FREE RADICAL SCAVENGING COMPOUNDS FROM *DENDROBIUM LINDLEYI*

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Pharmaceutical Sciences and Technology
Common Course
FACULTY OF PHARMACEUTICAL SCIENCES
Chulalongkorn University
Academic Year 2019

สารต้านอนุมูลอิสระจากเอื้องผึ้ง

นายพิชญาตรี ขุนฤทธิ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาเภสัชศาสตร์และเทคโนโลยี ไม่สังกัดภาควิชา/เทียบเท่า
คณะเภสัชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2562

Thesis Title	FREE RADICAL SCAVENGING COMPOUNDS FROM *DENDROBIUM LINDLEYI*
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Field of Study	Pharmaceutical Sciences and Technology
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พิชญาตรี ขุนฤทธิ์ : สารต้านอนุมูลอิสระจากเอื้องผึ้ง. (FREE RADICAL SCAVENGING COMPOUNDS FROM *DENDROBIUM LINDLEYI*) อ.ที่ปรึกษาหลัก : รศ. ภก. ดร.บุญชู ศรีตุลารักษ์, อ.ที่ปรึกษาร่วม : ศ. ภก. ดร.กิตติศักดิ์ ลิขิตวิทยาวุฒิ

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

สาขาวิชา	เภสัชศาสตร์และเทคโนโลยี	ลายมือชื่อนิสิต .....
ปีการศึกษา	2562	ลายมือชื่อ อ.ที่ปรึกษาหลัก .....
		ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

6270019033 : MAJOR PHARMACEUTICAL SCIENCES AND TECHNOLOGY

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

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

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

Field of Study:	Pharmaceutical Sciences and Technology	Student's Signature .....
Academic Year:	2019	Advisor's Signature .....
		Co-advisor's Signature .....

ACKNOWLEDGEMENTS

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

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

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

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

Pichayatri Khoonrit

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ABBREVIATIONS AND SYMBOLS

AAPH	=	2,2′-Azobis(2-amidinopropane) dihydrochloride
Acetone-d_6	=	Deuterated acetone
Ara	=	Arabinose
AUC	=	Area under a curve
α	=	Alpha
β	=	Beta
br s	=	Broad singlet (for NMR spectra)
br d	=	Broad doublet (for NMR spectra)
BuOH	=	Butanol
℃	=	Degree Celsius
CAT	=	Catalase
$CDCl_3$	=	Deuterated chloroform
cm	=	Centimeter
conc	=	Concentration
^{13}C-NMR	=	Carbon-13 nuclear magnetic resonance
C4H	=	Cinnamate-4-hydroxylase
4CL	=	4-Coumaroyl CoA ligase
2D NMR	=	Two-dimensional nuclear magnetic resonance
d	=	Doublet (for NMR spectra)
dd	=	Doublet of doublets (for NMR spectra)
δ	=	Chemical shift
DMSO	=	Dimethyl sulfoxide
DPPH	=	2,2-Diphenyl-1-picrylhydrazyl

ε	=	Molar absorptivity
EDTA	=	Ethylenediamine tetraacetic acid
Em-filter	=	Emission filter
ESI-MS	=	Electrospray ionization mass spectrometry
EtOAc	=	Ethyl acetate
Ex-filter	=	Excitation filter
g	=	Gram
Gal	=	Galactose
Glc	=	Glucose
HMBC	=	^{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}	=	Half maximal inhibitory concentration
IR	=	Infrared
J	=	Coupling constant
kg	=	Kilogram
L	=	Liter
LED	=	Light emitting diode
λ_{max}	=	Wavelength at maximal absorption
$[M+Na]^{+}$	=	Sodium-adduct molecular ion
m	=	Multiplet (for NMR spectra)

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

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

CHAPTER I

INTRODUCTION

A free radical can be described as an unstable atom or molecule with one or more unpaired electrons. It is a strongly reactive agent which able to attack other molecules by trapping their electrons to stabilize itself. This process is the initiation of a chain reaction because the attacked molecules become free radicals themselves. Both free radicals and molecules that can generate free radicals are called reactive oxygen species (ROS) (Halliwell, 2006; Phaniendra, Jestadi and Periyasamy, 2015). ROS is generally produced from metabolism in the cell, especially, organelles with high oxygen consumption including mitochondria, peroxisomes, and endoplasmic reticulum (Kontoghiorghes and Kontoghiorghe, 2019). On the other side, it can be generated from exogenous sources, for instance, alcohols, heavy metals, pesticides, radiations, and cigarette smoke (Phaniendra, Jestadi and Periyasamy, 2015). There are two different types of ROS which are radicals and non-radicals. The examples of radicals are superoxide radical ($\bullet O_2^-$), hydroxyl radical ($\bullet OH$), alkoxy radical ($RO\bullet$), and peroxyl radical ($ROO\bullet$). Non-radical species, for example, hydrogen peroxide (H_2O_2), hypochlorous acid (HOCl), hypobromous acid (HOBr), ozone (O_3), and singlet oxygen ($^1O_2$), are also harmful. Even if they might not directly harm to other molecules, they involve in the formation of the destructive radicals in organisms (Phaniendra, Jestadi and Periyasamy, 2015).

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

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

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

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

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

D. 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	**เอื้องมัจฉานุ** Ueang matchanu (Bangkok)
D. fimbriatum Hook.	**เอื้องคำน้อย** Ueang kham noi (Chiang Mai)
*D. findlayanu*m E.C.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. fytchianum 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.	**เอื้องมัจฉาเหลือง** Ueang matcha lueang (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. pandurifferum 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. **เอื้องไม้เท้าฤษี** 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 lindleyi Steud, known as "Ueang Pueng" in Thailand (Vaddhanaphuti, 2005), distributes in India, China, Hongkong, Bhutan, Thailand, Myanmar, Laos, and Vietnam (Cheng et al., 2019). It is a 6-10-centimeter-tall epiphytic orchid. Leaves are in oblong-elliptic shape. It flowers with inflorescences having up to 20 pale to bright yellow flowers. Lip bases are golden yellow and pubescent, bordered with paler yellow (Vaddhanaphuti, 2005).

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

Figure 1 *Dendrobium lindleyi* Steud

CHAPTER II

HISTORICAL

1. Chemical constituents of *Dendrobium* species

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

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

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

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

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

Table 1 Stilbenoids from *Dendrobium*

Stilbenoids	Plant	Plant part	Reference
Aloifol I [**1**]	*D. longicornu*	Stem	Hu et al., 2008a
	D. williamsonii	Whole plant	Yang et al., 2018b
	D. infundibulum	Whole plant	Na Ranong et al., 2019
Amoenylin [**2**]	*D. amoenum*	Whole plant	Majumder, Guha and Sen, 1999
	D. williamsonii	Whole plant	Yang et al., 2018
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., 2008b
	D. rotundatum	Whole plant	Majumder and Pal, 1992
	D. chrysotoxum	Whole plant	Li et al., 2009d
	D. draconis	Stem	Sritularak, Anuwat and Likhitwitayawuid, 2011
	D. formosum	Whole plant	Inthongkaew et al., 2017
	D. gratiosissimum	Stem	Zhang et al., 2008a
	D. loddigesii	Stem	Ito et al., 2010
	D. loddigesii	Stem	Ma et al., 2019b
	D. venustum	Whole plant	Sukphan et al., 2014

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

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

Stilbenoids	Plant	Plant part	Reference
	D. devonianum	Whole plant	Sun et al., 2014
	D. draconis	Stem	Sritularak, Anuwat and Likhitwitayawuid, 2011
	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., 2007c
	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
	D. scabrilingue	Whole plant	Sarakulwattana et al., 2018
	D. loddigesii	Stem	Ma et al., 2019b
	D. palpebrae	Whole plant	Kyokong et al., 2019
4-Hydroxy-3,5,3′-trimethoxybibenzyl [**17**]	*D. nobile*	Stem	Ye and Zhao, 2002
5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl [**18**]	*D. secundum*	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid, 2012
Isoamoenylin [**19**]	*D. amoenum*	Whole plant	Majumder, Guha and Sen, 1999
Moniliformine [**20**]	*D. candidum*	Stem	Li et al., 2008
	D. signatum	Whole plant	Mittraphab et al., 2016
	D. tortile	Whole plant	Limpanit et al., 2016
	D. williamsonii	Whole plant	Yang et al., 2018b

Stilbenoids	Plant	Plant part	Reference
Moscatilin [**21**]	*D. amoenum*	Whole plant	Majumder, Guha and Sen, 1999
	D. aurantiacum var. *denneanum*	Stem	Yang, Wang and Xu, 2006
	D. brymerianum	Whole plant	Klongkumnuankarn et al., 2015
	D. chrysanthum	Stem	Yang et al., 2006
	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
	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, Duangrak and Likhitwitayawuid, 2011
	D. aphyllum	Stem	Yang et al., 2015
	D. williamsonii	Whole plant	Yang et al., 2018b
	D. parishii	Whole plant	Kongkatitham et al., 2018
	D. loddigesii	Stem	Ma et al., 2019b
	D. palpebrae	Whole plant	Kyokong et al., 2019

Stilbenoids	Plant	Plant part	Reference
	D. infundibulum	Whole plant	Na Ranong et al., 2019)
3,3′,4-Trihydroxybibenzyl [**22**]	*D. longicornu*	Stem	Hu et al., 2008a
3,3′,5-Trihydroxy bibenzyl [**23**]	*D. cariniferum*	Whole plant	Liu et al., 2009a
	D. loddigesii	Stem	Ma et al., 2019b
3,5,4′-Trihydroxybibenzyl [**24**]	*D. gratiosissimum*	Stem	Zhang et al., 2008a
4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl [**25**]	*D. secundum*	Stem	Sritularak, Duangrak and Likhitwitayawuid, 2011
	D. ellipsophyllum	Whole plant	Tanagornmeatar et al., 2014
	D. parishii	Whole plant	Kongkatitham et al., 2018
	D. loddigesii	Stem	Ma et al., 2019b
	D. palpebrae	Whole plant	Kyokong et al., 2019
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
	D. loddigesii	Stem	Ma et al., 2019b
Dendromoniliside E [**27**]	*D. moniliforme*	Stem	Zhao et al., 2003
5,4′-Dihydroxy-3,4,3′-trimethoxybibenzyl [**28**]	*D. infundibulum*	Whole plant	Na Ranong et al., 2019

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

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

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

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

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

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

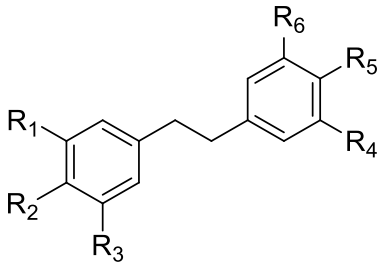
Stilbenoids	Plant	Plant part	Reference
	D. palpebrae	Whole plant	Kyokong et al., 2019
2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene [**111**]	*D. rotundatum*	Whole plant	Majumder and Pal, 1992
2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**112**]	*D. nobile*	Stem	Yang, Sung and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

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

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

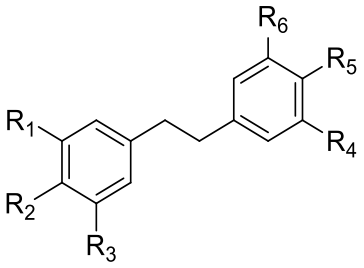
Stilbenoids	Plant	Plant part	Reference
3,4,8-Trimethoxy phenanthrene-2,5-diol [**140**]	*D. nobile*	Stem	Hwang et al., 2010
Aphyllone A [**141**]	*D. aphyllum*	Stem	Yang et al., 2015
2,4,5,9*S*-Tetrahydroxy-9,10-dihydro phenanthrene [**142**]	*D. fimbriatum*	Stem	Xu et al., 2014
1,5,7-Trimethoxy phenanthren-2-ol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

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



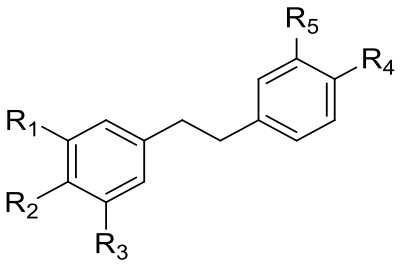
	R_1	R_2	R_3	R_4	R_5	R_6
[**1**] Aloifol I	OMe	OH	OMe	OH	H	H
[**2**] Amoenylin	OMe	OH	OMe	H	OMe	H
[**3**] Batatasin	OMe	H	H	OH	H	OH
[**4**] Batatasin III	OH	H	OMe	H	H	OH
[**5**] Brittonin A	OMe	OMe	OMe	OMe	OMe	OMe
[**6**] Chrysotobibenzyl	OMe	OMe	OMe	OMe	OMe	H
[**7**] Chrysotoxine	OMe	OH	OMe	OMe	OMe	H
[**8**] Crepidatin	OMe	OMe	OMe	OMe	OH	H
[**9**] Cumulatin	OMe	OMe	OH	OH	OMe	OMe
[**10**] Dendrobin A	OH	OH	OMe	H	H	OMe
[**11**] 3,3′-Dihydroxy-4,5-dimethoxybibenzyl	OMe	OMe	OH	H	H	OH
[**12**] 3,4′-Dihydroxy-5-methoxybibenzyl	OH	H	OMe	H	OH	H
[**13**] 3,4′-Dihydroxy-5,5′-dimethoxydihydrostilbene	OH	H	OMe	OMe	OH	H

Figure 2 Structures of stilbenoids from *Dendrobium*

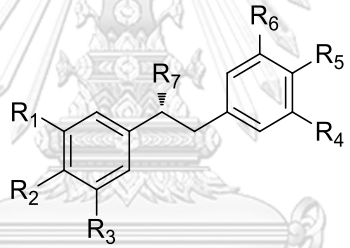


	R_1	R_2	R_3	R_4	R_5	R_6
[**14**] 4,5-Dihydroxy-3,3′-dimethoxybibenzyl	OMe	OH	OH	H	H	OMe
[**15**] Erianin	OMe	OMe	OMe	H	OMe	OH
[**16**] Gigantol	OMe	H	H	H	OH	OMe
[**17**] 4-Hydroxy-3,5,3′-trimethoxybibenzyl	OMe	OH	OMe	H	H	OMe
[**18**] 5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl	OMe	OMe	OH	OMe	OMe	OMe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

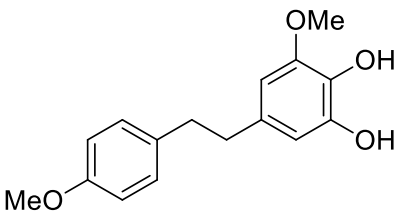


	R_1	R_2	R_3	R_4	R_5
[**25**] 4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl	OMe	OH	OH	OH	OMe
[**26**] Tristin	OH	H	OH	OH	OMe
[**27**] Dendromoniliside E	OGlc	OGlc	OMe	OMe	H
[**28**] 5,4′-Dihydroxy-3,4,3′-trimethoxybibenzyl	OH	OMe	OMe	OH	OMe
[**29**] 4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	OH	OH

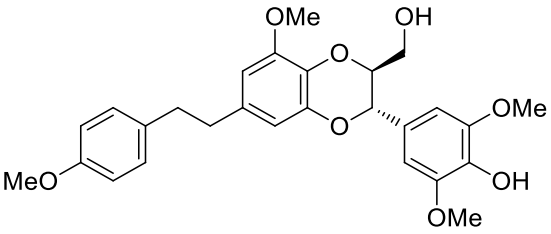


	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**30**] Dendrophenol	OMe	OH	OMe	OH	OH	H	H
[**31**] 4,4′-Dihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	H	OH	H	H
[**32**] Loddigesiinol C	OMe	OH	OMe	H	OH	OMe	OMe
[**33**] 3-*O*-Methylgigantol	OMe	H	OH	OMe	OMe	H	H

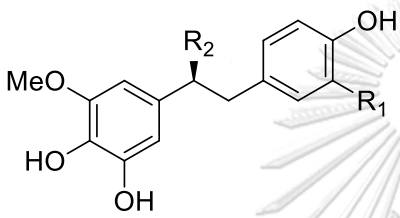
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



[**34**] Dendrocandin A



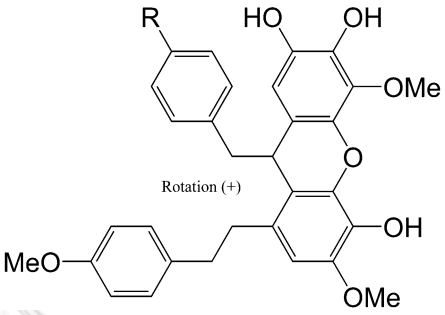
[**35**] Dendrocandin B



[**36**] Dendrocandin C R_1 = H R_2 = OMe

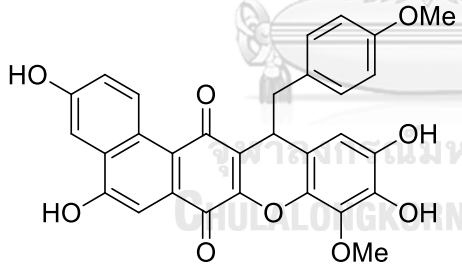
[**37**] Dendrocandin D R_1 = H R_2 = OEt

[**38**] Dendrocandin E R_1 = OH R_2 = H

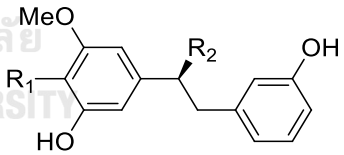


[**39**] Dendrocandin F R = OMe

[**40**] Dendrocandin G R = OH



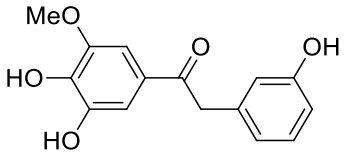
[**41**] Dendrocandin H



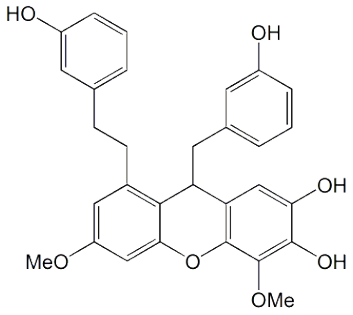
[**42**] Dendrosinen A R_1 = OMe R_2 = OH

[**43**] Dendrosinen B R_1 = OH R_2 = H

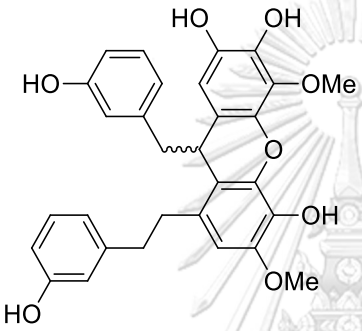
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



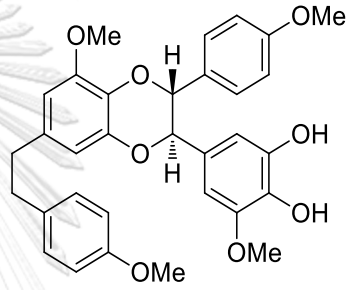
[**44**] Dendrosinen C



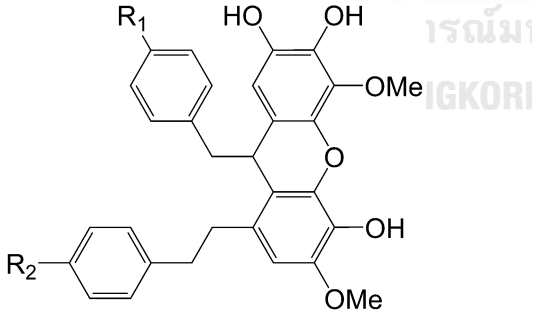
[**45**] Dendroscabrol B



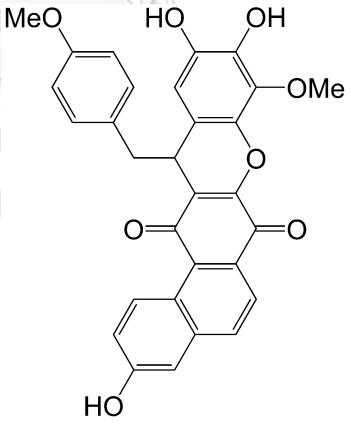
[**46**] Dendrosinen D



[**47**] Dendrocandin I

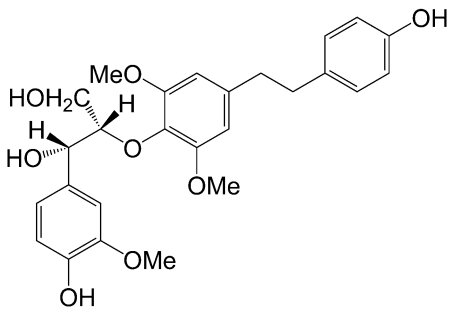


	R_1	R_2
[**48**] Dendrocandin J	OMe	OH
[**49**] Dendrocandin K	OH	OH

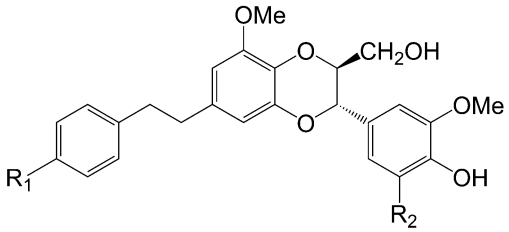


[**50**] Dendrocandin L

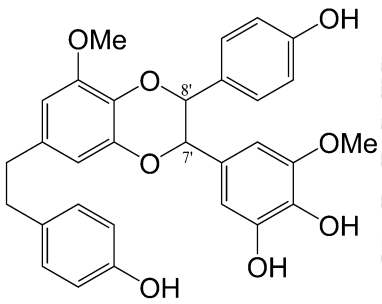
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



[**51**] Dendrocandin M

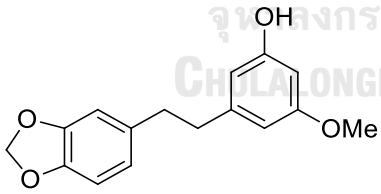


	R_1	R_2
[**52**] Dendrocandin N	OH	H
[**53**] Dendrocandin O	OH	OH

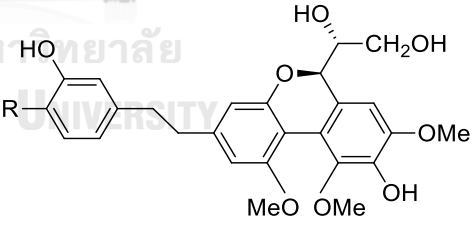


[**54**] Dendrocandin P H-7′, 8′ *cis*

[**55**] Dendrocandin Q H-7′, 8′ *trans*



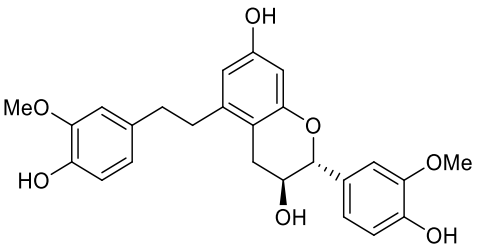
[**56**] Densiflorol A



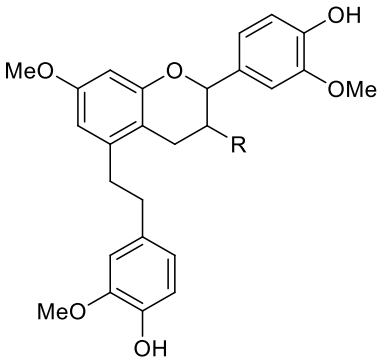
[**57**] Longicornuol A R = H

[**58**] Trigonopol A R = OMe

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

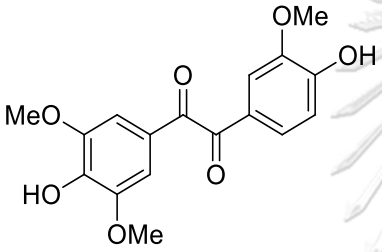


[**59**] Trigonopol B

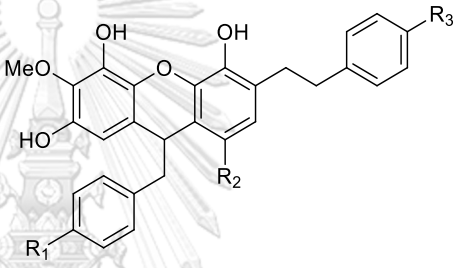


[**60**] Crepidatuol A R = H

[**61**] Crepidatuol B R = OH

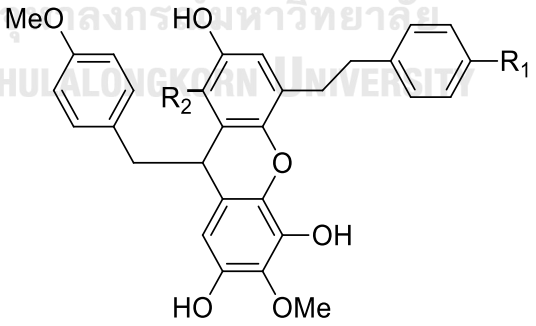


[**62**] Loddigesiinol D



[**63**] Dencryol A R_1 = OMe R_2 = R_3 = OH

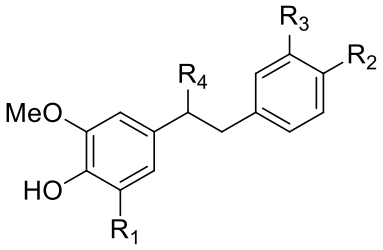
[**64**] Dencryol B R_1 = OH R_2 = R_3 = OMe



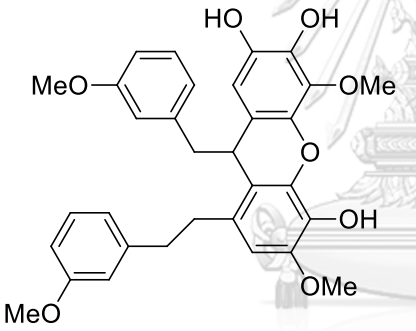
[**65**] Dengraol A R_1 = R_2 = OH

[**66**] Dengraol B R_1 = R_2 = OMe

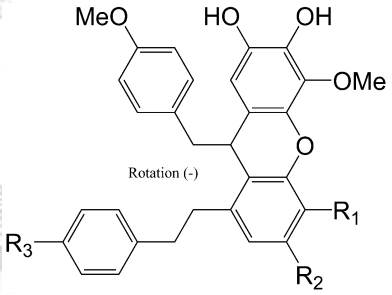
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



	R_1	R_2	R_3	R_4
[**67**] 4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol	OMe	H	OH	OMe
[**68**] Nobilin A	OH	H	OMe	OMe
[**69**] Nobilin B	OMe	OH	OMe	OMe
[**70**] Nobilin C	OMe	OMe	OMe	OMe
[**71**] Nobilin D	OMe	OH	OMe	OH

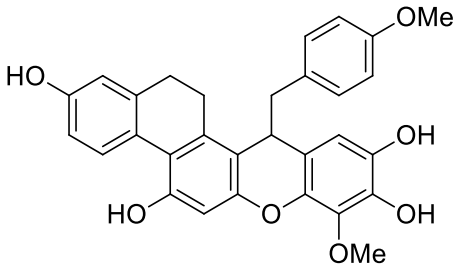


[**72**] Nobilin E



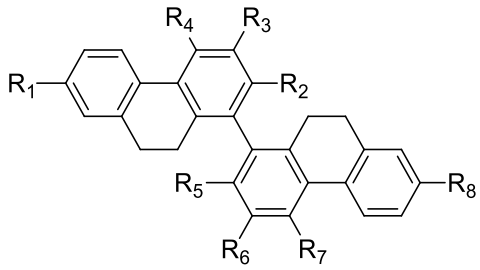
[**73**] Dendrofalconerol A R_1 = OH R_2 = R_3 = OMe

