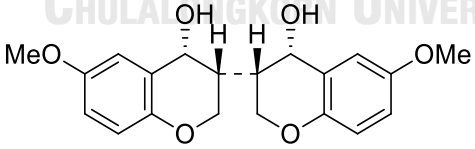
[**260**] Koaburaside



[**261**] Juniperoside

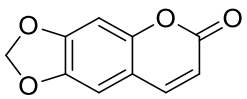


[**262**] Dehydrodiconiferyl alcohol-4-β-D-glucoside

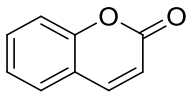


[**263**] (3*R*,3′*S*,4*R*,4′*S*)-3,3′,4,4′-Tetrahydro-6,6′-dimethoxy[3,3′-bi-2*H*-benzopyran]-4,4′-diol

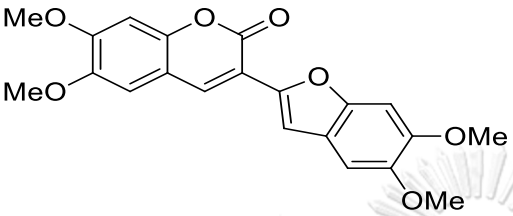
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



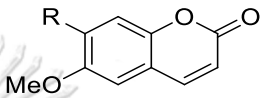
[**264**] Ayapin



[**265**] Coumarin

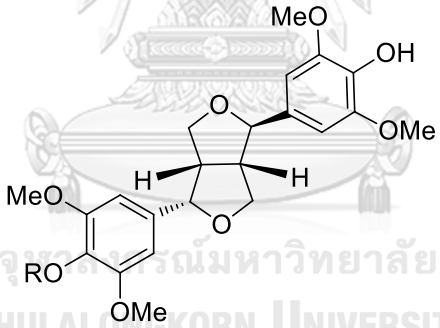


[**266**] Denthyrsin



[**267**] Scoparone: R = OMe

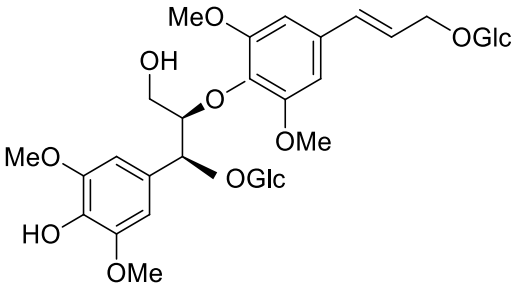
[**268**] Scopoletin: R = OH



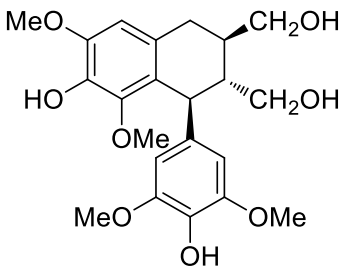
[**269**] Episyringaresinol: R = H

[**270**] Episyringaresinol 4″-*O*-β-D-glucopyranoside

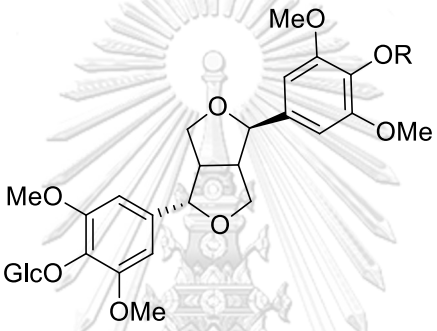
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



[**271**] (-)-(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

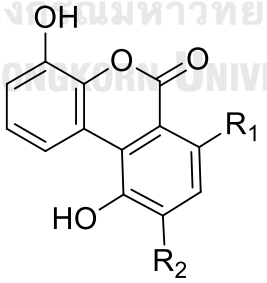


[**272**] Lyoniresinol



[**273**] (-)-Syringaresinol-4,4′-bis-*O*-β–D-glucopyranoside: R = Glc

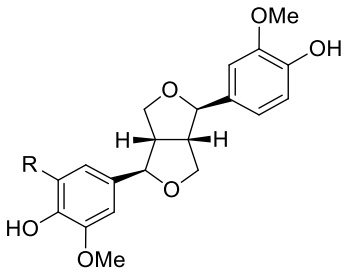
[**276**] Syringaresinol-4-*O*-D-monoglucopyranoside: R = H



[**274**] Dendrocoumarin: R_1 = H, R_2 = OH

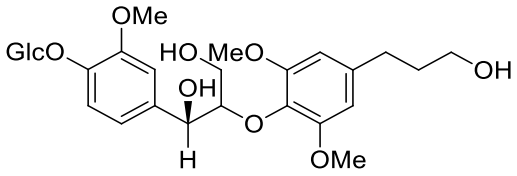
[**275**] Itolide A: R_1 = OH, R_2 = H

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

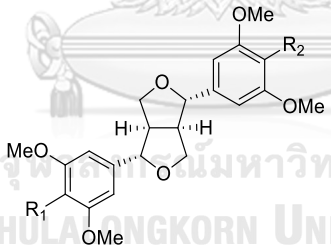


[**277**] (-)-Medioresinol: R = OMe

[**278**] (-)-Pinoresinol: R = H

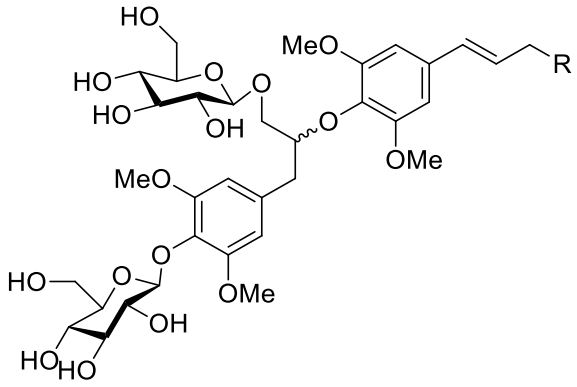


[**280**] Erythro-1-(4-*O*-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol



	R_1	R_2
[**279**] Syringaresinol	OH	OH
[**281**] Acanthoside B	OGlc	OH
[**282**] Liriodendrin	OGlc	OGlc

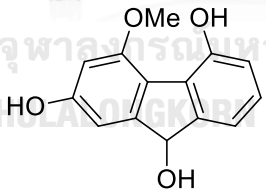
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



[**283**] (-)-(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 = OH; 8*R*

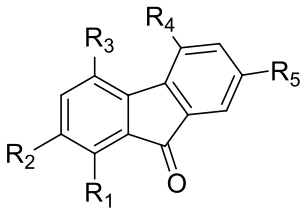
[**284**] (-)-(8*S*,7′*E*)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-O-β-D-glucopyranoside: R = OH; 8*S*

[**285**] (-)-(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 = OMe; 8*R*

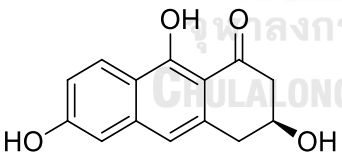


[**287**] Denchrysan B

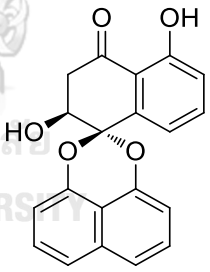
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4	R_5
[**286**] Denchrysan A	H	OH	OH	OMe	OH
[**288**] Dendroflorin	OH	H	OH	OMe	OH
[**289**] Dengibsin	H	OH	OMe	OH	H
[**290**] Nobilone	H	OH	H	OMe	OH
[**291**] 1,4,5-Trihydroxy-7-methoxy-9*H*-fluoren-9-one	OH	H	OH	OH	OMe
[**292**] 2,4,7-trihydroxy-1,5-dimethoxy-9-fluorenone	OMe	OH	OH	OMe	OH

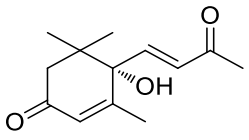


[**293**] 3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one

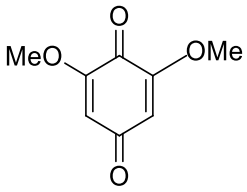


[**294**] Palmarumycin JC2

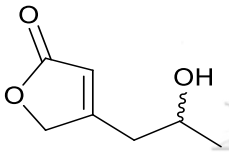
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



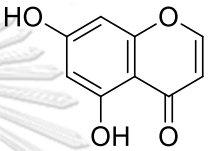
[**295**] Dehydrovomifoliol



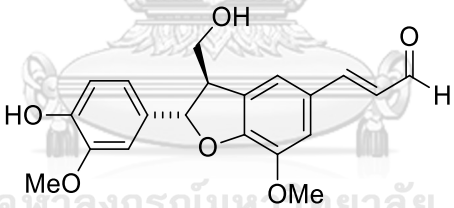
[**296**] 2,6-Dimethoxybenzoquinone



[**297**] 4-(2-Hydroxypropyl)-2(5*H*)-furanone

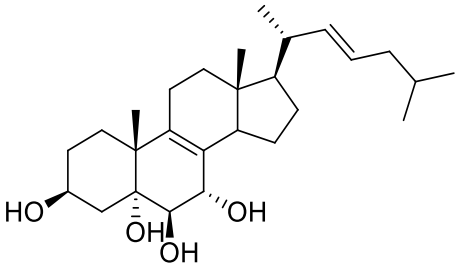


[**298**] 5,7-Dihydroxy-chromen-4-one

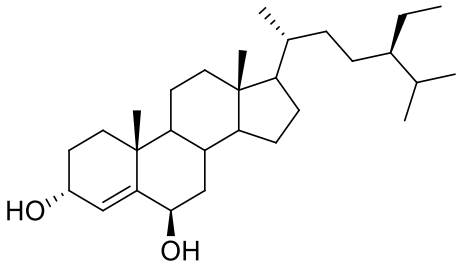


[**299**] Balanophonin

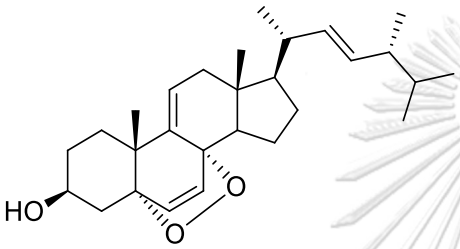
Figure 5 Structures of miscellaneous compounds isolated from *Dendrobium* species (continued)



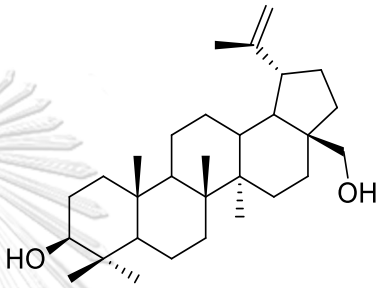
[**300**] Ergosta-8(9),22-diene-3,5,6,7-tetraol



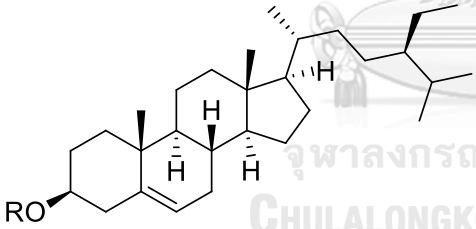
[**301**] Stigmast-4-en-3α, 6β-diol



[**302**] 3β-Hydroxy-5α,8α-epidioxyergosta-6,9,22-triene

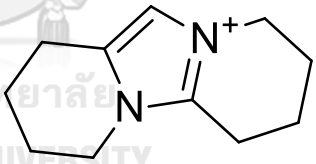


[**303**] Betulin



[**304**] β-Sitosterol: R = H

[**305**] Daucosterol: R = Glc



[**306**] Anosmine

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

2. Traditional uses and biological activities of *Dendrobium* species

Dendrobium plants have been used for the treatment of many diseases in traditional Chinese medicine (TCM). For example, they are used to promote the body fluid production, reduce fever, headache and swelling, treat red tongue, dry mouth, diabetes, and hyperglycemia. Furthermore, they are used to remedy kidney, stomach and lung diseases and relieve various symptoms such as thirst with blurred vision and dryness of the throat (Ng *et al*., 2012; Rungwichaniwa *et al*., 2014).

Several pharmacological activities of the chemical constituents of *Dendrobium* have been reported. Examples are antioxidant, anti-inflammatory, antiviral, antibacterial, antimalarial, antiplatelet aggregation, hemagglutinating, antidiabetic, anti-hyperthyroidism, hepatoprotective, neuroprotective, anticancer, antiangiogenic and immunomodulating activities, as well as beneficial action on bones and inhibition of cataractogenics (Teixeira da Silva and Ng, 2017b).

Regarding antioxidant activity, the ethyl acetate extract, *n*-butanol extract and water extract of *D. aurantiacum* have been shown to inhibit 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical with the IC_{50} values of 126.9, 49.5 and 132.5 μg/mL, respectively (Yang *et al*., 2007b). The extract of *D. candidum* has been studied for antidiabetic activity. It could reduce blood glucose concentration in streptozotocin and epinephrine-induced diabetic rats via increasing insulin secretion from β-cells, glycogenolysis and glycogen synthesis and decreasing glucagon secretion (Jiang *et al*., 2014). Furthermore, galactose-induced cataract formation in rats could be protected by the extract from the stem of *D. aurantiacum* var. *denneanum* through reducing aldose reductase and promoting nitric oxide synthase (NOS) activities (Fang *et al*., 2015). The compound dendrocandin E [**37**] from *D. candidum* was tested in DPPH assay and showed stronger activity (IC_{50} = 15.6 μM) as compared with vitamin C (positive control, IC_{50} = 23.2 μM) (Li *et al*., 2009b). Another compound, aphyllone B from *D. aphyllum* at the concentration of 100 μg/mL exhibited 87.97% inhibition of DPPH radical, comparing with Trolox® as positive control (Yang *et al*., 2015). Moreover, eight compounds (nobilin D [**61**], nonilin E [**62**], crepidatin [**8**], dendrobin A [**10**], chrysotoxine [**7**], moscatilin [**21**], gigantol [**16**] and dendroflorin [**288**]) from the stem

of *D. nobile* demonstrated inhibitory activity against DPPH radical (IC_{50} = 19.9, 21.0, 21.8, 40.3, 14.0, 14.5, 56.4 and 16.2, respectively) (Zhang *et al*., 2007b).

In addition, Dendrofalconerol A [**63**] and (2*S*)-eriodictyol [**143**] from *D. tortile* were able to inhibit the enzyme α-glucosidase with IC_{50} = 18.0 and 276.2 μM, respectively. In another study, loddigesiinols G-J [**131-134**] and crepidatuol B [**51**] from the stem of *D. loddigesii* showed stronger α-glucosidase inhibitory activity (IC_{50} = 16.7, 10.9, 2.7, 3.2, and 18.9 μM, respectively) than *trans*-resveratrol (Lu *et al*., 2014). Moreover, confusarin [**75**] and 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrene-quinone [**89**] from the whole plant of *D. formosum* displayed stronger α-glucosidase inhibitory activity (IC_{50} = 189.78 and 126.88 μM, respectively) than acarbose. Both compounds also inhibited pancreatic lipase with IC_{50} = 154.61 and 69.45 μM, respectively (Inthongkaew *et al*., 2017).

Phoyunnanin E [**70**] and densiflorol B [**83**] from *D. venustum* showed stronger antimalarial activity than batatasin III [**4**], gigantol [**16**], and phoyunnanin C [**69**] (Sukphan *et al*., 2014). In assays for platelet aggregation-inhibitory effect, moscatilin [**21**] and moscatin [**91**] from *D. loddigesii* stems could inhibit collagen and arachidonic acid-induced platelet aggregation *in vitro* (Chen *et al*., 1994). Moscatilin [**21**] trigonopol A [**48**] from *D. trigonopus* also exhibited antiplatelet aggregation activity (Fan *et al*., 2001; Hu *et al*., 2008b).

Several compounds from *Dendrobium* plants displayed anticancer activity. For instance, the bibenzyl derivatives from *D. brymerianum*, including moscatilin [**21**], gigantol [**16**] and lusianthridin [**99**], demonstrated cytotoxicity against human lung cancer cells with IC_{50} = 196.7, 23.4 and 65.0 μg/mL, respectively (Klongkumnuankarn *et al*., 2015). Moreover, the bibenzyl derivatives (3,4-dihydroxy-5,4′-dimethoxybibenzyl [**29**], dendrocandin I [**45**], dendrofalconerol A [**63**], dendrocandin B [**34**] and dendrosignatol [**65**]) from *D. signatum* were cytotoxic against breast cancer, hepatoma (HepG) and colorectal cancer cells (Mittraphab *et al*., 2016). In a previous study, chrysoeriol [**147**], luteolin [**148**], 4,4′-dihydroxy-3,5-dimethoxybibenzyl [**41**] and 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**25**] from *D. ellipsophyllum* exhibited cytotoxic,

antimetastatic, apoptosis-inducing and anoikis-sensitizing activities on H292 human lung cancer cells (Tanagornmeatar *et al*., 2014).

CHAPTER III

EXPERIMENTAL

1. Source of plant materials

The whole plant of *Dendrobium parishii* Rchb. f. was purchased from Chatuchak market, Bangkok, in November 2012. Identification of this plant was performed by Assoc. Prof. Thatree Phadungcharoen (Faculty of Pharmaceutical Sciences, Rangsit University). A voucher specimen (BS-DPar-112555) has been deposited at the herbarium in the Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University.

2. General techniques

2.1 Thin-layer chromatography (TLC)

Technique : One-dimension ascending

Absorbent : Silica gel 60 F254 (E. Merck) precoated plate

Temperature : Laboratory temperature (30-35 ºC)

Detection : 1. Ultraviolet light (UV) at wavelengths of 254 and 365 nm.

2. Spraying with anisaldehyde reagent (*p*-anisaldehyde 15 g in ethanol 250 mL and conc. Sulfuric acid 2.5 mL) and heating at 105 ºC for 10 min.

2.2 Column chromatography

2.2.1 Vacuum liquid chromatography (VLC)

Adsorbent : Silica gel 60 (No. 7734) particle size 0.063-0.200 mm (E. Merck)

Packing method : Dry packing

Sample loading : The sample was dissolved in a small amount of appropriate organic solvent, mixed with the adsorbent as much as necessary, triturated, dried and then placed on top of the column.

Detection : Each fraction was examined by TLC under UV light at the wavelengths of 254 and 365 nm.

2.2.2 Flash column chromatography (FCC)

Adsorbent : Silica gel 60 (No. 9385) particle size 0.040-0.063 mm (E. Merck)

Packing method : Dry packing

Sample loading : The sample was dissolved in a small amount of appropriate organic solvent, mixed with the adsorbent as much as necessary, triturated, dried and then placed on top of the column.

Detection : Fractions were examined as described in section 2.2.1.

2.2.3 Gel filtration chromatography

Gel filter : Sephadex LH-20 (GE Healthcare)

Packing method : Gel filter was suspended in an appropriate organic solvent and left to equilibrate for 24 hours prior to use and then poured into the column and left to set tightly.

Sample loading : The sample was dissolved in the same solvent for column packing and then filled on the top of the column.

Detection : Fractions were examined as described in section 2.2.1

2.3 Spectroscopy

2.3.1 Mass spectra

Mass spectra were recorded on a Bruker micro TOF mass spectrometer (HR-ESI-MS) (Department of Chemistry, Faculty of Science, Mahidol University).

2.3.2 1-D and 2-D nuclear magnetic resonance spectra

1-D NMR (^{1}H NMR, 300 MHz and ^{13}C NMR, 75 MHz) and 2-D NMR (NOESY, HSQC and HMBC) spectra were recorded on a Bruker Avance DPX-300 FT-NMR spectrometer (Faculty of Pharmaceutical Sciences, Chulalongkorn University) or a Varian Unity INOVA-500 MHz NMR spectrometer (Scientific and Technological Research Equipment Centre, Chulalongkorn University)

Solvents for NMR spectra were deuterated acetone (acetone-d_6), deuterated chloroform ($CDCl_3$) and deuterated methanol (CD_3OD). Chemical shifts were reported in ppm scale using the chemical shift of the solvent as the reference signal.

2.3.3 Ultraviolet (UV) spectra

UV spectra (in methanol) were obtained on a Milton Roy Spectronic 3000 Array spectrophotometer (Pharmaceutical Research Instrument Center, Faculty of Pharmaceutical Sciences, Chulalongkorn University).

2.3.4 Infrared (IR) spectra

IR spectra were recorded on a Perkin-Elmer FT-IR 1760X spectrophotometer (Scientific and Technology Research Equipment Center, Chulalongkorn University).

2.3.5 Optical rotation

Optical rotation was measured on a Perkin-Elmer 341 polarimeter (Pharmaceutical Research Instrument Center, Faculty of Pharmaceutical Sciences, Chulalongkorn University).

2.4 Solvents

All organic solvents employed throughout this work were of commercial grade and were redistilled prior to use.

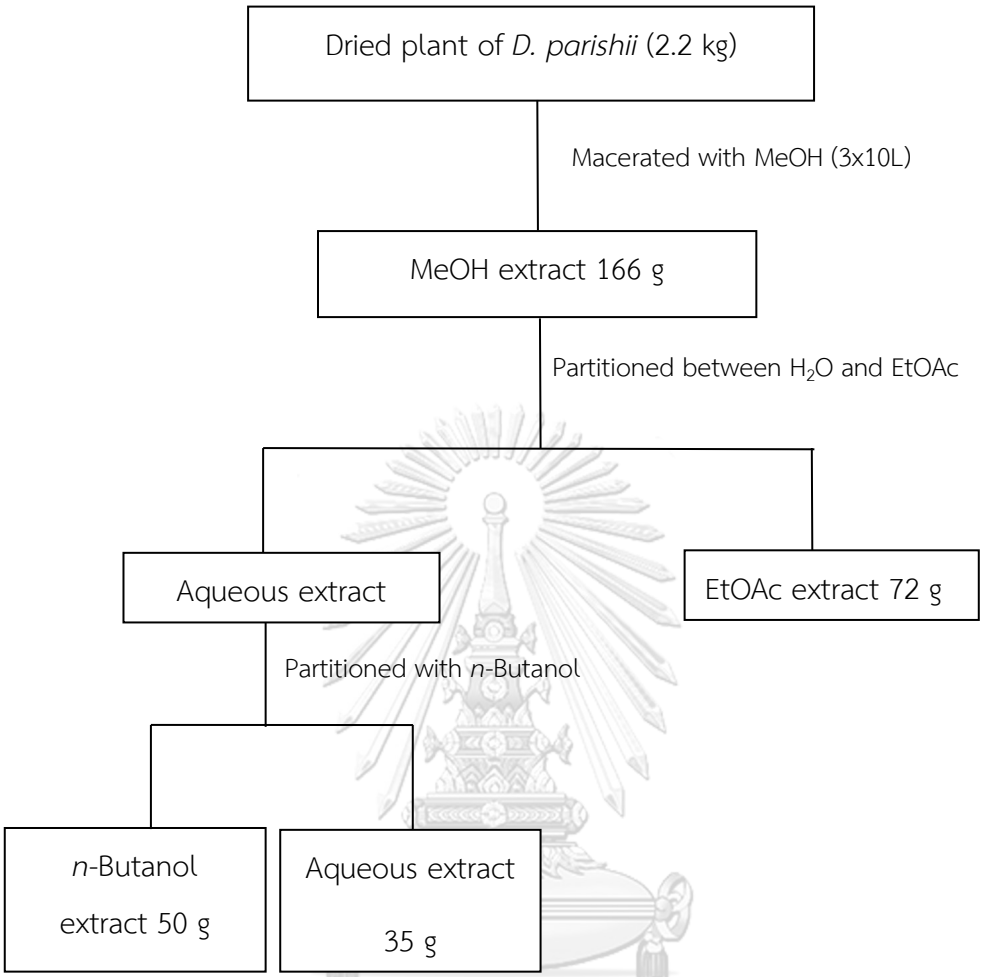
3. Extraction and isolation

3.1 Extraction

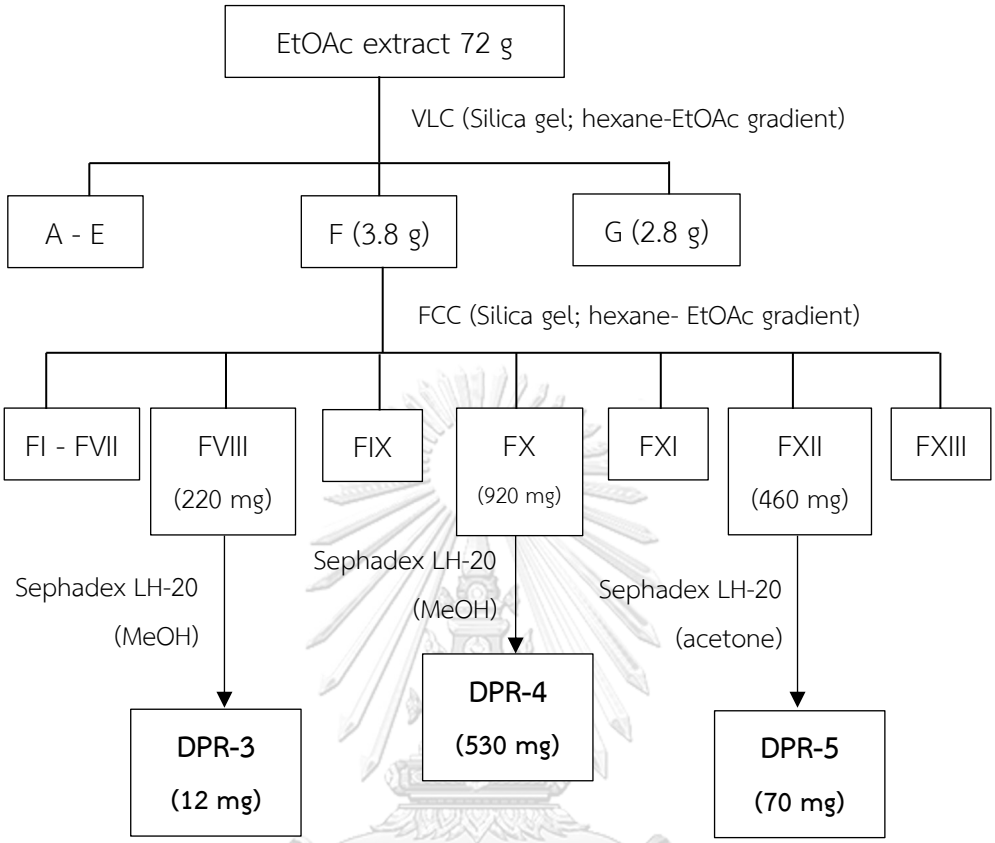
The dried whole plants of *D. parishii* (2.2 kg) were powdered and macerated with methanol (3×10 L) for 5 days three times. The solvent was evaporated under reduced pressure by rotary evaporator to give 166 g of methanol crude extract. Then, this extract was suspended in water and partitioned with EtOAc and *n*-butanol to give an EtOAc extract (72 g), an *n*-butanol extract (50 g), and an aqueous extract (35 g). All these extracts were tested for the DPPH radical scavenging activity assay. The EtOAc extract showed the highest activity with more than 80% inhibition at 100 µg/mL. Thus, the EtOAc extract was selected for further study (**Scheme 1**).

3.2 Isolation

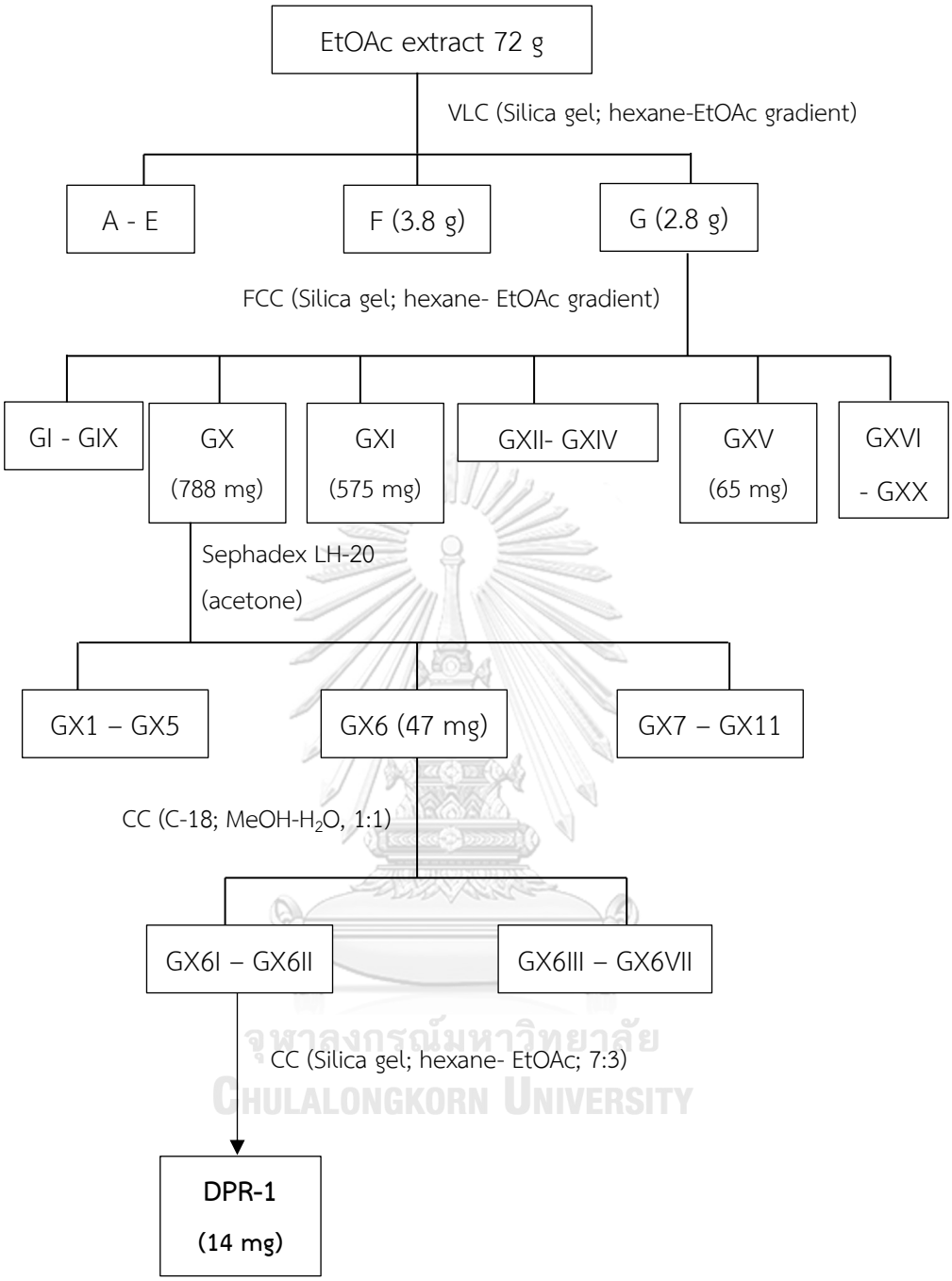
The EtOAc extract (72 g) was fractionated by vacuum liquid chromatography (VLC) as described in section 2.2.1 (**Scheme 2**). Silica gel (No.7734) was used as stationary phase, and a step gradient of hexane-EtOAc (1:0 to 0:1) was used as the mobile phase. About 500 mL of the eluates were collected per fraction, examined by TLC and combined to give seven fractions (A-G).



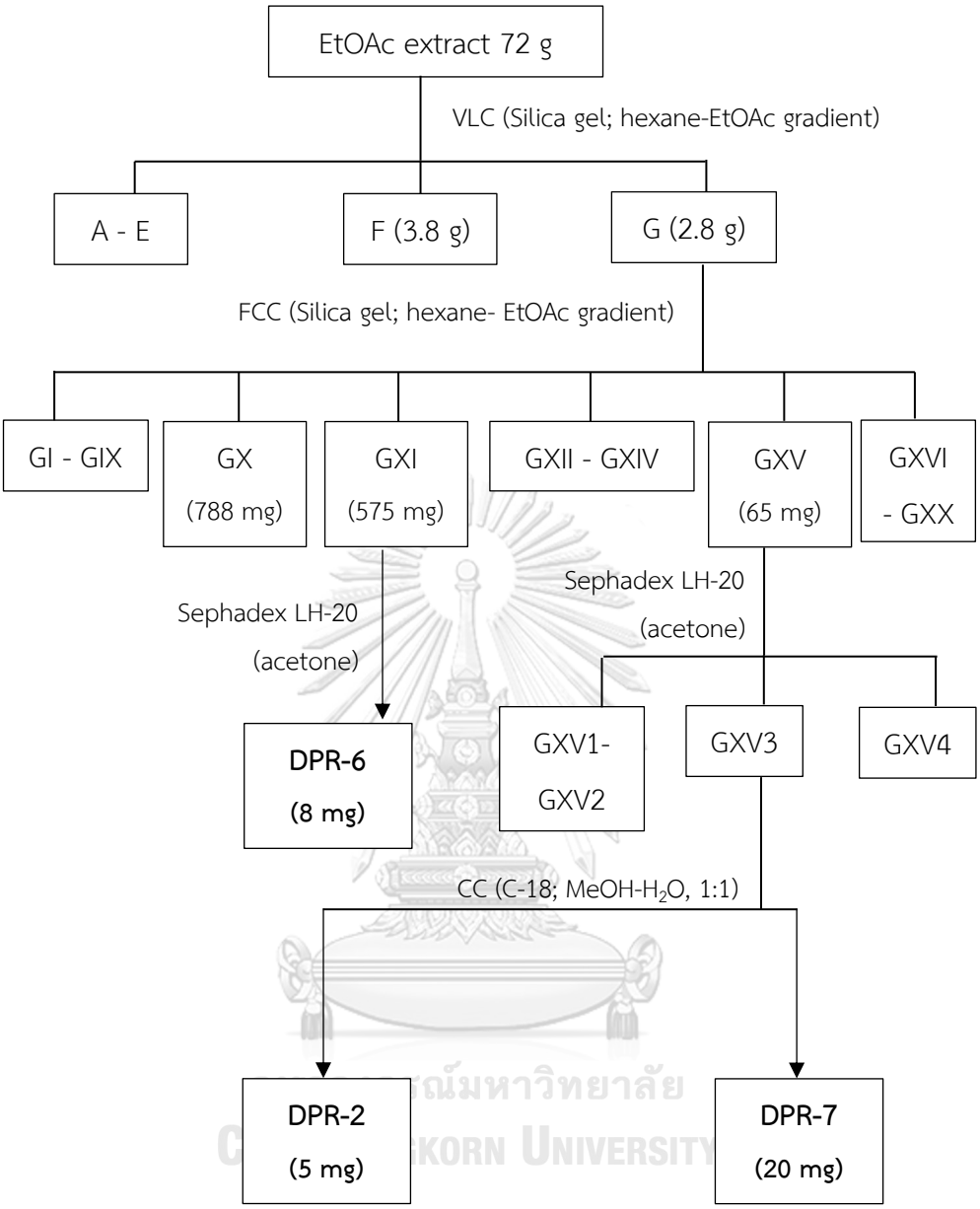
Scheme 1 Separation of the MeOH extract of *Dendrobium parishii*



Scheme 2 Separation of the EtOAc extract of *Dendrobium parishii*



Scheme 2 Separation of the EtOAc extract of *Dendrobium parishii* (continued)



Scheme 2 Separation of the EtOAc extract of *Dendrobium parishii* (continued)

3.2.1 Isolation of compound DPR-1 (4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl)

Fraction G (2.8 g) was separated by FCC using silica gel (No. 9385) and eluated with a gradient mixture of hexane-EtOAc (1:0 to 0:1) to give twenty fractions (GI-GXX).

Fraction GX (788 mg) was separated on a Sephadex LH-20 column, eluted with acetone to give 11 fractions (GX1-GX11). Fraction GX6 (47 mg) was further separated on a C-18 column, with a mixture of methanol-water (1:1) as the mobile phase. Then this fraction was purified by CC using silica gel and eluted with hexane-EtOAc (7:3) to afford DPR-1 (14 mg). This compound was characterized as 4,3′,4′-trihydroxy-3,5-dimethoxybibenzyl [**307**], a new structure.

3.2.2 Isolation of compound DPR-6 (Dendrocandin E)

Fraction GXI (575 mg) was purified by Sephadex LH-20 using acetone as the mobile phase to give DPR-6 (8 mg), which was identified as dendrocandin E [**37**].

3.2.3 Isolation of compound DPR-2 [(−)-Dendroparishiol] and DPR-7 (Asiatic acid)

Fraction GXV (65 mg) was separated on a Sephadex LH-20 using acetone as the mobile phase and then purified by CC on C-18, eluted with methanol-water (1:1) to give compound DPR-2 (5 mg) and DPR-7 (20 mg). Compound DPR-2 was characterized as a new compound named (−)-dendroparishiol [**308**]. Compound DPR-7 was identified as asiatic acid [**309**].

3.2.4 Isolation of compound DPR-3 (Flavanthrinin)

Fraction F (3.8 g) was separated by FCC using silica gel (No. 9385) and eluted with a gradient mixture of hexane-EtOAc (1:0 to 0:1) to give thirteen fractions (FI-FXIII). Sephadex LH20 using methanol as the mobile phase was

used to purify fraction FVIII (220 mg) to give compound DPR-3 (12 mg), which was later identified as flavanthrinin [**119**].

3.2.5 Isolation of compound DPR-4 (Moscatilin)

Fraction FX (920 mg) was purified on Sephadex LH-20 using methanol as the mobile phase column to afford compound DPR-4 (530 mg). It was identified as moscatilin [**21**].

3.2.6 Isolation of compound DPR-5 (4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl)

Fraction FXII (460 mg) was purified on Sephadex LH-20 using acetone as the mobile phase to give compound DPR-5 (70 mg). This compound was identified as 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**25**].

4. Physical and spectral data of isolated compounds

4.1 Compound DPR-1 (4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl)

Compound DPR-1 was obtained as a brown amorphous solid, (14.0 mg, 0.00064 % based on dried weight of whole plant). It was soluble in acetone and methanol.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 313.1052 ($C_{16}H_{18}O_5Na$); see **Figure 6**

FT-IR : ν_{max} (film): 3434, 2918, 2851, 1698, 1616, 1518, 1463, 1109 cm^{-1}; see **Figure 7**

UV : λ_{max} in methanol at 218 nm (log ε = 4.10) and 282 nm (log ε = 3.59); see **Figure 8**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 5**, **Figure 9**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 5**, **Figure 10**

4.2 Compound DPR-2 [(–)-Dendroparishiol]

Compound DPR-2 was obtained as a red amorphous powder (5.0 mg, 0.00023 % based on dried weight of whole plant). It was soluble in methanol.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 537.1521 ($C_{30}H_{26}O_8Na$); see **Figure 14**

IR : ν_{max} (film): 3245, 2934, 2847, 1606, 1514, 1467, 1263, 1235 cm^{-1}; see **Figure 15**

UV : λ_{max} in methanol at 203 nm (log ε = 4.82) and 282 nm (log ε = 4.40); see **Figure 16**

Optical rotation : $[\alpha]_D^{20}$: –9.2 (*c* 0.1, MeOH)

^{1}H NMR : δ ppm, 500 MHz, in CD_3OD; see **Table 6**, **Figure 17**

^{13}C NMR : δ ppm, 125 MHz, in CD_3OD; see **Table 6**, **Figure 18**

4.3 Compound DPR-3 (Flavanthrinin)

Compound DPR-3 was obtained as a brown amorphous solid (12.0 mg, 0.00054 % based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 263.0686 ($C_{15}H_{12}O_3Na$); see **Figure 23**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 7**, **Figure 24**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 7**, **Figure 25**

4.4 Compound DPR-4 (Moscatilin)

Compound DPR-4 was obtained as a brown amorphous solid (530.0 mg, 0.024 % based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 327.1219 ($C_{17}H_{20}O_5Na$); see **Figure 29**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 8**, **Figure 30**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 8**, **Figure 31**

4.5 Compound DPR-5 (4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl)

Compound DPR-5 was obtained as a brown amorphous solid (70.0 mg, 0.0032 % based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 313.1058 ($C_{16}H_{18}O_5Na$); see **Figure 34**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 9**, **Figure 35**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 9**, **Figure 36**

4.6 Compound DPR-6 (Dendrocandin E)

Compound DPR-6 was obtained as a red amorphous solid (8.0 mg, 0.00036 % based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 299.0900 ($C_{15}H_{16}O_5Na$); see **Figure 39**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 10**, **Figure 40**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 10**, **Figure 41**

4.7 Compound DPR-7 (Asiatic acid)

Compound DPR-7 was obtained as a white powder (20.0 mg, 0.00091 % based on dried weight of whole plant). It was soluble in methanol.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 511.3497 ($C_{30}H_{48}O_5Na$); see **Figure 44**

^{1}H NMR : δ ppm, 300 MHz, in CD_3OD; see **Table 11**, **Figure 45**

^{13}C NMR : δ ppm, 75 MHz, in CD_3OD; see **Table 11**, **Figure 46**

5. Free radical scavenging activity assays

5.1 DPPH free radical scavenging activity assay

The 2,2-diphenyl-1-picryl-hydrazyl (DPPH) free radical scavenging activity assay is one of the widely used method for evaluating antioxidant potential of plant constituents. The method makes use of the stable free radical DPPH, which can produce a violet color. Any sample that can donate a hydrogen atom to the DPPH radical (antioxidant) will turn the color to yellow. The proportion of changing color from violet to yellow is determined as radical scavenging activity (RSA) (Likhitwitayawuid *et al*., 2006).

5.1.1 Materials and instruments

- 2,2-diphenyl-1-picryl-hydrazyl (DPPH) (Sigma-Aldrich)
- Dimethyl sulfoxide (DMSO) (Sigma-Aldrich)
- 96-well microplate (Corning)
- Microplate reader (CLARIOstar, BMG LABTECH)
- Ultrasonic bath (Transsonic 570/H, Elma)
- Vortex mixer (Vortex-Genie2, Scientific Industries)

5.1.2 Determination of DPPH free radical scavenging activity assay

DPPH was dissolved in methanol to make a solution with concentration of 150 µM. Each sample 3 mg was dissolved in 300 µL of dimethyl sulfoxide (DMSO) to give a stock solution. The stock solution was diluted with methanol to achieve a concentration of 50 µg/mL. 22 µL of the diluted sample was transferred into a 96-well plate and 200 µL of 150 µM DPPH was added. The plate was covered and left standing in the dark at room temperature for 30 min. Then, the absorbance was measured at 517 nm using a microplate reader (CLARIOstar, BMG LABTECH, Germany). The absorbance was converted to the percentage of radical scavenging activity (%RSA) using the following formula:

$$\%RSA = [(A_{blank} - A_{sample}) / A_{blank}] \times 100$$

Where A_{blank} and A_{sample} are the absorbance. The experiment was performed in triplicate, and each concentration consisted of three repetitions. Methanol was used as a blank.

5.2 Oxygen radical absorbance capacity (ORAC) assay

ORAC assay is an antioxidant test for the peroxyl radical which can be generated by the reaction between 2,2'-azobis (2-amidinopropane) dihydrochloride (AAPH) and oxygen. The generated peroxyl radical may react with fluorescein (fluorescent substance) and then decrease the absorbance of fluorescein. Any sample that can donate a hydrogen atom to the peroxyl radical (antioxidant) can protect the fluorescence of fluorescein from peroxyl radical damaging (Huang *et al*., 2002).

5.2.1 Materials and instruments

- 2,2-azobis (2-amidinopropane) dihydrochloride (AAPH) (Sigma-Aldrich)
- 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox®) (Sigma-Aldrich)
- 96-well microplate (Corning)
- Fluorescein (Sigma-Aldrich)
- Black 96-well microplate (Corning)
- Microplate reader (CLARIOstar, BMG LABTECH)
- Ultrasonic bath (Transsonic 570/H, Elma)
- Vortex mixer (Vortex-Genie2, Scientific Industries)

5.2.2 Determination of ORAC assay

The ORAC assay was performed at 37 °C under pH 7.4 condition. Trolox® was used as a standard for making a standard curve. Each sample 3 mg was dissolved in 300 µL of dimethyl sulfoxide (DMSO) to give a stock solution. Fluorescein (FL) was used as a substrate. The diluted sample at 50 µg/mL or Trolox® 25 µL was added into a black 96-well plate and then 150 µL of

fluorescein in buffer pH 7.4 and 25 µL of AAPH were added. The blank contained the same mixture without the sample or Trolox®. To monitor this reaction, fluorescence intensity of FL was recorded every minute after the addition of AAPH, at excitation and emission wavelengths of 485 and 530 nm, respectively. Each result was derived from the difference between the area under the curve of the blank and that of the sample compared with the Trolox® standard curve. The final results were determined as micromole Trolox® equivalent (TE) per gram of the sample (µmol TE/g).

5.3 Deoxyribose degradation assay

The deoxyribose degradation assay is a method for testing antioxidant activity against the hydroxyl radical. Hydroxyl radicals can be generated from the reaction between the complex of $FeCl_3$ with ethylene diamine tetra-acetic acid (EDTA) and hydrogen peroxide (H_2O_2). Then, the generated hydroxyl radical can react with deoxyribose to give malondialdehyde (MDA). Thiobarbituric acid (TBA) is then added to form a complex with MDA in acidic condition to yield a malondialdehyde–thiobarbituric acid complex (pink color). The absorbance of the reaction mixture is then measured. Any sample that can donate a hydrogen atom to the hydroxyl radical (antioxidant) can reduce MDA formation and decrease the absorbance. (Gutteridge and Halliwell, 1988).

5.3.1 Materials and instruments

- 96-well microplate (Corning)
- KH_2PO_4 (Merck)
- KOH (Merck)
- Deoxyribose (Sigma-Aldrich)
- Ferric chloride ($FeCl_3$) (Sigma-Aldrich)
- Ethylene diamine tetra acetic acid (EDTA) (Merck)
- Ascorbic acid (Sigma-Aldrich)
- Hydrogen peroxide (H_2O_2) (Merck)

- Thiobarbituric acid (TBA) (Sigma-Aldrich)

- Trichloroacetic Acid (TCA) (Merck)

- 6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox®) (Sigma-Aldrich)

- Microplate reader (CLARIOstar, BMG LABTECH)

- Ultrasonic bath (Transsonic 570/H, Elma)

- Vortex mixer (Vortex-Genie2, Scientific Industries)

5.3.2 Determination of deoxyribose degradation assay

Each sample 3 mg was dissolved in 300 µL of dimethyl sulfoxide (DMSO) to give a stock solution. The reaction mixture contained 200 µL of 100 mM KH_2PO_4/KOH, 200 µL of 15 mM deoxyribose, 200 µL of 500 µM $FeCl_3$, 100 µL of 1 mM EDTA, 100 µL of 1 mM ascorbic acid, 100 µL of 10 mM H_2O_2 and 100 µL of the diluted sample (concentration 50 µg/mL), which gave the final volume of 1 mL. The mixtures were incubated at 37 °C for 1 hour. After that, 1 mL of 1% w/v TBA and 1 mL of 2.8% w/v TCA were added to the mixture. Then, the mixture was heated on a water bath at 90 °C for 20 min to form a complex of malondialdehyde–thiobarbituric acid (pink color), and the absorbance was measured at wavelength 532 nm. Blank contained the same mixture without the sample. The percentage of hydroxyl radical inhibition of samples was calculated using the following formula:

$$\%\text{hydroxyl radical inhibition} = [(A_{blank} - A_{sample})/A_{blank}] \times 100$$

Where A_{blank} and A_{sample} are the absorbance of the blank and the sample, respectively.

5.4 Intracellular antioxidant activity in cell cultures

Seven compounds (DPR-1 – DPR-7) were tested for antioxidant activity in H_2O_2-induced cells. The reduction of cellular ROS synthesis was estimated for the intracellular antioxidant activity of these compounds. Non-fluorescent DCFH-DA (2′,7′-

dichlorofluorescein diacetate) diffuses into cells containing esterases to cleave DCFH-DA to form DCFH, which can be oxidized by ROS to the fluorescent DCF (2′,7′-dichlorofluorescein). Therefore, ROS levels were measured by monitoring fluorescent signals generated from the oxidized DCFH-DA (Soh, 2006).

5.4.1 Materials and instruments

- RAW 264.7 (ATCC TIB71) murine macrophage cell lines
- 2′,7′-Dichlorofluorescein diacetate (DCFH-DA) (Sigma-Aldrich)
- Hydrogen peroxide (H_2O_2) (Merck)
- Dulbecco's modified eagle's medium (DMEM) (Invitrogen)
- Heat-inactivated fetal bovine serum (FBS) (Invitrogen)
- Penicillin (Invitrogen)
- Streptomycin (Invitrogen)
- Quercetin (Sigma-Aldrich)
- Black 96-well culture plate (Corning)
- Fluorescence microplate reader (CLARIOstar, BMG LABTECH)
- Incubator (Forma Series II, Thermo Scientific)
- Ultrasonic bath (Transsonic 570/H, Elma)
- Vortex mixer (Vortex-Genie2, Scientific Industries)

5.4.2 Determination of intracellular antioxidant activity in cell cultures

Murine macrophage RAW264.7 cells (ATCC TIB71) were cultured in 100 µg/mL penicillin, 100 µg/mL streptomycin and DMEM supplemented with 10% heat-inactivated FBS. Cell cultures were kept at 37 °C in humidified atmosphere of 5% CO_2/95% air.