[**74**] Dendrofalconerol B R_1 = H R_2 = R_3 = OH

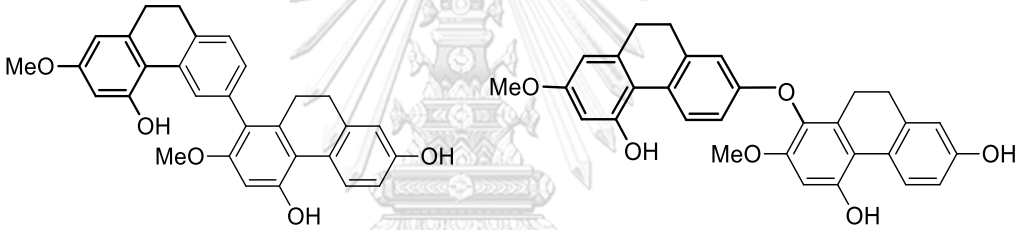


[**75**] Dendrosignatol

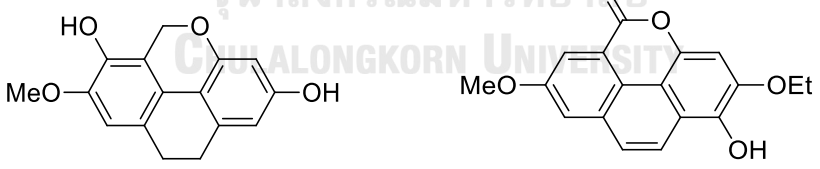
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
[**76**] 2,2′-Dihydroxy-3,3′,4,4′,7,7′-hexamethoxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OMe	OH	OMe	OMe	OH	OMe	OMe	OMe
[**77**] 2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OH	OMe	H	OH	OMe	H	OH	OH
[**78**] Flavanthrin	OH	OH	H	OMe	OH	H	OMe	OH

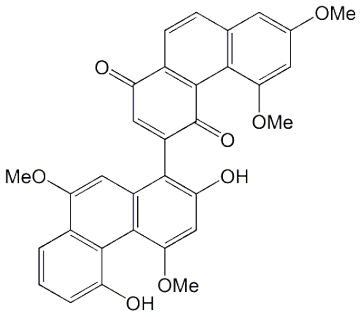


[**79**] Phoyunnanin C [**80**] Phoyunnanin E

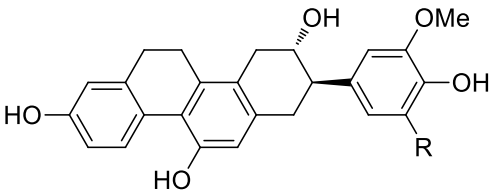


[**81**] Amoenumin [**82**] Crystalltone

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

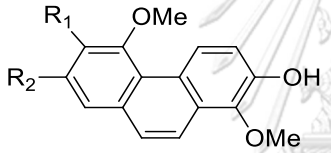


[**83**] Dendropalpebrone



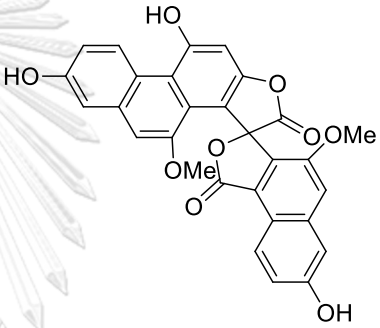
[**84**] Chrysotoxol A R = H

[**85**] Chrysotoxol B R = OMe

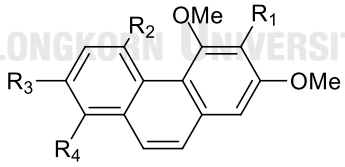


[**86**] Confusarin R_1 = OMe R_2 = OH

[**87**] Denthyrsinin R_1 = OH R_2 = OMe

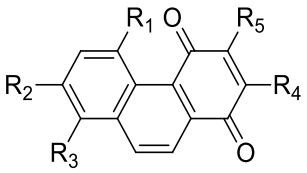


[**88**] Dendrochrysanene

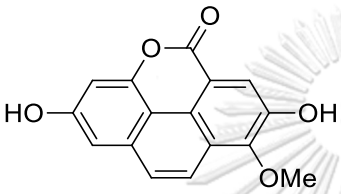


	R_1	R_2	R_3	R_4
[**89**] Bulbophyllanthrin	OH	OH	H	H
[**90**] 5-Hydroxy-2,4-dimethoxyphenanthrene	H	OH	H	H
[**91**] 3-Hydroxy-2,4,7-trimethoxyphenanthrene	OH	H	OMe	H

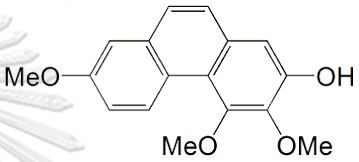
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



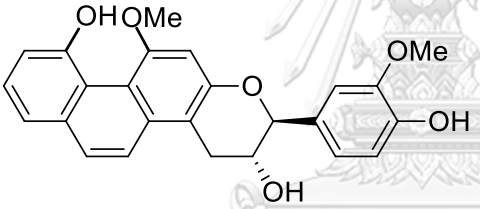
	R_1	R_2	R_3	R_4	R_5
[**92**] Cypripedin	H	OH	OMe	OMe	H
[**93**] Densiflorol B	H	OH	H	OMe	H
[**94**] Denbinobin	OH	OMe	H	H	OMe



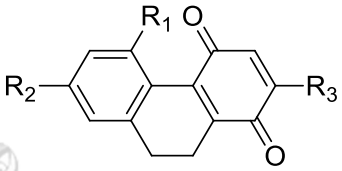
[**95**] Fimbriatone



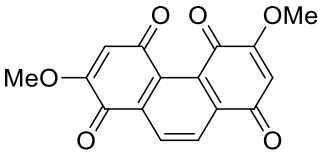
[**96**] Dendroscabrol A



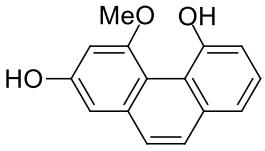
[**97**] Loddigesiinol B



	R_1	R_2	R_3
[**98**] Dendronone	OH	OMe	H
[**99**] Ephemeranthoquinone	H	OH	OMe
[**100**] 5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone	OMe	OH	H

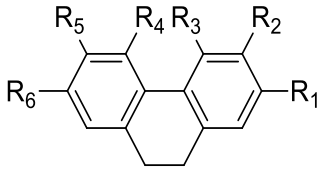


[**101**] Moniliformin



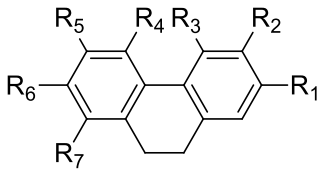
[**102**] Moscatin

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



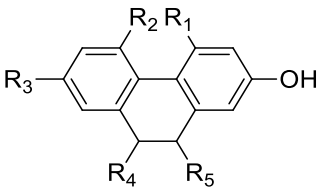
	R_1	R_2	R_3	R_4	R_5	R_6
[**103**] Coelonin	OH	H	OMe	H	H	OH
[**104**] 9,10-Dihydromoscatin	H	H	OH	OMe	H	OH
[**105**] 9,10-Dihydrophenanthrene-2,4,7-triol	OH	H	OH	H	H	OH
[**106**] 4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	OH	H	H
[**107**] 4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	OMe	H
[**108**] 4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene	H	OMe	OH	OH	H	OMe
[**109**] 4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	H	H
[**110**] Lusianthridin	OMe	H	OH	H	H	OH

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

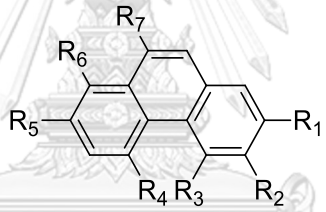


	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**111**] 2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**112**] 2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene	OH	OMe	OMe	H	H	OMe	OH
[**113**] 4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	H	OMe	OH	H
[**114**] Ephemeranthol A	OH	H	H	OH	OMe	OMe	H
[**115**] Ephemeranthol C	OH	OH	OMe	OH	H	H	H
[**116**] Erianthridin	OH	OMe	OMe	H	H	OH	H
[**117**] Flavanthridin	OH	H	H	OMe	OH	OMe	H
[**118**] Hircinol	OH	H	OMe	OH	H	H	H
[**119**] 3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene	OMe	OH	OMe	H	H	OMe	H
[**120**] 7-Hydroxy-2,3,4-trimethoxy-9,10-dihydrophenanthrene	OH	H	H	OMe	OMe	OMe	H
[**121**] Dendroinfundin A	OMe	OMe	OH	H	H	OMe	H
[**122**] Dendroinfundin B	OMe	OMe	OH	OH	H	H	OMe
[**123**] 3,4-Dimethoxy-1-(methoxymethyl)-9,10-dihydrophenanthrene-2,7-diol	OH	H	H	OMe	OMe	OH	$-CH_2OMe$

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

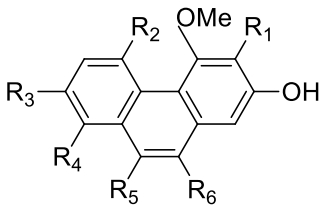


	R_1	R_2	R_3	R_4	R_5
[**124**] 2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene	OMe	H	OMe	H	H
[**125**] 7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol	OH	OH	OMe	H	H
[**126**] 2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene	OMe	OH	OH	H	H
[**127**] Plicatol C	H	OMe	OH	H	OMe
[**128**] Rotundatin	H	OMe	OH	H	OH

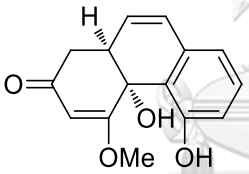


	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**129**] 2,5-Dihydroxy-3,4-dimethoxyphenanthrene	OH	OMe	OMe	OH	H	H	H
[**130**] 2,5-Dihydroxy-4,9-dimethoxyphenanthrene	OH	H	OMe	OH	H	H	OMe
[**131**] 2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**132**] Epheranthol B	H	H	OMe	OH	OMe	H	H
[**133**] Fimbriol B	OH	OMe	OH	H	H	H	H
[**134**] Flavanthrinin	OH	H	OMe	H	OH	H	H

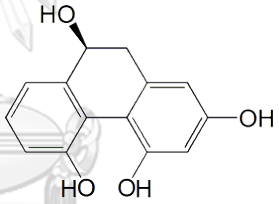
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



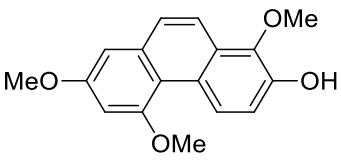
	R_1	R_2	R_3	R_4	R_5	R_6
[**135**] Loddigesiinol A	H	OMe	H	H	OH	H
[**136**] Nudol	OMe	H	OH	H	H	H
[**137**] Plicatol A	H	OH	H	H	OMe	OMe
[**138**] Plicatol B	H	OH	H	H	H	H
[**139**] 2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene	OH	OH	H	H	OMe	H
[**140**] 3,4,8-Trimethoxyphenanthrene-2,5-diol	OMe	OH	H	OMe	H	H



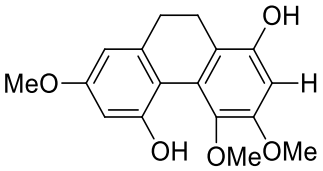
[**141**] Aphyllone A



[**142**] 2,4,5,9*S*-Tetrahydroxy-9,10-dihydrophenanthrene

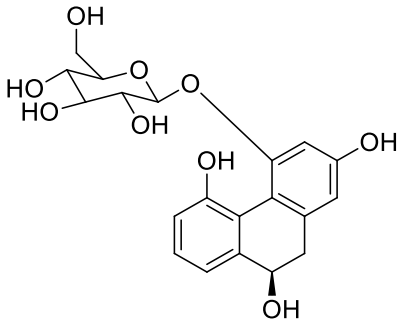


[**143**] 1,5,7-Trimethoxyphenanthren-2-ol

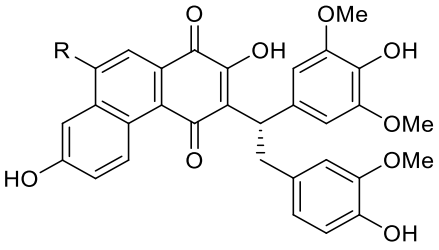


[**144**] 1,5-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene

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

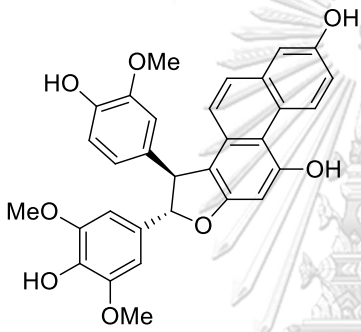


[**145**] 2,5,9*S*-Trihydroxy-9,10-dihydrophenanthrene -4-*O*-β-D-glucopyranoside

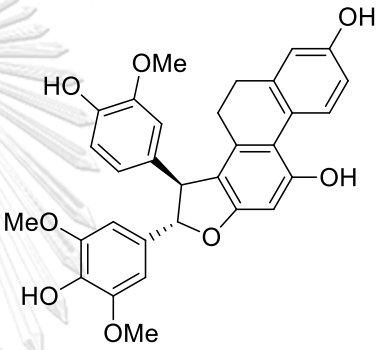


[**146**] Loddigesiinol G R = H

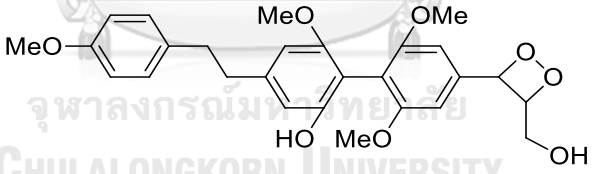
[**147**] Loddigesiinol H R = OH



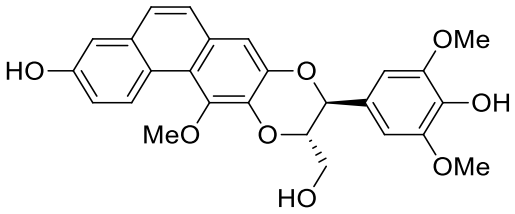
[**148**] Loddigesiinol I



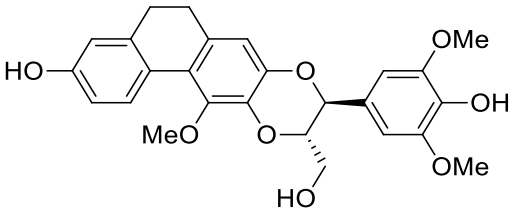
[**149**] Loddigesiinol J



[**150**] Dendrowillol A

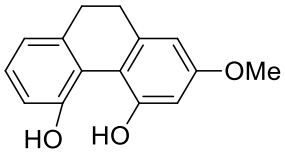


[**151**] Dendrocandin P1

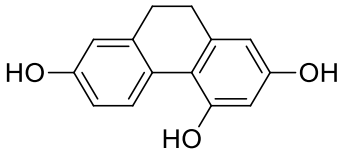


[**152**] Dendrocandin P2

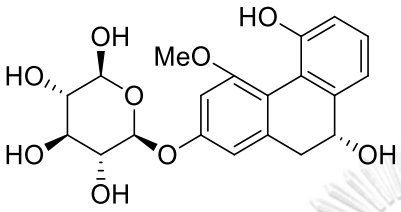
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)



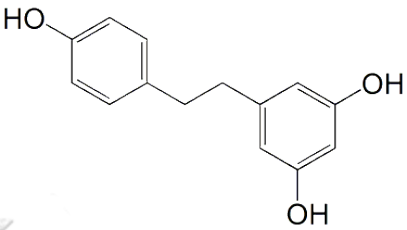
[**153**] Orchinol



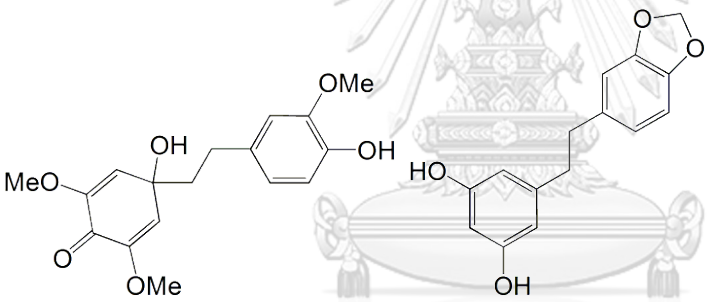
[**154**] 2,4,7-Trihydroxy-9,10-dihydrophenanthrene



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

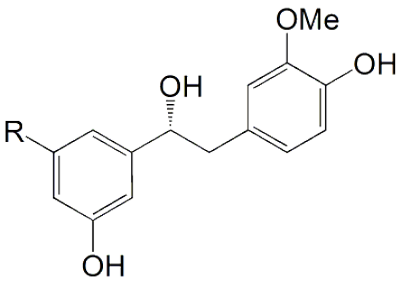


[**156**] Dihydroresveratrol



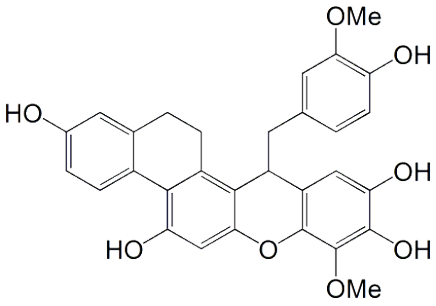
[**157**] Aphyllone B

[**158**] Aphyllal C

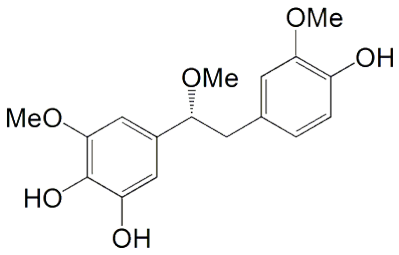


[**159**] Aphyllal D R = OH

[**160**] Aphyllal E R = OMe

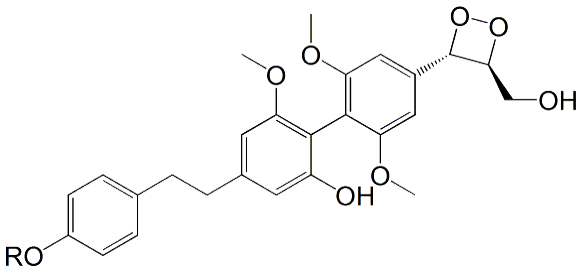


[**161**] (-)-Dendroparishiol



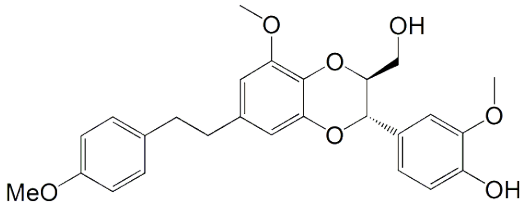
[**162**] (*R*)-4,5,4′-Trihydroxy-3,3′,α-trimethoxybibenzyl

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

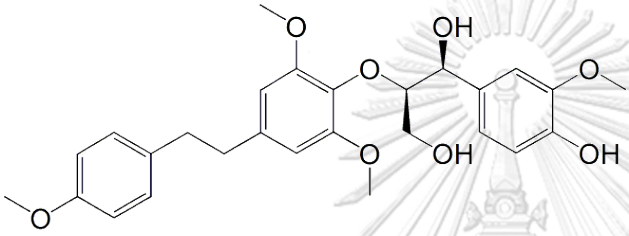


[**163**] Dendrofindlaphenol A R = Me

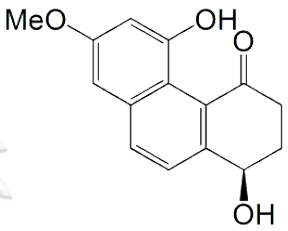
[**164**] 6″-De-*O*-methyldendrofindlaphenol A R = H



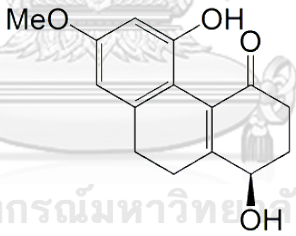
[**165**] Dendrofindlaphenol B



[**166**] Dendrofindlaphenol C



[**167**] Dendrodevonin A



[**168**] Dendrodevonin B

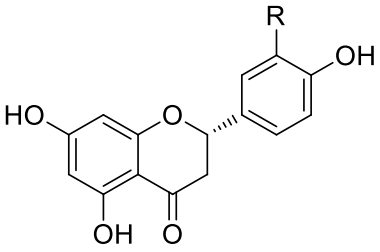
Figure 2 Structures of stilbenoids from *Dendrobium* (continued)

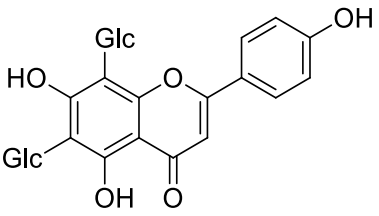
Table 2 Flavonoids from *Dendrobium*

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

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

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

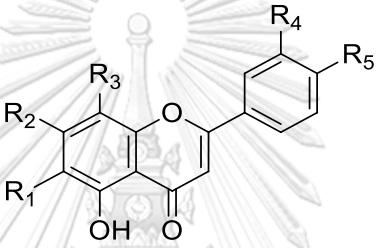




[**169**] (2*S*)-Homoeriodictyol R = OMe [**172**] Vicenin II

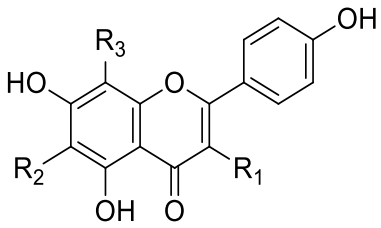
[**170**] Naringenin R = H

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

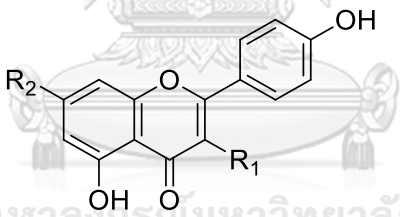


	R_1	R_2	R_3	R_4	R_5
[**173**] Apigenin	H	OH	H	H	OH
[**174**] 5,6-Dihydroxy-4′-methoxyflavone	OH	H	H	H	OMe
[**175**] Chrysoeriol	H	OH	H	OMe	OH
[**176**] Luteolin	H	OH	H	OH	OH
[**177**] 6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-galactopyranosyl] apigenin	-Ara	OH	-Gal-Rha	H	OH
[**178**] 6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-glucopyranosyl] apigenin	-Ara	OH	-Glc-Rha	H	OH

Figure 3 Structures of flavonoids from *Dendrobium*

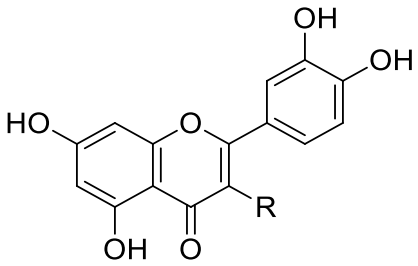


	R_1	R_2	R_3
[**179**] 6‴-Glucosyl-vitexin	H	H	-Glc
[**180**] Isoschaftoside	H	-Ara	-Glc
[**181**] Isoviolanthin	H	-Rha	-Glc
[**182**] 6-*C*-[(2-*O*-α-Rhamnopyranosyl)-β-glucopyranosyl]-8-*C*-(α-arabinopyranosyl) apigenin	H	-Glc-Rha	-Ara
[**183**] 6-*C*-(β-Xylopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-glucopyranosyl] apigenin	H	-Xyl	-Glc-Rha
[**184**] Kaempferol	OH	H	H



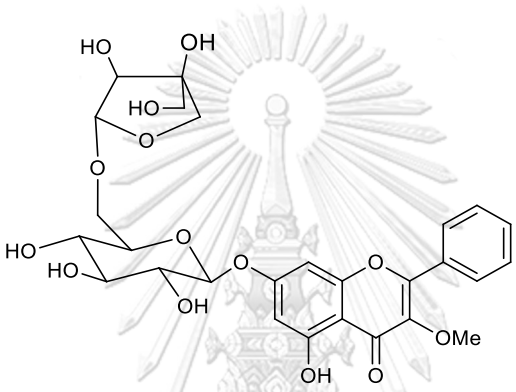
	R_1	R_2
[**185**] Kaempferol-3-*O*-α-L-rhamnopyranoside	O-Rha	OH
[**186**] Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside	O-Rha	O-Rha
[**187**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1→2)-β-D-glucopyranoside	O-Glc-Rha	OH
[**188**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1→2)-β-D-xylopyranoside	O-Xyl-Rha	OH

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

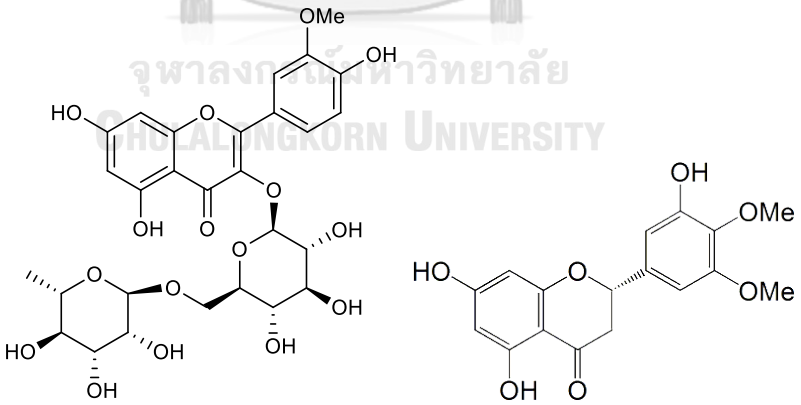


[**189**] Quercetin-3-*O*-α-L-rhamnopyranoside R = O-Rha

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



[**191**] 5-Hydroxy-3-methoxyflavone-7-*O*-[β-D-apiosyl-(1→6)]-β-D-glucoside



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

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

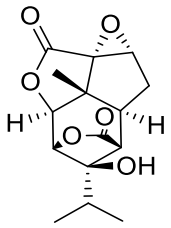
Table 3 Terpenoids from *Dendrobium*

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

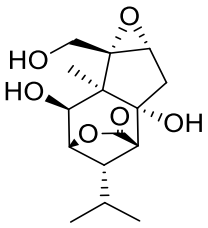
Terpenoids	Plant	Plant part	Reference
Dendrowardol A [**213**]	*D. wardianum*	Stem	Fan et al., 2013
Dendrowardol B [**214**]	*D. wardianum*	Stem	Fan et al., 2013
Dendrowardol C [**215**]	*D. wardianum*	Stem	Fan et al., 2013
Corchoionoside C [**216**]	*D. polyanthum*	Stem	Hu et al., 2009
Crystallinin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

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

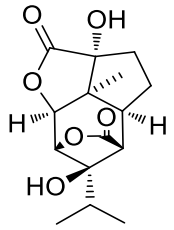
Terpenoids	Plant	Plant part	Reference
(+)-(1*R*,2*S*,3*R*,4*S*,5*R*,6*S*,9*R*)-3,11,12-Trihydroxypicrotoxane-2(15)-lactone [**251**]	*D. nobile*	Stem	Ma et al., 2019a
(-)-(1*S*,2*R*,3*S*,4*R*,5*S*,6*R*,9*S*,12*R*)-3,11,13-Trihydroxypicrotoxane-2(15)-lactone [**252**]	*D. nobile*	Stem	Ma et al., 2019a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



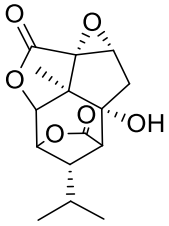
[**194**] Aduncin



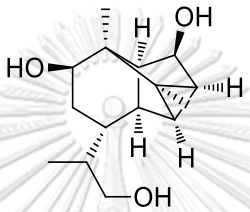
[**195**] Amoenin



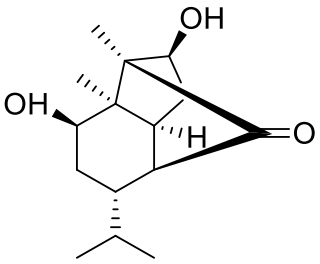
[**196**] Amotin



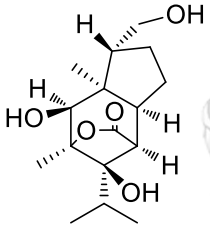
[**197**] α-Dihydropicrotoxinin



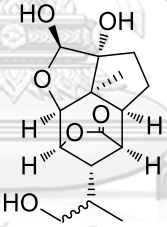
[**198**] Dendrobane A



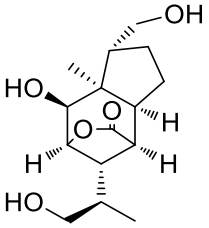
[**199**] Dendronobilin A



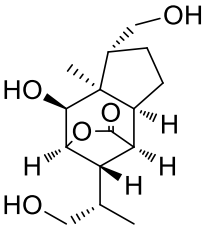
[**200**] Dendronobilin B



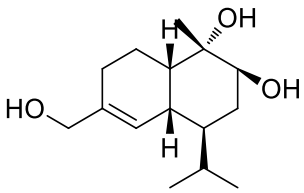
[**201**] Dendronobilin C



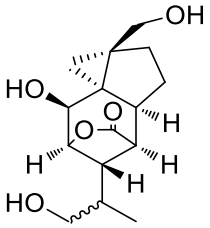
[**202**] Dendronobilin D



[**203**] Dendronobilin E

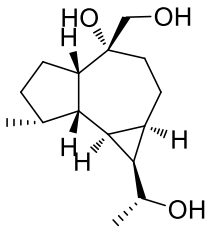


[**204**] Dendronobilin F

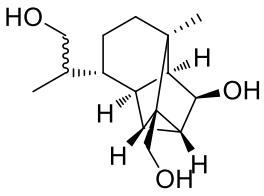


[**205**] Dendronobilin G

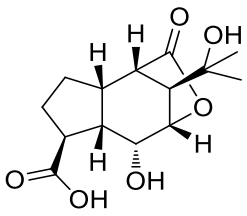
Figure 4 Structures of terpenoids from *Dendrobium*



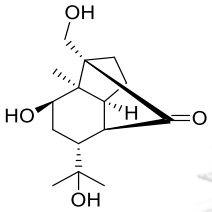
[**206**] Dendronobilin H



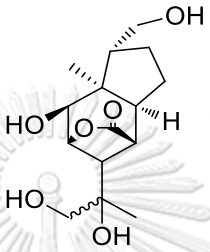
[**207**] Dendronobilin I



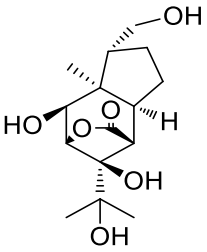
[**208**] Dendronobilin J



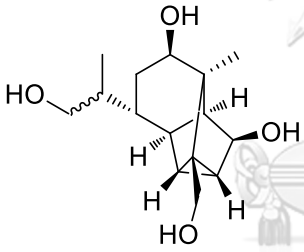
[**209**] Dendronobilin K



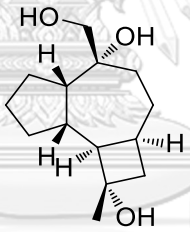
[**210**] Dendronobilin L



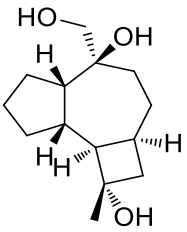
[**211**] Dendronobilin M



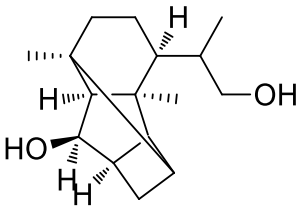
[**212**] Dendronobilin N



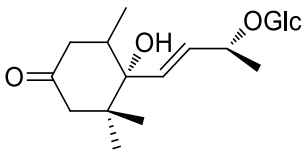
[**213**] Dendrowardol A



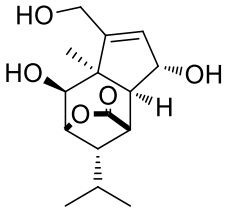
[**214**] Dendrowardol B



[**215**] Dendrowardol C

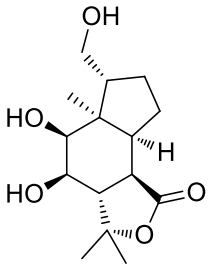


[**216**] Corchoionoside C

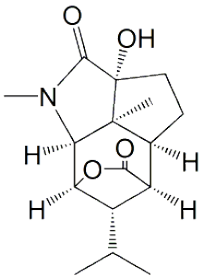


[**217**] Crystallinin

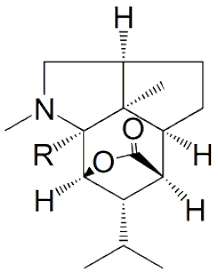
Figure 4 Structures of terpenoids from *Dendrobium* (continued)



[**218**] Findlayanin

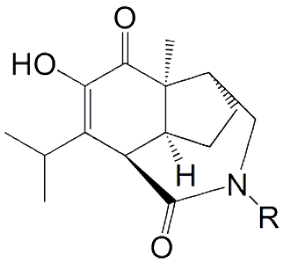


[**219**] 3-Hydroxy-2-oxodendrobine



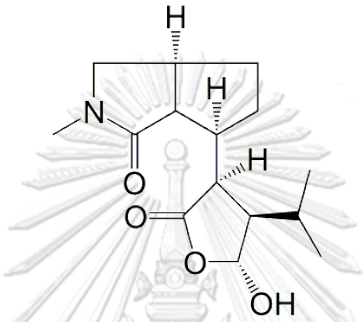
[**220**] Dendrobine R = H

[**221**] 2-Hydroxydendrobine R = OH

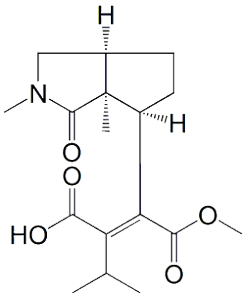


[**222**] Findlayine A R = Me

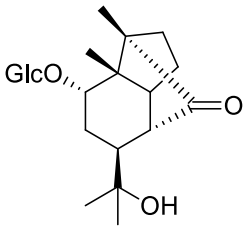
[**223**] Findlayine B R = H



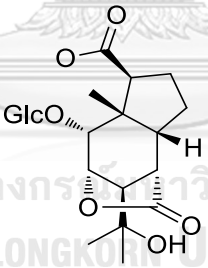
[**224**] Findlayine C



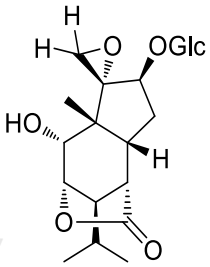
[**225**] Findlayine D



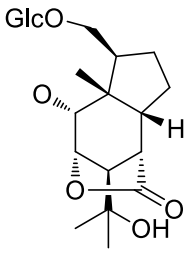
[**226**] Dendromoniliside A



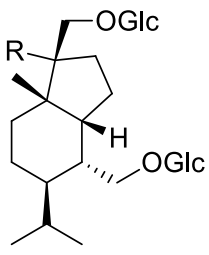
[**227**] Dendromoniliside B



[**228**] Dendromoniliside C

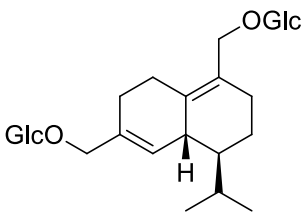


[**229**] Dendromoniliside D



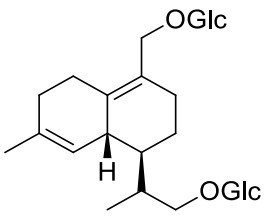
[**230**] Dendronobiloside A R = H

[**231**] Dendronobiloside B R = OH

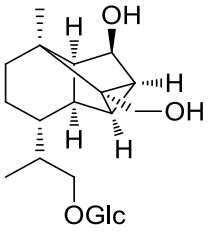


[**232**] Dendronobiloside C

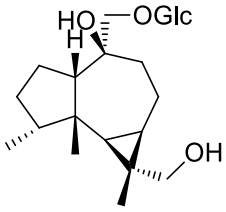
Figure 4 Structures of terpenoids from *Dendrobium* (continued)



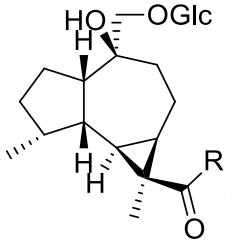
[**233**] Dendronobiloside D



[**234**] Dendronobiloside E

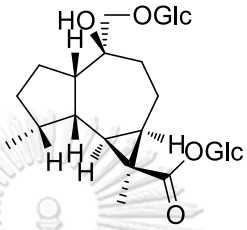


[**235**] Dendroside A

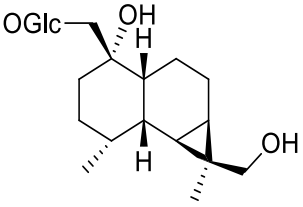


[**236**] Dendroside B R = OGlc

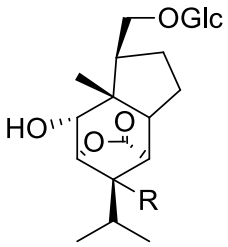
[**237**] Dendroside C R = OH



[**238**] Dendroside D

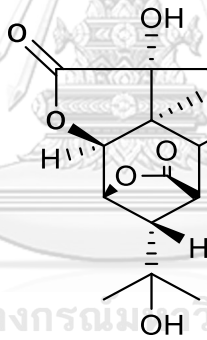


[**239**] Dendroside E



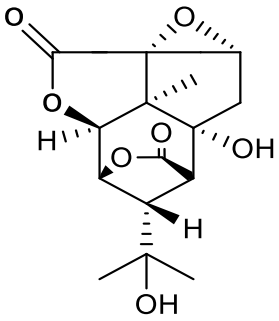
[**240**] Dendroside F R = H

[**241**] Dendroside G R = OH

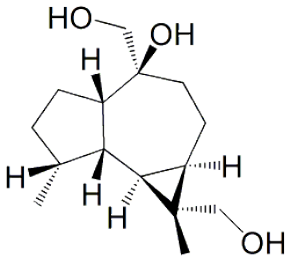


[**242**] Dendrowillin A R = OH

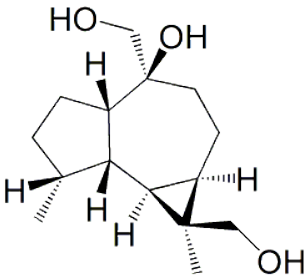
[**243**] Dendrowillin B R = H



[**244**] (-)-Picrotin

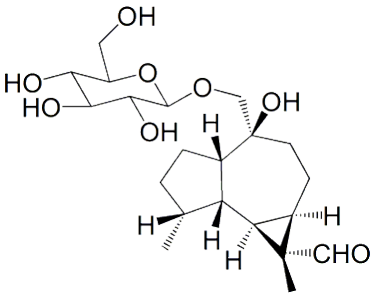


[**245**] 10β,12,14-Trihydroxyaromadendrane

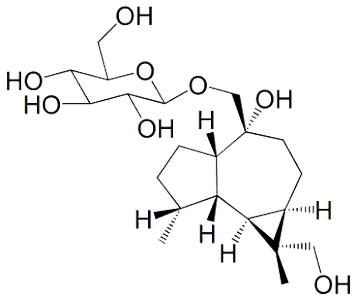


[**246**] 10β,13,14-Trihydroxyaromadendrane

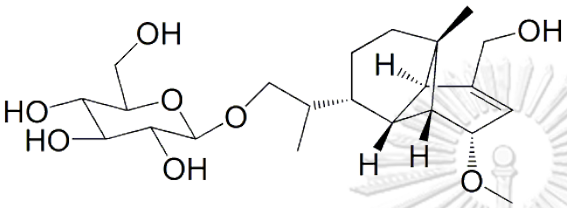
Figure 4 Structures of terpenoids from *Dendrobium* (continued)



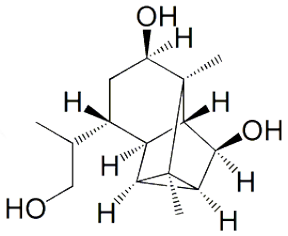
[**247**] Dendrofindlayanoside A



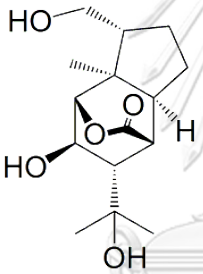
[**248**] Dendrofindlayanoside B



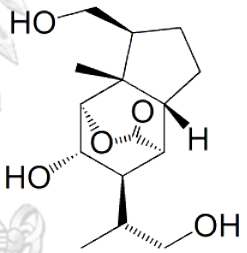
[**249**] Dendrofindlayanoside C



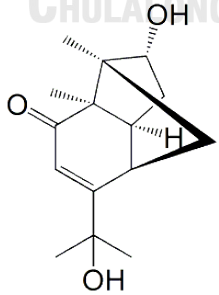
[**250**] Dendrofindlayanobilin



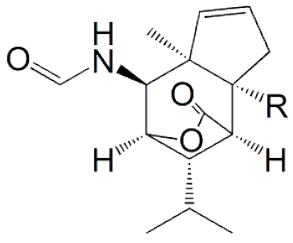
[**251**] (+)-(1*R*,2*S*,3*R*,4*S*,5*R*,6*S*,9*R*)-3,11,12-Trihydroxypicrotoxane-2(15)-lactone



[**252**] (-)-(1*S*,2*R*,3*S*,4*R*,5*S*,6*R*,9*S*,12*R*)-3,11,13-Trihydroxypicrotoxane-2(15)-lactone



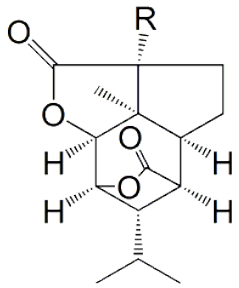
[**253**] (+)-(1*R*,5*R*,6*S*,8*R*,9*R*)-8,12-Dihydroxycopacamphan-3-en-2-one



[**254**] Dendroterpene A R = H

[**255**] Dendroterpene B R = OH

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



[**256**] Dendroterpene C R = H

[**257**] Dendroterpene D R = OH

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

Table 4 Miscellaneous compounds from *Dendrobium*

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

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

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

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

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

Categories and compounds	Plant	Plant part	Reference
Dehydrodiconiferyl alcohol-4-β-D-glucoside [**319**]	*D. nobile*	Stem	Zhou et al., 2017
(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 [**320**]	*D. williamsonii*	Whole plant	Yang et al., 2018b
threo-7-*O*-Ethyl-9-*O*-(4-hydroxyphenyl) propionyl-guaiacylglycerol [**321**]	*D. loddigesii*	Stem	Ma et al., 2019a
Coumarins			
Ayapin [**322**]	*D. densiflorum*	Stem	Fan et al., 2001
Coumarin [**323**]	*D. aurantiacum* var. *denneanum*	Stem	Yang, Wang and Xu, 2006
	D. clavatum var. *aurantiacum*	Stem	Chang, Lin and Chen, 2001
Denthyrsin [**324**]	*D. thyrsiflorum*	Stem	Zhang et al., 2005
Scoparone [**325**]	*D. densiflorum*	Stem	Fan et al., 2001
	D. thyrsiflorum	Stem	Zhang et al., 2005
	D. williamsonii	Whole plant	Yang et al., 2018b
	D. palpebrae	Whole plant	Kyokong et al., 2019
Scopoletin [**326**]	*D. densiflorum*	Stem	Fan et al., 2001
Lignans and neolignans			
Episyringaresinol [**327**]	*D. chrysotoxum*	Stem	Hu et al., 2012
	D. longicornu	Stem	Hu et al., 2008a
	D. nobile	Stem	Zhang et al., 2008c

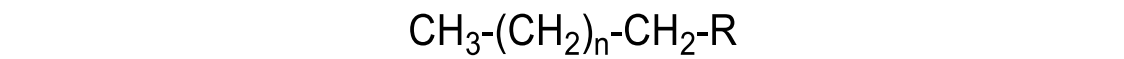
Categories and compounds	Plant	Plant part	Reference
Episyringaresinol 4″-*O*-β-D-glucopyranoside [**328**]	*D. moniliforme*	Stem	Zhao et al., 2003
(-)-(7*S*,8*R*,7′*E*)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-7,9′-bis-*O*-β-D-glucopyranoside [**329**]	*D. aurantiacum* var. *denneanum*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

Categories and compounds	Plant	Plant part	Reference
	D. secundum	Stem	Sritularak, Duangrak and Likhitwitayawuid, 2011
	D. williamsonii	Whole plant	Yang et al., 2018b
Acanthoside B [**340**]	*D. chrysanthum*	Stem	Ye, Zhao and Qin, 2004
Liriodendrin [**341**]	*D. brymerianum*	Whole plant	Chen, Yu and Liu, 2014
	D. pulchellum	Stem	Chanvorachote et al., 2013
(-)-(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 [**342**]	*D. auranticum* var. *denneanum*	Stem	Li et al., 2014a
(-)-(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 [**343**]	*D. auranticum* var. *denneanum*	Stem	Li et al., 2014a
(-)-(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 [**344**]	*D. auranticum* var. *denneanum*	Stem	Li et al., 2014a
Fluorenones			
Denchrysan B [**345**]	*D. brymerianum*	Whole plant	Klongkumnuankarn et al., 2015
	D. chrysotoxum	Whole plant	Li et al., 2009d
Denchrysan A [**346**]	*D. chrysotoxum*	Whole plant	Li et al., 2009d
Dendroflorin [**347**]	*D. aurantiacum* var. *denneanum*	Stem	Yang, Wang and Xu, 2006

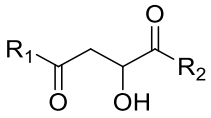
Categories and compounds	Plant	Plant part	Reference
	D. brymerianum	Whole plant	Klongkumnuankarn et al., 2015
	D. palpebrae	Whole plant	Kyokong et al., 2019
Dengibsin [**348**]	*D. aurantiacum var. denneanum*	Stem	Yang, Wang and Xu, 2006b
	D. chrysanthum	Stem	Yang et al., 2006a
	D. chrysotoxum	Whole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

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

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

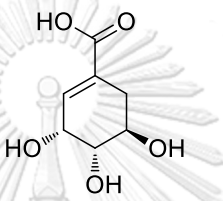


[**258**] Aliphatic acids R = COOH n = 19-31 [**259**] Aliphatic alcohols R = OH n = 22-32

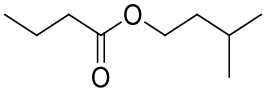


[**260**] Malic acid $R_1 = R_2 = OH$

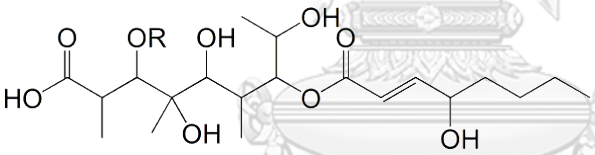
[**261**] Dimethyl malate $R_1 = R_2 = OMe$



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

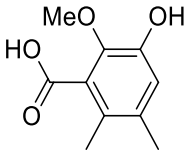


[**263**] Isopentyl butyrate

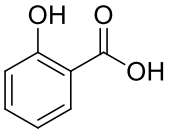


[**264**] Dendrodevonic acid A R = H

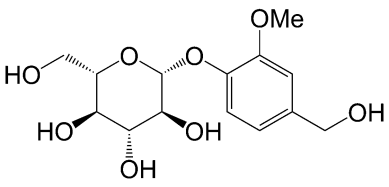
[**265**] Dendrodevonic acid B R = acetyl



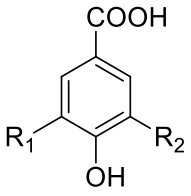
[**266**] 3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid



[**267**] Salicylic acid



[**268**] Vanilloloside



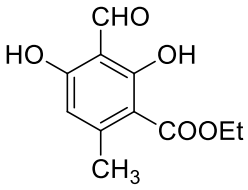
[**269**] Gallic acid $R_1 = OH$ $R_2 = OH$

[**270**] Syringic acid $R_1 = OMe$ $R_2 = OMe$

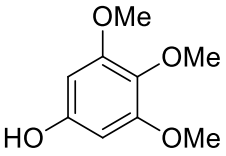
[**271**] Vanillic acid $R_1 = H$ $R_2 = OMe$

[**272**] Protocatechuic acid $R_1 = H$ $R_2 = OH$

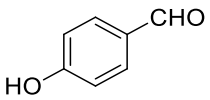
Figure 5 Structures of miscellaneous compounds from *Dendrobium*



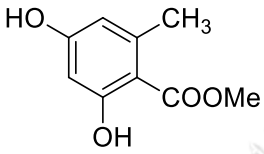
[**273**] Antiarol



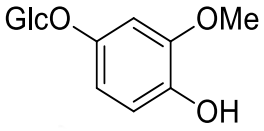
[**274**] Ethylhaematommate



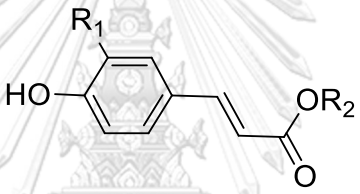
[**275**] *p*-Hydroxybenzaldehyde



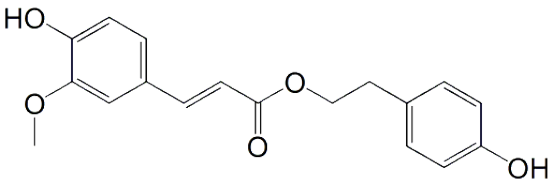
[**276**] Methyl β-orsellinate



[**277**] Tachioside

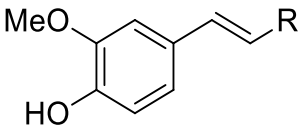


[**278**] Alkyl 4′-hydroxy *trans*-cinnamates	R_1 = H	$R_2 = C_nH_{2n+1}$ n =22-32
[**279**] Alkyl *trans*-ferulates	R_1 = OMe,	$R_2 = C_nH_{2n+1}$ n = 18-28, 30
[**280**] Defuscin	R_1 = OMe	$R_2 = (CH_2)_{27}CH_3$
[**281**] *n*-Octacosyl ferulate	R_1 = OMe	$R_2 = (CH_2)_{28}CH_3$
[**282**] *n*-Triacontyl-*p*-hydroxy *cis*-cinnamate	R_1 = H	$R_2 = C_{30}H_{61}$
[**283**] Tetratriacontanyl *trans*-*p*-coumarate	R_1 = H	$R_2 = (CH_2)_{33}CH_3$



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

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



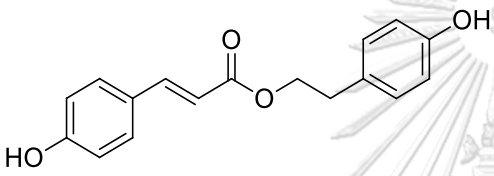
[**285**] *n*-Docosyl *trans*-ferulate: R = $COOCH_2(CH_2)_{20}CH_3$

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

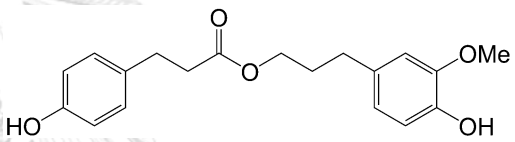
[**287**] *cis*-Hexacosanoyl ferulate R = $COOCH_2(CH_2)_{24}CH_3$

[**288**] Ferulaldehyde R = CHO

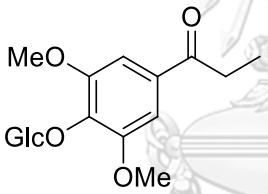
[**289**] Ferulic acid R = COOH



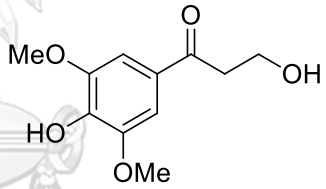
[**290**] 2-(*p*-Hydroxyphenyl) ethyl *p*-coumarate



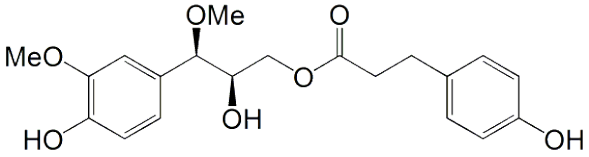
[**291**] Dihydroconiferyl dihydro-*p*-coumarate



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

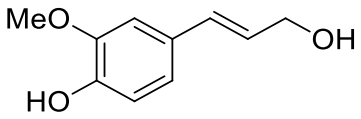


[**293**] 3-Hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-1-propanone

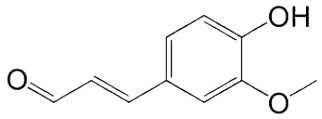


[**294**] 2-Hydroxy-3-(4-hydroxy-3-methoxyphenyl)-3-methoxypropyl-3-(4-hydroxylphenyl) propanoate

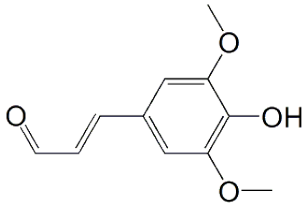
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



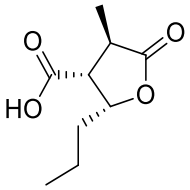
[**295**] Coniferyl alcohol



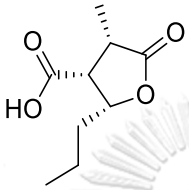
[296] (*E*)-Coniferyl aldehyde



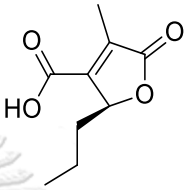
[**297**] Sinapicaldehyde



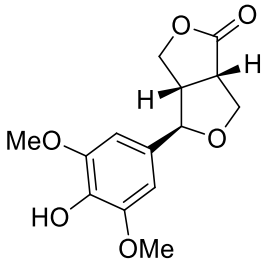
[**298**] Decumbic acid A



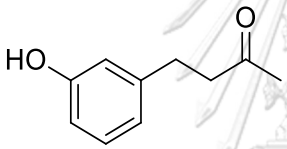
[**299**] Decumbic acid B



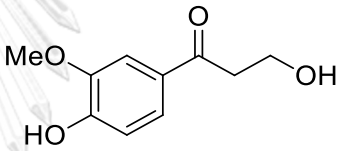
[**300**] (-)-Decumbic acid



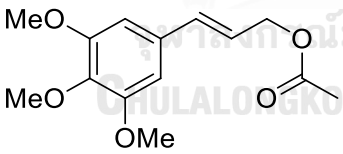
[**301**] (+)-Dendrolactone



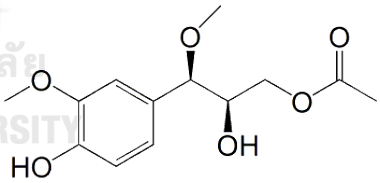
[**302**] 4-(3-Hydroxyphenyl)-2-butanone



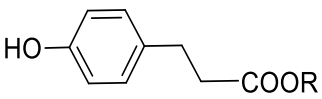
[**303**] 3-Hydroxy-1-(3-methoxy-4-hydroxyphenyl)-propan-1-one



[**304**] 3′,4′,5′-Trimethoxy cinnamyl acetate

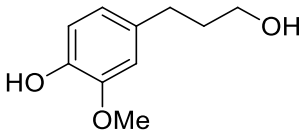


[**305**] Alatusol A



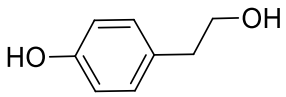
[**306**] *p*-Hydroxyphenyl propionic methyl ester R = CH_3

[**307**] Phloretic acid R = OH

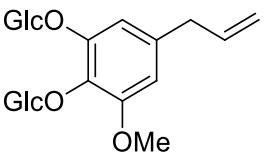


[**308**] Dihydroconiferyl alcohol

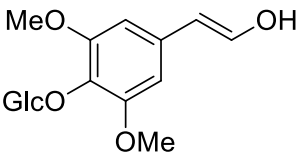
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