RAW 264.7 cells were plated at 2×10^4 cells/mL in black 96-well culture plates. Then, they were incubated at 37 °C in a humidified atmosphere of 5%

CO_2/95% air for 24 hours. Cells were washed with serum-free medium (free phenol red) and treated with 50.0 µg/mL of seven compounds (DPR-1–DPR-7) for 24 hours. Cells were washed, added with 5 µM DCFH-DA in serum free medium and incubated for 30 minutes. Then, 1 mM H_2O_2 was added to induce cellular oxidative stress and further incubated for 30 minutes. The fluorescence intensity was determined by fluorescence microplate reader at 485 nm (excitation state) and 530 nm (emission state). The percentage of ROS inhibition of samples was calculated using the following formula:

$$\%\text{ROS inhibition} = 100 - [(FL_{sample} \times 100) / FL_{Hydrogen\ peroxide})]$$

Where $FL_{Hydrogen\ peroxide}$ and FL_{sample} are the fluorescent intensity of the H_2O_2-treated cells and the sample, respectively.

In addition, (–)-dendroparishiol [DPR-2, **308**] was selected for further evaluation of intracellular antioxidant activity in cell culture at the concentrations that did not affect cell viability (12.5, 25.0, and 50.0 µg/mL).

5.5 Effects on antioxidant enzymes in cell cultures

The imbalance between antioxidants and the ROS system in the cells is called oxidative stress. In human cells, there are many antioxidative mechanisms such as antioxidant enzymes including glutathione peroxidase (GPx), catalase (CAT) and superoxide dismutase (SOD). The co-operation of these three enzymes can neutralize the superoxide radical through converting the radical into H_2O_2 and O_2 by SOD. Then, GPx and CAT can degrade H_2O_2 into O_2 and H_2O (Weydert and Cullen, 2010).

5.5.1 Materials and instruments

- RAW 264.7 (ATCC TIB71) murine macrophage cell lines
- Hydrogen peroxide (H_2O_2) (Merck)
- lysis buffer (Sigma-Aldrich)
- Quercetin (Sigma-Aldrich)
- Dulbecco's modified eagle's medium (DMEM) (Invitrogen)

- Heat-inactivated fetal bovine serum (FBS) (Invitrogen)

- Penicillin (Invitrogen)

- Streptomycin (Invitrogen)

- SOD, GPx, and CAT cellular activity assay kit (Cayman Chemical)

- 6-well culture plates (Corning)

- Fluorescence microplate reader (CLARIOstar, BMG LABTECH)

- Incubator (Forma Series II, Thermo Scientific)

- Ultrasonic bath (Transsonic 570/H, Elma)

- Vortex mixer (Vortex-Genie2, Scientific industries)

5.5.2 Determination of effects on antioxidant enzyme in cell cultures

Murine macrophage RAW264.7 cells (ATCC TIB71) were cultured in 100 µg/mL penicillin, 100 µg/mL streptomycin and DMEM supplemented with 10% heat-inactivated FBS. Cell cultures were kept at 37 °C in humidified atmosphere of 5% CO_2/95% air.

RAW 264.7 cells were plated with 1×10^6 cells/mL in 6-well culture plates. Then, they were incubated at 37 °C in a humidified atmosphere of 5% CO_2/95% air for 24 hours. Cells were washed with serum-free medium (free phenol red) and treated with 12.5, 25.0 and 50.0 µg/mL of (–)-dendroparishiol for 24 hours. Then, 1 mM H_2O_2 was added to induce cellular oxidative stress, and the mixture was incubated for 30 minutes. Treated cells were resuspended in an ice-cold lysis buffer at 4 °C for 30 minutes and centrifuged at 13,500×g at 4 °C for 5 minutes to produce cell lysate for measurement of antioxidant enzyme activities. The CAT, GPx and SOD activity was each evaluated by using CAT, GPx and SOD cellular activity assay kits.

CHAPTER IV
RESULTS AND DISCUSSION

In this study, the dried and ground whole plants of *Dendrobium parishii* (2.2 kg) was extracted with methanol to give a dried methanol extract (166 g) after removal of the solvent. The methanol extract was suspened in water and then partitioned with EtOAc and *n*-butanol to give 72 g of EtOAc extract, 50 g of *n*-butanol extract and 35 g of aqueous extract. At 100 µg/mL, only the EtOAc extract showed more than 80% inhibition in the DPPH radical scavenging assay. Thus, the EtOAc extract was subjected to repeated chromatographic separation to give 7 compounds including two new compounds (DPR-1 and DPR-2), one phenanthrene (DPR-3), three bibenzyls (DPR-4, DPR-5 and DPR-6) and one triterpenoid (DPR-7). These isolated structures were characterized by spectroscopic techniques, including MS and NMR and were tested for free radical scavenging activities.

1. Structure determination of isolated compounds

1.1 Structure determination of compound DPR-1

Compound DPR-1 was obtained as a brown amorphous solid. The HR-ESI mass spectrum (**Figure 6**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 313.1052 (calcd. for $C_{16}H_{18}O_5Na$ 313.1051), suggesting the molecular formula $C_{16}H_{18}O_5$. The IR spectrum (**Figure 7**) presented hydroxyl (3434 cm^{-1}), aromatic ring (2918, 1698 cm^{-1}) and methylene (1463 cm^{-1}) bands. The UV maximal absorption peaks (**Figure 8**) at 218 nm (log ε = 4.10) and 282 nm (log ε = 3.59) were suggestive of a bibenzyl nucleus (Zhang *et al*., 2007b).

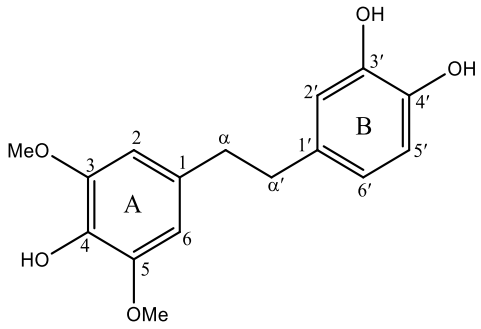
The ^{1}H-NMR spectrum (**Figure 9** and **Table 5**) indicated the presence of four methylene protons at δ_H 2.75 (*br* s, H_2-α, H_2-α'), five aromatic protons at δ_H 6.49 (2H, *s*, H-2 and H-6), 6.54 (1H, *br d*, *J*=8.0 Hz, H-6′), 6.70 (1H, *d*, *J*=3.0 Hz, H-2′) and 6.72 (1H, *d*, *J*=8.0 Hz, H-5′) and two methoxyl groups at δ_H 3.78 (6H, *s*). The ^{1}H-NMR spectrum for ring A, presented a singlet of two equivalent protons H-2 and H-6 at δ_H 6.49. For

ring B, the ^{1}H-NMR spectrum showed an ABM spin system at δ_H 6.54 (1H, *J*=8.0 Hz, H-6′) and 6.72 (1H, *J*=8.0 Hz, H-5′) and 6.70 (1H, *d*, *J*=3.0 Hz, H-2′). These spectral data presented the symmetrical substitution on the ring A and two substitutions on the ring B.

The ^{13}C-NMR spectrum (**Figure 10** and **Table 5**) displayed sixteen carbon signals, including two equivalent methoxyl groups at the same chemical shift (at δ_C 55.7). The other fourteen carbon signals of DPR-1 could be classified as representing two methylene carbons at δ_C 37.4 (C-α′) and 38.1 (C-α), five methine carbons at δ_C 105.9 (C-2 and C-6), 115.0 (C-5′), 115.5 (C-2′) and 119.6 (C-6′) and seven quaternary carbon signals at δ_C 132.4 (C-4), 133.7 (C-1′), 134.1 (C-1), 143.0 (C-4′), 144.8 (C-3′) and 147.6 (C-3 and C-5). HSQC spectrum (**Figure 11**) showed proton signals for a bibenzyl structure at δ_H 2.75 (H_2-α, H_2-α′) that had correlation peaks with carbon atoms at δ_C 37.4 (C-α′) and 38.1 (C-α).

The NOESY spectrum (**Figure 12**) suggested that the two methoxyl groups (δ_H = 3.78, *s*, 6H) should be at the positions C-3 and C-5 (δ_C = 147.6), based on correlation peak of the proton signals at δ_H 6.49 (H-2 and H-6) with the methoxy signals at δ_H 3.78 (3-OMe and 5-OMe). From HMBC spectrum (**Figure 13**), C-3 and C-5 (δ_C = 147.6) showed a correlation peak with methoxy proton signals, placing the two methoxyl groups at C-3 and C-5.

Based on the above spectral evidence, DPR-1 was characterized as a new compound and its structure was quite similar to moscatilin [**21**]. It was established as 4,3′,4′-trihydroxy-3,5-dimethoxybibenzyl [**307**].



4,3′,4′-trihydroxy-3,5-dimethoxybibenzyl [**307**]

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

Position	Compound DPR-1	
	δ_H (mult., *J* in Hz)	δ_C
1	-	134.1
2	6.49 (*s*)	105.9
3	-	147.6
4	-	132.4
5	-	147.6
6	6.49 (*s*)	105.9
1′	-	133.7
2′	6.70 (*d*, 3.0)	115.5
3′	-	144.8
4′	-	143.0
5′	6.72 (*d*, 8.0)	115.0
6′	6.54 (*br d*, 8.0)	119.6
α	2.75 (*br s*)	38.1
α′	2.75 (*br s*)	37.4
3-OMe	3.78 (*s*)	55.7
5-OMe	3.78 (*s*)	55.7

1.2 Structure determination of compound DPR-2

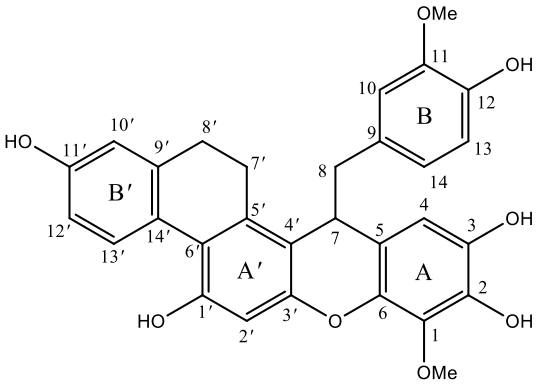
Compound DPR-2 was obtained as a red amorphous powder. The HR-ESI mass spectrum (**Figure 14**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 537.1521 (calcd. for $C_{30}H_{26}O_8Na$; 537.1525), suggesting the molecular formula $C_{30}H_{26}O_8$. The IR spectrum (**Figure 15**) showed the presence of hydroxyl (3245 cm^{-1}), aromatic ring (2934, 1514 cm^{-1}) and ether (1235 cm^{-1}) bands. The UV maximal absorption peaks (**Figure 16**) at 203 nm (log ε = 4.82) and 282 nm (log ε = 4.40) were suggestive of a bibenzyl-dihydrophenanthrene skeleton (Guo *et al*., 2007; Yao *et al*., 2008).

The ^{1}H-NMR spectrum (**Figure 17** and **Table 6**) exhibited aliphatic protons at δ_H 2.60 (2H, *m*, H-8′), 2.75 (2H, *m*, H-8), 2.57, 2.75 (1H, *m*, H-7′) and 4.26 (1H, *t*, *J*=5.5 Hz, H-7). The ^{13}C-NMR spectrum (**Figure 18** and **Table 6)** represented thirty carbons including two methoxyl groups at δ_C 56.0 (11-OMe) and 61.6 (1-OMe), methylene carbon signals at δ_C 26.4 (C-7′), 30.9 (C-8′) and 45.8 (C-8), a methine carbon signal at δ_C 39.6 (C-7) and aromatic carbon signals at δ_C 102.9 (C-2′), 110.1 (C-4), 113.6 (C-12′), 114.6 (C-4′), 114.7 (C-10 and C-10′), 115.3 (C-13), 117.5 (C-5), 119.2 (C-6′), 123.3 (C-14), 126.5 (C-14′), 130.5 (C-13′), 130.8 (C-9), 137.1 (C-1), 138.3 (C-2), 138.8 (C-5′), 140.6 (C-6 and C-9′), 142.3 (C-3), 145.7 (C-12), 147.9 (C-11), 152.7 (C-3′), 154.7 (C-1′) and 156.3 (C-11′).

Comparison of ^{1}H and ^{13}C NMR spectra of DPR-2 with those of dendrosignatol [**65**] which is a bibenzyl-dihydrophenanthrene derivative from *Dendrobium signatum* (Mittraphab *et al*., 2016), showed close similarity in rings A, A′ and B′. On ring B′ showed the ABM spin system at δ_H 6.63 (1H, *dd*, *J*=9.0, 2.5 Hz, H-12′), 6.65 (1H, *br s*, H-10′) and 8.16 (1H, *d*, *J*=9.0 Hz, H-13′). The ^{1}H NMR spectrum showed two methoxyl signals at δ_H 3.51 (3H, *s*) and 3.75 (3H, *s*), two doublet signals at δ_H 5.89 (*J*=2.0 Hz, H-10) and 6.47 (*J*=8.0 Hz, H-13), and a double doublet at δ_H 6.03 (*J*=8.0, 2.0 Hz, H-14). The HSQC spectrum (**Figure 19**) showed the correlation peaks between H-8′, H-8, H-7′ and H-7 with carbon atoms at δ_C 30.9 (C-8′), 45.8 (C-8), 26.4 (C-7′) and 39.6 (C-7), respectively, indicated a bibenzyl-dihydrophenanthrene skeleton.

In the HMBC spectrum (**Figure 20, and 21**), the signal of H-7 at δ_H 4.26 (*t*, 5.5) had correlation peaks with C-4 (δ_C = 110.1), C-6 (δ_C = 140.6), C-9 (δ_C = 130.8), C-3′ (δ_C = 152.7) and C-5′ (δ_C = 138.8) proposed that ring A′ of dihydrophenanthrene connected to ring A of bibenzyl by an ether linkage and methine bridge. Furthermore, the singlet H-4 proton of ring A at δ_H 6.40 showed HMBC correlations with C-2 (δ_C = 138.3), C-6 (δ_C = 140.6), and C-7 (δ_C = 39.6). The signal at δ_H 6.41 was determined as that of H-2′ of ring A′ based on 3-bond correlation to C-4′ (δ_C = 114.6) and C-6′ (δ_C = 119.2). The NOESY correlation of H-10′ and H-8′ and the HMBC correlation of H-10′ and C-8′ (δ_C = 30.9) predicted a hydroxyl group position at C-11′. H-10 and H-14 had correlation peaks with C-8 indicated a methoxy group or a hydroxyl group was di-oxygenated at C-11 and C-12. The NOESY (**Figure 22**) correlation between the signal of a methoxyl group and H-10, placing this methoxyl group at C-11. In addition, this compound had a chiral carbon at C-7 then, the optical rotation was measured in methanol with value −9.2 (*c* 0.1).

Based on the above spectral data, compound DPR-2 was characterized as a new bibenzyl-dihydrophenanthrene derivative. It was named as (−)-dendroparishiol [**308**].



(–)-Dendroparishiol [**308**]

Table 6 ^{1}H NMR 500 MHz and ^{13}C NMR 125 MHz spectral data of compound DPR-2 (in CD_3OD)

Position	Compound DPR-2		Position	Compound DPR-2	
	δ_H (mult., *J* in Hz)	δ_C		δ_H (mult., *J* in Hz)	δ_C
1	-	137.1	2′	6.41 (*s*)	102.9
2	-	138.3	3′	-	152.7
3	-	142.3	4′	-	114.6
4	6.40 (*s*)	110.1	5′	-	138.8
5	-	117.5	6′	-	119.2
6	-	140.6	7′	2.57 (*m*), 2.75 (*m*)	26.4
7	4.26 (*t*, 5.5)	39.6	8′	2.60 (*m*)	30.9
8	2.75 (*m*)	45.8	9′	-	140.6
9	-	130.8	10′	6.65 (*br s*)	114.7
10	5.89 (*d*, 2.0)	114.7	11′	-	156.3
11	-	147.9	12′	6.63 (d*d*, 9.0, 2.5)	113.6
12	-	145.7	13′	8.16 (*d*, 9.0)	130.5
13	6.47 (*d*, 8.0)	115.3	14′	-	126.5
14	6.03 (d*d*, 8.0, 2.0)	123.3	1-OMe	3.75 (3H, *s*)	61.6
1′	-	154.7	11-OMe	3.51 (3H, *s*)	56.0

1.3 Structure determination of compound DPR-3

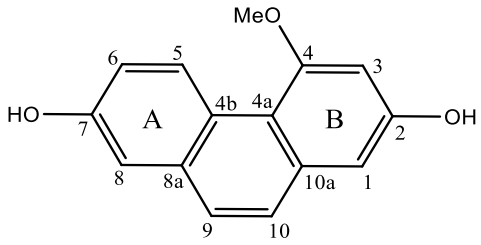
Compound DPR-3 was obtained as a brown amorphous solid. The HR-ESI-MS of this compound (**Figure 23**) showed an $[M+Na]^+$ peak at *m/z* 263.0686 (calcd. for $C_{15}H_{12}O_3Na$; 263.0684), suggesting the molecular formula $C_{15}H_{12}O_3$.

The ^{1}H-NMR spectrum of DPR-3 (**Figure 24** and **Table 7**) exhibited the presence of a phenanthrene skeleton. It showed the signals of *ortho*- coupled aromatic protons at δ_H 7.52 (1H, *d*, *J*=9.0 Hz, H-10) and 7.65 (1H, *d*, *J*=9.0 Hz, H-9). The signals of aromatic protons of ring A appeared at δ_H 7.45 (1H, *d*, *J*=7.5 Hz, H-5), δ_H 7.11 (1H, d*d*, *J*=7.5, 2.5 Hz, H-6) and δ_H 7.43 (1H, *d*, *J*=2.5 Hz, H-8). For ring B, the ^{1}H-NMR spectrum showed two doublets at δ_H 7.00 (1H, *d*, *J*=2.5 Hz, H-3) and δ_H 7.08 (1H, *d*, *J*=2.5 Hz, H-1). In addition, the ^{1}H-NMR spectrum revealed signals for one methoxyl group at δ_H 4.17 (*s*, 4-OMe).

The ^{13}C-NMR (**Figure 25** and **Table 7**) and HSQC (**Figure 26**) spectral data displayed fifteen carbon signals, including one signal of methoxyl group at δ_C 57.7. The other fourteen carbon signals could be differentiated into seven methine carbon signals at δ_C 106.9 (C-1), 101.7 (C-3), 126.6 (C-5), 116.1 (C-6), 120.2 (C-8), 128.9 (C-9) and 126.1 (C-10) and seven quaternary carbon signals at δ_C 156.5 (C-2), 155.5 (C-4), 113.0 (C-4a), 118.9 (C-4b), 154.3 (C-7), 134.1 (C-8a), 136.2 (C-10a).

The NOESY spectrum (**Figure 27**), showed correlation from the methoxy protons (δ_H = 4.17) to the signal of H-3, supporting the position of the methoxyl group at C-4. The HMBC (**Figure 28**) correlation from this methoxy proton signal to C-4 confirmed this placement.

Based on the above data and comparison of its ^{1}H, ^{13}C-NMR and MS with previously reported data (Klongkumnuankarn *et al*., 2015), DPR-3 was identified as flavanthrinin [**119**]. The first report of flavanthrinin in *Dendrobium* species has been from *D. nobile* (Zhang *et al*., 2008c). Besides, this compound also has been found in other *Dendrobium* species such as *D. venustum* (Sukphan *et al*., 2014) and *D. brymerianum* (Klongkumnuankarn *et al*., 2015).



Flavanthrinin [**119**]

Table 7 ^{1}H NMR 300 MHz and ^{13}C NMR 75 MHz spectral data of compound DPR-3 (in acetone-d_6) and flavanthrinin (in $CDCl_3$)

Position	Compound DPR-3		Flavanthrinin[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	7.08 (*d*, 2.5)	106.9	6.97 (*d*, 2.5)	107.7
2	-	156.5	-	156.3
3	7.00 (*d*, 2.5)	101.7	6.84 (*d*, 2.5)	102.5
4	-	155.5	-	157.3
4a	-	113.0	-	114.0
4b	-	118.9	-	119.9
5	7.45 (*d*, 7.5)	126.6	7.47 (*d*, 7.6)	127.4
6	7.11 (*dd*, 7.5, 2.5)	116.1	7.22 (*dd*, 7.6, 1.5)	116.9
7	-	154.3	-	155.2
8	7.43 (*d*, 2.5)	120.2	7.40 (*d*, 1.5)	121.0
8a	-	134.1	-	134.9
9	7.65 (*d*, 9.0)	128.9	7.62 (*d*, 8.8)	129.7
10	7.52 (*d*, 9.0)	126.1	7.43 (*d*, 8.8)	126.9
10a	-	136.2	-	137.0
4-OMe	4.17 (*s*)	57.7	4.08 (*s*)	58.5

[a](Klongkumnuankarn *et al*., 2015).

1.4 Structure determination of compound DPR-4

Compound DPR-4 was obtained as a brown amorphous solid. The HR-ESI-MS of this compound (**Figure 29**) showed an $[M+Na]^+$ peak at *m/z* 327.1219 (calcd. for $C_{17}H_{20}O_5Na$; 327.1208), suggesting the molecular formula $C_{17}H_{20}O_5$.

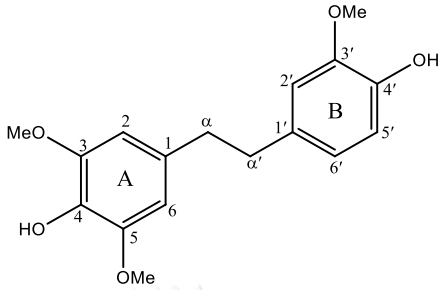
Comparing the ^{1}H-NMR spectrum of DPR-4 with DPR-1, it was found that the aromatic proton peaks were quite similar to DPR-1, suggesting that DPR-4 also possessed a bibenzyl skeleton. The ^{1}H-NMR spectrum of compound DPR-4 (**Figure 30** and **Table 8**) showed methylene proton signals at δ_H 2.84 (4H, *m*, H_2-α, H_2-α'), signals of three methoxy groups at δ_H 3.86 (9H, *s*, 3′-OMe, 3-OMe, 5-OMe) and five aromatic protons at δ_H 6.38 (2H, *s*, H-2, H-6), 6.66 (1H, *d*, *J*=2.0 Hz, H-2′), 6.70 (1H, *dd*, *J*=8.0, 2.0 Hz, H-6′) and 6.86 (1H, *d*, *J*=8.0 Hz, H-5′). This spectrum showed the presence of five substituted on the two aromatic rings, with one ring symmetrically substituted.

The ^{13}C-NMR spectrum (**Figure 31** and **Table 8**) showed signals of seventeen carbons consisting of two methylene carbons at δ_C 38.0 (C-α') and 38.5 (C-α), five methines carbon at δ_C 105.2 (C-2 and C-6), 111.3 (C-2′), 114.2 (C-5′) and 121.1 (C-6′), seven quaternary carbons at δ_C 132.9 (C-1, C-4), 133.7 (C-1′), 143.8 (C-4′), 146.3 (C-3′) and 146.9 (C-3, C-5) and three methoxyl groups at δ_C 55.9 (3′-OMe) and 56.3 (3-OMe and 5-OMe).

In the NOESY spectrum (**Figure 32**), the methoxyl group at δ_H 3.86 (3′-OMe) had a correlation peak with H-2′. Two other methoxyl groups at δ_H 3.86 (3-OMe and 5-OMe) exhibited a cross peak with H-2 (H-6). These observations supported the location of the methoxyl groups at C-3′, C-3 and C-5, respectively. From the HMBC spectrum (**Figure 33**), the three methoxy protons had correlation peaks with C-3′, C-3 and C-5, respectively, confirming their positions.

Based on the above data and comparison of the ^{1}H, ^{13}C-NMR and MS data of this compound with previously published data (Majumder and Sen, 1987), DPR-4 was identified as moscatilin [**21**]. This compound has been frequently found in *Dendrobium* plants, such as *D. amoenum* (Majumder *et al*., 1999), *D. chrysanthum* (Yang *et al*.,

2006a), *D. densiflorum* (Fan *et al*., 2001), *D. gratiosissimum* (Zhang *et al*., 2008a), *D. moscatum* (Majumder and Sen, 1987), *D. nobile* (Miyazawa *et a*l., 1999), *D. loddigesii* (Chen *et al*., 1994; Ito *et al*., 2010), and *D. secundum* (Sritularak *et al*., 2011b).