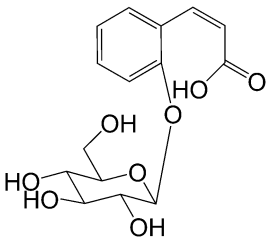
[**309**] Salidrosol



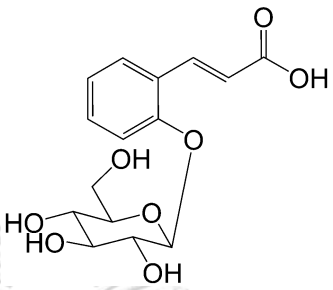
[**310**] Shashenoside I



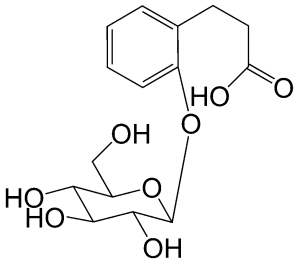
[**311**] Syringin



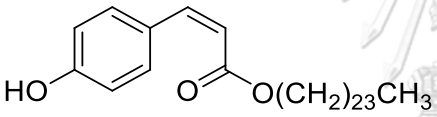
[**312**] *cis*-Melilotoside



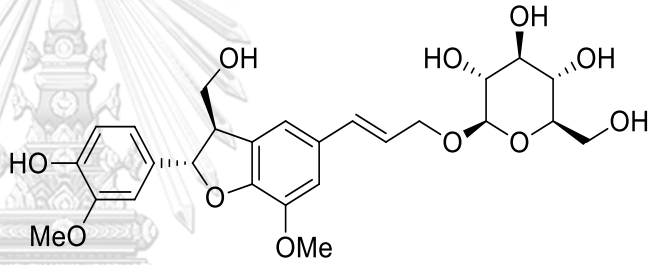
[**313**] *trans*-Melilotoside



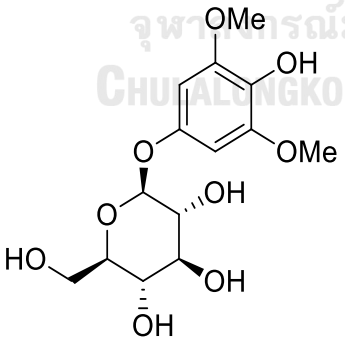
[**314**] Dihydromelilotoside



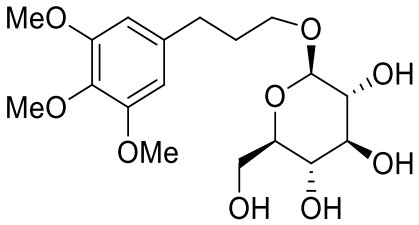
[**315**] Tetracosyl (*Z*)-*p*-coumarate



[**316**] (7*S*,8*R*)-Dehydrodiconiferyl alcohol 9′-β-D-glucopyranoside

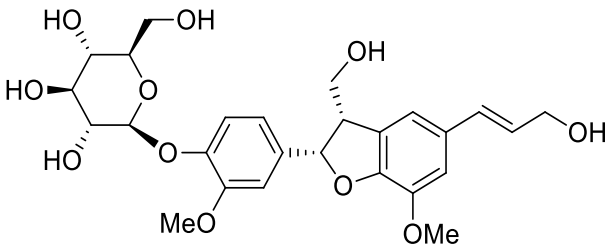


[**317**] Koaburaside

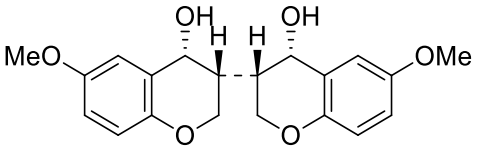


[**318**] Juniperoside

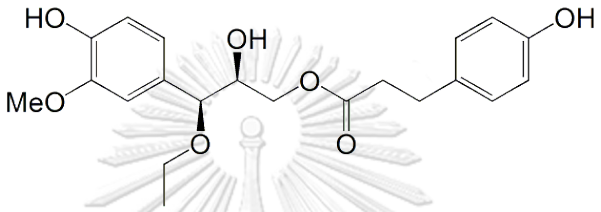
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



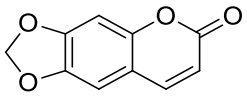
[**319**] Dehydrodiconiferyl alcohol-4-β-D-glucoside



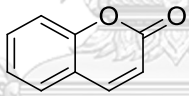
[**320**] (3*R*,3′*S*,4*R*,4′*S*)-3,3′,4,4′-Tetrahydro-6,6′-dimethoxy[3,3′-bi-2*H*-benzopyran]-4,4′-diol



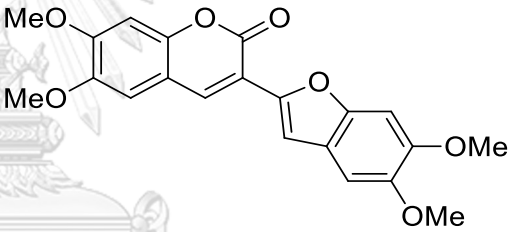
[**321**] *threo*-7-*O*-Ethyl-9-*O*-(4-hydroxyphenyl) propionyl-guaiacylglycerol



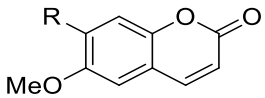
[**322**] Ayapin



[**323**] Coumarin

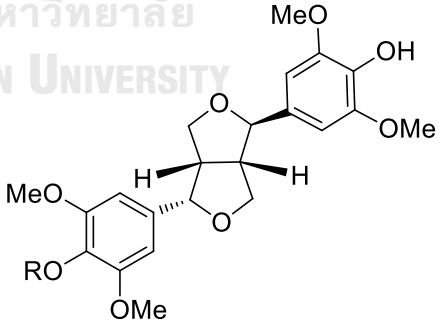


[**324**] Denthyrsin



[**325**] Scoparone R = OMe

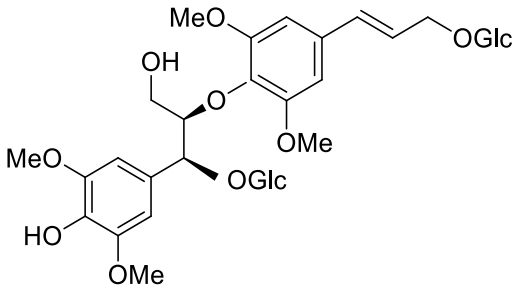
[**326**] Scopoletin R = OH



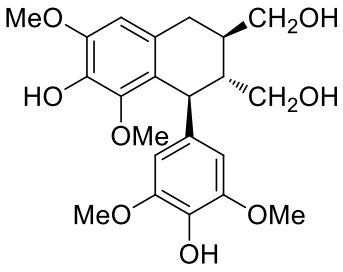
[**327**] Episyringaresinol R = H

[**328**] Episyringaresinol 4″-*O*-β-D-glucopyranoside R = β-D-glucose

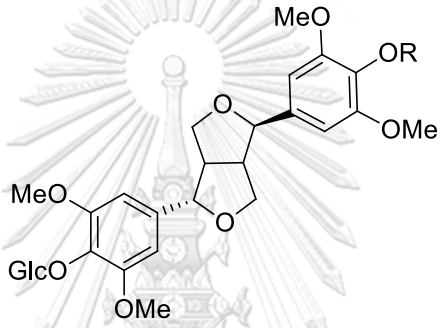
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



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

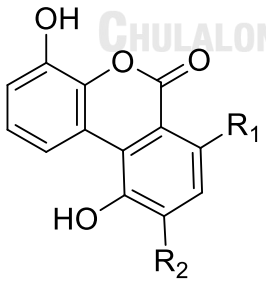


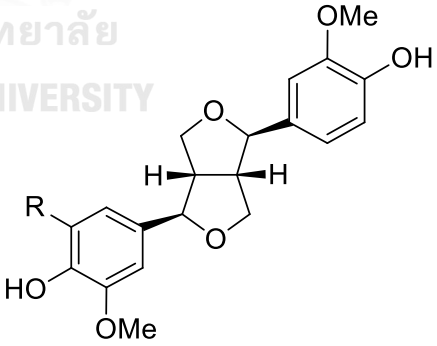
[**330**] Lyoniresinol



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

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





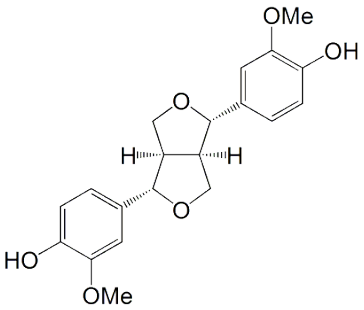
[**333**] Dendrocoumarin R_1 = H R_2 = OH

[**334**] Itolide A R_1 = OH R_2 = H

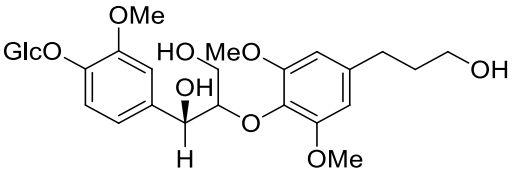
[**335**] (-)-Medioresinol R = OMe

[**336**] (-)-Pinoresinol R = H

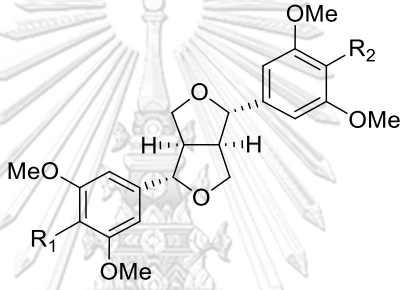
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



[**337**] (+)-Pinoresinol

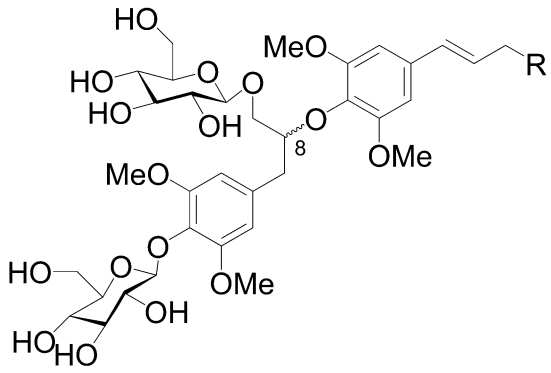


[**338**] *erythro*-1-(4-*O*-β-D-Glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol



	R_1	R_2
[**339**] Syringaresinol	OH	OH
[**340**] Acanthoside B	OGlc	OH
[**341**] Liriodendrin	OGlc	OGlc

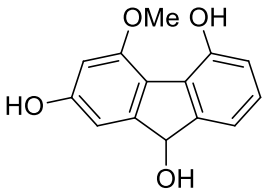
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



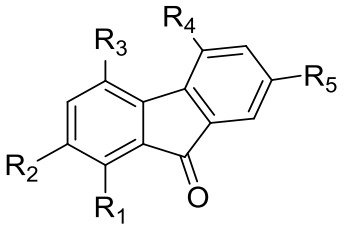
[**342**] (-)-(8*R*,7′*E*)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-*O*-β-D-glucopyranoside R = OH; 8*R*

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

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

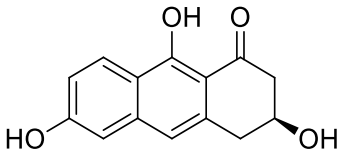


[**345**] Denchrysan B

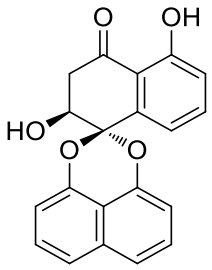


	R_1	R_2	R_3	R_4	R_5
[**346**] Denchrysan A	H	OH	OH	OMe	OH
[**347**] Dendroflorin	OH	OH	H	OH	OMe
[**348**] Dengibsin	H	OH	OMe	OH	H
[**349**] Nobilone	H	OH	H	OMe	OH
[**350**] 1,4,5-Trihydroxy-7-methoxy-9*H*-fluoren-9-one	OH	H	OH	OH	OMe
[**351**] 2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone	OMe	OH	OH	OMe	OH

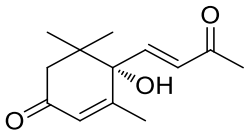
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



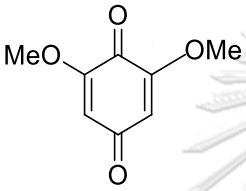
[**352**] 3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one



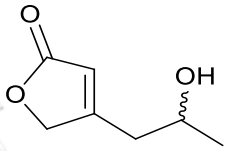
[**353**] Palmarumycin JC2



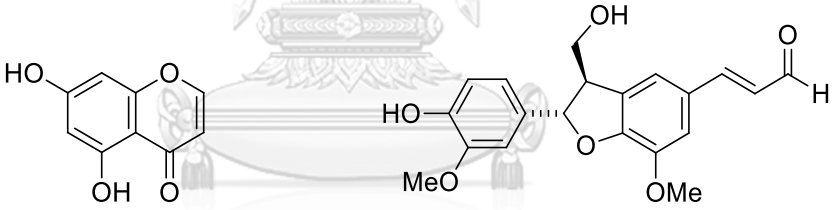
[**354**] Dehydrovomifoliol



[**355**] 2,6-Dimethoxybenzoquinone

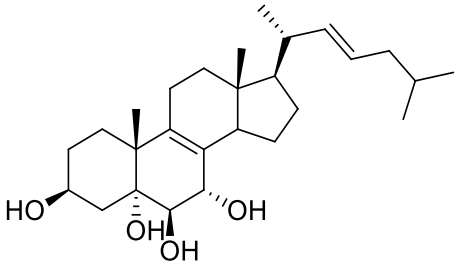


[**356**] 4-(2-Hydroxypropyl)-2(5*H*)-furanone

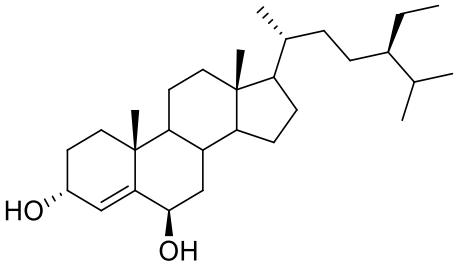


[**357**] 5,7-Dihydroxychromen-4-one

[**358**] Balanophonin

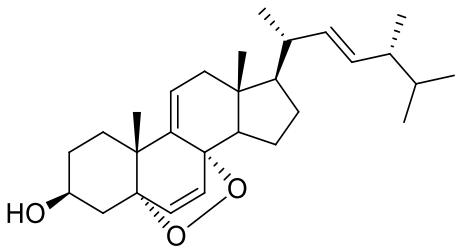


[**359**] Ergosta-8(9),22-diene-3,5,6,7-tetraol

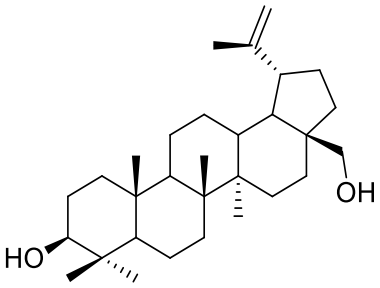


[**360**] Stigmast-4-en-3α,6β-diol

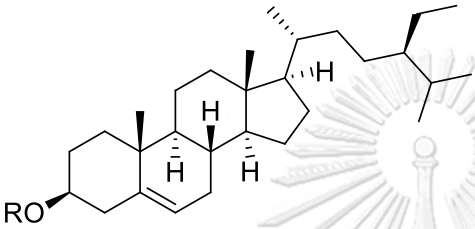
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



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

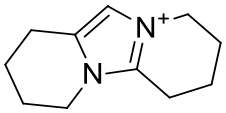


[**362**] Betulin

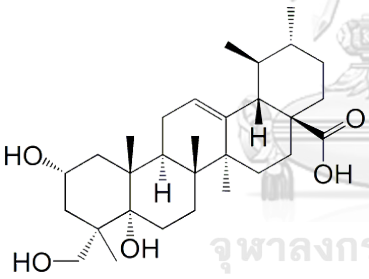


[**363**] β-Sitosterol R = H

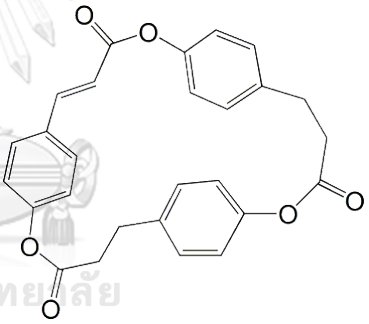
[**364**] Daucosterol R = Glc



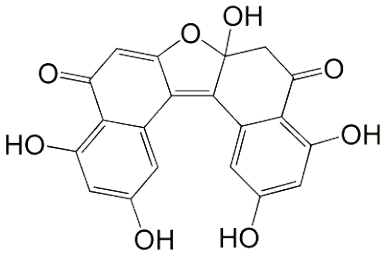
[**365**] Anosmine



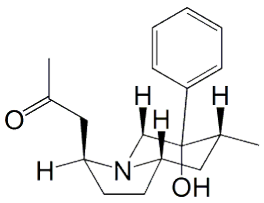
[**366**] Asiatic acid



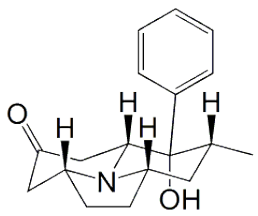
[**367**] Di-*p*-hydroxyphenylpropionic acidic-*p*-coumaric acid lactone



[**368**] RF-3192C

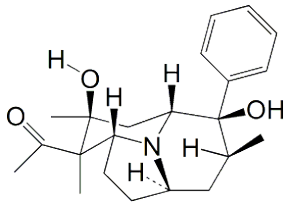


[**369**] Crepidatumine C

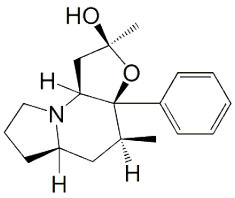


[**370**] Crepidatumine D

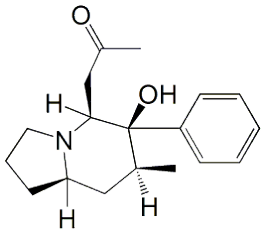
Figure 5 Structures of miscellaneous compounds from *Dendrobium* (continued)



[**371**] Crepidine



[**372**] Isocrepidamine



[**373**] Crepidamine

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

2. Free radical scavenging activities of *Dendrobium* species

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

To seek the radical scavengers from *D. aurantiacum* var. *denneanum*, a bio-guided fractionation strategy was applied in Yang et al. (2007). The *n*-butanol part manifested the highest DPPH radical scavenging activity. Subsequently, the *n*-butanol extract was further isolated by chromatographic procedures to give *cis*-melilotoside [**312**], *trans*-melilotoside [**313**], and dihydromelilotoside [**314**] with IC_{50} of 280, 135, and 102 μg/mL for DPPH assay, respectively. In the preliminary study of Zhang et al. (2007c), EtOAc-soluble fraction, showed relevant DPPH scavenging activity, was separated to yield ten compounds. Of these, crepidatin [**8**], chrysotoxine [**7**], moscatilin [**21**], and dendroflorin [**347**] exhibited the activity higher than vitamin C in both DPPH and peroxyl radical scavenging tests. New bibenzyl derivatives were isolated from *D. candidum* in the studies of Li et al. (2009b); Li et al. (2009c); Li et al. (2014b). Four of these were potent DPPH radical scavengers including dendrocandins E [**38**], H [**41**], I [**47**], and P [**54**] with IC_{50} of 15.6, 19.8, 21.3, and 22.3 μM, respectively. *D. draconis*, which has been used as a blood tonic, was extracted, isolated, and studied for the antioxidant activity in Sritularak, Anuwat and Likhitwitayawuid (2011). The result showed the effective DPPH radical scavenging property of 7-methoxy-9,10-dihydrophenanthrene-2,4,5-triol [**125**] with IC_{50} of 10.2 μM. Moscatilin [**21**], syringaresinol [**339**], 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**25**], and ferulic acid [**289**] isolated from *D. secundum* were reported as appreciable DPPH radical scavengers with IC_{50} of 5.14, 11.38, 15.87, and 37.52 μM in Sritularak, Duangrak and Likhitwitayawuid (2011), respectively. To evaluate the efficacy of *D. aphyllum* in clinical use, Yang et al. (2015) examined chemical components from *D. aphyllum* and assessed their antioxidant activity. Out of the tested compounds, aphyllone B [**157**] significantly scavenged DPPH free radical by 87.97% at 100 μg/mL. Recently, the results of Ma et al. (2019b) indicated that crepidatin [**8**], moscatilin [**21**], 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**25**], gigantol [**16**], tristin [**26**], dihydroconiferyl dihydro-*p*-

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

Table 5 Radical scavenging compounds from *Dendrobium*

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

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

* 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, **oxygen radical absorbance capacity (ORAC) assay, ***significantly decreased ROS in H_2O_2-stimulated RAW264.7 cells and improved activity of antioxidant enzymes.

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

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

CHAPTER III

EXPERIMENTAL

1. Source of plant materials

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

2. Extraction and isolation

2.1 General techniques

2.1.1 Thin-layer chromatography (TLC)

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

2.1.2 Adsorption column chromatography

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

2.1.3 Size-exclusion chromatography

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

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

2.2 Extraction

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

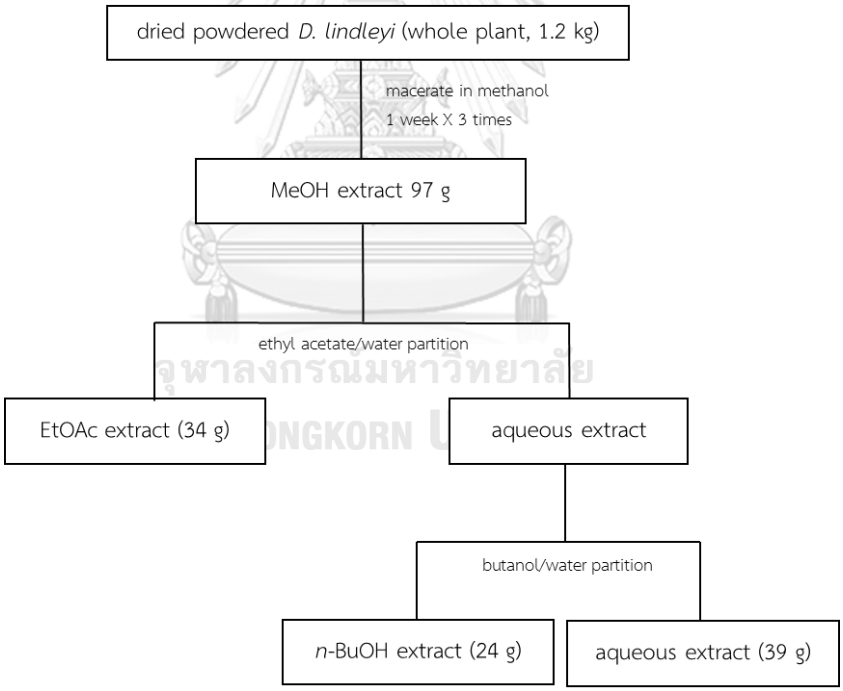


Figure 6 Extraction of *Dendrobium lindleyi*

2.3 Isolation

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

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

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

2.3.2 Isolation of chrysotoxine, gigantol, and cypripedin

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

2.3.3 Isolation of moscatilin

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

2.4 Solvents

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

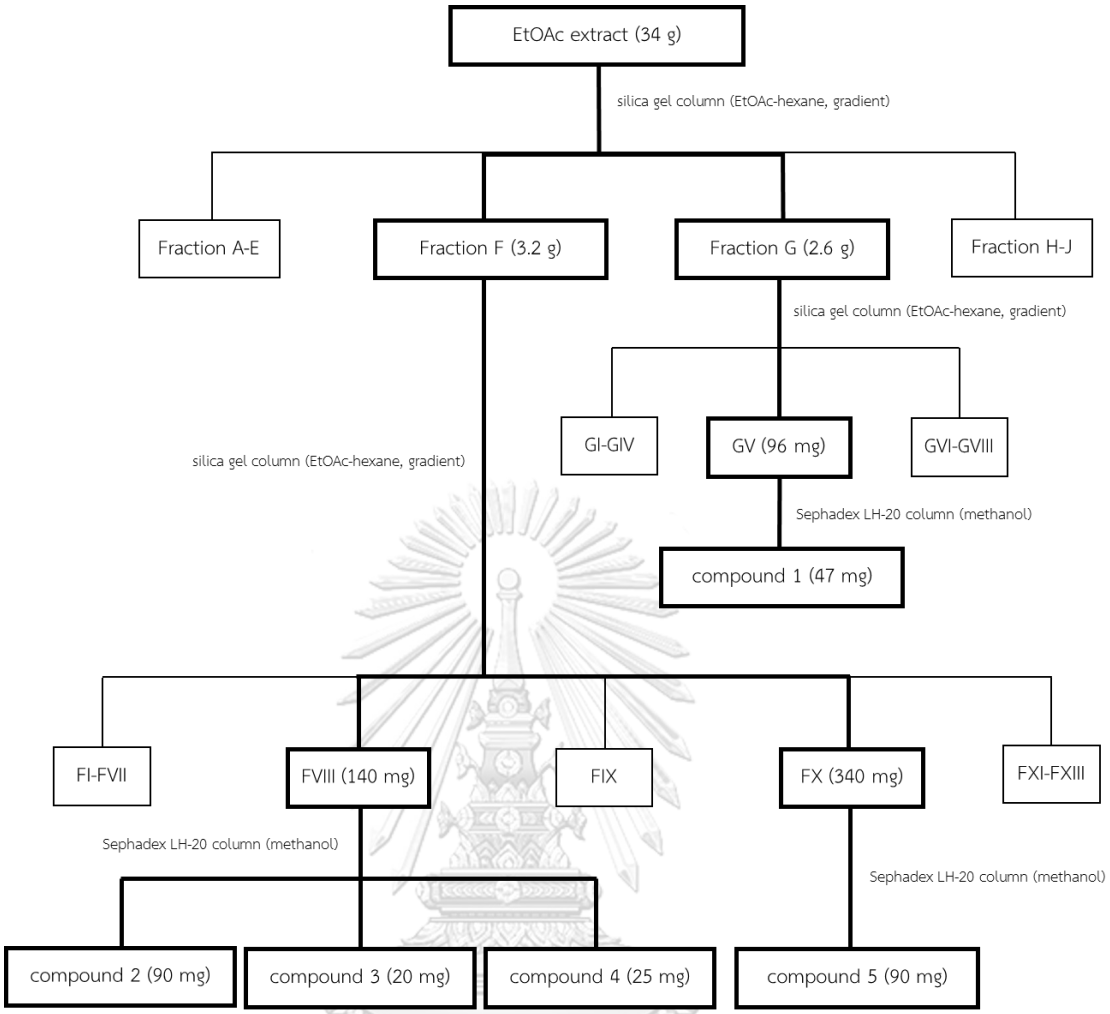


Figure 7 Isolation of the EtOAc extract from *Dendrobium lindleyi*

3. Identification of isolated compounds

3.1 General techniques

3.1.1 Mass spectrometry (MS)

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

3.1.2 Nuclear magnetic resonance (NMR) spectroscopy

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

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

3.1.3 Ultraviolet (UV) spectroscopy

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

3.1.4 Infrared (IR) spectroscopy

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

3.2 Physical and spectral data

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

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

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

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

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

^{1}H NMR: see Appendices A.4-A.6

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

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

3.2.2 compound 2 (chrysotoxine)

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

HR-ESI-MS: *m/z* 341.1366 $[M+Na]^+$ (calcd for $C_{18}H_{22}O_5Na$, 341.1365). (see Appendix B.1)

^{1}H NMR: see Appendix B.2

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

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

3.2.3 compound 3 (gigantol)

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

HR-ESI-MS: *m/z* 297.1111 $[M+Na]^+$ (calcd for $C_{16}H_{18}O_4Na$, 297.1103). (see Appendix C.1).

^{1}H NMR: see Appendix C.2

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

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

3.2.4 compound 4 (cypripedin)

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

HR-ESI-MS: *m/z* 307.0582 $[M+Na]^+$ (calcd. for $C_{16}H_{12}O_5Na$, 307.0582) (see Appendix D.1).

^{1}H NMR: see Appendix D.2

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

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

3.2.5 compound 5 (moscatilin)

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

HR-ESI-MS: *m/z* 327.1219 $[M+Na]^+$ (calcd for $C_{17}H_{20}O_5Na$, 327.1208) (see Appendix E.1).