Moscatilin [**21**]

Table 8 ^{1}H NMR 300 MHz and ^{13}C NMR 75 MHz spectral data of compound DPR-4 (in acetone-d_6) and moscatilin (in acetone-d_6)

Position	Compound DPR-4		Moscatilin[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	132.9	-	132.8
2	6.38 (*s*)	105.2	6.36 (*s*)	105.2
3	-	146.9	-	146.8
4	-	132.9	-	133.5
5	-	146.9	-	146.8
6	6.38 (*s*)	105.2	6.36 (*s*)	105.2
α	2.84 (*m*)	38.5	2.89 (*s*)	38.3
α′	2.84 (*m*)	38.0	2.89 (*s*)	37.7
1′	-	133.7	-	132.8
2′	6.66 (*d*, 2.0)	111.3	6.65 (*d*, 2.0)	111.2
3′	-	146.3	-	146.1
4′	-	143.8	-	143.7
5′	6.86 (*d*, 8.0)	114.2	6.94 (*d*, 8.0)	114.1
6′	6.70 (*dd*, 8.0, 2.0)	121.1	6.75 (*dd*, 8.0, 2.0)	121.0
3′-OMe	3.86 (*s*)	55.9	3.81 (*s*)	55.8
3-OMe	3.86 (*s*)	56.3	3.81 (*s*)	56.1
5-OMe	3.86 (*s*)	56.3	3.81 (*s*)	56.1

[a](Majumder and Sen, 1987)

1.5 Structure determination of compound DPR-5

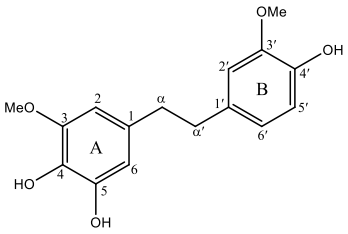
Compound DPR-5 was obtained as a brown amorphous solid. The HR-ESI-MS of this compound (**Figure 34**) showed an $[M+Na]^+$ peak at *m/z* 313.1058 (calcd. for $C_{16}H_{18}O_5Na$; 313.1052), suggesting the molecular formula $C_{16}H_{18}O_5$.

Comparing the ^{1}H-NMR spectrum of DPR-5 with DPR-1 and DPR-4, it was found that the splitting patterns of aromatic protons of DPR-5 were quite similar to DPR-1 and DPR-4. It was suggestive that DPR-5 had a bibenzyl skeleton. The ^{1}H-NMR spectrum of compound DPR-5 (**Figure 35** and **Table 9**) showed signals of four methylene protons at δ_H 2.74 (4H, *m*, H_2-α, H_2-α'), two methoxyl groups at δ_H 3.77 (3H, *s*, 3-OMe) and 3.78 (3H, *s*, 3′-OMe) and five aromatic protons at δ_H 6.25 (1H, *d*, *J*=2.0 Hz, H-2), 6.30 (1H, *d*, *J*=2.0 Hz, H-6), 6.59 (1H, *dd*, *J*=8.0, 2.0 Hz H-6′), 6.65 (1H, *d*, *J*=2.0 Hz, H-2′) and 6.69 (1H, *d*, *J*=8.0 Hz, H-5′). This spectral data showed the presence of five substituted on the two aromatic rings, with one methoxyl group substituted on each ring.

The ^{13}C-NMR spectrum (**Figure 36** and **Table 9**) showed sixteen carbon signals, including those of two methoxy carbons at δ_C 54.9 (3′-OMe) and 55.1 (3-OMe), two methylene carbons at δ_C 37.5 (C-α') and 37.9 (C-α), five methane carbons at δ_C 103.7 (C-2), 108.7 (C-6), 112.1 (C-2′), 114.5 (C-5′) and 120.6 (C-6′). and seven quaternary carbons at δ_C 131.7 (C-1), 132.8 (C-4), 133.5 (C-1′), 144.1 (C-4′), 144.9 (C-5), 147.2 (C-3′) and 148.0 (C-3).

In the NOESY spectrum (**Figure 37**), the proton signals at δ_H 3.78 (3′-OMe) was correlated to proton signals at δ_H 6.65 (H-2′) and the proton signals at δ_H 3.77 (3-OMe) showed the correlation peak with H-2. These observations supported the locations of the two methoxyl groups at C-3′ and C-3, respectively. From the HMBC spectrum (**Figure 38**), the methoxyl signal at δ_H 3.78 (3′-OMe) had a correlation peak with C-3′, and the other methoxyl signal at δ_H 3.77 (3-OMe) had a correation peak with C-3.

By comparing ^{1}H, ^{13}C-NMR and MS data of this compound with previously published data (Sritularak *et al*., 2011), DPR-5 was identified as 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**25**].



4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**25**]

Table 9 ^{1}H NMR 300 MHz and ^{13}C NMR 75 MHz spectral data of compound DPR-5 (in acetone-d_6) and 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl (in acetone-d_6)

Position	Compound DPR-5		4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	131.7	-	130.4
2	6.25 (*d*, 2.0)	103.7	6.21 (*d*, 2.0)	103.5
3	-	148.0	-	146.6
4	-	132.8	-	133.7
5	-	144.9	-	143.7
6	6.30 (*d*, 2.0)	108.7	6.42 (*d*, 2.0)	108.6
α	2.74 (*m*)	37.9	2.75 (*m*)	38.2
α′	2.74 (*m*)	37.5	2.78 (*m*	37.7
1′	-	133.5	-	133.8
2′	6.65 (*d*, 2.0)	112.1	6.60 (*d*, 2.0)	111.2
3′	-	147.2	-	146.2
4′	-	144.1	-	143.7
5′	6.69 (*d*, 8.0)	114.5	6.80 (*d*, 8.0)	114.1
6′	6.59 (*dd*, 8.0, 2.0)	120.6	6.65 (*dd*, 8.0, 2.0)	121.0
3′-OMe	3.78 (*s*)	54.9	3.83 (*s*)	55.9
3-OMe	3.77 (*s*)	55.1	3.80 (*s*)	56.1

[a](Sritularak *et al*., 2011)

1.6 Structure determination of compound DPR-6

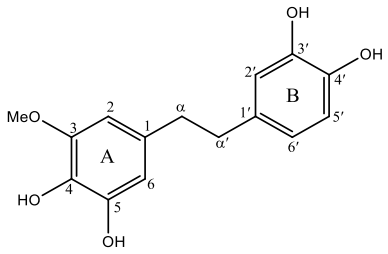
Compound DPR 6 was obtained as a red amorphous solid. The HR-ESI-MS of this compound (**Figure 39**) showed an $[M+Na]^+$ peak at *m/z* 299.0900 (calcd. for $C_{15}H_{16}O_5Na$; 299.0895), suggesting the molecular formula $C_{15}H_{16}O_5$.

Comparing the ^{1}H-NMR spectrum of DPR-6 with DPR-1, DPR-4 and DPR-5, it was found that the aromatic proton peaks of this compound were quite similar to those of DPR-1, DPR-4 and DPR-5. It was suggestive that DPR-6 had a bibenzyl skeleton. The ^{1}H-NMR spectrum of compound DPR-6 (**Figure 40** and **Table 10**) exhibited signals of four methylene protons at δ_H 2.71 (4H, *m*, H_2-α, H_2-α'), a methoxy group at δ_H 3.78 (3H, *s*, 3-OMe) and five aromatic protons at δ_H 6.36 (1H, *br s*, H-2), 6.37 (1H, *br s*, H-6), 6.55 (1H, *dd*, *J*=8.0, 2.0 Hz H-6′), 6.71 (1H, *br s*, H-2′) and 6.73 (1H, *d*, *J*=8.0 Hz, H-5′).

The ^{13}C-NMR spectrum (**Figure 41** and **Table 10**) showed fifteen carbon signals belonging to one methoxyl group at δ_C 55.5 (3-OMe), two methylene carbons at δ_C 37.4 (C-α') and 37.9 (C-α), five methane carbons at δ_C 103.7 (C-2), 108.8 (C-6), 115.0 (C-5′), 115.5 (C-2′), and 119.6 (C-6′), and seven quaternary carbons at δ_C 131.8 (C-4), 132.9 (C-1), 133.8 (C-1′), 145.2 (C-5), 143.0 (C-4′), 144.8 (C-3′) and 147.9 (C-3).

In the NOESY spectrum (**Figure 42**), the proton at δ_H 3.78 (3-OMe) showed correlation peak with H-2 signal at δ_H 6.36. From HMBC spectrum (**Figure 43**), the methoxyl signal at δ_H 3.78 (3-OMe) had a correlation peak with C-3, confirming the location of methoxyl group at C-3.

Based on the previous spectral evidence and comparing ^{1}H, ^{13}C-NMR and MS data of this compound with previously published data (Li *et al*., 2009b), DPR-6 was identified as dendrocandin E [**37**].



Dendrocandin E [**37**]

Table 10 ^{1}H NMR 300 MHz and ^{13}C NMR 75 MHz spectral data of compound DPR-6 (in acetone-d_6) and dendrocandin E (in acetone-d_6)

Position	Compound DPR-6		Dendrocandin E[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	132.9	-	134.3
2	6.36 (*br s*)	103.7	6.22 (*d*, 1.5)	105.1
3	-	147.9	-	149.4
4	-	131.8	-	133.1
5	-	145.2	-	146.3
6	6.37 (*br s*)	108.8	6.17 (*d*, 1.5)	109.9
α	2.71 (*s*)	37.9	2.62 (*s*)	39.3
α′	2.71 (*s*)	37.4	2.62 (*s*)	38.7
1′	-	133.8	-	135.0
2′	6.71 (*br s*)	115.5	6.52 (*d*, 2.0)	116.7
3′	-	144.8	-	145.9
4′	-	143.0	-	144.2
5′	6.73 (*d*, 8.0)	115.0	6.58 (*d*, 8.0)	116.2
6′	6.55 (*dd*, 8.0, 2.0)	119.6	6.41 (*dd*, 8.0, 2.0)	120.8
3-OMe	3.78 (*s*)	55.5	3.70 (*s*)	56.5

[a](Li *et al*., 2009b)

1.7 Structure determination of compound DPR-7

Compound DPR-7 was isolated as a white powder. Its HR-ESI-MS (**Figure 44**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 511.3497 (calcd. for $C_{30}H_{48}O_5Na$; 511.3399), suggesting the molecular formula $C_{30}H_{48}O_5$.

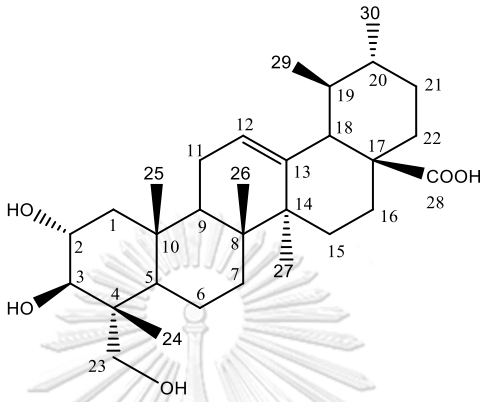
The ^{1}H-NMR spectrum (**Figure 45** and **Table 11**) showed an olefinic proton signal at δ_H 5.24 (*br s*, H-12), four methine proton signals at δ_H 2.25 (*d*, *J*=11.3 Hz, H-18), 3.30 (*d*, *J*=10.5 Hz, H-23), 3.40 (*d*, *J*=9.5 Hz, H-3) and 3.72 (*br t*, H-2), four tertiary methyl groups at δ_H 0.74 (*s*, H-24), 0.84 (*s*, H-26), 0.90 (*d*, *J*=6.5 Hz, H-29) and 1.05 (*s*, H-25), two secondary methyl groups at δ_H 0.98 (*br s*, H-30) and 1.14 (*s*, H-27) and overlapped signals at δ_H 1.2 - 2.1 (H-1, H-6, H-7, H-11, H-16, H-18, H-21 and H-22) suggesting an ursane-type triterpenoid.

The ^{13}C-NMR spectrum (**Figure 46** and **Table 11**) revealed thirty carbon signals including a carboxylic carbon at δ_C 177.7 (C-28), two olefinic carbon signals at δ_C 125.2 (C-12) and 138.5 (C-13), two oxygenated methine carbon signals at δ_C 68.1 (C-2) and 77.6 (C-3), a hydroxymethylene signal at 66.3 (C-23) and six methyl signals at 13.0 (C-24), 16.7 (C-29), 16.8 (C-25), 16.9 (C-26), 20.6 (C-30) and 23.1 (C-27). These spectral data suggested that compound DPR-7 was an ursane-28-oic-acid.

From the HMBC spectrum (**Figure 47**), the oxygenated methylene protons at δ_H 3.30 (*d*, *J*=10.5 Hz, H-23) had correlation peaks with C-3 (δ_C = 77.6), C-4 (δ_C = 42.5) and C-5 (δ_C = 47.5), presenting that one hydroxyl was linked at C-23. Furthermore, the HMBC correlations from the H-2 (δ_H = 3.72) to C-1 (δ_C = 46.7), C-3 (δ_C =77.6) and from H-3 (δ_H = 3.40) to C-2 (δ_C = 68.1) and C-4 (δ_C = 42.5) confirmed the location of two hydroxyl groups at C-2 and C-3.

Based on the ^{1}H- and ^{13}C-NMR data and comparing with previously reported data, compound DPR-7 was identified as asiatic acid [**309**]. Asiatic acid is a triterpenoid which was previously reported from *Centella asiatica* (Monti *et al*., 2005). This compound has been found in *Oenothera cheiranthifolia* (Nakanishi *et al*., 2007), *Mucuna birdwoodaina* (Ding *et al*., 1991), *Schefflera octophylla* (Sung *et al*., 1992),

Symplocos lancifolia (Acebey-Castellon *et al*., 2011), *Actinidia arguta* (Jang *et al*., 2008), *Combretum nelsonii* (Masoko *et al*., 2008) and *Melastoma malabathricum* (Wong *et al*., 2012). This compound was found at the first time in *Dendrobium* plants.



Asiatic acid [**309**]

Table 11 ^{1}H NMR 300 MHz and ^{13}C NMR 75 MHz spectral data of compound DPR-7 (in CD_3OD) and Asiatic acid (in CD_3OD)

Position	Compound DPR-7		Asiatic acid[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	1.2 - 2.1	46.7	*	47.6
2	3.72 (*br t*)	68.1	3.67 (*d*, 4.0)	69.7
3	3.40 (*d*, 9.5)	77.6	3.33 (*d*, 9.5)	78.3
4	-	42.5	-	44.1
5	-	47.5	-	48.2
6	1.2 - 2.1	17.8	*	19.1
7	1.2 - 2.1	32.6	*	33.7
8	-	39.5	-	40.8
9	-	47.3	-	47.6
10	-	37.7	-	39.0
11	1.2 - 2.1	23.2	*	24.5
12	5.24 (*br s*)	125.2	5.23 (*br s*)	126.7
13	-	138.5	-	139.8
14	-	42.1	-	43.4
15	-	27.9	-	29.2

[a](Monti *et al*., 2005) * = Not reported

Table 11 ^{1}H NMR 300 MHz and ^{13}C NMR 75 MHz spectral data of compound DPR-7 (in CD_3OD) and Asiatic acid (in CD_3OD) (continued)

Position	Compound DPR-7		Asiatic acid[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
16	1.2 - 2.1	24.1	*	25.3
17	-	47.4	-	48.0
18	2.25 (*d*, 11.3)	53.0	2.20 (*d*, 11.3)	53.5
19	-	39.0	-	40.4
20	-	38.9	-	40.4
21	1.2 - 2.1	30.4	*	31.8
22	1.2 - 2.1	36.7	*	38.1
23	3.30 (*d*, 10.5)	66.3	3.26 (*d*, 10.5)	66.4
24	0.74 (*s*)	13.0	0.69 (*s*)	13.9
25	1.05 (*s*)	16.8	1.04 (*s*)	17.7
26	0.84 (*s*)	16.9	0.84 (*s*)	17.9
27	1.14 (*s*)	23.1	1.13 (*s*)	24.2
28	-	177.7	-	181.6
29	0.90 (*d*, 6.5)	16.7	0.89 (*d*, 6.5)	17.6
30	0.98 (*br s*)	20.6	0.96 (*br s*)	21.6

[a]{Monti, 2005 #122} * = Not reported

2. Free radical scavenging activities

The compounds from *D. parishii* were evaluated at a concentration of 50 µg/mL in assays for free radical scavenging activity including DPPH, ORAC and deoxyribose degradation assays. Results from the DPPH assay (**Table 12**) and the deoxyribose degradation assay (**Table 13**) are reported as %inhibition. In the ORAC assay, the results were determined as micromole Trolox® equivalent (TE) per gram (µmol TE/g).

As shown in **Table 12**, seven pure compounds were tested in the DPPH assay. The new compounds (4,3′,4′-trihydroxy-3,5-dimethoxybibenzyl [DPR-1, **307**] and (–)-dendroparishiol [DPR-2, **308**]) exhibited 9.91 ± 0.31 and 40.59 ± 1.61 %inhibition of DPPH radical, respectively. The other five compounds (flavanthrinin [DPR-3, **119**], moscatilin [DPR-4, **21**], 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [DPR-5, **25**], dendrocandin E [DPR-6, **37**] and asiatic acid [DPR-7, **309**]) will able to inhibit DPPH radical 18.86 ± 1.13, 25.65 ± 0.56, 9.41 ± 0.71, 27.73 ± 0.64 and 4.00 ± 0.89%, respectively.

In the deoxyribose degradation assay (**Table 12)**, among the isolated compounds, (–)-dendroparishiol [DPR-2, **308**] manifested the highest %inhibition of hydroxyl radical (62.66 ± 0.32%), but the activity was still less than the positive control (Trolox®, 90.45 ± 0.54%). The other six compounds (4,3′,4′-trihydroxy-3,5-dimethoxy-bibenzyl [DPR-1, **307**], flavanthrinin [DPR-3, **119**], moscatilin [DPR-4, **21**], 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [DPR-5, **25**], dendrocandin E [DPR-6, **37**] and asiatic acid [DPR-7, **309**]) inhibited hydroxyl radical by 32.58 ± 0.87, 17.99 ± 0.38, 34.84 ± 1.51, 21.92 ± 0.66, 24.96 ± 1.02 and 38.52 ± 1.41%, respectively.

Table 12 Percentage of DPPH and hydroxyl radical inhibition by compounds DPR-1 – DPR-7

Compounds	%Inhibition	
	DPPH radical	Hydroxyl radical
4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl [DPR-1, **307**]	9.91 ± 0.31	32.58 ± 0.87
(–)-Dendroparishiol [DPR-2, **308**]	40.59 ± 1.61	62.66 ± 0.32
Flavanthrinin [DPR-3, **119**]	18.86 ± 1.13	17.99 ± 0.38
Moscatilin [DPR-4, **21**]	25.65 ± 0.56	34.84 ± 1.51
4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl [DPR-5, **25**]	9.41 ± 0.71	21.92 ± 0.66
Dendrocandin E [DPR-6, **37**]	27.73 ± 0.64	24.96 ± 1.02
Asiatic acid [DPR-7, **309**]	4.00 ± 0.89	38.52 ± 1.41
Positive control (Trolox®)	-	90.45 ± 0.54

For ORAC assay, as shown in **Table 13**, among the isolated compounds, (–)-dendroparishiol [DPR-2, **308**] exhibited the strongest peroxyl radical reduction equivalent to 510.93 ± 14.27 μmol Trolox®/g. The other six pure compounds (4,3′,4′-trihydroxy-3,5-dimethoxybibenzyl [DPR-1, **307**], flavanthrinin [DPR-3, **119**], moscatilin [DPR-4, **21**], 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [DPR-5, **25**], dendrocandin E [DPR-6, **37**] and asiatic acid [DPR-7, **309**]) were able to reduce peroxyl radical equivalent to 407.95 ± 22.74, 441.79 ± 18.59, 434.26 ± 16.19, 455.54 ± 11.37, 446.65 ± 25.56 and 259.11 ± 10.42 μmol Trolox®/g, respectively.

Table 13 Trolox® equivalent (TE) (in micromole per gram) of compounds DPR-1 – DPR-7 in deoxyribose degradation assay

Compounds	μmol TE/g
	Peroxyl radical
4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl [DPR-1, **307**]	407.95 ± 22.74
(–)-Dendroparishiol [DPR-2, **308**]	510.93 ± 14.27
Flavanthrinin [DPR-3, **119**]	441.79 ± 18.59
Moscatilin [DPR-4, **21**]	434.26 ± 16.19
4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl [DPR-5, **25**]	455.54 ± 11.37
Dendrocandin E [DPR-6, **37**]	446.65 ± 25.56
Asiatic acid [DPR-7, **309**]	259.11 ± 10.42

The inhibitory effects of isolated compounds on intracellular ROS production in RAW 264.7 murine macrophage cells induced by H_2O_2 are shown in **Table 14**. (–)-dendroparishiol [DPR-2, **308**] also showed the strongest %ROS inhibition with 66.67 ± 0.62% similar to the results in the DPPH, deoxyribose degradation and ORAC assays. Therefore, (–)-dendroparishiol was selected for further study for antioxidant activity in RAW 264.7 murine macrophage cells at non-toxic concentrations (12.5 – 50.0 μg/mL). As shown in **Table 15**, (–)-dendroparishiol can reduce ROS production in a dose-dependent manner in H_2O_2 treated-RAW 264.7 cells. Furthermore, (–)-dendroparishiol at a concentration of 50 μg/ml showed more than 50% reduction of ROS production in cells (302.00 ± 9.00) when compared with 1 μg/mL of H_2O_2 treated group (1023.00 ± 7.55).

Table 14 Inhibitory effects on ROS production in RAW 264.7 murine macrophage cells induced by H_2O_2 of isolated compounds from *D. parishii*

Compounds	%ROS inhibition
4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl [DPR-1, **307**]	29.87 ± 1.16
(–)-Dendroparishiol [DPR-2, **308**]	66.67 ± 0.62
Flavanthrinin [DPR-3, **119**]	23.92 ± 1.27
Moscatilin [DPR-4, **21**]	30.85 ± 0.89
4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl [DPR-5, **25**]	22.68 ± 1.24
Dendrocandin E [DPR-6, **37**]	37.60 ± 1.00
Asiatic acid [DPR-7, **309**]	40.90 ± 1.55

Table 15 Inhibitory effects on ROS production in RAW 264.7 murine macrophage cells induced by H_2O_2 of (–)-dendroparishiol at non-toxic concentrations

Groups	ROS production (AU)
Control	293.67 ± 9.61
H_2O_2 (1 μg/mL)	1023.00 ± 7.55
(–)-Dendroparishiol (12.5 μg/mL) + H_2O_2	877.33 ± 13.32
(–)-Dendroparishiol (25.0 μg/mL) + H_2O_2	654.67 ± 6.03
(–)-Dendroparishiol (50.0 μg/mL) + H_2O_2	355.00 ± 12.53
(–)-Dendroparishiol (50.0 μg/mL)	302.00 ± 9.00

The effects of seven isolated compounds on antioxidant enzymes in induced RAW 264.7 cells are shown in **Table 16**. (–)-Dendroparishiol can significantly increase the SOD, GPx and CAT activities in a dose-dependent manner with $p < 0.05$ in H_2O_2 induced RAW 264.7 cells. Thus, (–)-dendroparishiol exhibited antioxidant activities by reduction the ROS production and enhancing the anti-oxidative enzyme activities in H_2O_2 induced-RAW 264.7 murine macrophage cells.

Table 16 Effects of compound (–)-dendroparishiol on antioxidant enzymes in induced RAW 264.7 macrophage cells

Groups	Antioxidant enzymes		
	SOD (Unit per mg protein)	GPx (nmol min^{-1} mg^{-1} protein)	CAT (nmol min^{-1} mg^{-1} protein)
Control	31.52 ± 1.17	92.37 ± 5.13	34.47 ± 2.30
H_2O_2 (1 mM)	12.77 ± 0.32*	45.67 ± 4.12*	14.43 ± 0.78*
(–)-Dendroparishiol (12.5 µg/mL) + H_2O_2	15.20 ± 0.74#	53.49 ± 4.86#	16.98 ± 0.78#
(–)-Dendroparishiol (25.0 µg/mL) + H_2O_2	21.72 ± 0.14#	61.97 ± 6.14#	19.36 ± 1.35#
(–)-Dendroparishiol (50.0 µg/mL) + H_2O_2	26.56 ± 0.52#	76.58 ± 25.90#	23.60 ± 0.78#
(–)-Dendroparishiol (50.0 µg/mL)	29.90 ± 1.02	99.50 ± 4.73	41.09 ± 3.89

* $p < 0.05$ indicates significant differences from the control group value.

# $p < 0.05$ indicates significant differences from the H_2O_2 stimulation value.

CHAPTER V
CONCLUSION

In this study, the EtOAc extract of *Dendrobium parishii* Rchb.f. (Orchidaceae) was separated using several chromatographic techniques to give two new compounds i.e. 4,3′,4′-trihydroxy-3,5-dimethoxybibenzyl [**307**] and (–)-dendroparishiol [**308**] and five known compounds including flavanthrinin [**119**], moscatilin [**21**], 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**25**], dendrocandin E [**37**] and asiatic acid [**309**]. All the isolated compounds were investigated for their antioxidant activities. The new compound (–)-dendroparishiol [**308**] showed the strongest free radicals (DPPH, peroxyl and hydroxyl radical) reduction when compared with other six compounds. Moreover, (–)-dendroparishiol exhibited the strongest %ROS inhibition in H_2O_2-induced RAW 264.7 murine macrophage cells. Thus, (–)-dendroparishiol was further studied for antioxidant activity in H_2O_2-treated RAW 264.7 murine macrophage cells at non-toxic concentrations (12.5 – 50.0 µg/m. At a concentration of 50 µg/ml, it could reduce ROS production more than 50% and, in a dose-dependent manner. Furthermore, (–)-dendroparishiol could enhance the anti-oxidative enzymes (SOD, GPx and CAT) activities in a dose-dependent manner. The phytochemical data obtained in this study would be useful for the chemotaxonomic study of *Dendrobium* plants. The data on free radical scavenging and antioxidant activities of the isolated compounds would be of interest to the natural product research community.