^{1}H NMR: see Appendix E.2

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

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

4. Free radical scavenging assay

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

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

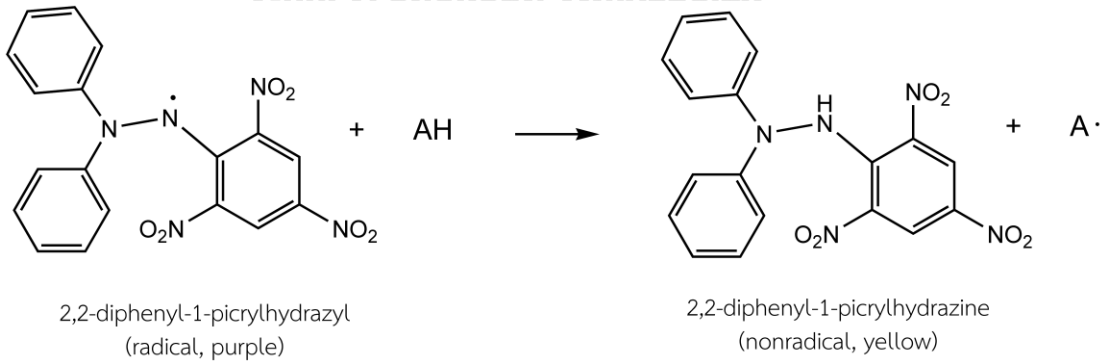


Figure 8 The reaction between DPPH and antioxidant (A)

4.1.1 Materials and instruments

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

4.1.2 DPPH radical scavenging method

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

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

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

4.2 Superoxide radical scavenging activity assay

Although the superoxide radical ($\bullet O_2^-$) is a common and less reactive radical generated in mitochondria (Phaniendra, Jestadi and Periyasamy, 2015), it causes the more reactive and dangerous ROS including hydroxyl radical (•OH) and singlet oxygen ($^1O_2$) (Alam, Bristi and Rafiquzzaman, 2013). In the assay, the riboflavin-light-NBT system was utilized (Beauchamp and Fridovich, 1971). In the presence of light, the riboflavin

is generally degraded to yield the superoxide radical ($\bullet O_2^-$) which then reacts to the NBT. Eventually, the purple-blue NBT formazan is produced. (Figure 9). The UV absorbance at 590 nm can be measured to determine the inhibition of formazan production which corresponds to the superoxide radical scavenging activity (Bagul et al., 2003).

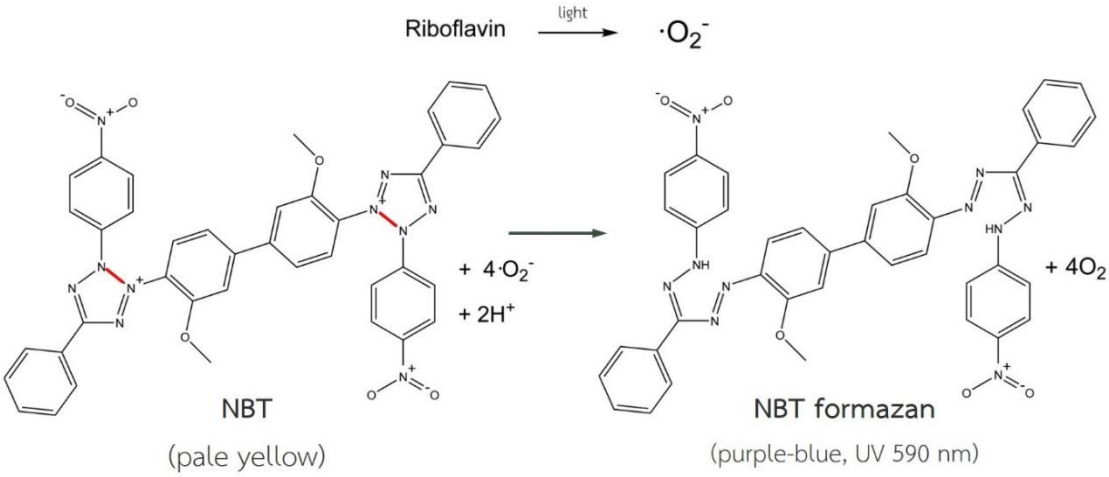


Figure 9 The reaction in riboflavin-light-NBT system

4.2.1 Materials and instruments

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

4.2.2 Superoxide radical scavenging activity method

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

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

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

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

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

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

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

4.3 Oxygen radical absorbance capacity (ORAC) assay

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

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

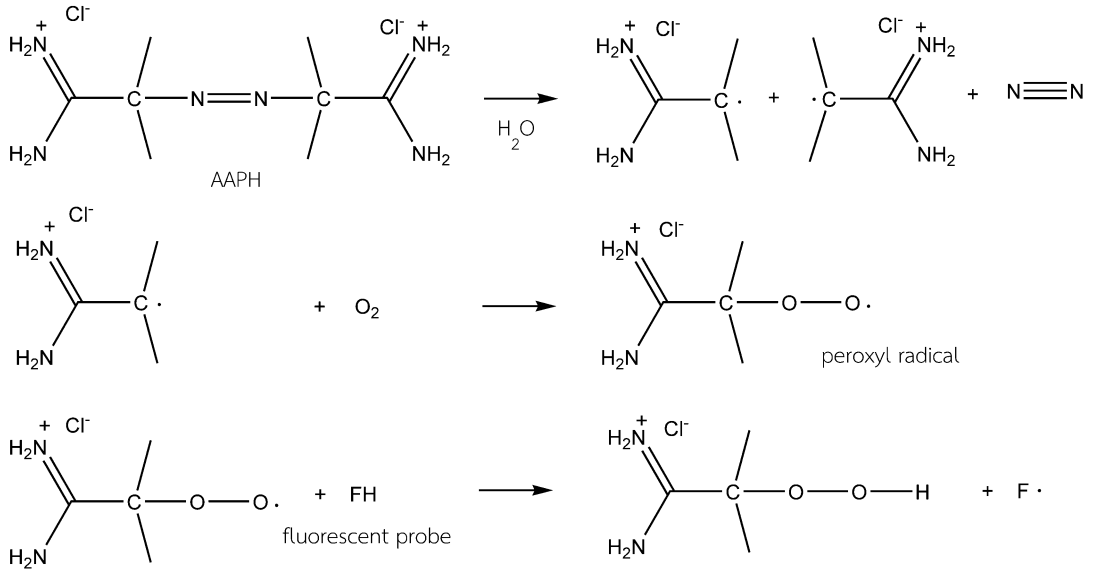


Figure 10 The production of peroxyl radical from AAPH

4.3.1 Materials and instruments

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

4.3.2 ORAC method

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

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

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

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

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

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

$$TE = \frac{\text{equivalent Trolox concentration (in µM) x MW}}{\text{sample conc (in µg/mL) x 1000}} \quad \text{(equation 3)}$$

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

CHAPTER IV
RESULTS AND DISCUSSION

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

1. Identification of isolated compounds

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

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

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

The UV absorption peaks at 220, 229 and 285 nm (Appendix A.3). were indicative of a bibenzyl nucleus (Zhang et al., 2007c). The ^{1}H NMR spectrum revealed the presence of five aromatic protons at δ_H 6.26-6.82 ppm and three methoxy groups at δ_H 3.85 (3H, *s*, MeO-3), 3.87 (3H, s, MeO-3′) and 3.88 (3H, *s*, MeO-4′). The ^{13}C NMR spectrum displayed signals for twelve aromatic (δ_C 103.5-148.7), three methoxy (δ_C 56.1, 55.9, and 55.8) and two methylene (δ_C 37.6 and 38.0) carbons. In support of the bibenzyl skeleton, the HSQC spectrum showed cross peaks at δ_C 38.0/δ_H 2.81 (C-α/H_2-α) and δ_C 37.6/δ_H 2.84 (C-α′/ (H_2-α′).

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

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

The HBMC spectrum was further analyzed to obtain NMR assignments for the other quaternary carbons. For example, the peak at δ_C 133.7 was assigned to C-1 from its HMBC correlations to H_2-α (δ_H 2.81) and H_2-α′ (δ_H 2.84). The carbon at δ_C 146.6 was assigned as C-3 from its HMBC 2-bond coupling with H-2 (δ_H 6.26) and 3-bond couplings with HO-4 (δ_H 5.25) and MeO-3 (δ_H 3.85) protons. All of the HMBC correlations of **1** are summarized in Table 9 and the key HMBC are shown in Figure 11.

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

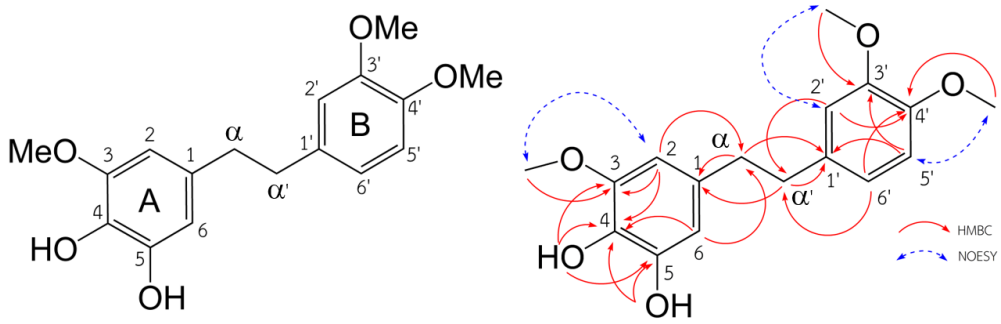


Figure 11 Chemical structure of **compound 1** [**374**] and key correlations of HMBC and NOESY

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

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

*Two-bond coupling

1.2 Identification of compound 2 (chrysotoxine)

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

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

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

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

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

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

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

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

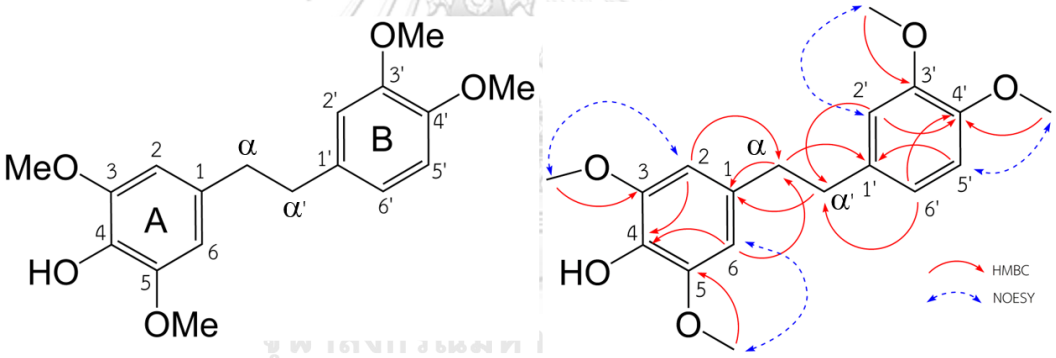


Figure 12 Chemical structure of **compound 2** [**7**] and key correlations of HMBC and NOESY

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

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

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

1.3 Identification of compound 3 (gigantol)

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

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

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

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

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

The HMBC spectral data was applied to define ^{13}C NMR. The carbon at δ_C 144.7 was indicated as C-1 because of its correlations with H_2-α′ (δ_H 2.78). The carbon at δ_C 161.0 was identified as C-3 due to its correlations with MeO-3 (δ_H 3.71), H-2 (δ_H 6.30), and H-4 (δ_H 6.24). The carbon at δ_C 158.4 was defined as C-5 because of its relationship with H-4 (δ_H 6.24). The carbon at δ_C 133.2 was specified as C-1′ based on its correlations with H-5′ (δ_H 6.73) and H_2-α (δ_H 2.78). The carbon at δ_C 147.2 was identified as C-3′ because it related to MeO-3′ (δ_H 3.80) and H-5′ (δ_H 6.73). The peak at δ_C 144.3 was defined as C-4′ due to its correlations with H-2′ (δ_H 6.81) and H-6′ (δ_H 6.66). These HMBC correlations were shown in Figure 13.

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

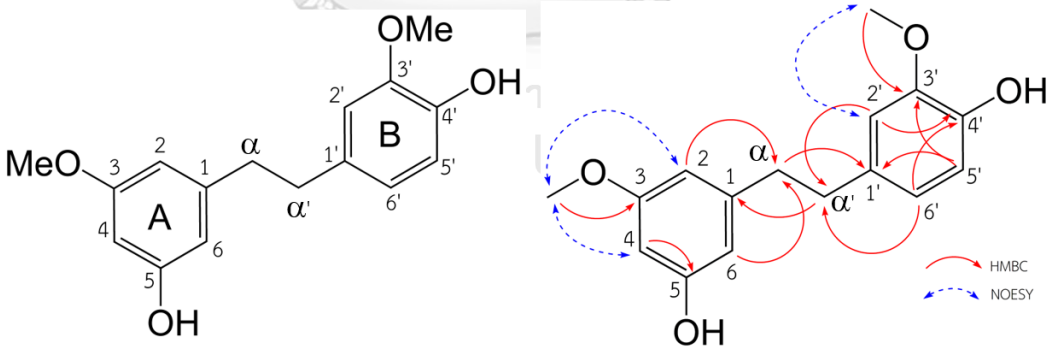


Figure 13 Chemical structure of **compound 3** [**16**], and key correlations of HMBC and NOESY

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

Position	Compound 3		Gigantol[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	144.7	-	145.4
2	6.30 (1H, *t*, 2.1)	108.0	6.22 (1H, *t*, 2.0)	108.8
3	-	161.0	-	159.1
4	6.24 (1H, *t*, 2.1)	98.8	6.28 (1H, *t*, 2.0)	99.6
5	-	158.4	-	161.7
6	6.31 (1H, *t*, 2.1)	105.4	6.30 (1H, *t*, 2.0)	106.2
α	2.78 (4H, *s*)	38.2	2.78 (4H, *m*)	39.0
α′	2.78 (4H, *s*)	37.1	2.78 (4H, *m*)	37.9
1′	-	133.2	-	134.0
2′	6.81 (1H, *d*, 1.8)	112.0	6.79 (1H, *d*, 1.5)	115.4
3′	-	147.2	-	147.9
4′	-	144.3	-	145.1
5′	6.73 (1H, *d*, 8.1)	114.7	6.69 (1H, *d*, 8.0)	112.8
6′	6.66 (1H, *dd*, 8.1, 1.8)	120.7	6.64 (1H, *dd*, 8.0, 1.5)	121.5
MeO-3	3.71 (3H, *s*)	54.4	3.69 (3H, *s*)	55.2
MeO-3′	3.80 (3H, *s*)	55.3	3.78 (3H, *s*)	56.0

[a] (Klongkumnuankarn et al., 2015)

1.4 Identification of compound 4 (cypripedin)

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

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

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

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

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

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

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

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

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

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

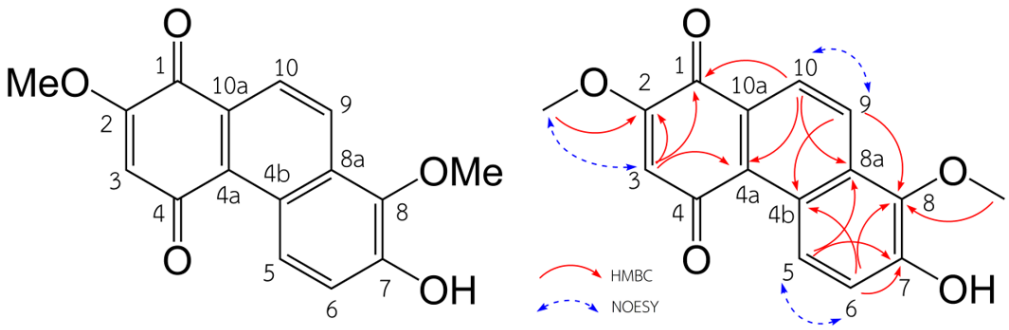


Figure 14 Chemical structure of **compound 4** [**92**] and key correlations of HMBC and NOESY

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

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

[a] (Wattanathamsan et al., 2018)

1.5 Identification of compound 5 (moscatilin)

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

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

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

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

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

The HMBC was used to defined ^{13}C NMR. The carbon at δ_C 132.4 was specified as C-1 because of its correlations with H-2, H-6 (δ_H 6.49), and H_2-α' (δ_H 2.80). The carbon at δ_C 147.7 was defined as C-3 and C-5 due to the correlations with H-2, H-6 (δ_H 6.49), MeO-3, and MeO-5 (δ_H 3.77). The carbon at δ_C 134.1 was identified as C-4 because it correlated with H-2, and H-6 (δ_H 6.49). The carbon at δ_C 133.4 was determined as C-1′ due to its relationships with H-5′ (δ_H 6.74) and H_2-α (δ_H 2.80). The peak at δ_C 147.2 was defined as C-3′ based on the correlations with MeO-3′ (δ_H 3.79) and H-5′ (δ_H 6.74). The peak at δ_C 144.7 was defined as C-4′ because it correlated with H-2′ (δ_H 6.79) and H-6′ (δ_H 6.65). The key HMBC correlations were shown in Figure 15.

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

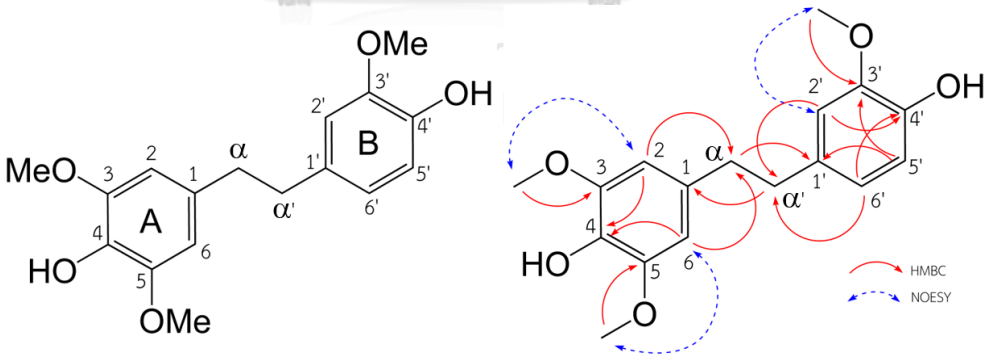


Figure 15 Chemical structure of **compound 5** [**21**] and key correlations of HMBC and NOESY

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

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

[a] (Klongkumnuankarn et al., 2015)

2. Free radical scavenging activities

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

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

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

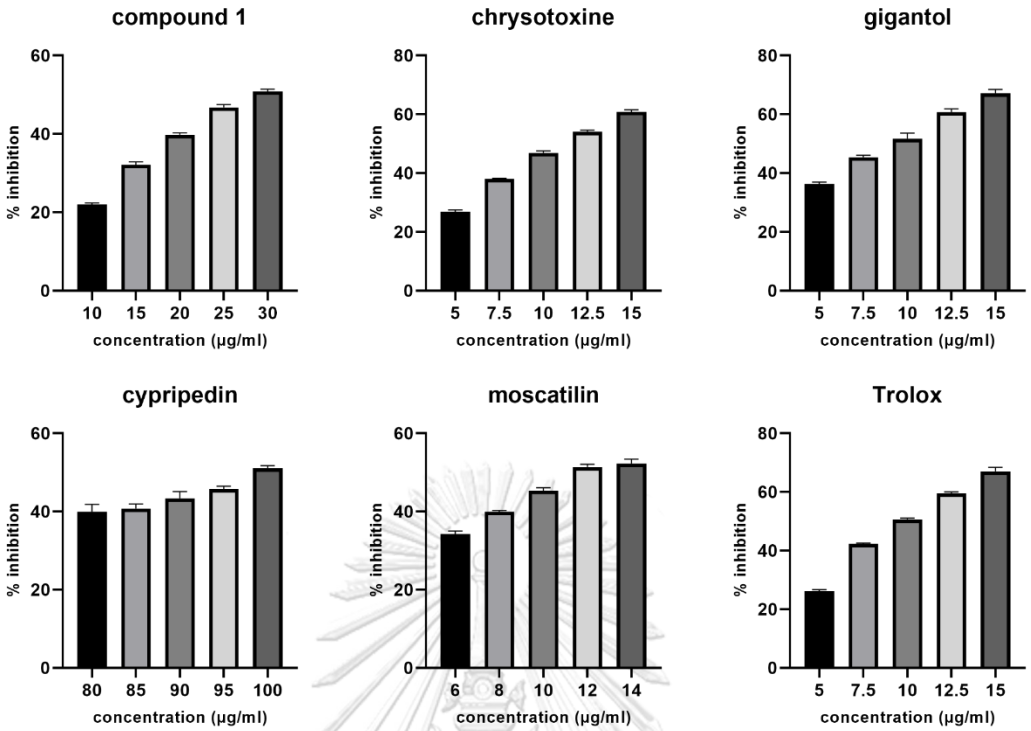


Figure 16 Concentration-dependent DPPH radical scavenging activity of **compound 1**, chrysotoxine, gigantol, cypripedin, moscatilin, and Trolox.

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

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

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

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

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

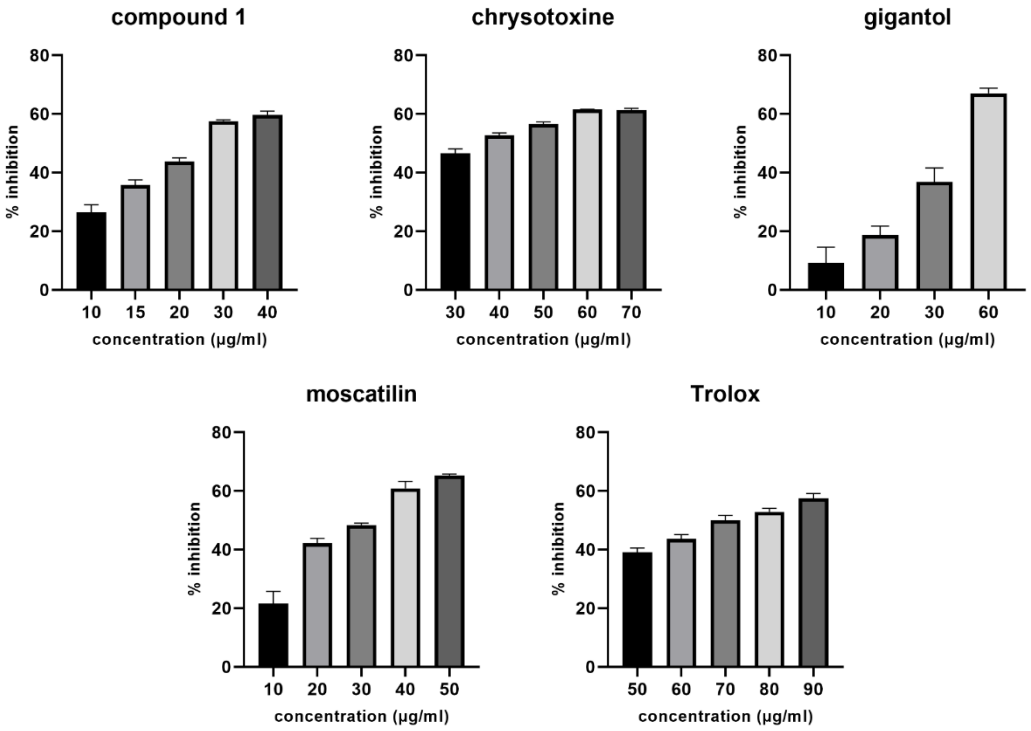


Figure 17 Concentration-dependent superoxide radical scavenging activity of **compound 1**, chrysotoxine, gigantol, moscatilin, and Trolox.

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

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

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

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

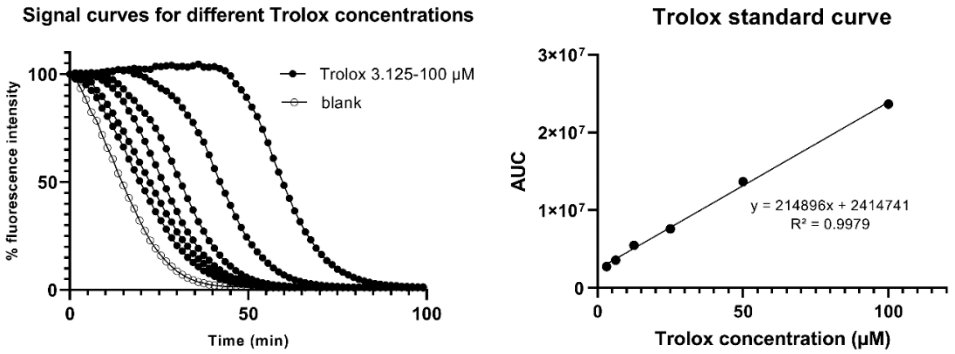


Figure 18 Signal curve for different Trolox concentrations (A) and Trolox standard curve (B)

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

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

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

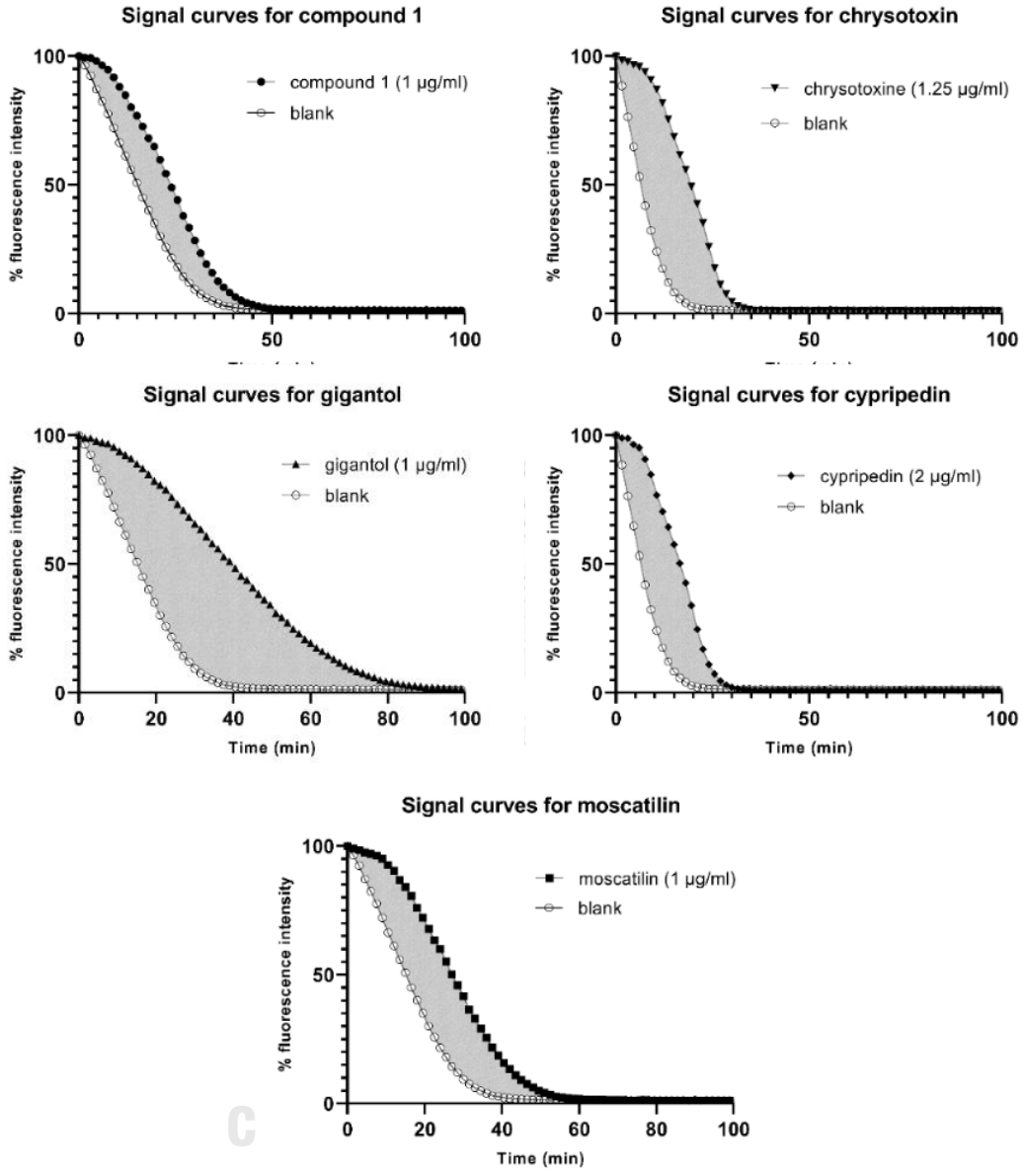


Figure 19 Signal curve for **compound 1**, chrysotoxine, gigantol, cypripedin, and moscatilin