REFERENCES

Acebey-Castellon, I. L., Voutquenne-Nazabadioko, L., Doan, T. M. H., Roseau, N., Bouthagane, N., Muhammad, D. and Lavaud, C. (2011). Triterpenoid saponins from *Symplocos lancifolia*. Journal of Natural Products 74(2), 163-168.

Bi, Z. M., Wang, Z. T. and Xu, L. S. (2004). Chemical constituents of *Dendrobium moniliforme*. Acta Botanica Sinica 46(1), 124-126.

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(1), 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, X. J., Mei, W. L., Cai, C. H., Guo, Z. K., Song, X. Q. and Dai, H. F. (2014a). Four new bibenzyl derivatives from *Dendrobium sinense*. Phytochemistry Letters 9(1), 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., Liu, Y., Jiang, J., Zhang, Y. and Yin, B. (2008). Dendronone, a new phenanthrenequinone from *Dendrobium cariniferum*. Food Chemistry 111(1), 11-12.

Chen, Y. G., Li, J. T., Wang, L. Q. and Liu, Y. (2008a). Aromatic compounds from *Dendrobium aphyllum*. Biochemical Systematics and Ecology 36(5-6), 458-460.

Chen, Y. G., Yu, H. and Liu, Y. (2014b). Chemical constituents from *Dendrobium brymerianum* Rchb. f. Biochemical Systematics and Ecology 57, 175-177.

Dahmen, J. and Leander, K. (1978). Amotin and amoenin, two sesquiterpenes of the picrotoxane group from *Dendrobium amoenum*. Phytochemistry 17(11), 1949-1952.

Devasagayam, T. P. A., Tilak, J. C., Boloor, K. K., Sane, K. S., Ghaskadbi, S. S. and Lele, R. D. (2004). Free radicals and antioxidants in human health: Current status and future prospects. Journal of the Association of Physicians of India 52, 794-804.

Dewick, P. M. (2002). The shikimate pathway: Aromatic amino acids and phenylpropanoids. *Medicinal Natural Products*. Nottingham: Wiley.

Ding, Y., Kinjo, J., Yang, C. R. and Nohara, T. (1991). Triterpenes from *Mucuna birdwoodiana*. Phytochemistry 30(11), 3703-3707.

Fan, C. Q., Wang, W., Wang, Y. P., Qin, G. W. and Zhao, W. M. (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. and Hu, J. M. (2013). Dendrowardol C, a novel sesquiterpenoid from *Dendrobium wardianum* Warner. Natural Products and Bioprospecting 3(3), 89-92.

Fang, H., Hu, X., Wang, M., Wan, W., Yang, Q., Sun, X. and Wei, X. (2015). Anti-osmotic and antioxidant activities of gigantol from *Dendrobium aurantiacum* var. *denneanum* against cataractogenesis in galactosemic rats. Journal of Ethnopharmacology 172, 238-246.

Fraunberger, E. A., Scola, G., Laliberte, V. L., Duong, A. and Andreazza, A. C. (2016). Redox modulations, antioxidants, and neuropsychiatric disorders. Oxidative Medicine and Cellular Longevity. Advanced online publication, DOI: 10.1155/2016/4729192.

Guo, X. Y., Wang, J., Wang, N. L., Kitanaka, S. and Yao, X. S. (2007). 9, 10-Dihydrophenanthrene derivatives from *Pholidota yunnanensis* and scavenging activity on DPPH free radical. Journal of Asian Natural Products Research 9(2), 165-174.

Forest herbarium, forest and plant conservation research office, department of national parks, wildlife and plant conservation. (2014). *Thai plant names Tem Smitinand, revised* edition 2014. In (pp. 185-191). Bangkok: National Buddhist Department Printing.

Gutteridge, J. M. C. and Halliwell, B. (1988). The deoxyribose assay: An assay both for 'free' hydroxyl radical and for site-specific hydroxyl radical production. Biochemical Journal Letters 253(3), 932-933.

Honda, C. and Yamaki, M. (2000). Phenanthrenes from *Dendrobium plicatile*. Phytochemistry 53(8), 987-990.

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(7-8), 653-657.

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. J., Ou, B., Hampsch-Woodill, M., Flanagan, J. 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. 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.

Jang, D. S., Lee, G. Y., Kim, J., Lee, Y. M., Kim, J. M., Kim, Y. S. and Kim, J. S. (2008). A new pancreatic lipase inhibitor isolated from the roots of *Actinidia arguta*. Archives of Pharmacal Research 31(5), 666-670.

Jiang, W., Jiang, B., Mantri, N., Wu, Z., Mao, L., Lu, H. and Tao, Z. (2014). Comparative ecophysiological analysis of photosynthesis, biomass allocation, polysaccharide and alkaloid content in three *Dendrobium candidum* cultivars. Plant Omics Journal 7(2), 117-122.

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. Advanced online publication, DOI: 10.1155/2015/350410.

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. Advanced online publication, DOI: 10.1155/2015/841752.

Leander, K. and Luning, B. (1968). Studies on Orchidaceae alkaloids VIII: An imidazolium salt from *Dendrobium anosmum* Lindl. and *Dendrobium parishii* Rchb. f. Tretrahedron Letters 9(8), 905-908.

Li, C. B., Wang, C., Fan, W. W., Dong, F. W., Xu, F. Q., Wan, Q. L. 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., & Ye, 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. and Zhang, T. M. (2014). Three new neolignan glucosides from the stems of *Dendrobium aurantiacum* var. *denneanum*. Phytochemistry Letters 9(1), 37-40.

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 57(2), 218-219.

Li, Y. P., Qing, C., Fang, T. T., Liu, Y. and Chen, Y. G. (2009c). Chemical constituents of *Dendrobium chrysotoxum*. Chemistry of Natural Compounds 45(3), 414-416.

Likhitwitayawuid, K., Sornsute, A., Sritularak, B. and Ploypradith, P. (2006). Chemical transformations of oxyresveratrol (trans-2,4,3',5'-tetrahydroxystilbene) into a potent tyrosinase inhibitor and a strong cytotoxic agent. Bioorganic and Medicinal Chemistry Letters 16(21), 5650-5653.

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.

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.

Lobo, V., Patil, A., Phatak, A. and Chandra, N. (2010). Free radicals, antioxidants and functional foods: Impact on human health. Pharmacognosy Reviews 4(8), 118-126.

Lu, Y., Kuang, M., Hu, G. P., Wu, R. B., Wang, J., Liu, L. and Lin, Y. C. (2014). Loddigesiinols G-J: Alpha-glucosidase inhibitors from *Dendrobium loddigesii*. Molecules 19(6), 8544-8555.

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.

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.

Masoko, P., Mdee, L. K., Mampuru, L. J. and Eloff, J. N. (2008). Biological activity of two related triterpenes isolated from *Combretum nelsonii* (Combretaceae) leaves. Natural Product Research 22(12), 1074-1084.

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. I., 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.

Mohammed, M. T., Kadhim, S. M., Jassimand, A. M. N. and Abbas, S. I. (2015). Free radicals and human health. International Journal of Innovation Sciences and Research 4(6), 218-223.

Monti, D., Candido, A., Cruz Silva, M. M., Kren, V., Riva, S. and Danieli, B. (2005). Biocatalyzed generation of molecular diversity: Selective modification of the saponin asiaticoside. Advanced Synthesis and Catalysis 347(7-8), 1168-1174.

Nakanishi, T., Inatomi, Y., Murata, H., Ishida, S. S., Fujino, Y., Miura, K. and Murata, J. (2007). Triterpenes and flavonol glucuronides from *Oenothera cheiranthifolia*. Chemical and Pharmaceutical Bulletin 55(2), 334-336.

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.

Nimse, S. B. and Pal, D. (2015). Free radicals, natural antioxidants, and their reaction mechanisms. RSC Advances 5(35), 27986-28006.

Pan, H. M., Chen, B., Li, F. and Wang, M. K. (2012). Chemical Constituents of *Dendrobium denneanum*. Chinese Journal of Appplied Environmental Biology 18(3), 378-380.

Pham-Huy, L. A., He, H. and Pham-Huy, C. (2008). Free radicals, antioxidants in disease and health. International Journal of Biomedical Science 4(2), 89-96.

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.

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.

Rungwichaniwat, P., Sritularak, B. and Likhitwitayawuid, K. (2014). Chemical constituents of *Dendrobium williamsonii*. Pharmacognosy Journal 6(3), 36-41.

Sanga Sabhasri Research and Development Department, The Botanical Garden Organization. BGO Plant Databases. [Online]. 2011. Available from: http://www.qsbg.org/database/botanic_book%20full%20option/search_detail.asp?botanic_id=1308. [2017, Sep 20]

Schrader, J. and Bohlmann, J. (2015). *Biotechnology of isoprenoids*. New York: Springer.

Soh, N. (2006). Recent advances in fluorescent probes for the detection of reactive oxygen species. Analytical and Bioanalytical Chemistry 386(3), 532-543.

Sritularak, B., Anuwat, M. and Likhitwitayawuid, K. (2011a). A new phenanthrenequinone from *Dendrobium draconis*. Journal of Asian Natural Products Research 13(3), 251-255.

Sritularak, B., Duangrak, N. and Likhitwitayawuid, K. (2011b). A new bibenzyl from *Dendrobium secundum*. Zeitschrift für Naturforschung 66c(5-6), 205-208.

Sritularak, B. and Likhitwitayawuid, K. (2009). New bisbibenzyls from *Dendrobium falconeri*. Helvetica Chimica Acta 92(4), 740-744.

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. and Chen, Y. (2014). Isolation of alpha-glucosidase inhibitors including a new flavonol glycoside from *Dendrobium devonianum*. Natural Product Research 28(21), 1900-1905.

Sung, T. V., Lavaud, C., Porzel, A., Steglich, W. and Adam, G. (1992). Triterpenoids and their glycosides from the bark of *Schefflera octophylla*. Phytochemistry 31(1), 227-231.

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.

Teixeira da Silva, J. A., Hossain, M. M., Sharma, M., Dobránszki, J., Cardoso, J. C. and Zeng, S. (2017a). Acclimatization of in vitro-derived *Dendrobium*. Horticultural Plant Journal 3(3), 110-124.

Teixeira da Silva, J. A. and Ng, T. B. (2017b). The medicinal and pharmaceutical importance of *Dendrobium* species. Applied Microbiology and Biotechnology 101(6), 2227-2239.

Thanan, R., Oikawa, S., Hiraku, Y., Ohnishi, S., Ma, N., Pinlaor, S. and Murata, M. (2014). Oxidative stress and its significant roles in neurodegenerative diseases and cancer. International Journal of Molecular Sciences 16(1), 193-217.

Tsopmo, A., Awah, F. M. and Kuete, V. (2013). Lignans and stilbenes from African medicinal plants (Medicinal Plant Research in Africa: Pharmacology and Chemistry) Atlanta: Elsevier, 435-478.

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.

Wang, H. and Zhao, T. F. (1985). Dendrobine and 3-hydroxy-3-oxodendrobine from *Dendrobium nobile*. Journal of Natural Products 48(5), 796-801.

Wang, L., Zhang, C. F., Wang, Z. T., Zhang, M., & Xu, L. S. (2009). Five new compounds from *Dendrobium crystallinum*. Journal of Asian Natural Products Research 11(11), 903-911.

Wang, Q., Sun, P., Li, G., Zhu, K., Wang, C. and Zhao, X. (2014). Inhibitory effects of *Dendrobium candidum* Wall ex Lindl. on azoxymethane- and dextran sulfate sodium-induced colon carcinogenesis in C57BL/6 mice. Oncology Letters 7(2), 493-498.

Weydert, C. J. and Cullen, J. J. (2010). Measurement of superoxide dismutase, catalase and glutathione peroxidase in cultured cells and tissue. Nature Protocols 5(1), 51-66.

Wong, K. C., Hag Ali, D. M. and Boey, P. L. (2012). Chemical constituents and antibacterial activity of *Melastoma malabathricum* L. Natural Product Research 26(7), 609-618.

Xiong, L., Cao, Z. X., Peng, C., Li, X. H., Xie, X. F., Zhang, T. M. 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. and Hu, J. M. (2014). Cytotoxic bibenzyl dimers from the stems of *Dendrobium fimbriatum* Hook. Bioorganic and Medicinal Chemistry Letters 24(22), 5268-5273.

Yamaki, M. and Honda, C. (1996). The stilbenoids from *Dendrobium plicatile*. Phytochemistry 43(1), 207-208.

Yang, D., Liu, L. Y., Cheng, Z. Q., Xu, F. Q., Fan, W. W., Zi, C. 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 C., K. Y. (2007a). 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. (2007b). 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. 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. (2017a). Two new picrotoxane-type sesquiterpenoid lactones from *Dendrobium williamsonii*. Journal of Asian Natural Products Research Advanced online publication, DOI: 10.1080/ 10286020.2017.1394294

Yang, M., Zhang, Y., Chen, L. and Chen, Y. (2017b). A new (propylphenyl)bibenzyl derivative from *Dendrobium williamsonii*. Natural Product Research 32(14) 1-7.

Yao, S., Tang, C. P., Li, X. Q. and Ye, Y. (2008). Phochinenins A– F, dimeric 9,10-dihydrophenanthrene derivatives, from *Pholidota chinensis*. Helvetica Chimica Acta 91(11), 2122-2129.

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. (2002a). Immunomodulatory sesquiterpene glycosides from *Dendrobium nobile*. Phytochemistry 61(8), 885-890.

Ye, Q. H. and Zhao, W. M. (2002b). 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. and Xu, L. S. (2005). Bi-bicyclic and bi-tricyclic compounds from *Dendrobium thyrsiflorum*. Phytochemistry 66(10), 1113-1120.

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. and Wang, Z. (2007a). 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. (2007b). Bioactive bibenzyl derivatives and fluorenones from *Dendrobium nobile*. Journal of Natural Products 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.

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.

Zhitao, N., Shuying, Z., Jiajia, P., Ludan, L., Jing, S. and Xiaoyu, D. (2017). Comparative analysis of *Dendrobium plastomes* and utility of plastomic mutational hotspots. Scientific Reports 7(1), 1-11.

Zhou, X. M., Zhang, B., Chen, G. Y., Han, C. R., Jiang, K. C., Luo, M. Y. and Lin, S. D. (2018). Dendrocoumarin: a new benzocoumarin derivative from the stem of *Dendrobium nobile*. Natural Product Research, Advanced online publication, DOI:10.1080/14786419.2017.1419241.

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.

APPENDIX

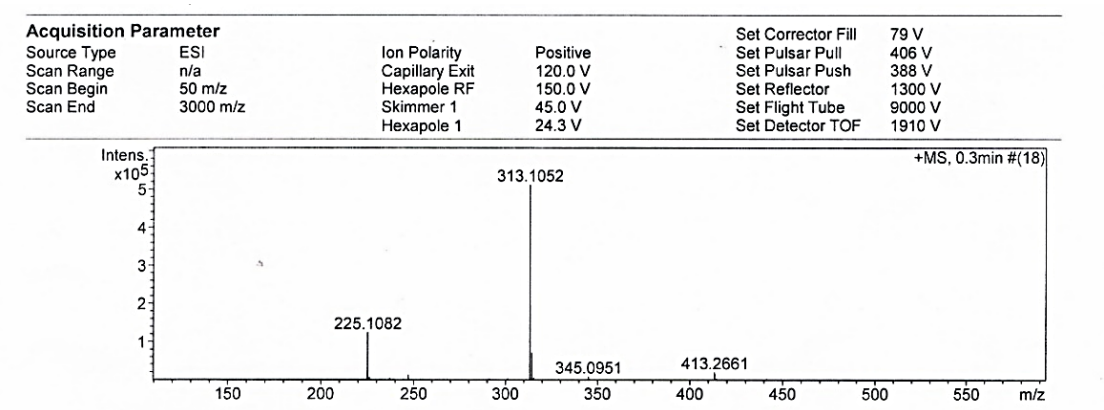


Figure 6 Mass spectrum of compound DPR-1

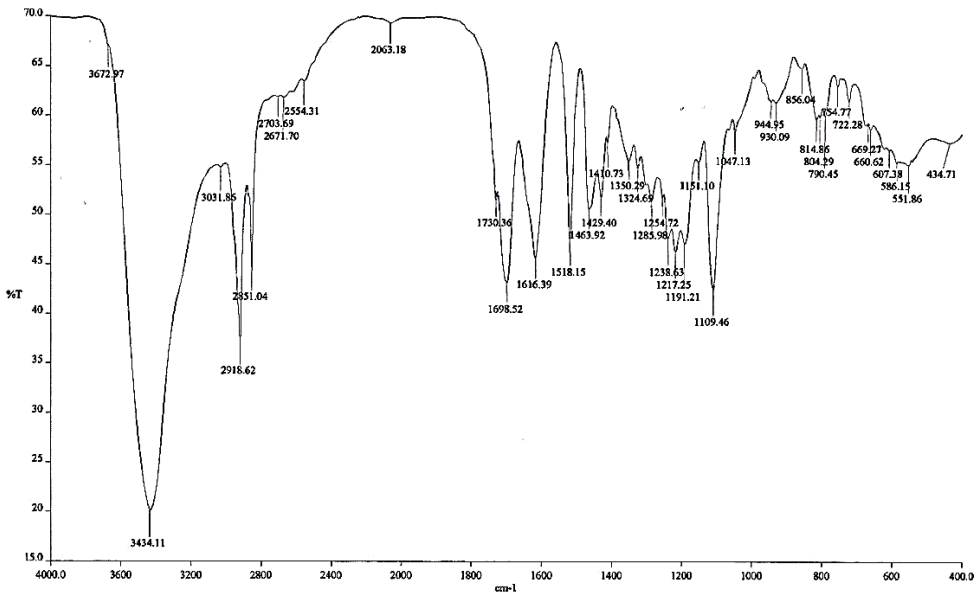


Figure 7 Infrared spectrum of compound DPR-1

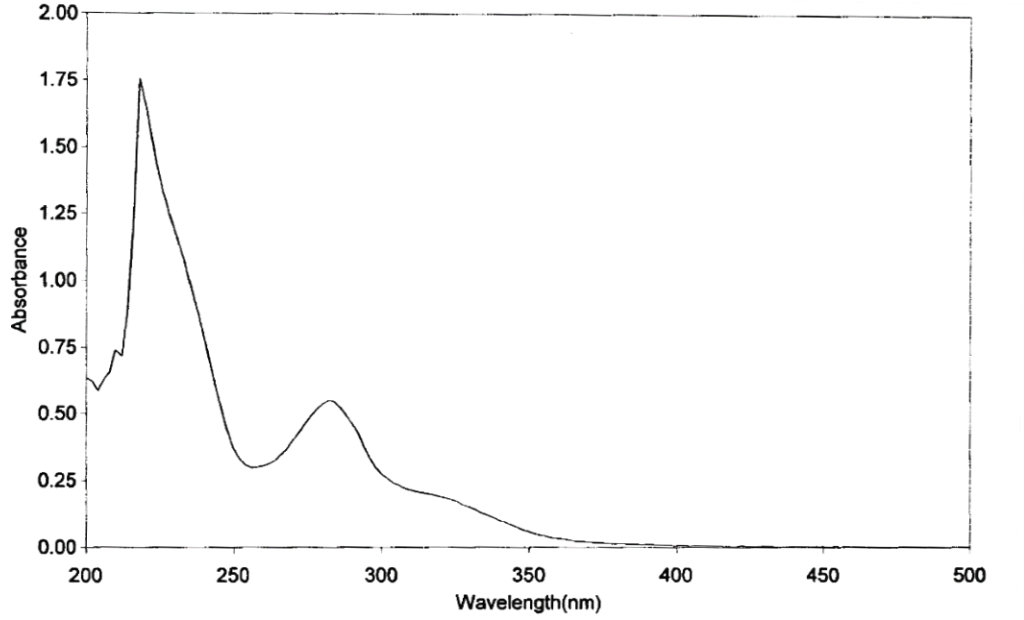


Figure 8 UV spectrum of compound DPR-1

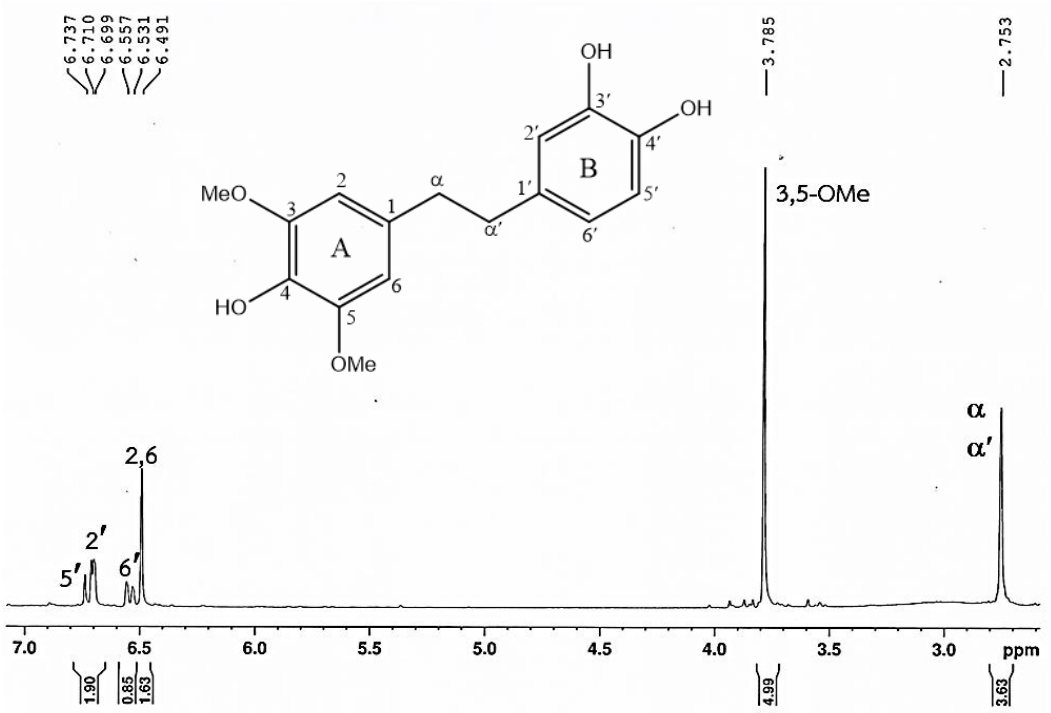


Figure 9 ^{1}H-NMR (300 MHz) spectrum of compound DPR-1 (in acetone-d_6)

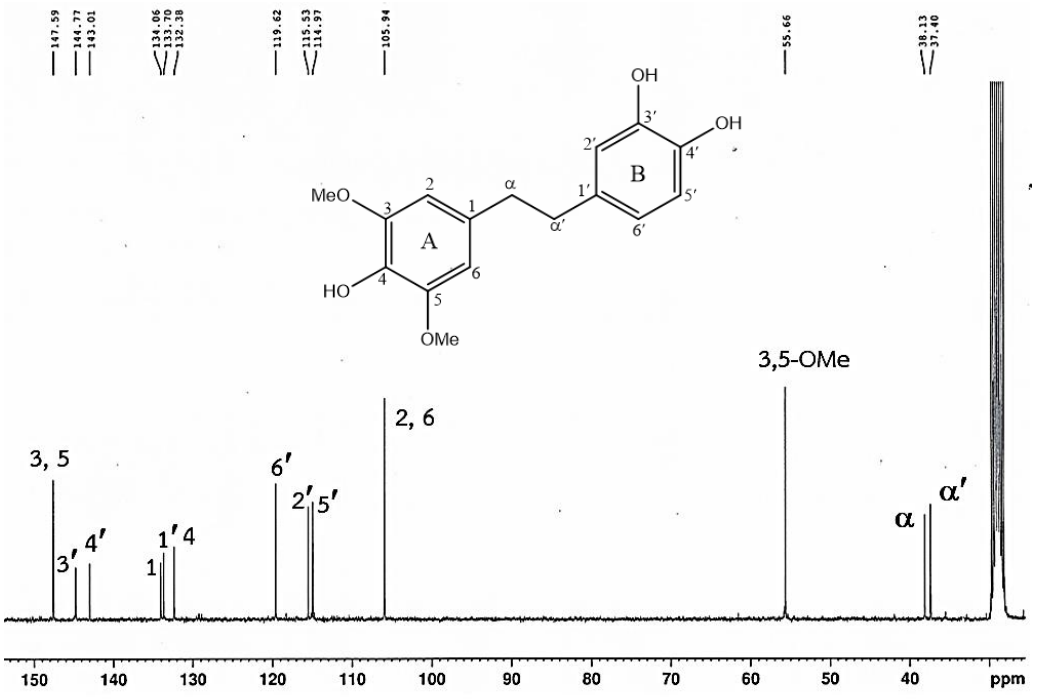


Figure 10 ^{13}C-NMR (75 MHz) spectrum of compound DPR-1 (in acetone-d_6)