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

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

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

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

CHAPTER V
CONCLUSION

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

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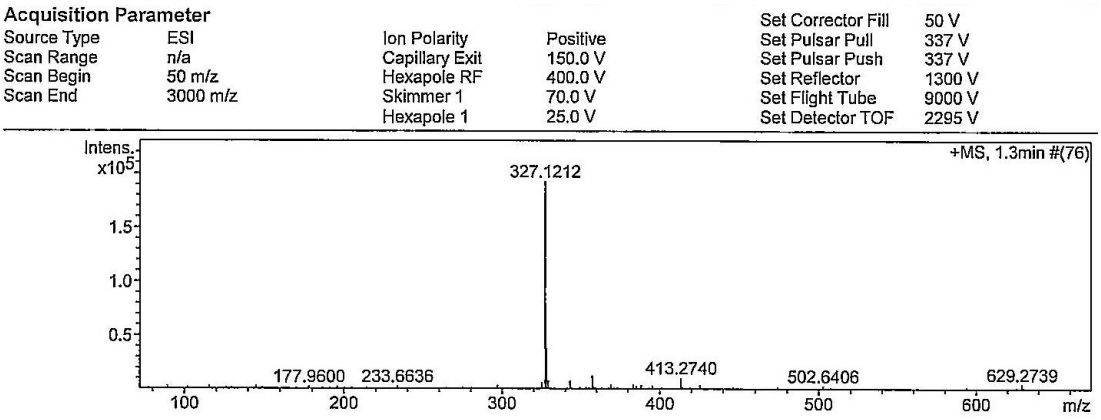
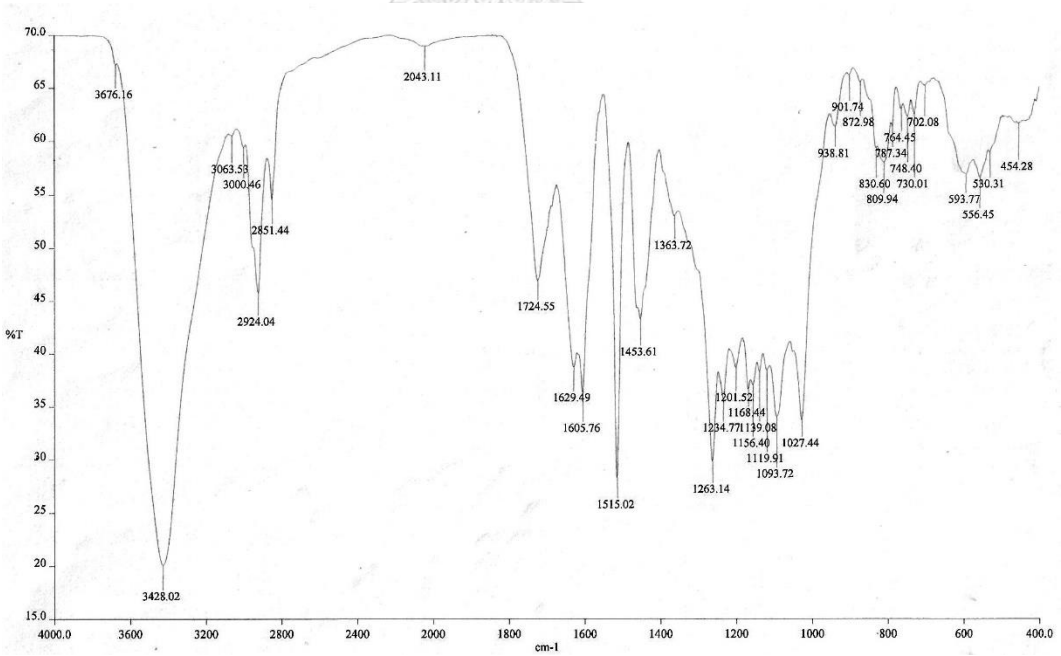
APPENDICES

Appendix A: The spectral data of compound 1

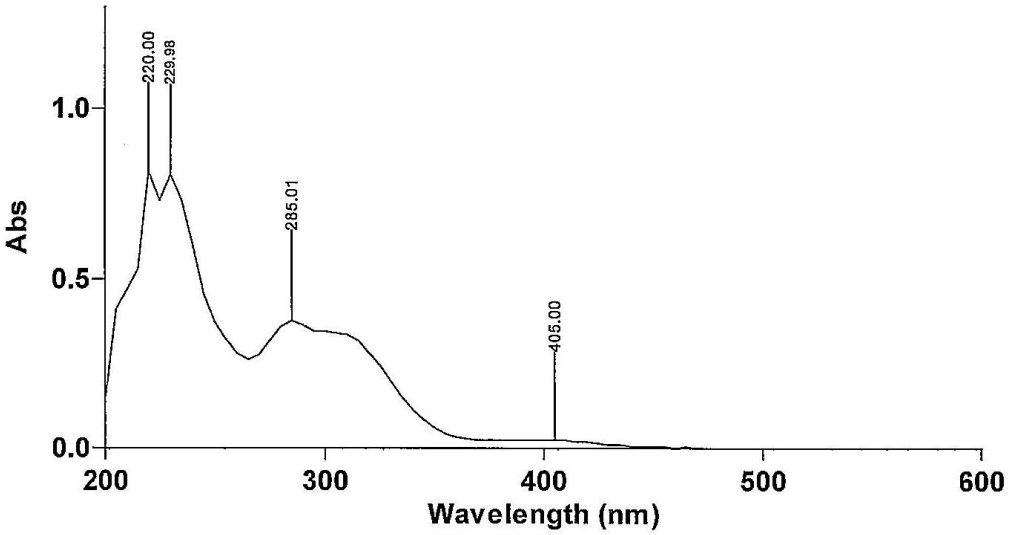
A.1 Mass spectrum of compound 1



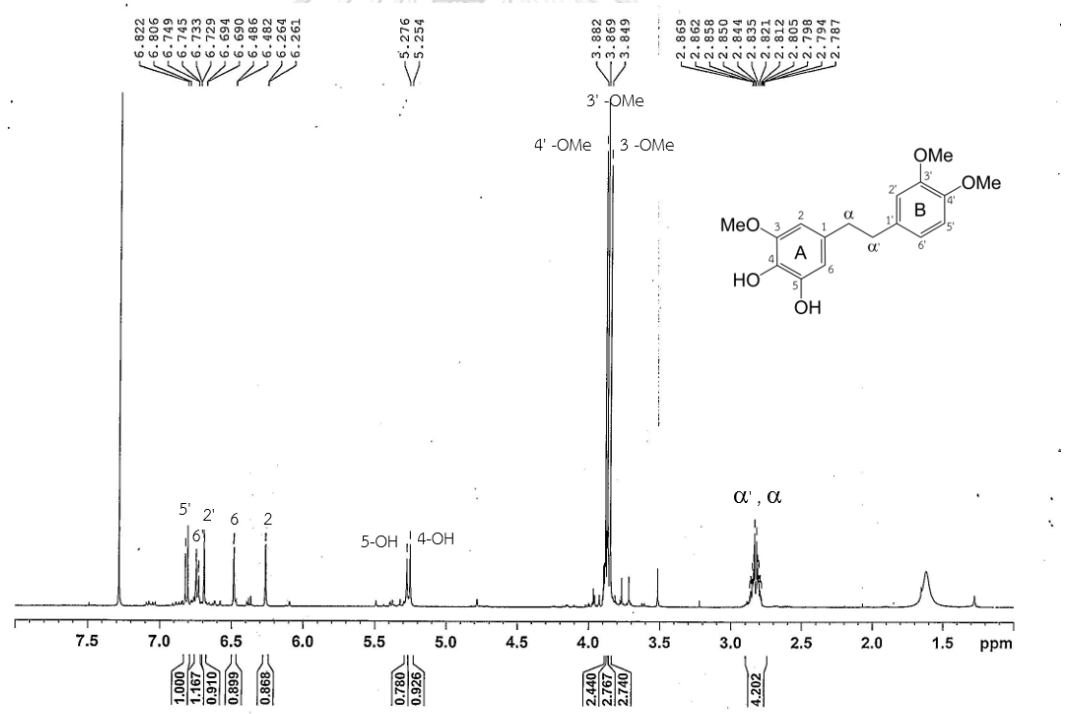
A.2 Infrared spectrum of compound 1



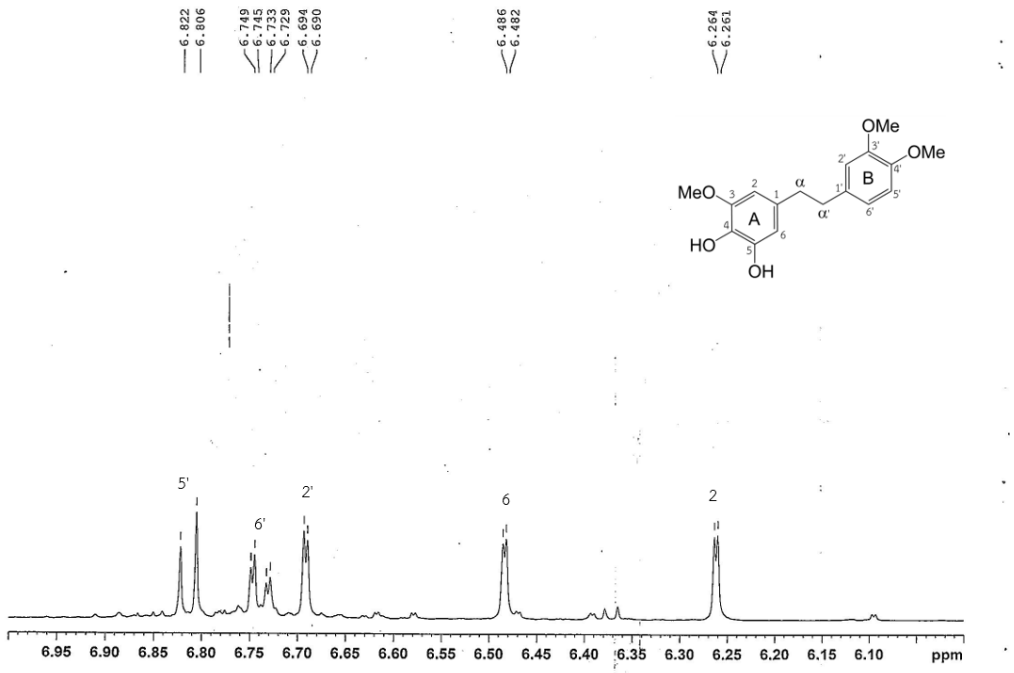
A.3 UV spectrum of compound 1



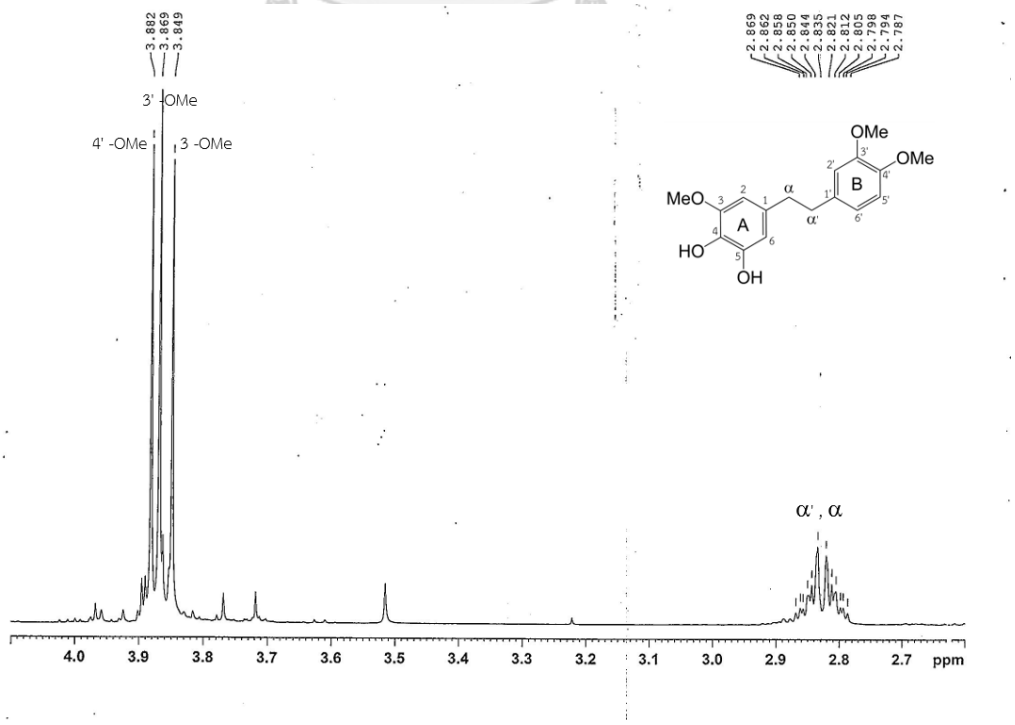
A.4 ^{1}H NMR (500 MHz) spectrum of compound 1 in $CDCl_3$



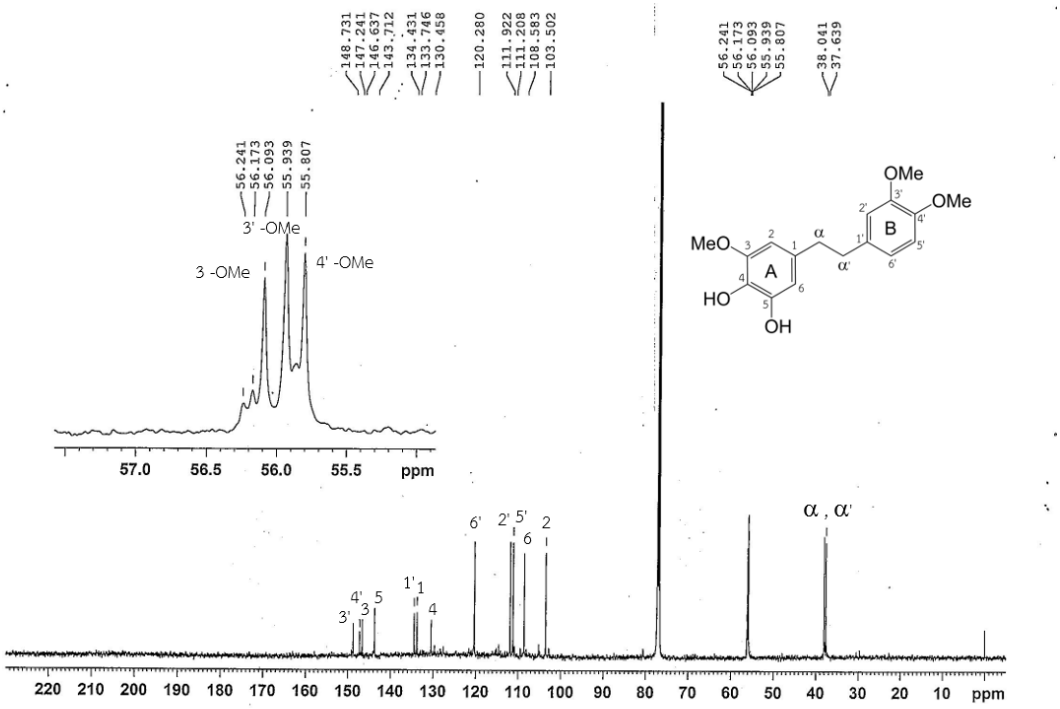
A.5 ^{1}H NMR (500 MHz) spectrum of compound 1 in $CDCl_3$ (expansion from δ_H 6.00-7.00)



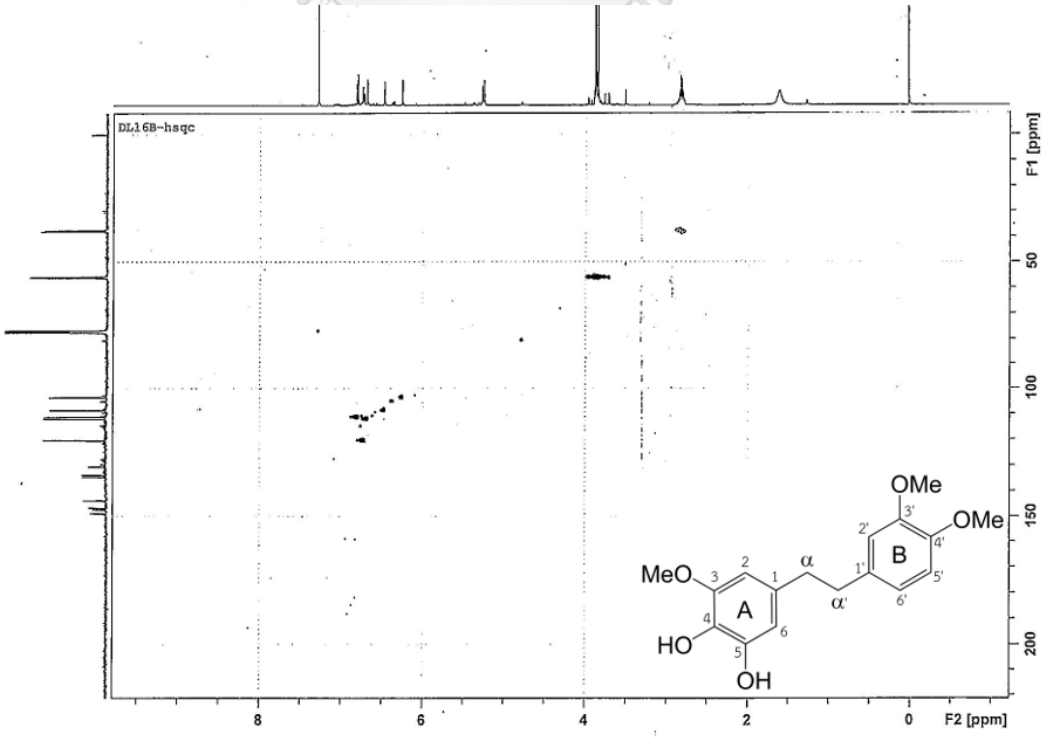
A.6 ^{1}H NMR (500 MHz) spectrum of compound 1 in $CDCl_3$ (expansion from δ_H 2.60-4.10)



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

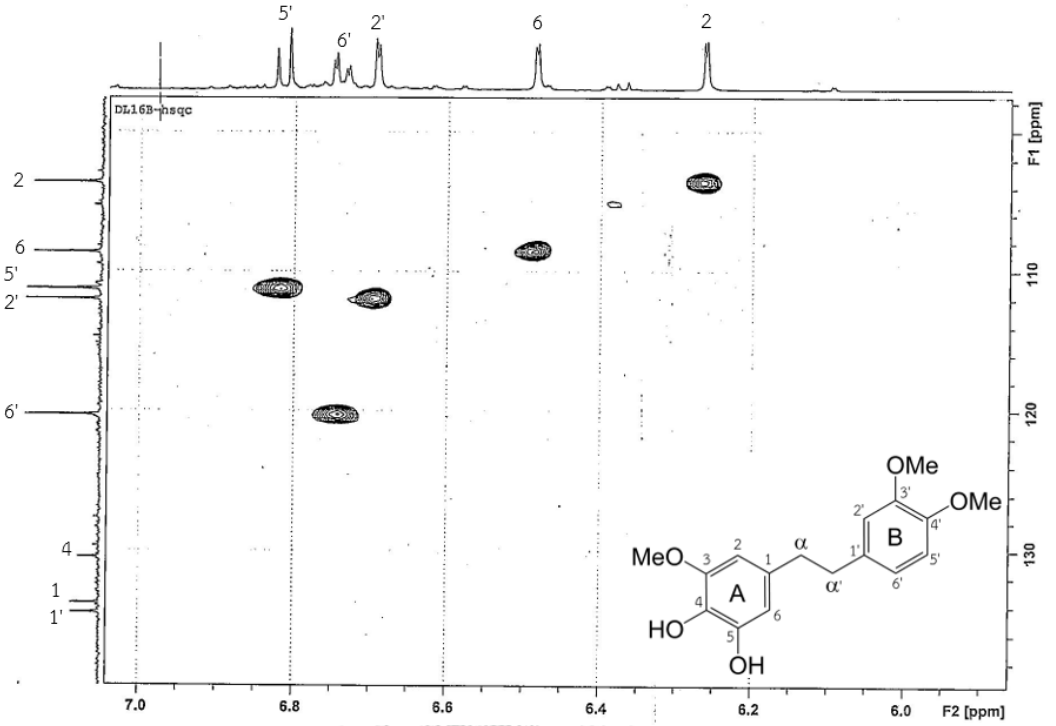


A.8 HSQC spectrum of compound 1 in $CDCl_3$



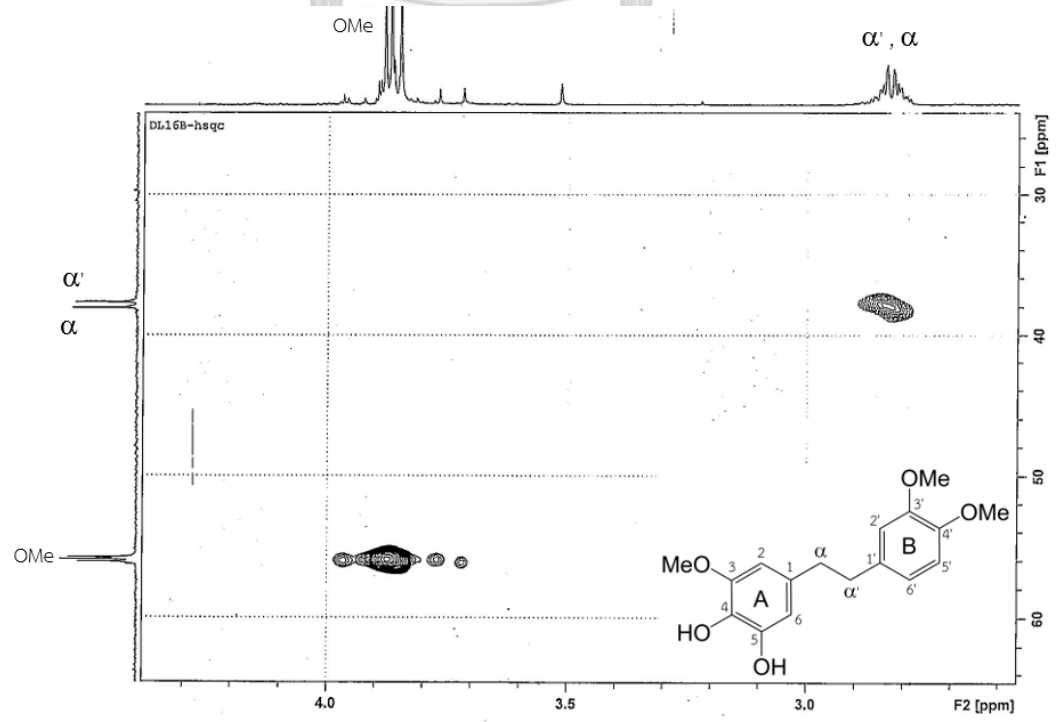
A.9 HSQC spectrum of compound 1 in $CDCl_3$

(expansion from δ_C 98.0-140.0 (F1) and δ_H 2.60-3.96 (F2))



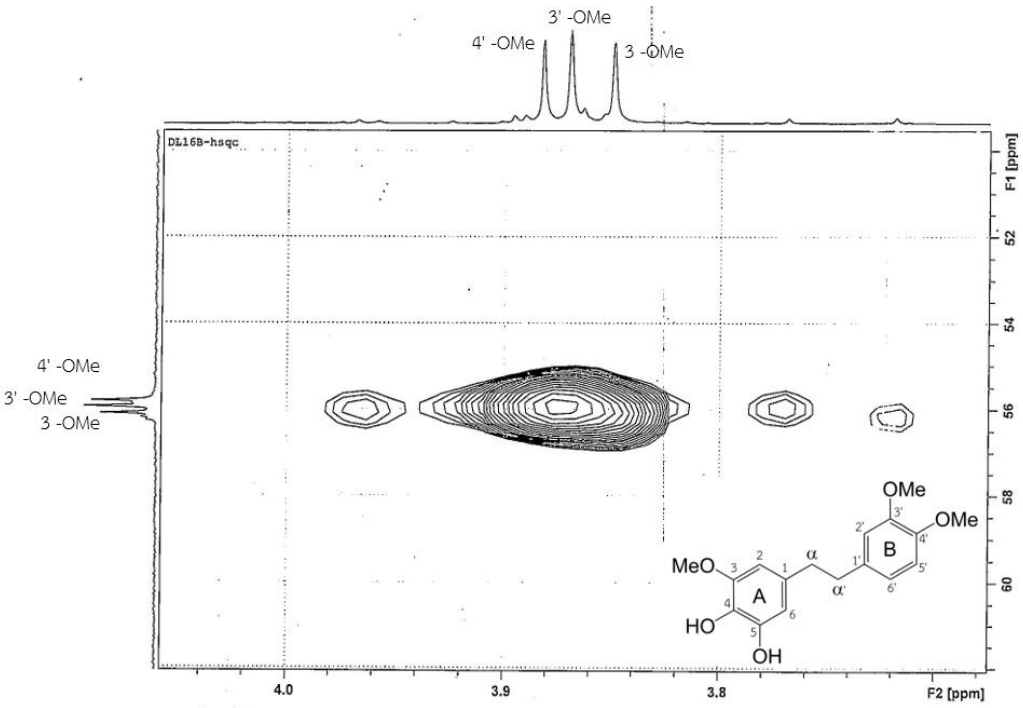
A.10 HSQC spectrum of compound 1 in $CDCl_3$

(expansion from δ_C 24.0-64.0 (F1) and δ_H 2.60-4.80 (F2))



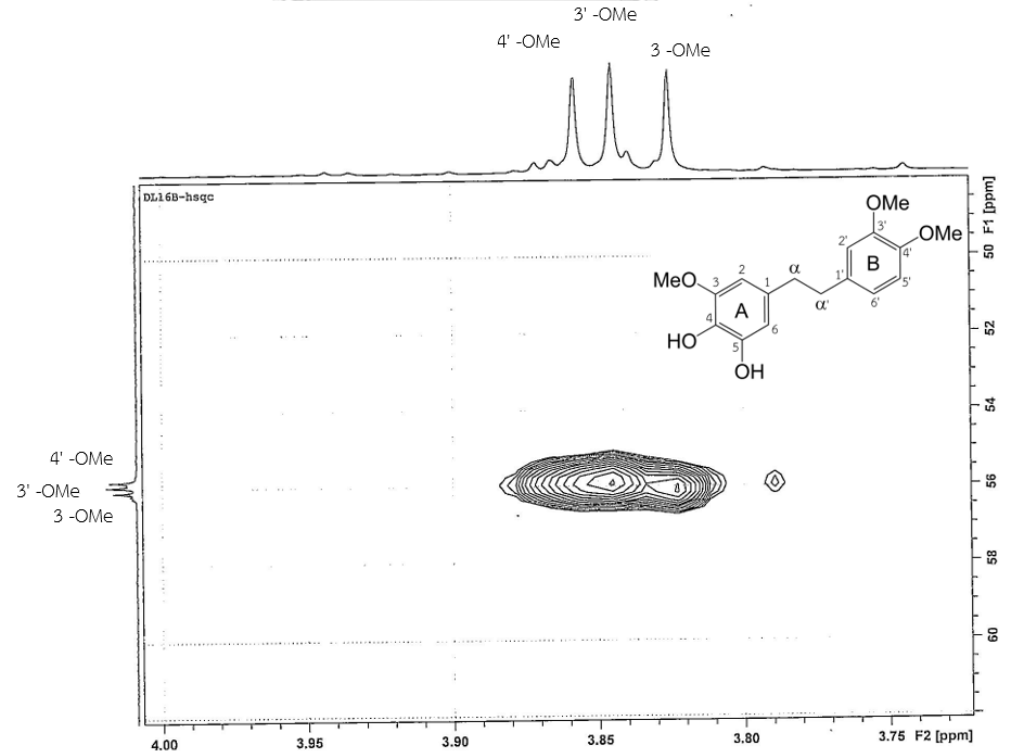
A.11 HSQC spectrum of compound 1 in $CDCl_3$