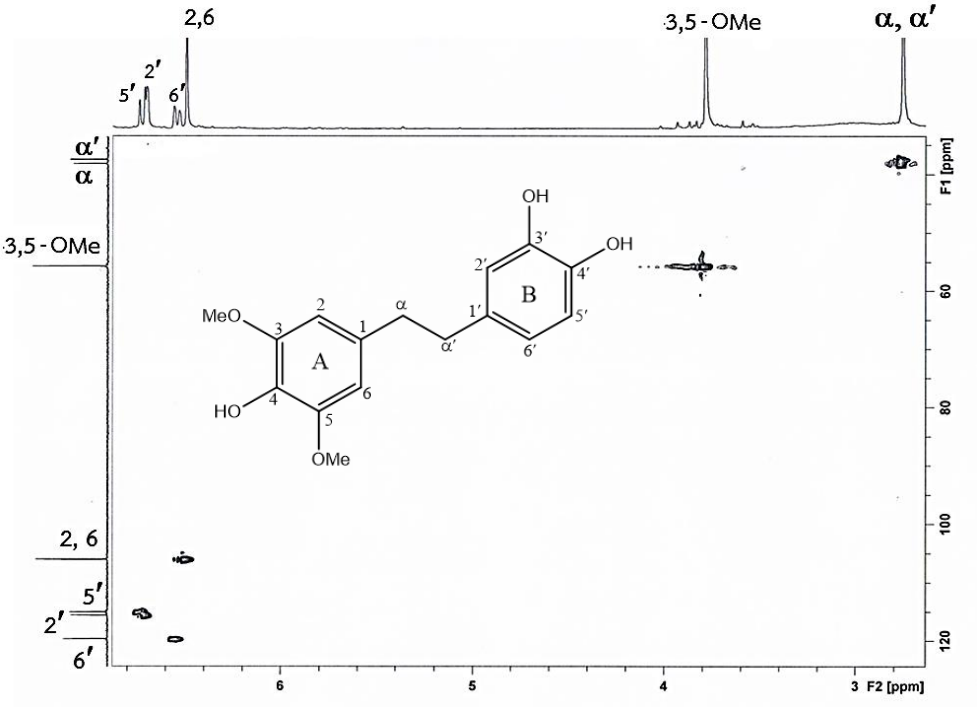


Figure 11 HSQC spectrum of compound DPR-1 (in acetone-d_6)

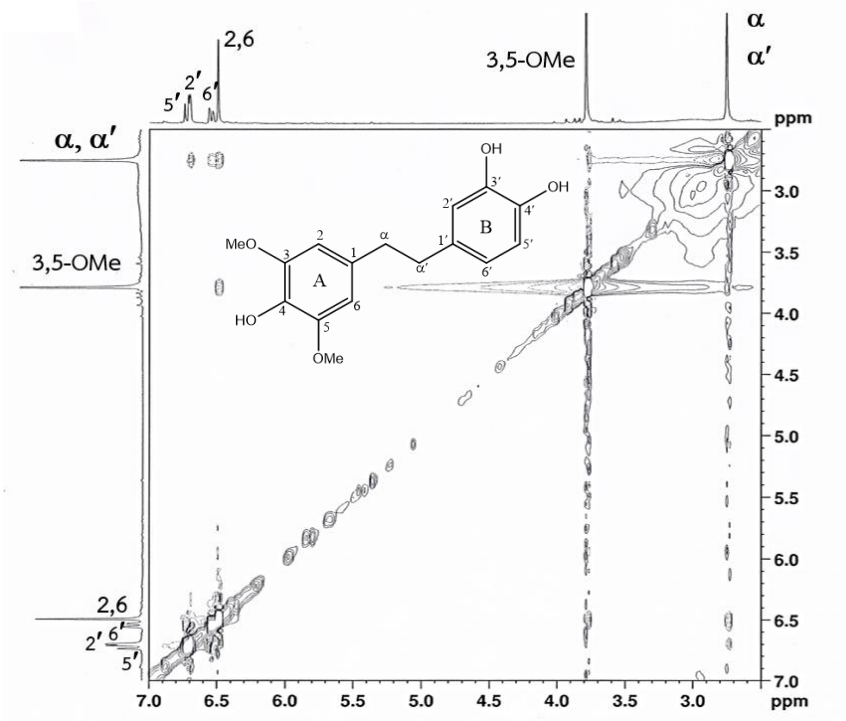


Figure 12 NOESY spectrum of compound DPR-1 (in acetone-d_6)

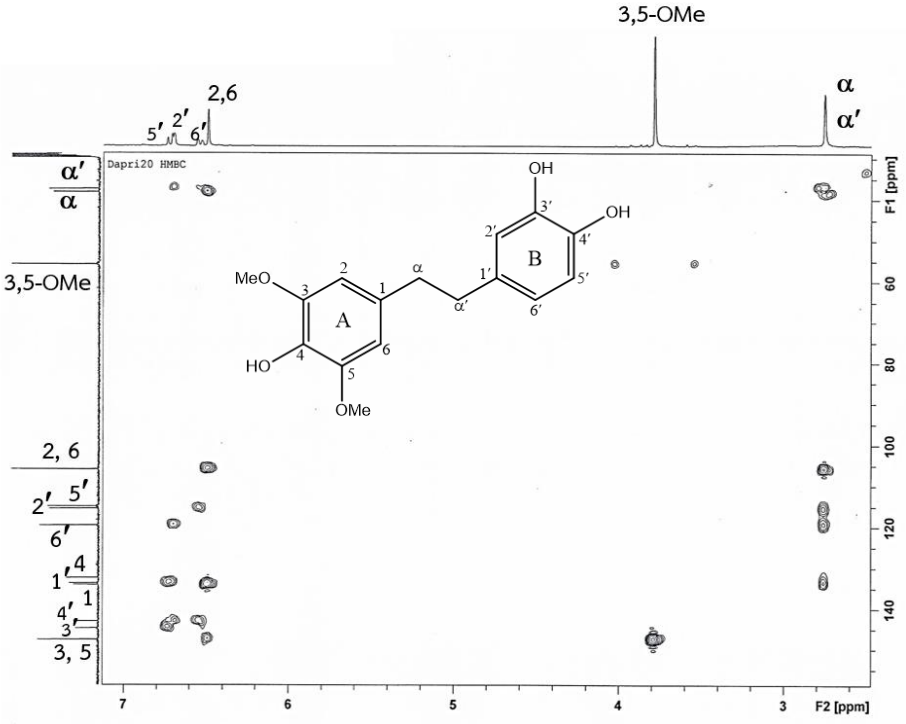


Figure 13 HMBC spectrum of compound DPR-1 (in acetone-d_6)

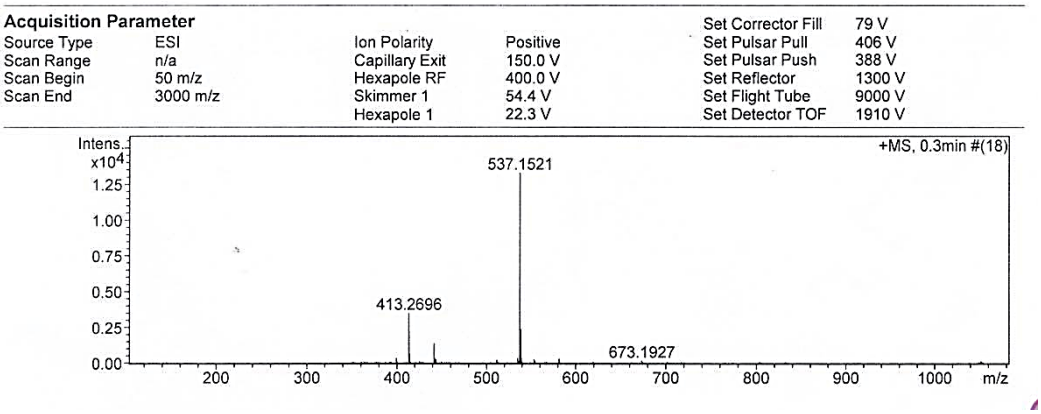


Figure 14 Mass spectrum of compound DPR-2

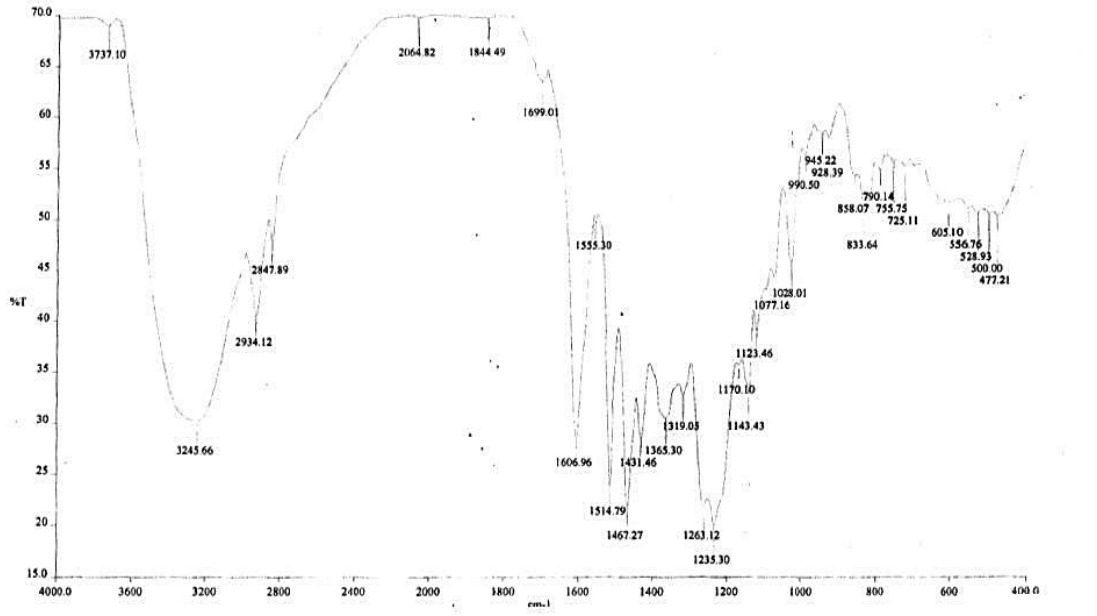


Figure 15 Infrared spectrum of compound DPR-2

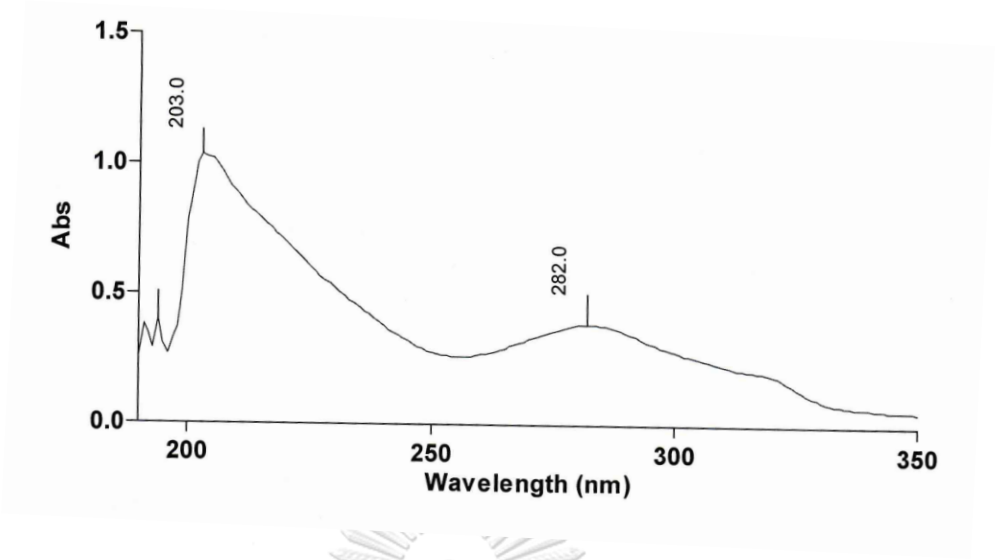


Figure 16 UV spectrum of compound DPR-2

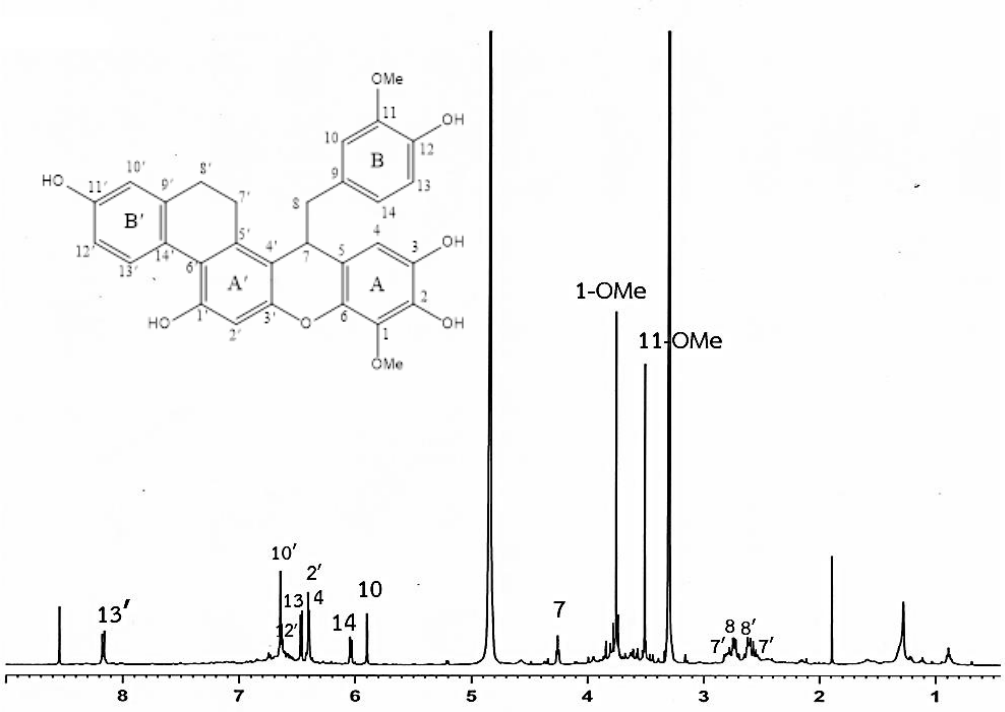


Figure 17 ^{1}H-NMR (500 MHz) spectrum of compound DPR-2 (in CD_3OD)

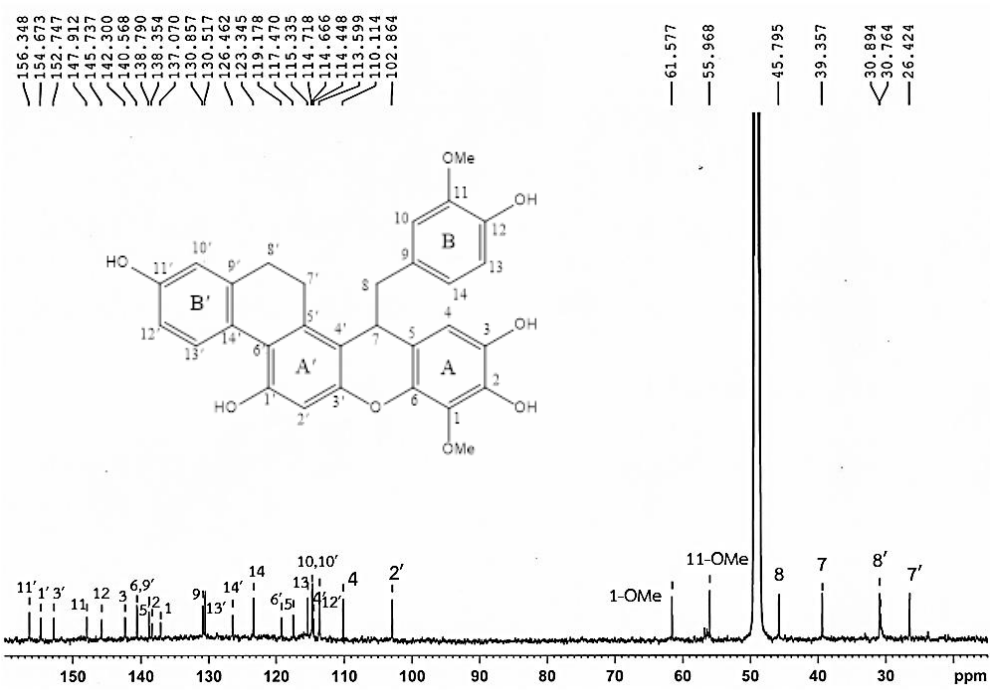


Figure 18 ^{13}C-NMR (125 MHz) spectrum of compound DPR-2 (in CD_3OD)

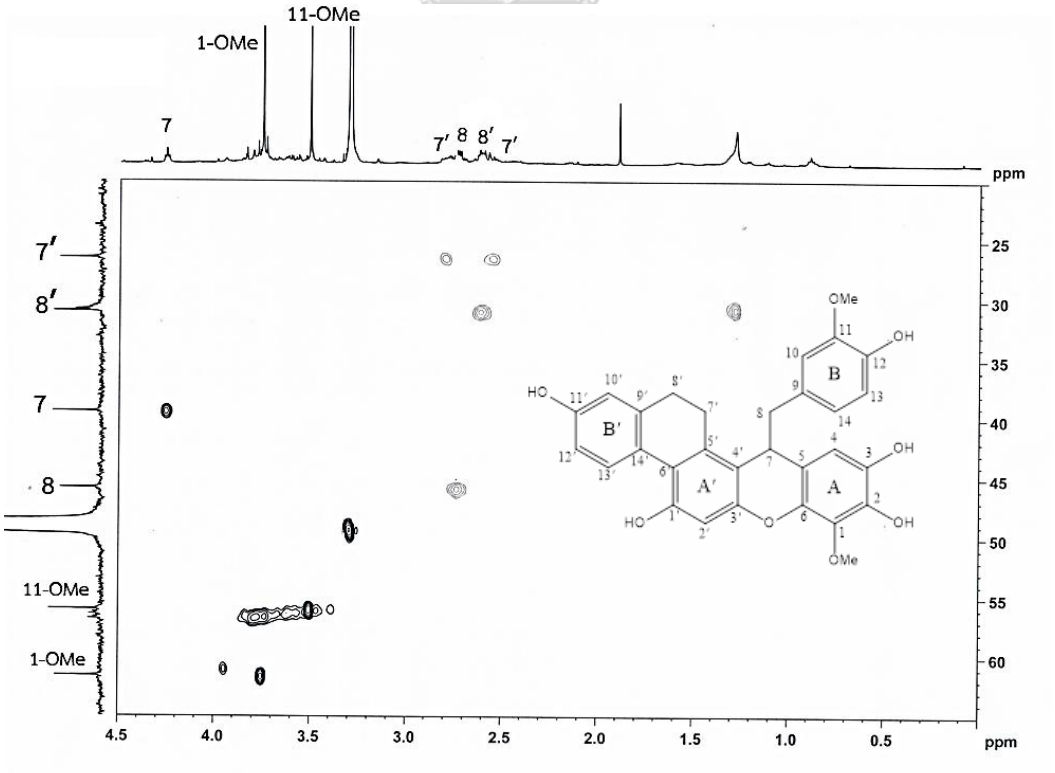


Figure 19 HSQC spectrum of compound DPR-2 (in CD_3OD)

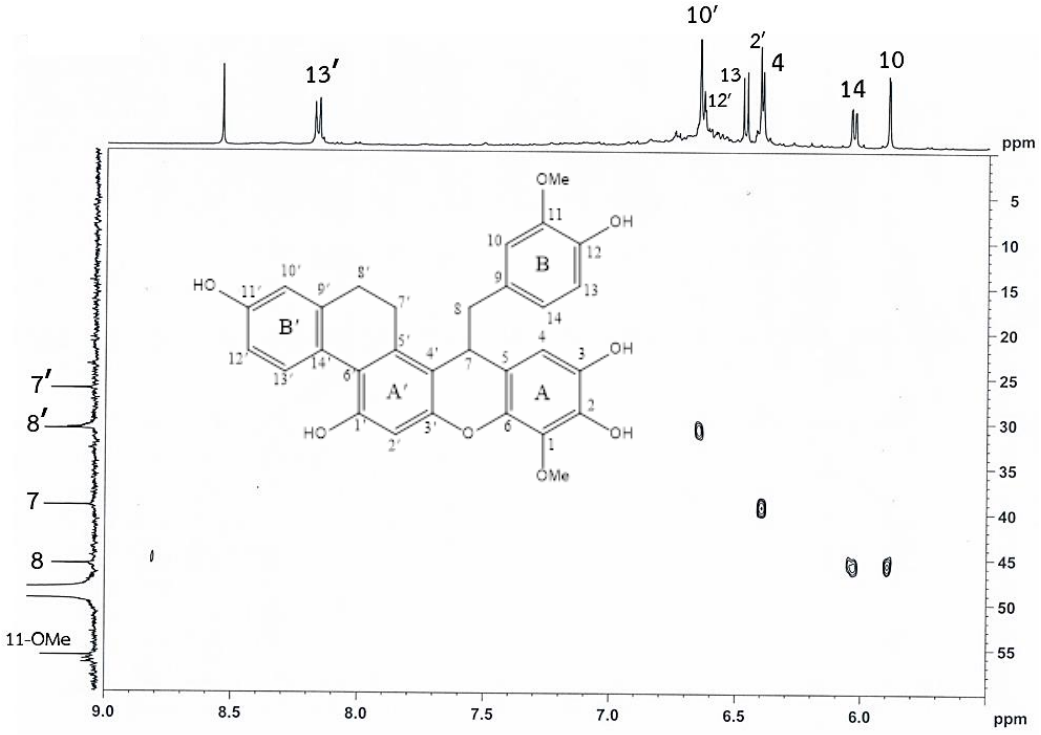


Figure 20 HMBC spectrum of compound DPR-2 (in CD_3OD)

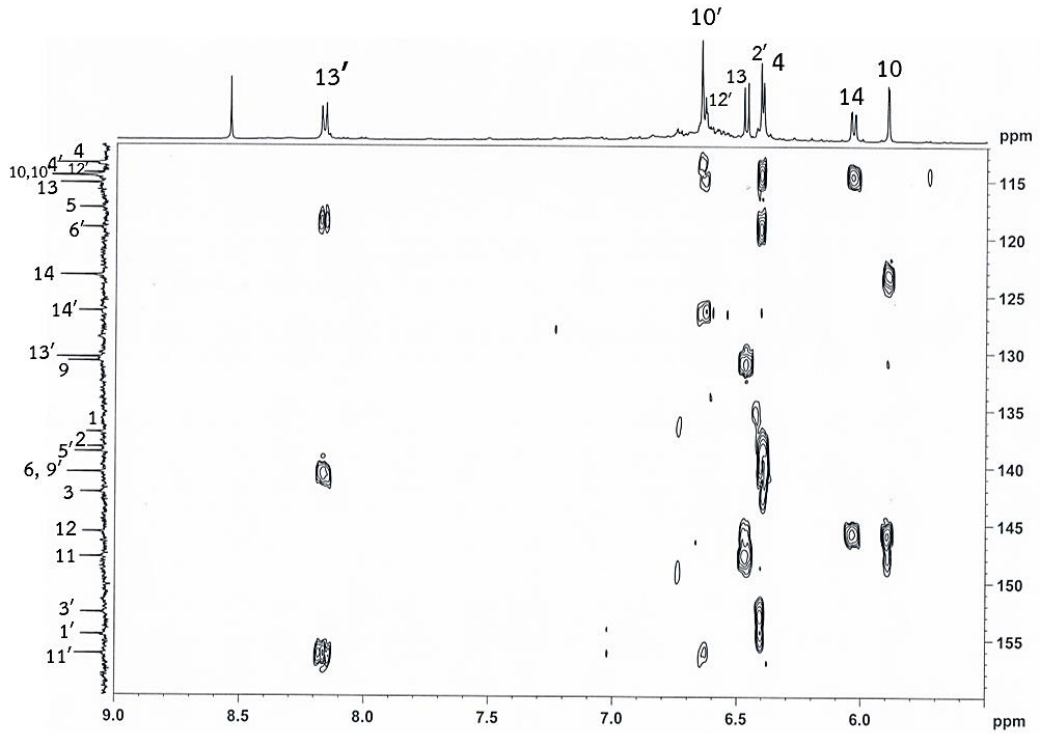


Figure 21 HMBC spectrum of compound DPR-2 (in CD_3OD) (continued)