(expansion from δ_C 50.0-62.0 (F1) and δ_H 3.68-4.06 (F2))



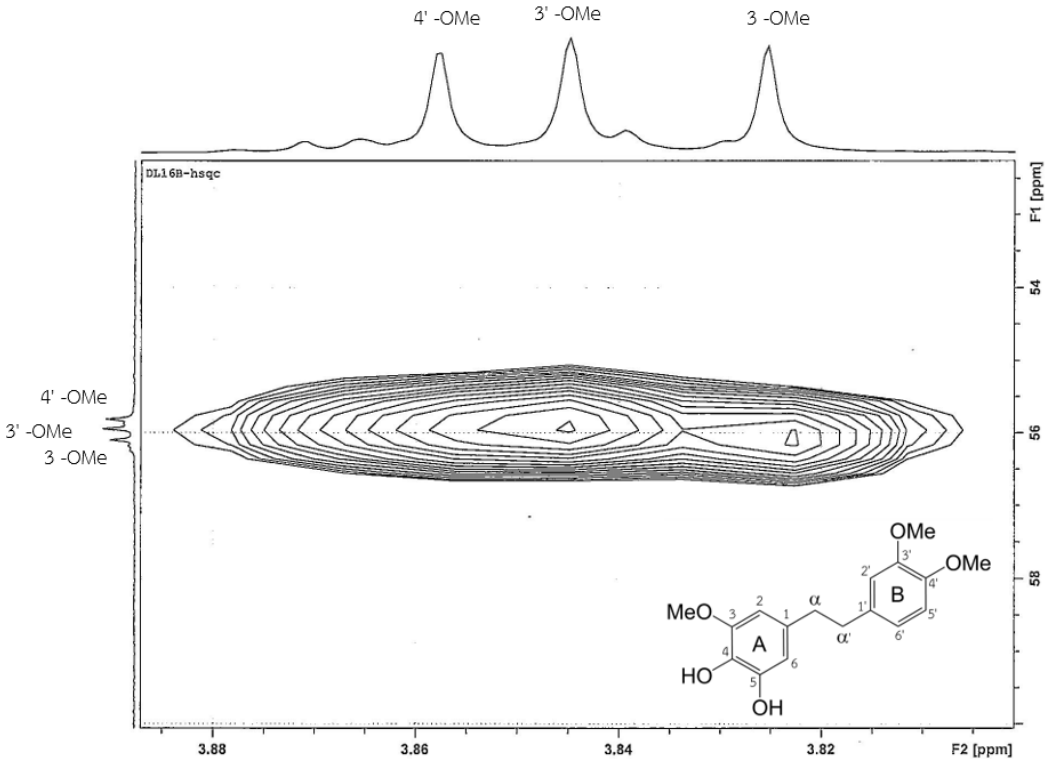
A.12 HSQC spectrum of compound 1 in $CDCl_3$

(expansion from δ_C 48.0-62.0 (F1) and δ_H 3.72-4.01 (F2))

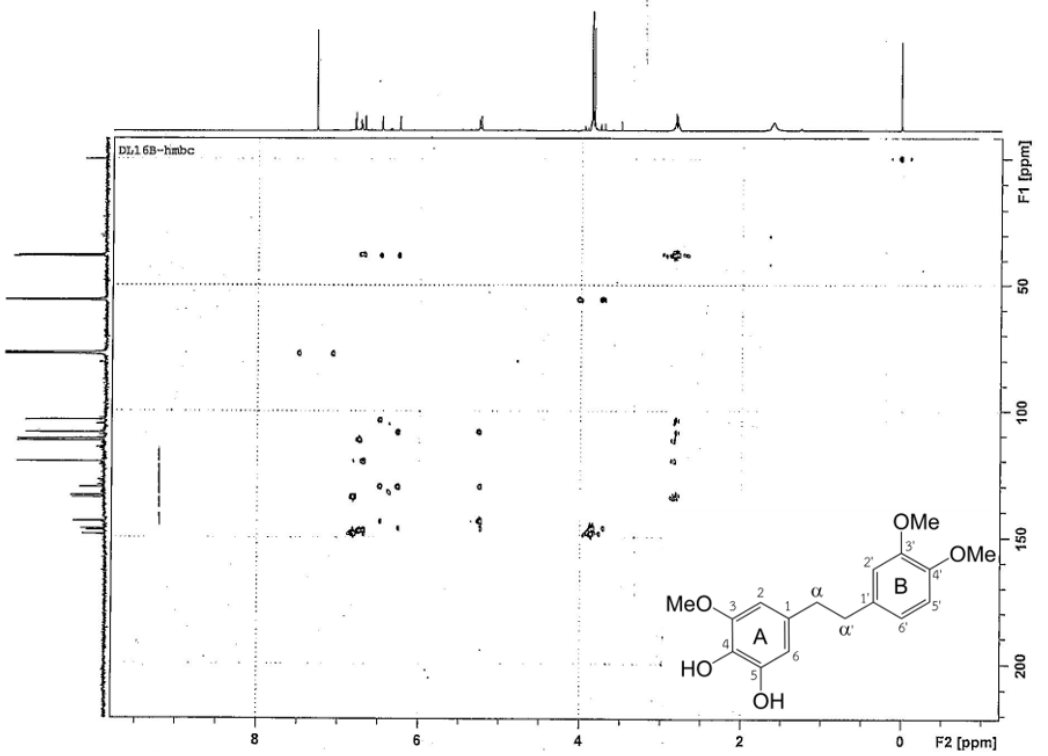


A.13 HSQC spectrum of compound 1 in $CDCl_3$

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

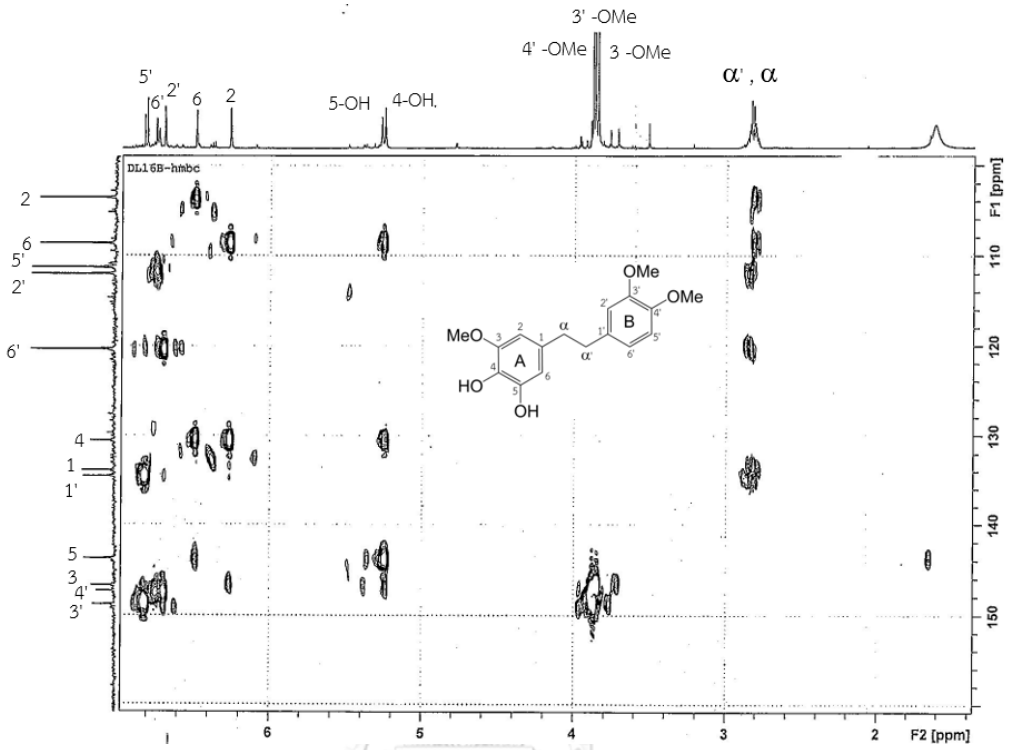


A.14 HMBC spectrum of compound 1 in $CDCl_3$



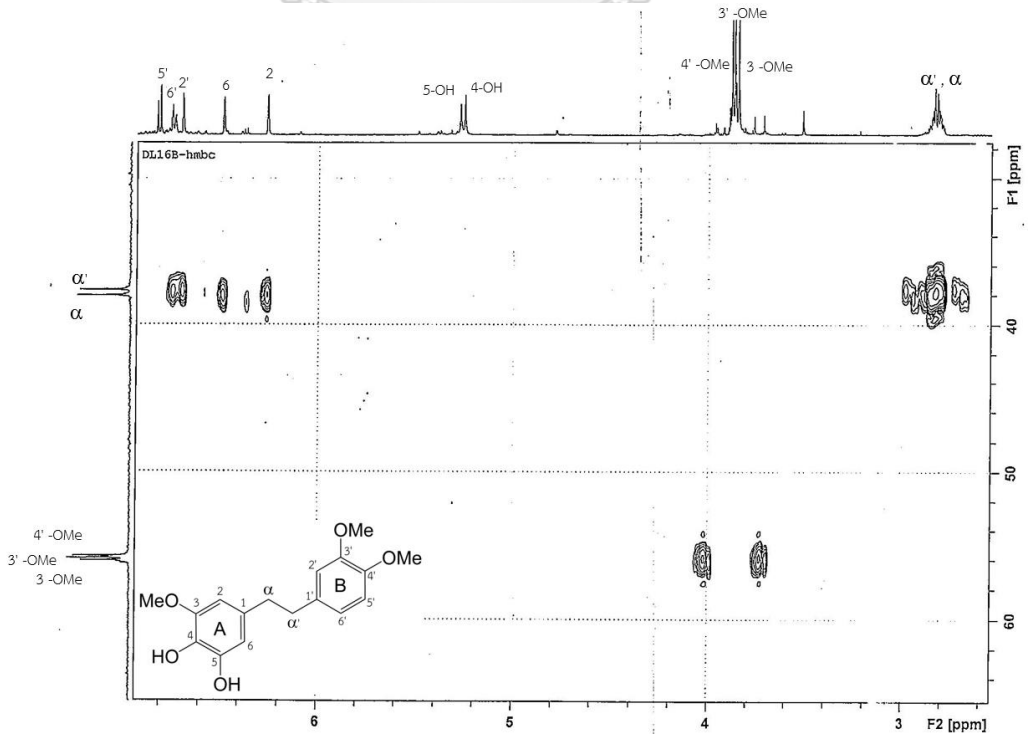
A.15 HMBC spectrum of compound 1 in $CDCl_3$

(expansion from δ_C 100.0-160.0 (F1) and δ_H 1.40-7.00 (F2))



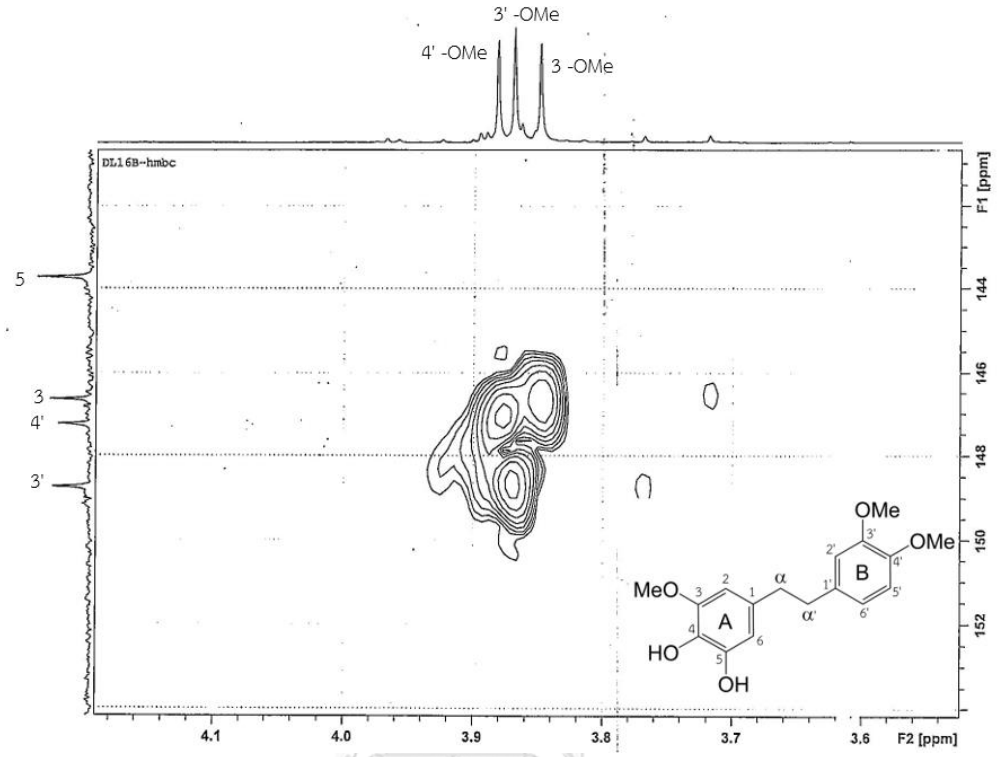
A.16 HMBC spectrum of compound 1 in $CDCl_3$

(expansion from δ_C 28.0-66.0 (F1) and δ_H 2.60-6.90 (F2))



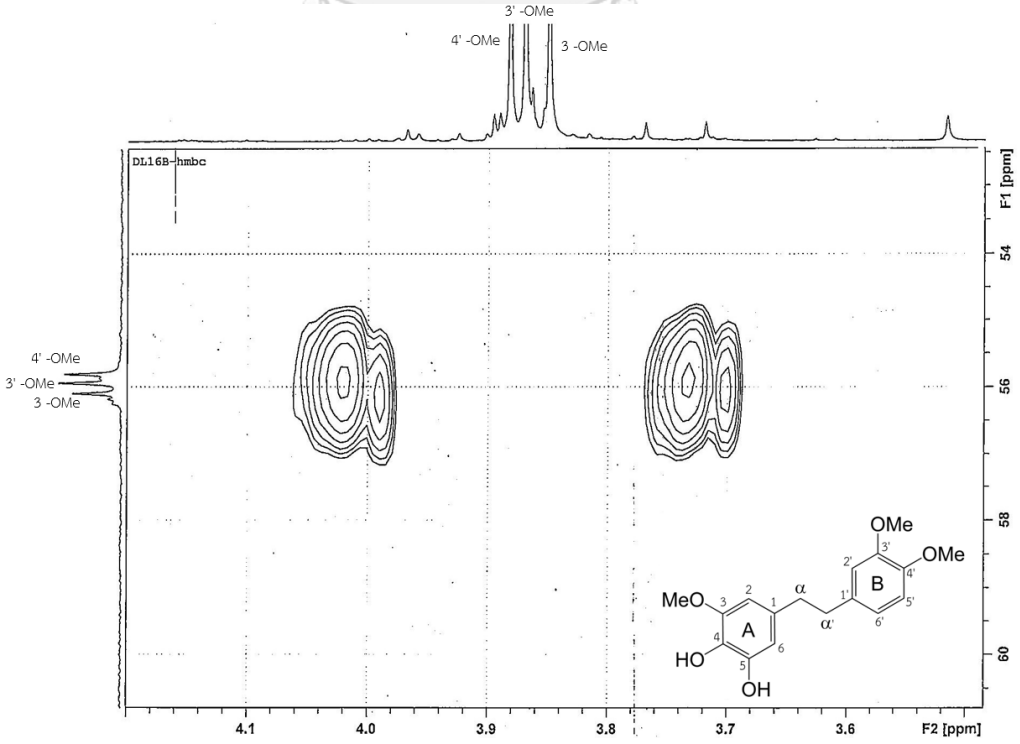
A.17 HMBC spectrum of compound 1 in $CDCl_3$

(expansion from δ_C 143.0-154.0 (F1) and δ_H 3.50-4.20 (F2))

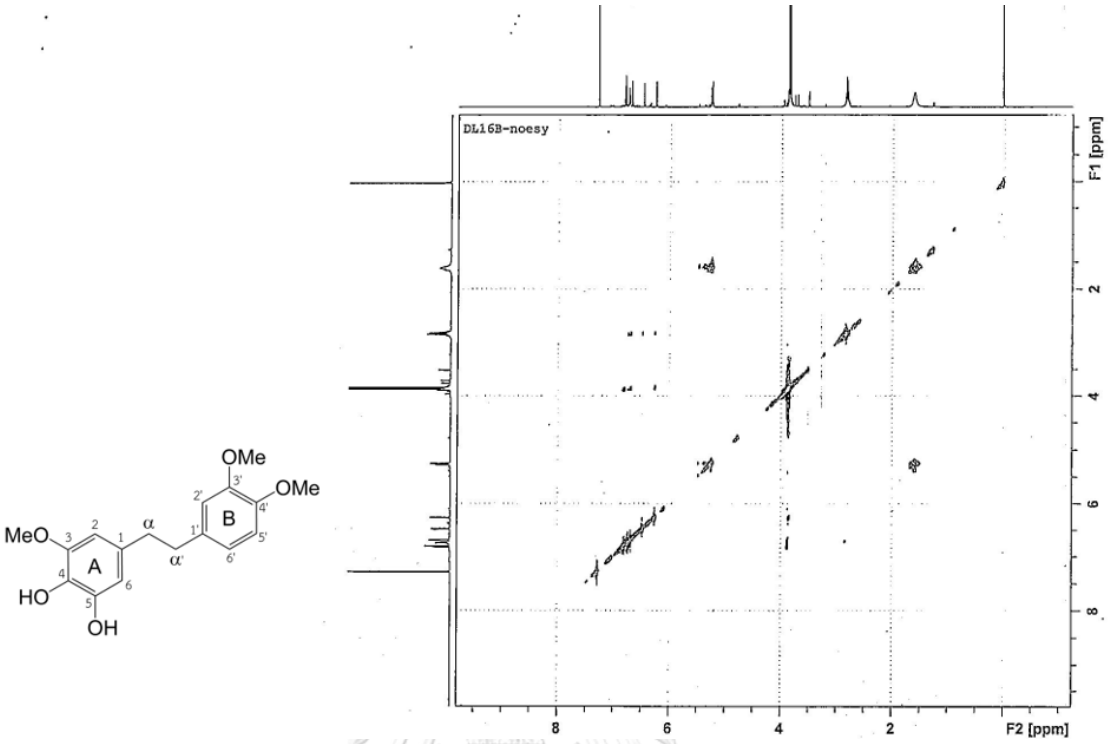


A.18 HMBC spectrum of compound 1 in $CDCl_3$

(expansion from δ_C 52.5-60.8 (F1) and δ_H 3.48-4.20 (F2))

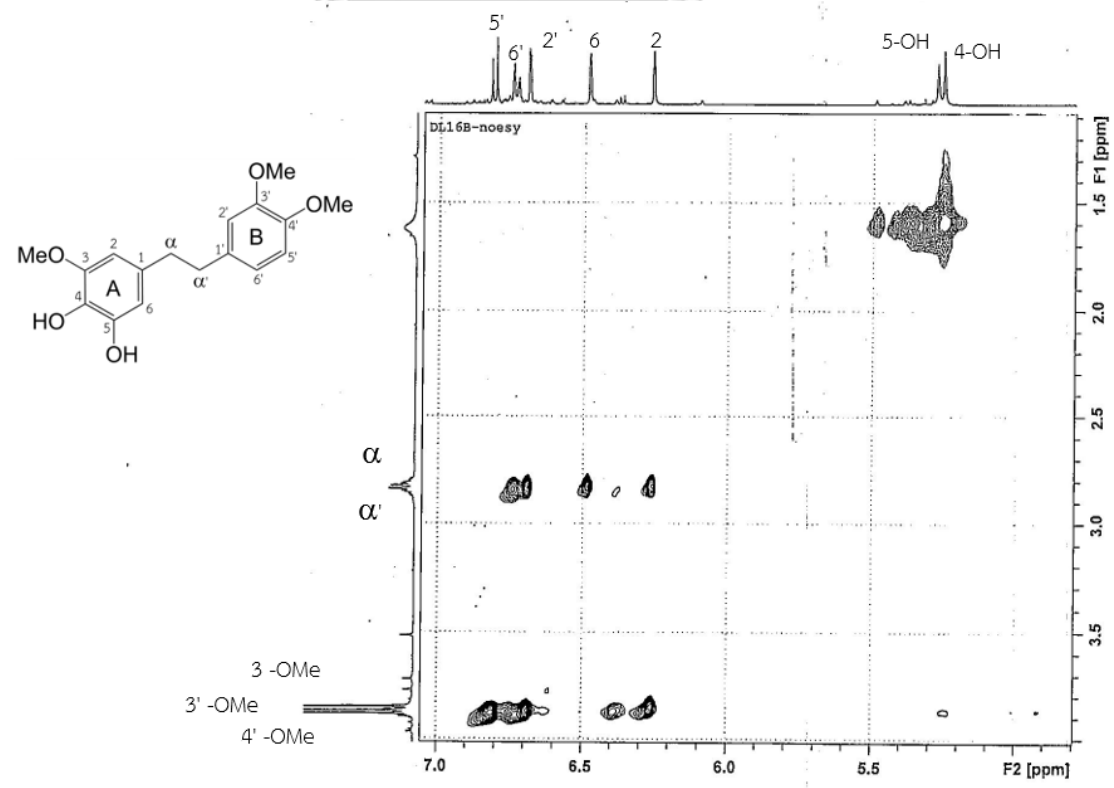


A.19 NOESY spectrum of compound 1 in $CDCl_3$



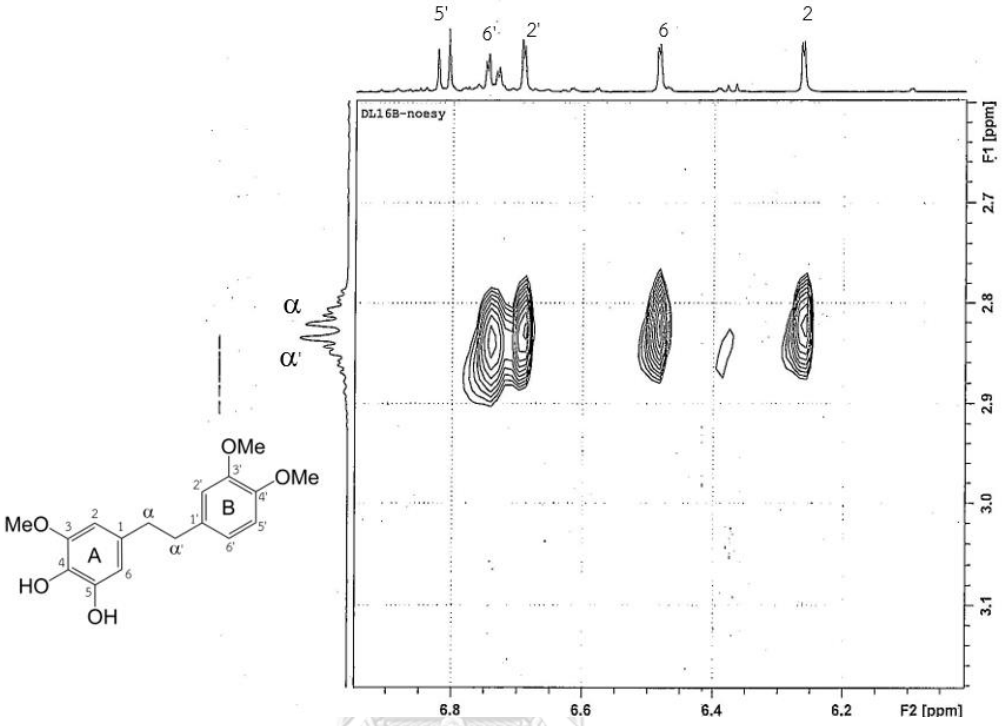
A.20 NOESY spectrum of compound 1 in $CDCl_3$

(expansion from δ_H 1.10-4.00 (F1) and δ_H 4.80-7.05 (F2))



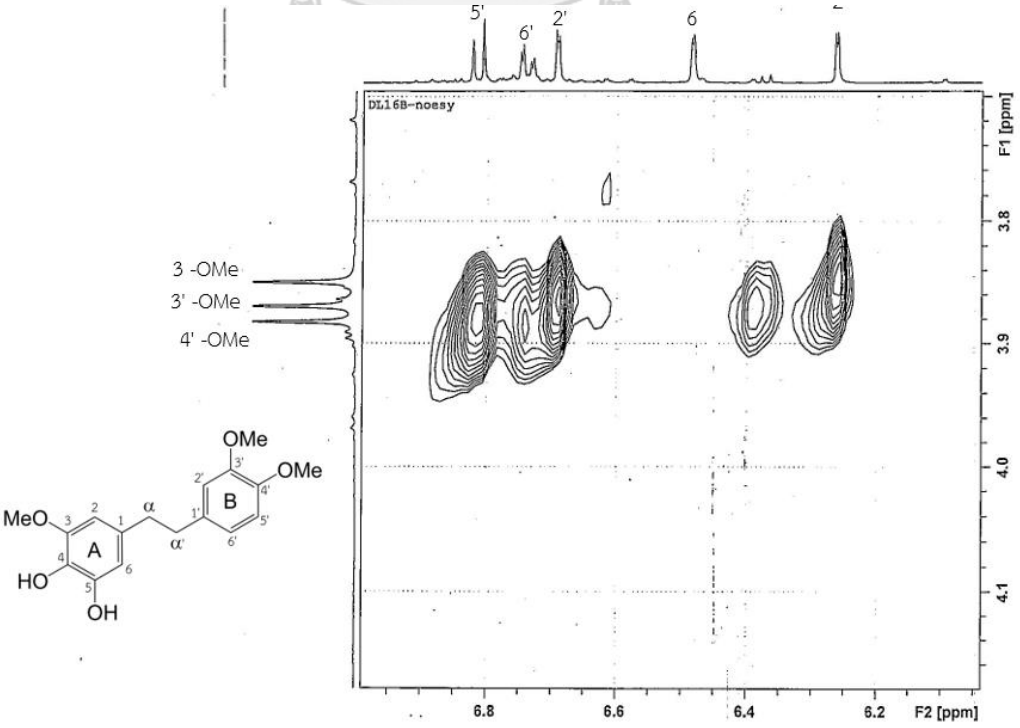
A.21 NOESY spectrum of compound 1 in $CDCl_3$

(expansion from δ_H 2.60-3.18 (F1) and δ_H 6.00-6.95 (F2))



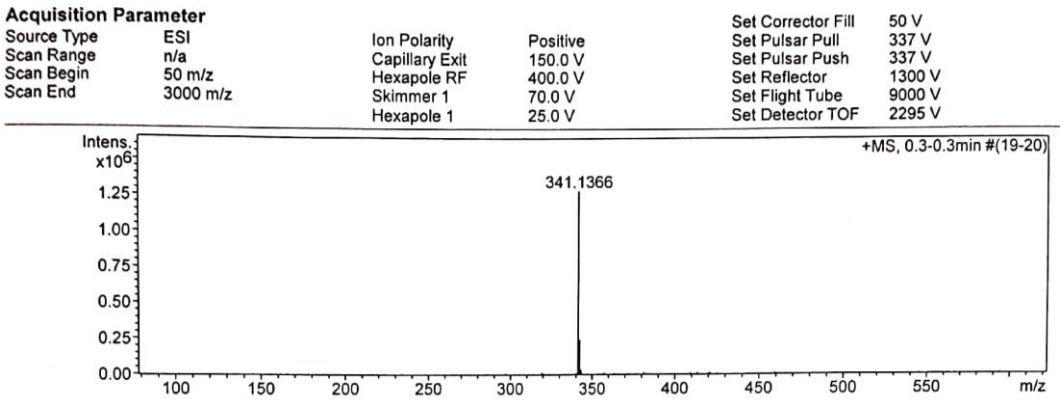
A.22 NOESY spectrum of compound 1 in $CDCl_3$