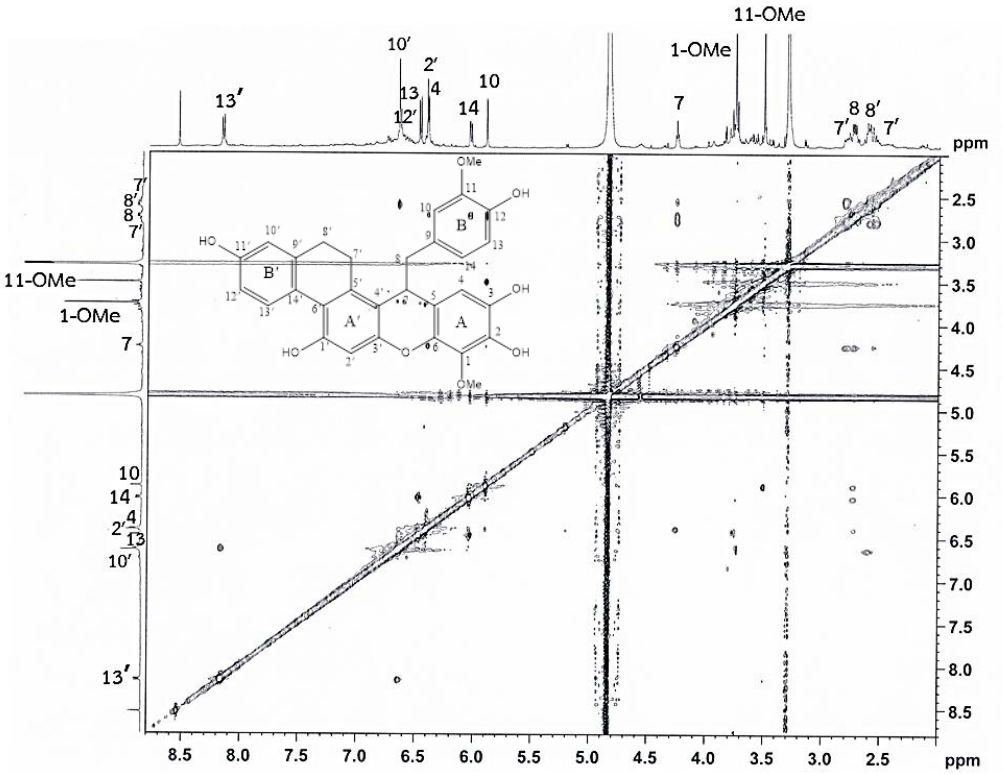


Figure 22 NOESY spectrum of compound DPR-2 (in CD_3OD)

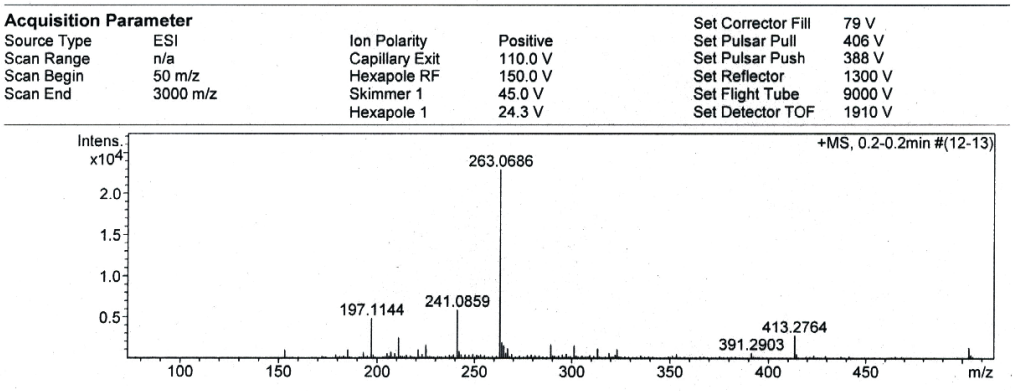


Figure 23 Mass spectrum of compound DPR-3

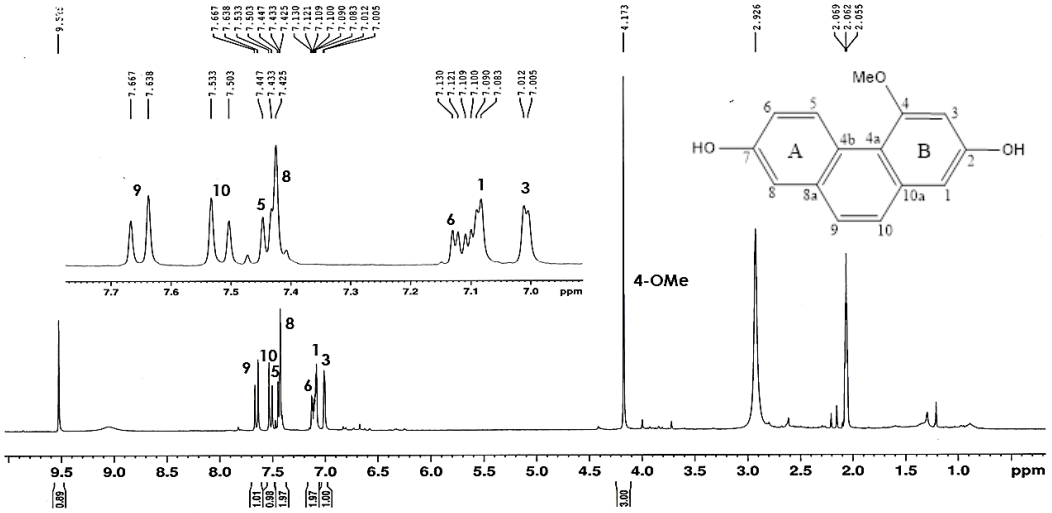


Figure 24 ^{1}H-NMR (300 MHz) spectrum of compound DPR-3 (in acetone-d_6)

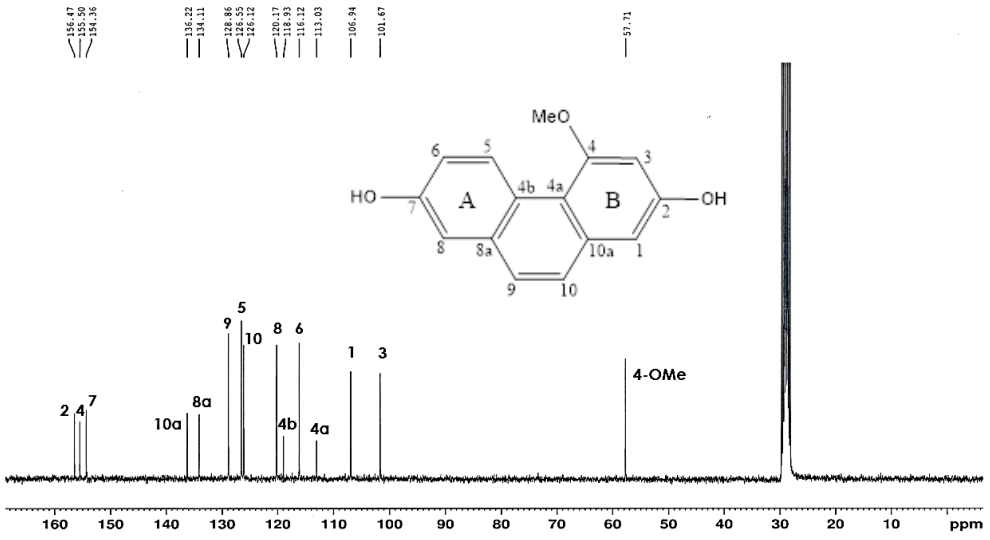


Figure 25 ^{13}C-NMR (75 MHz) spectrum of compound DPR-3 (in acetone-d_6)

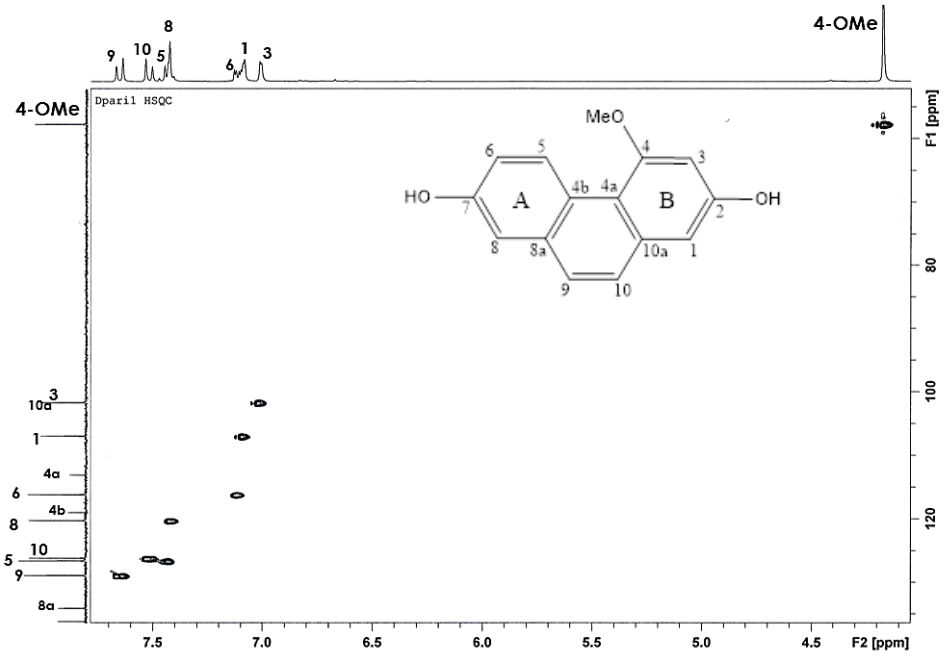


Figure 26 HSQC spectrum of compound DPR-3 (in acetone-d_6)

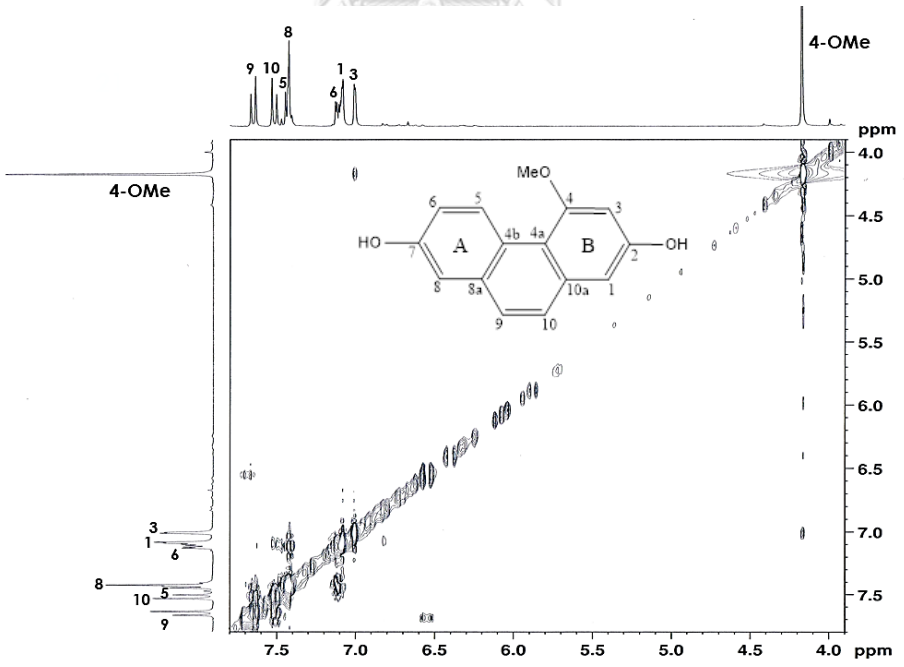


Figure 27 NOESY spectrum of compound DPR-3 (in acetone-d_6)

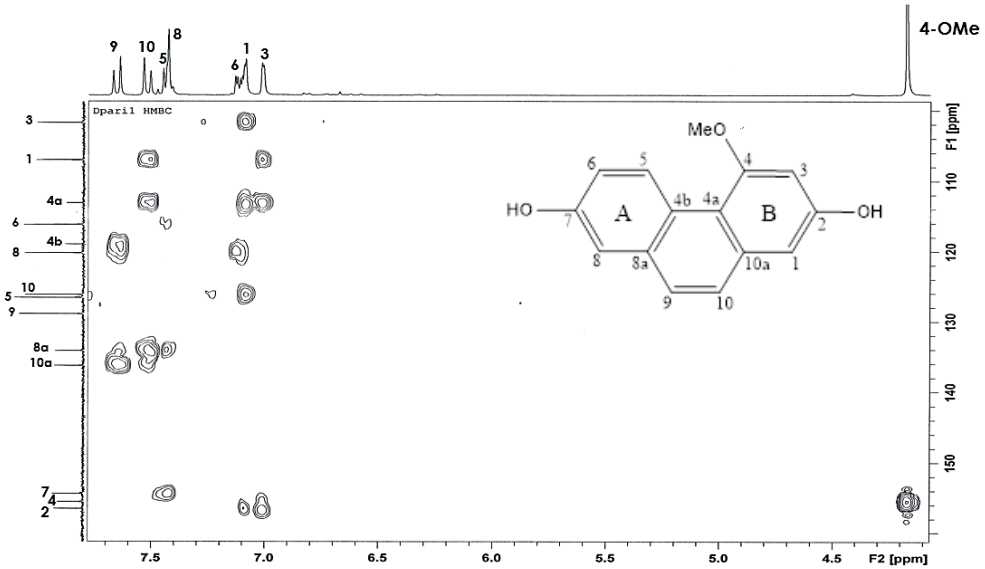


Figure 28 HMBC spectrum of compound DPR-3 (in acetone-d_6)

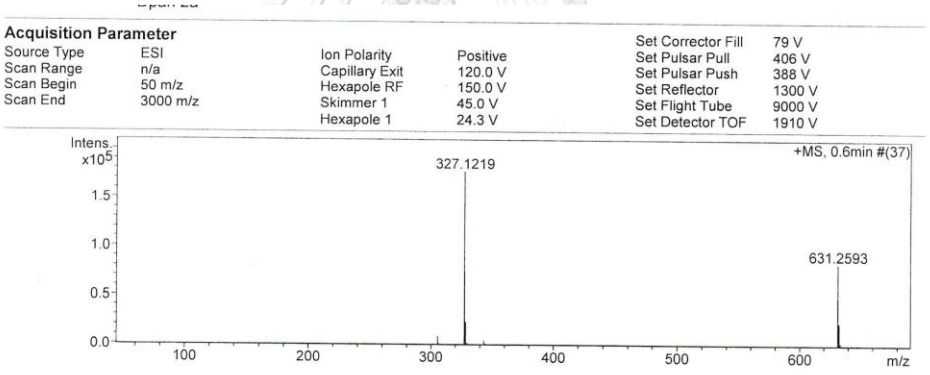


Figure 29 Mass spectrum of compound DPR-4

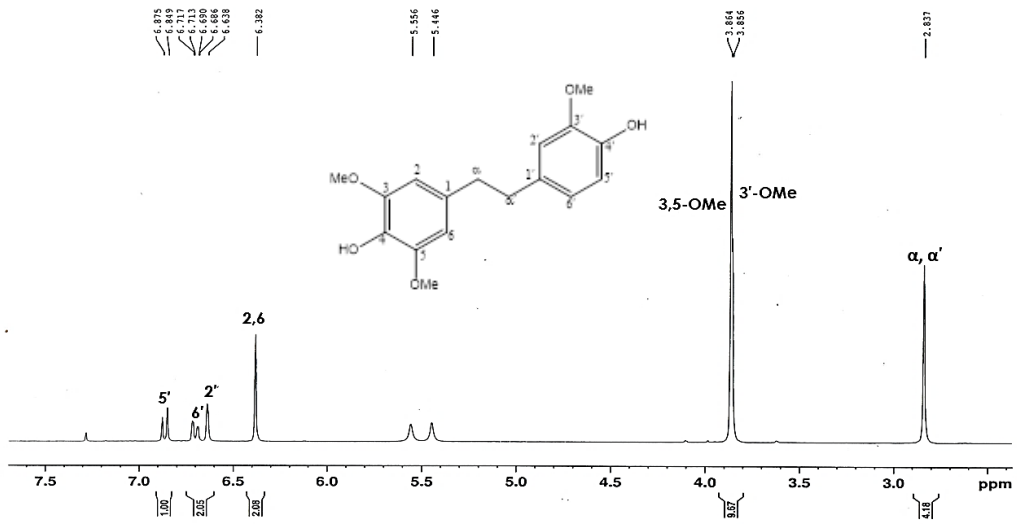


Figure 30 ^{1}H-NMR (300 MHz) spectrum of compound DPR-4 (in acetone-d_6)

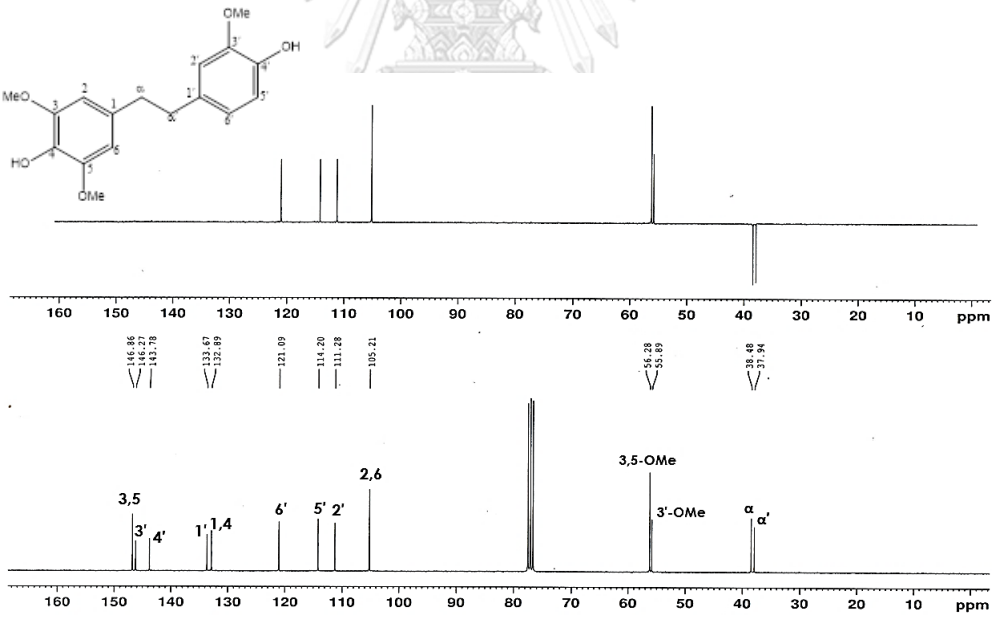


Figure 31 ^{13}C-NMR (75 MHz) spectrum of compound DPR-4 (in acetone-d_6)

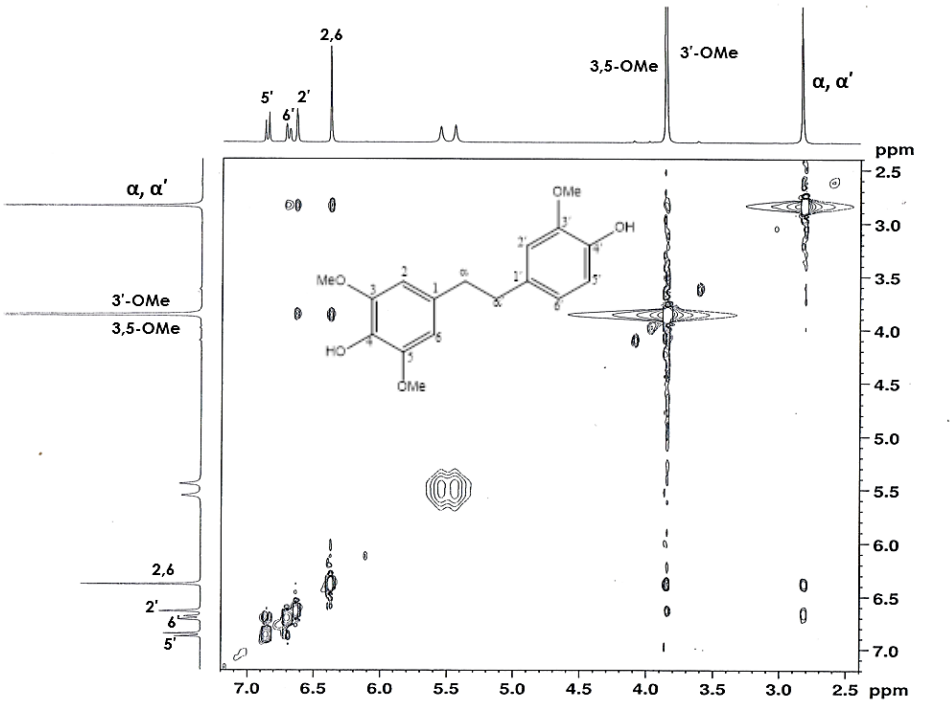


Figure 32 NOESY spectrum of compound DPR-4 (in acetone-d_6)

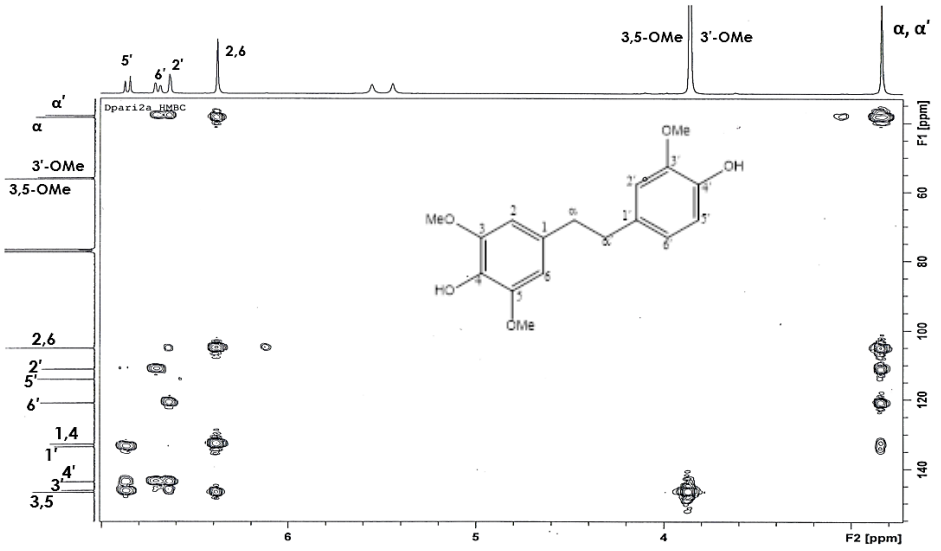


Figure 33 HMBC spectrum of compound DPR-4 (in acetone-d_6)

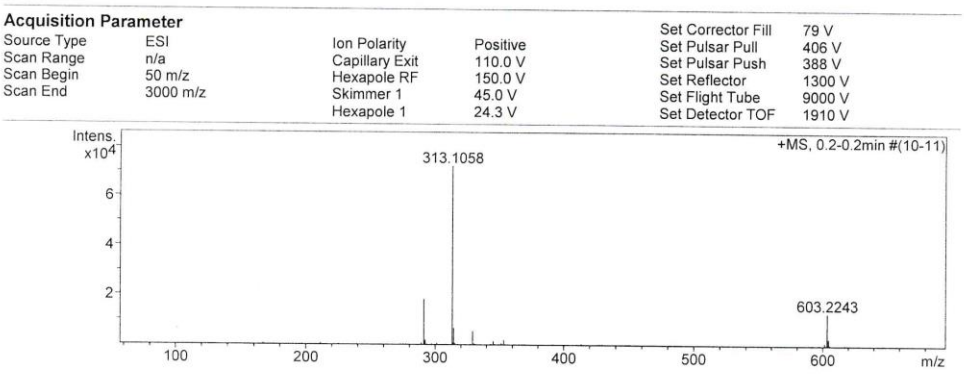


Figure 34 Mass spectrum of compound DPR-5

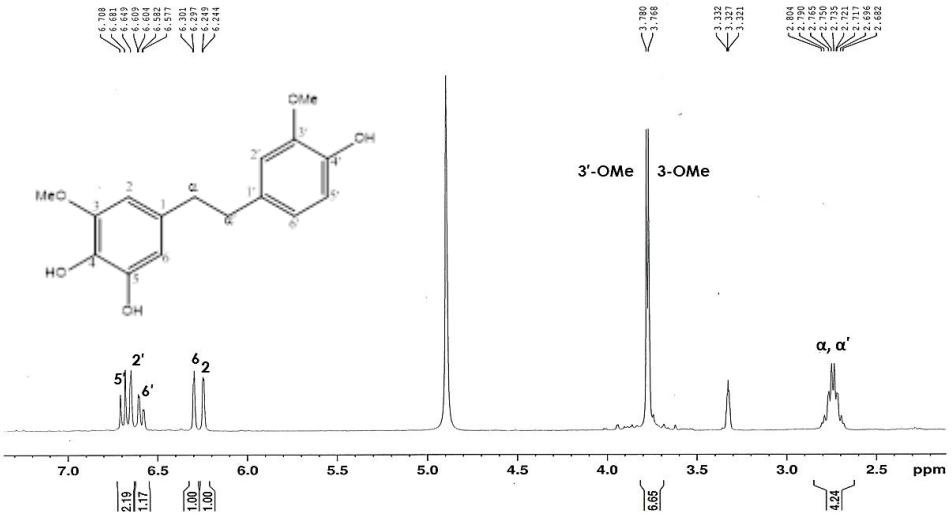


Figure 35 ^{1}H-NMR (300 MHz) spectrum of compound DPR-5 (in acetone-d_6)

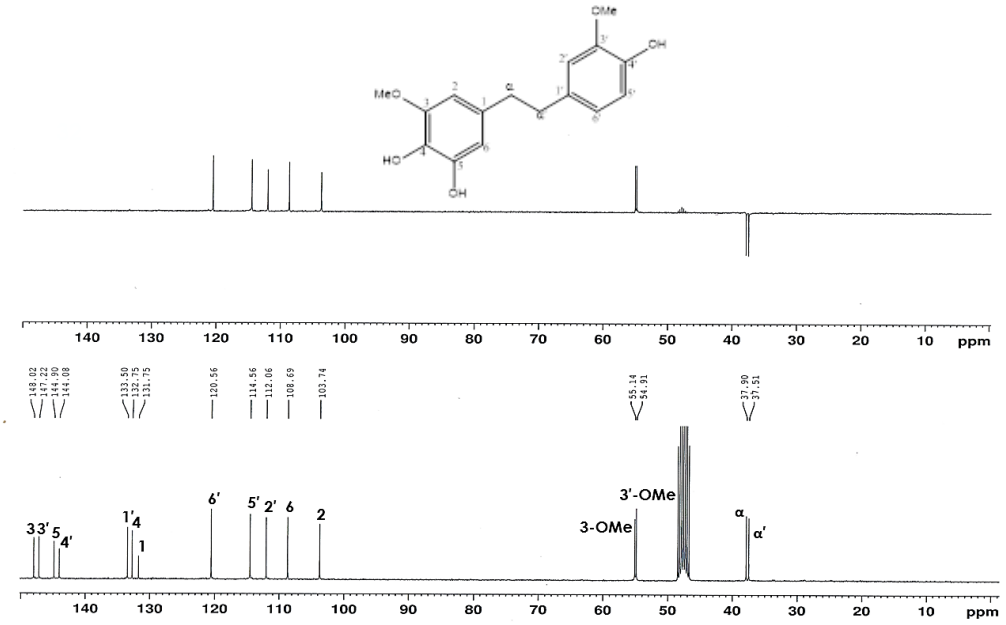


Figure 36 ^{13}C-NMR (75 MHz) spectrum of compound DPR-5 (in acetone-d_6)

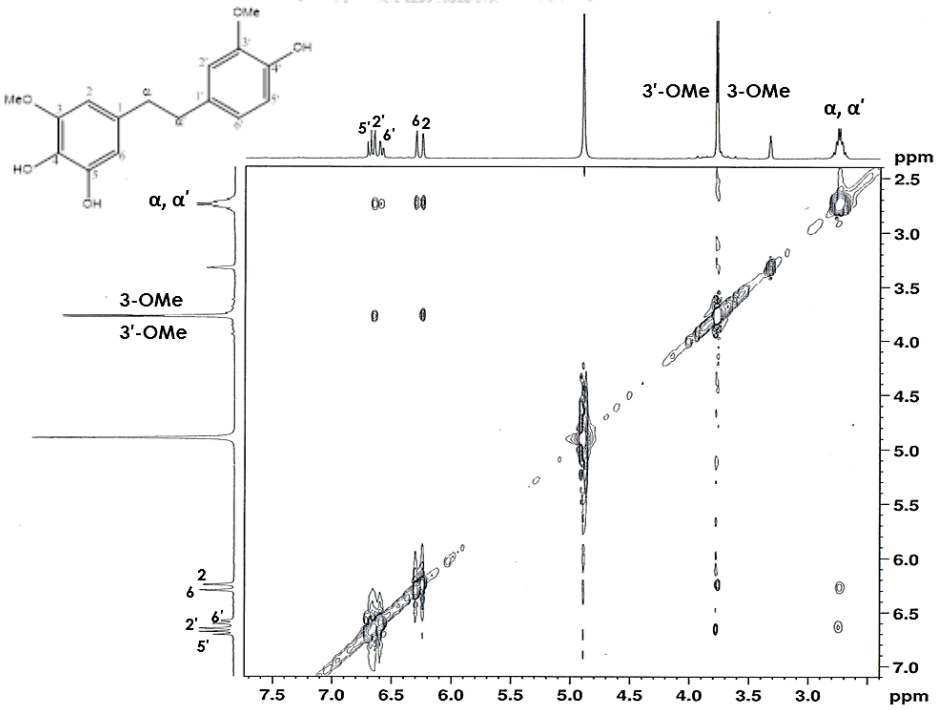


Figure 37 NOESY spectrum of compound DPR-5 (in acetone-d_6)

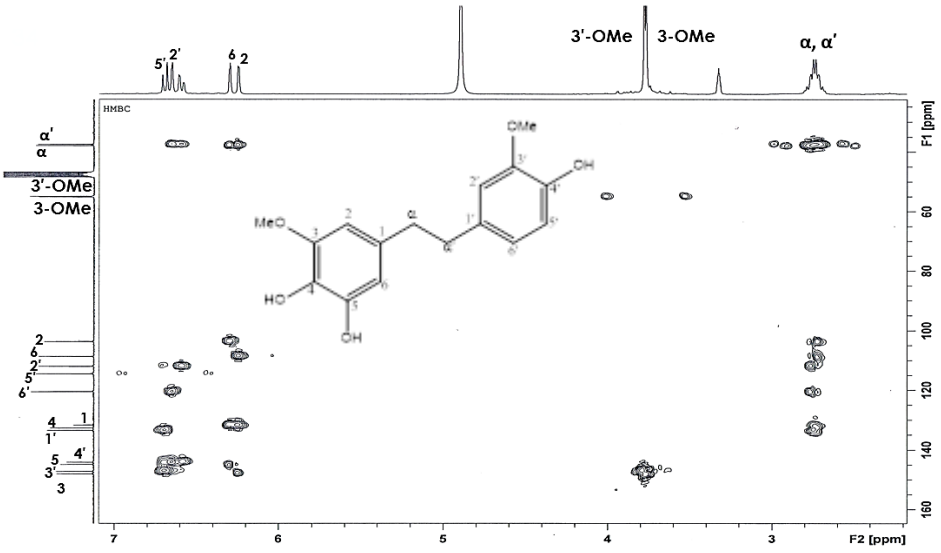


Figure 38 HMBC spectrum of compound DPR-5 (in acetone-d_6)

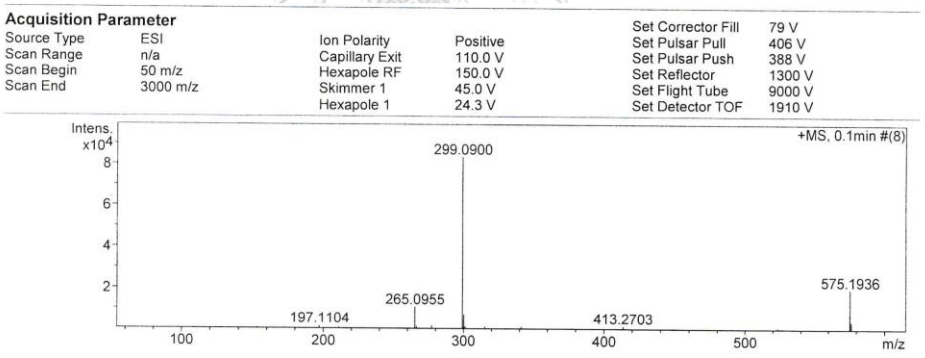


Figure 39 Mass spectrum of compound DPR-6

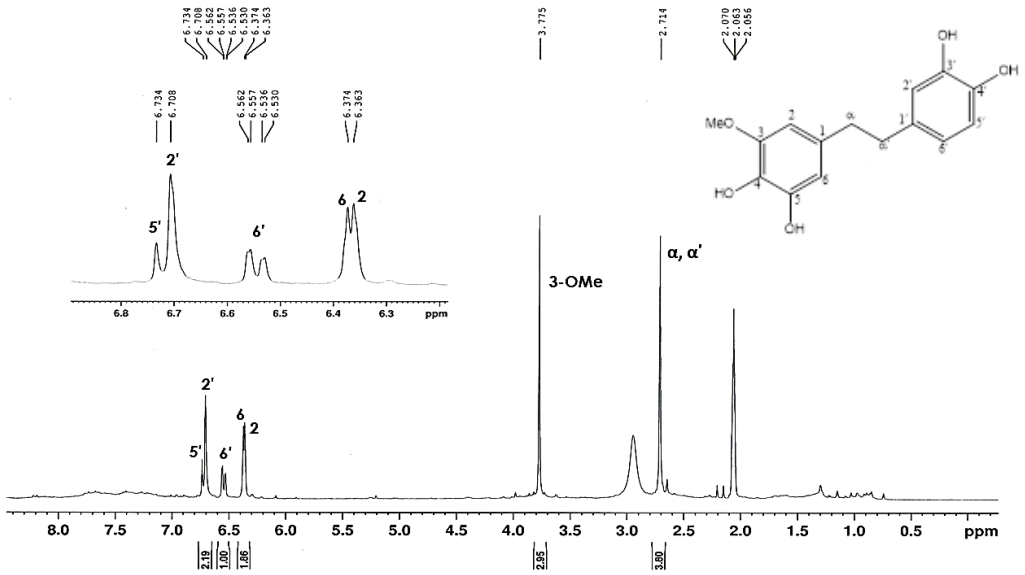


Figure 40 ^{1}H-NMR (300 MHz) spectrum of compound DPR-6 (in acetone-d_6)

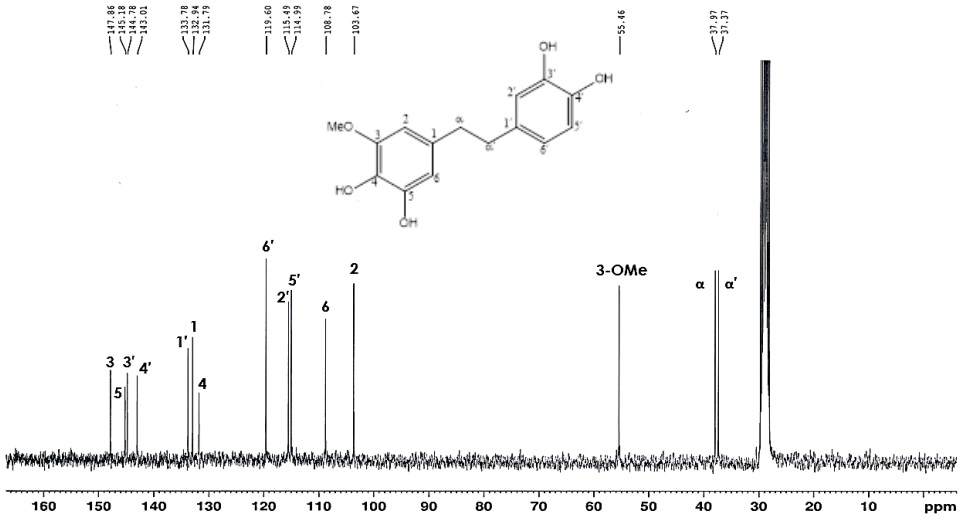


Figure 41 ^{13}C-NMR (75 MHz) spectrum of compound DPR-6 (in acetone-d_6)

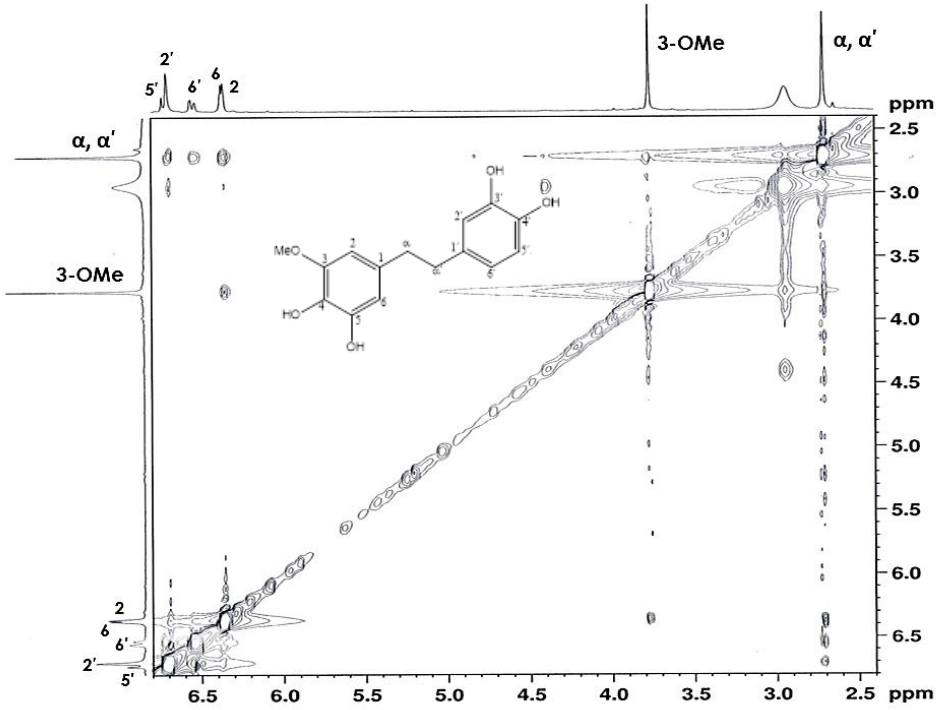


Figure 42 NOESY spectrum of compound DPR-6 (in acetone-d_6)

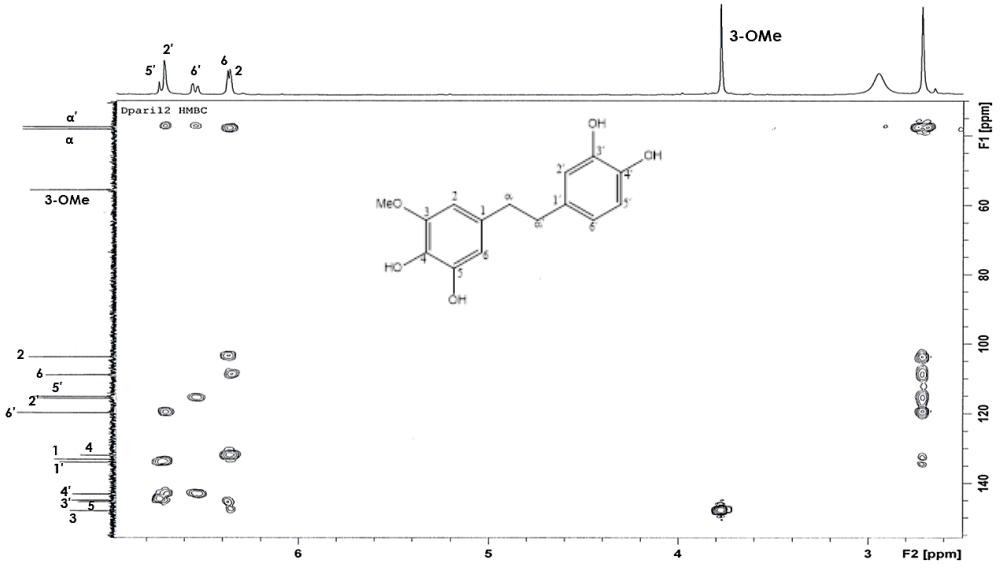


Figure 43 HMBC spectrum of compound DPR-6 (in acetone-d_6)

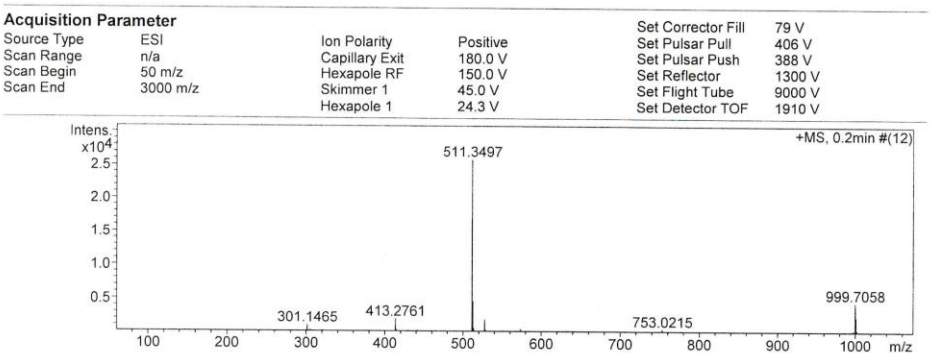


Figure 44 Mass spectrum of compound DPR-7

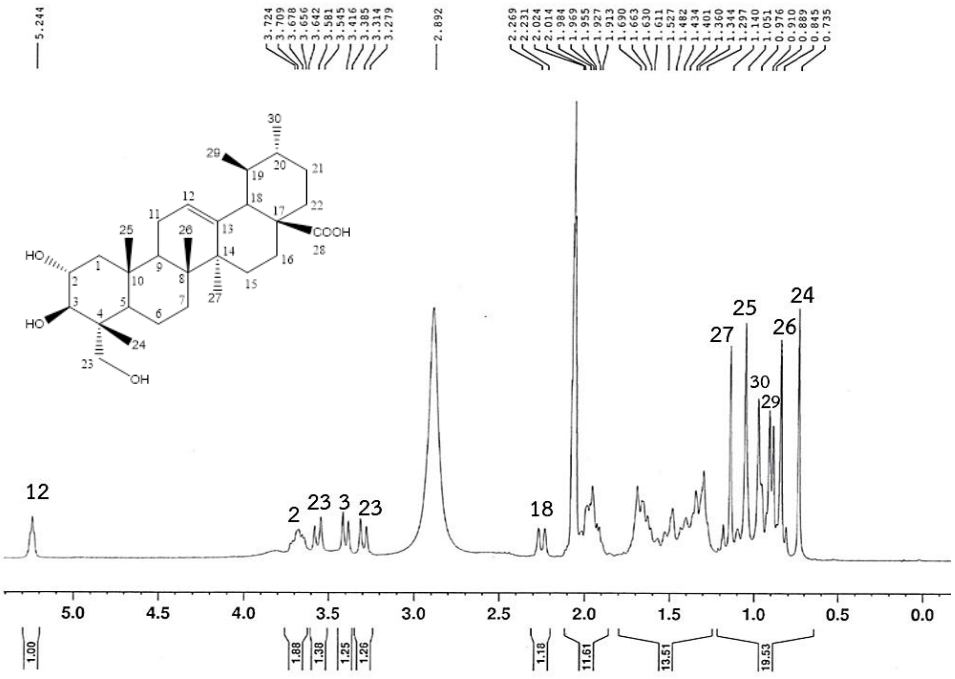


Figure 45 ^{1}H-NMR (300 MHz) spectrum of compound DPR-7 (in CD_3OD)

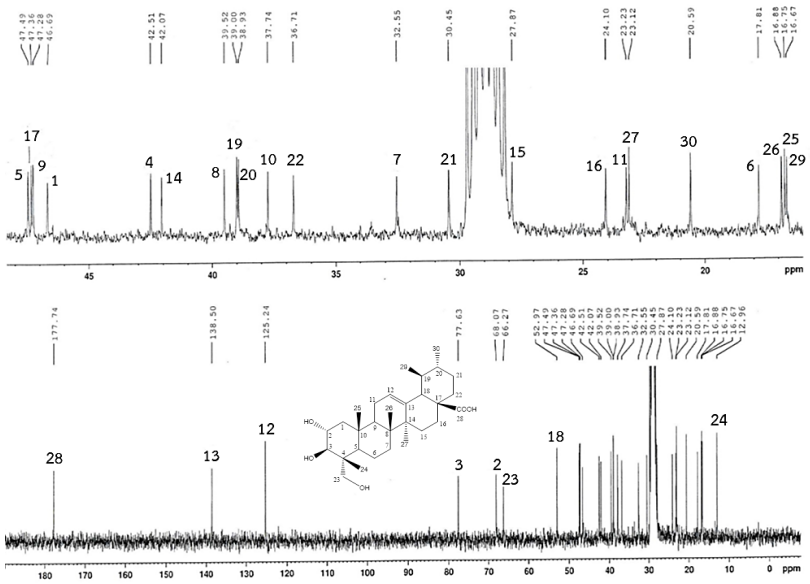


Figure 46 ^{13}C-NMR (75 MHz) spectrum of compound DPR-7 (in CD_3OD)

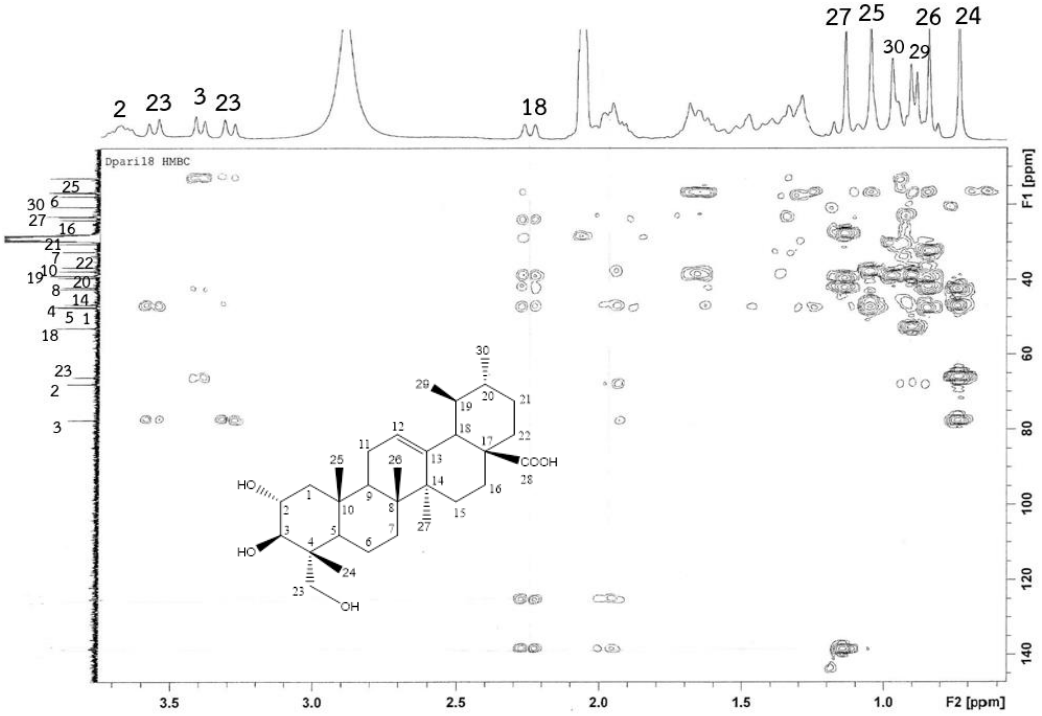


Figure 47 HMBC spectrum of compound DPR-7 (in CD_3OD)

VITA

Mr. Virunh Kongkatitham was born on September 24, 1992, in Bangkok, Thailand. He graduated with Bachelor's degree in Pharmacy in 2017 from the Faculty of Pharmaceutical Sciences, Chulalongkorn University. He was awarded 2016 Japan Student Services Organization (JASSO) Scholarship and 2017 Chulalongkorn University Graduate Scholarship to Commemorate the 72nd Anniversary of His Majesty King Bhumibol Adulyadej.

Publications:

Kongkatitham V., Muangnoi C., Kyokong N., Thaweesest 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.

Kyokong N., Muangnoi C., Thaweesest W., Kongkatitham V., Likhitwitayawuid K., Rojsitthisak P. and Sritularak B. (2018). A new phenanthrene dimer from Dendrobium palpebrae. Journal of Asian Natural Products Research. Advanced online publication, DOI: 10.1080/10286020.2018.1429416

Nuntawong P., Kongkatitham V., Likhitwitayawuid K., Mekboonsonglarp W., Sukrong S., Tanasupawat S. and Sritularak B. (2017). New 2-arylbenzofurans from the root bark of Artocarpus gomezianus and their alpha-glucosidase inhibitory activity. Natural Product Research. Advanced online publication, DOI: 10.1080/14786419.2017.1419238