(expansion from δ_H 3.70-4.18 (F1) and δ_H 6.05-7.00 (F2))

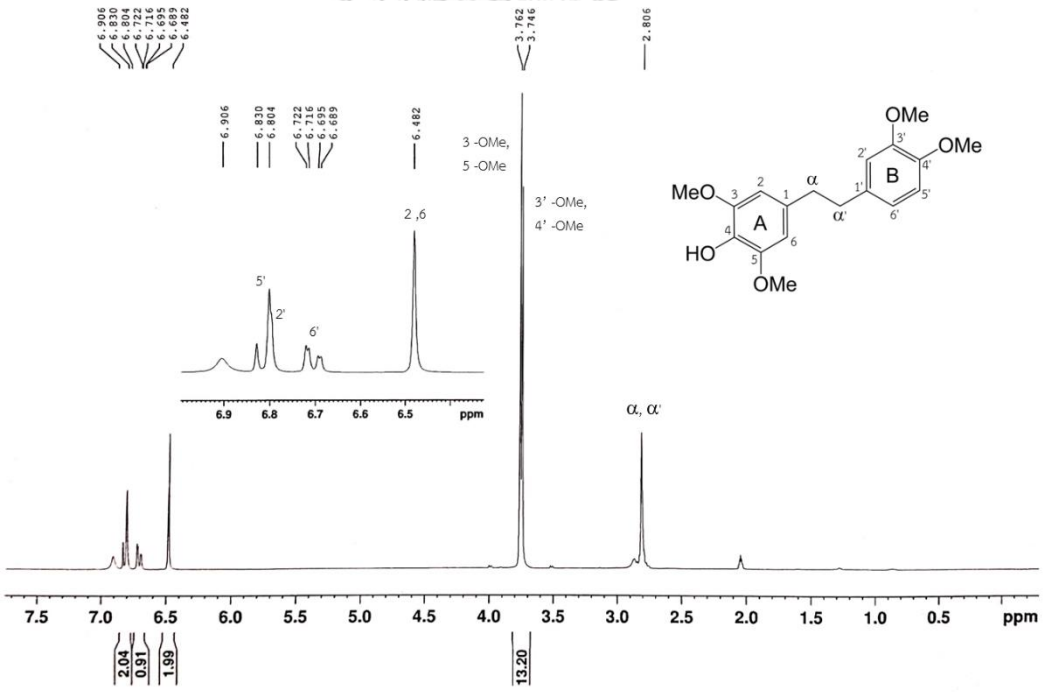


Appendix B: The spectral data of compound 2

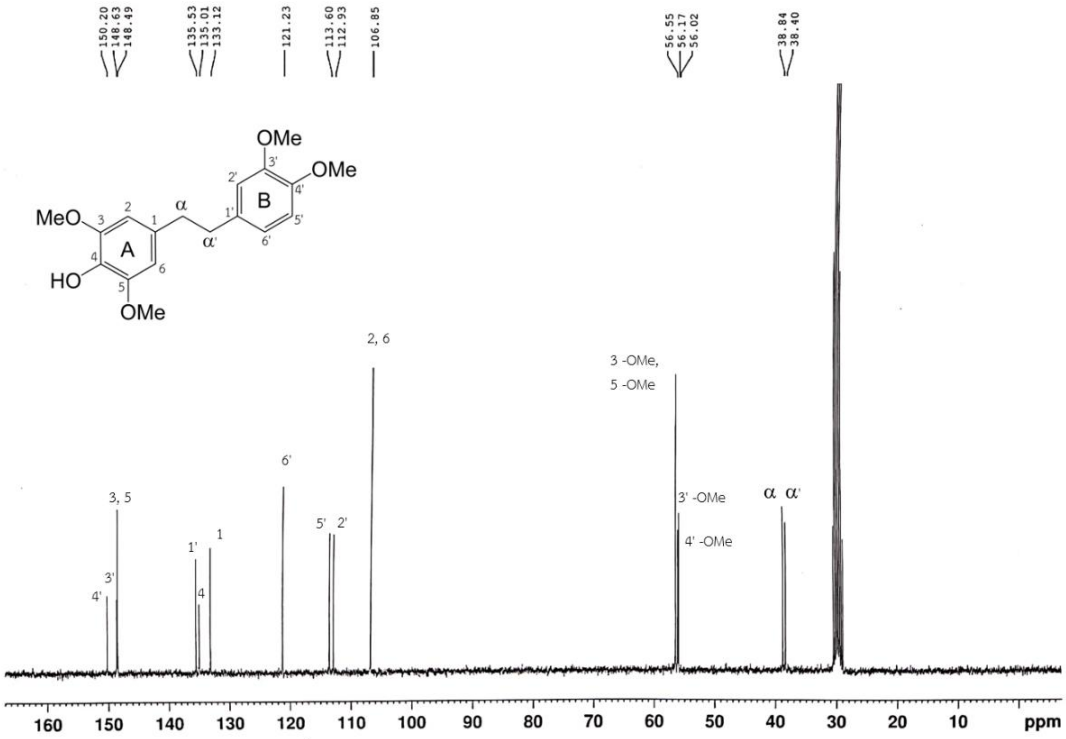
B.1 Mass spectrum of compound 2



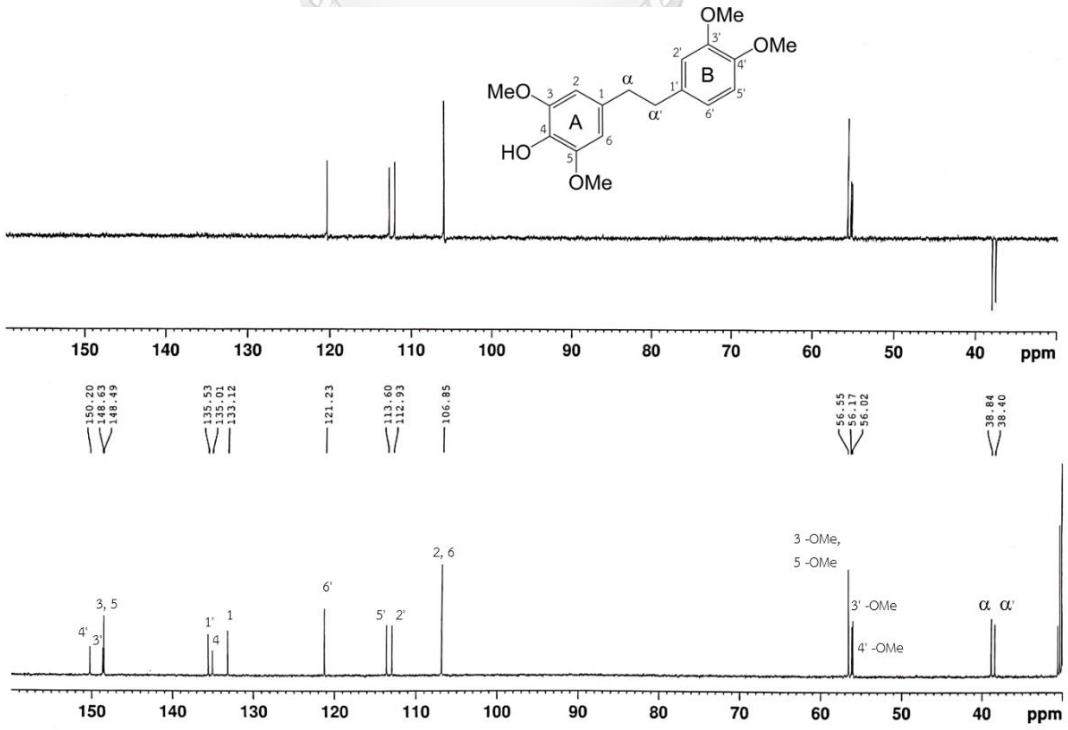
B.2 ^{1}H NMR (300 MHz) spectrum of compound 2 in acetone-d_6



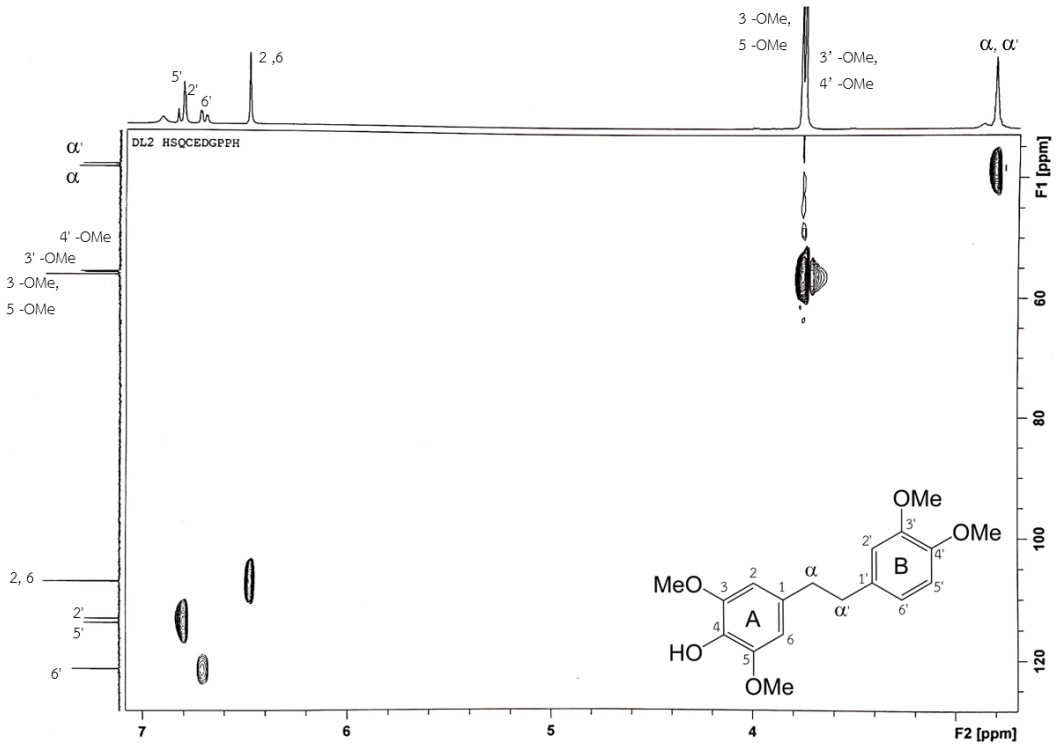
B.3 ^{13}C NMR (75 MHz) spectrum of compound 2 in acetone-d_6



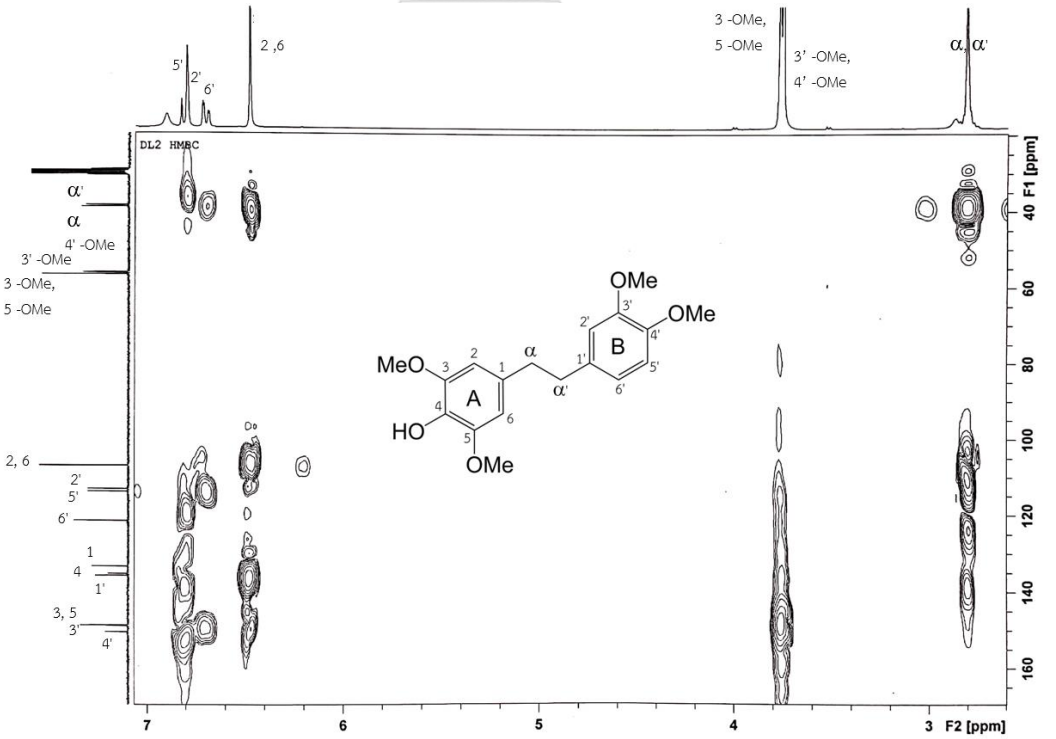
B.4 ^{13}C NMR (75 MHz) spectrum of compound 2 in acetone-d_6 (expansion from δ_C 30.0-160.0)



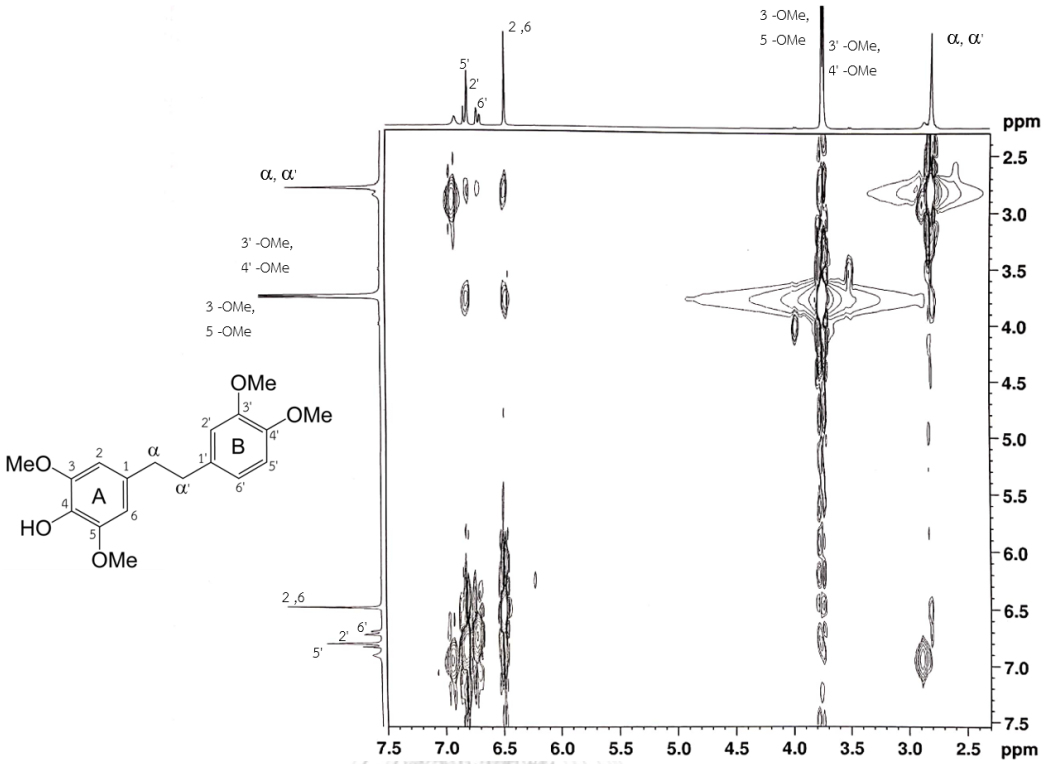
B.5 HSQC spectrum of compound 2 in acetone-d_6



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

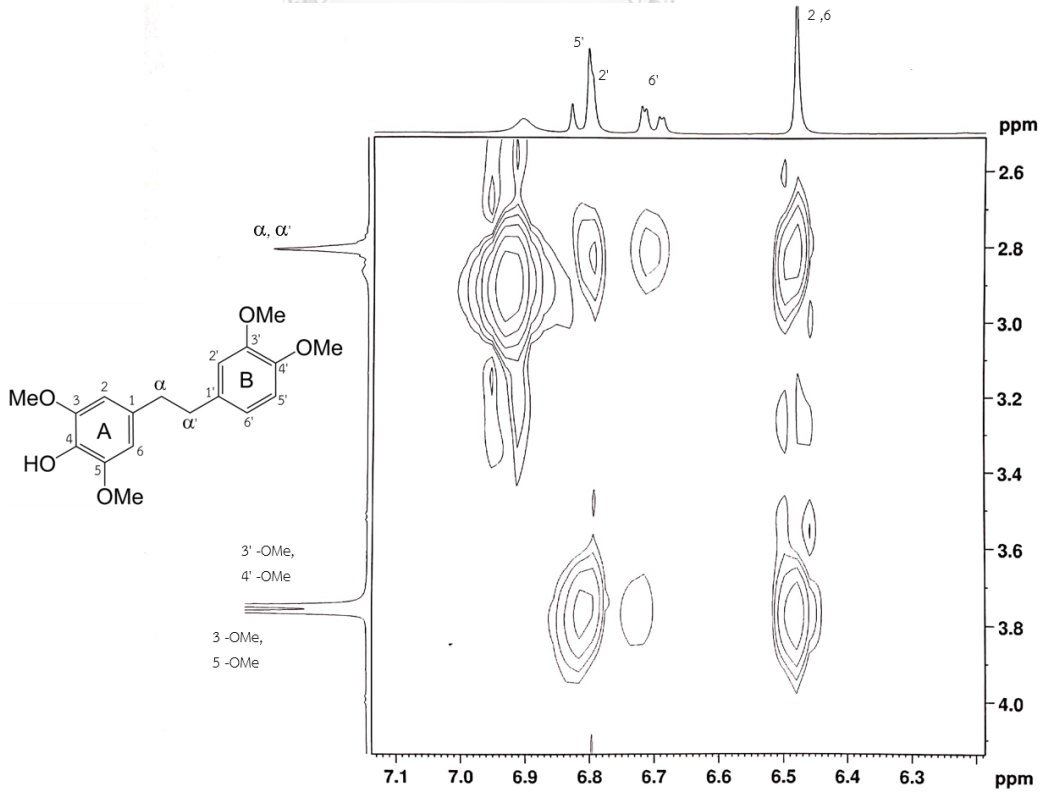


B.7 NOESY spectrum of compound 2 in acetone-d_6



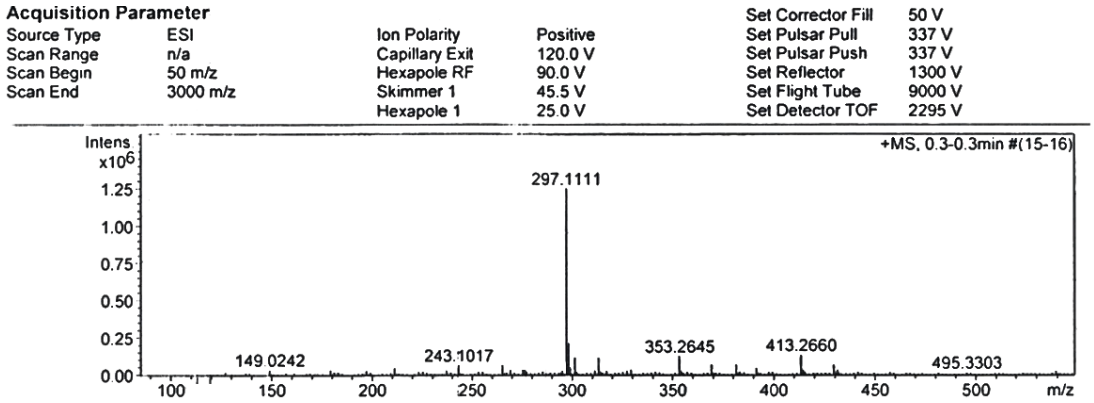
B.8 NOESY spectrum of compound 2 in acetone-d_6

(expansion from δ_H 2.50-4.15 (F1) and δ_H 6.19-7.14 (F2))

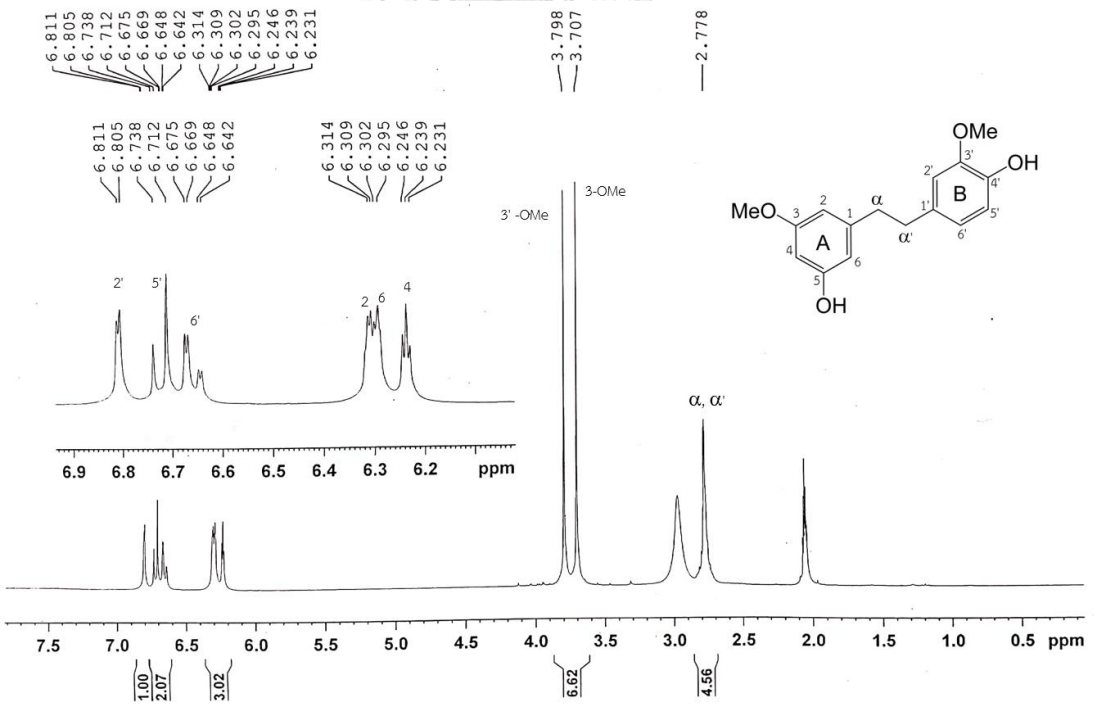


Appendix C: The spectral data of compound 3

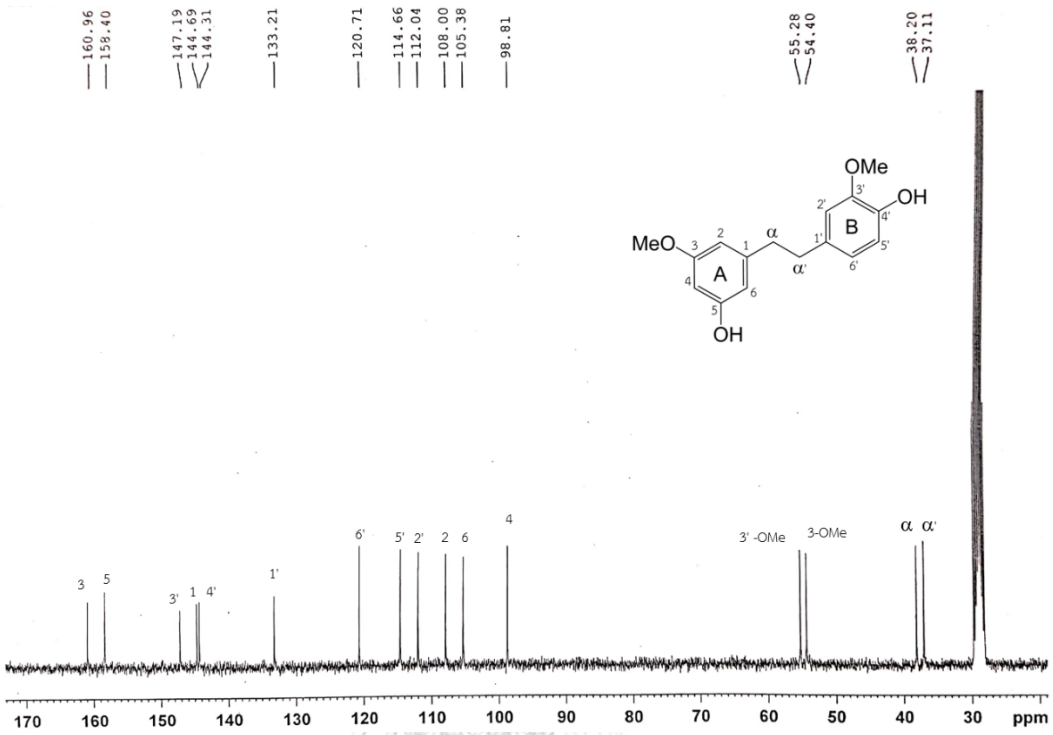
C.1 Mass spectrum of compound 3



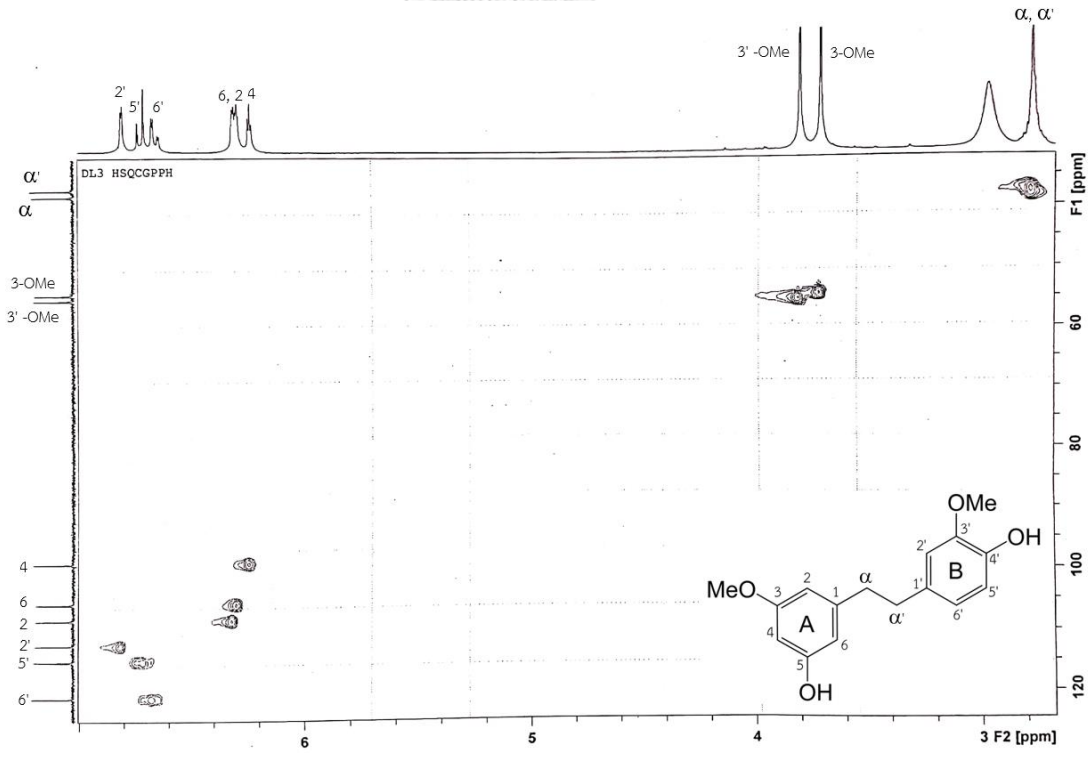
C.2 ^{1}H NMR (300 MHz) spectrum of compound 3 in acetone-d_6



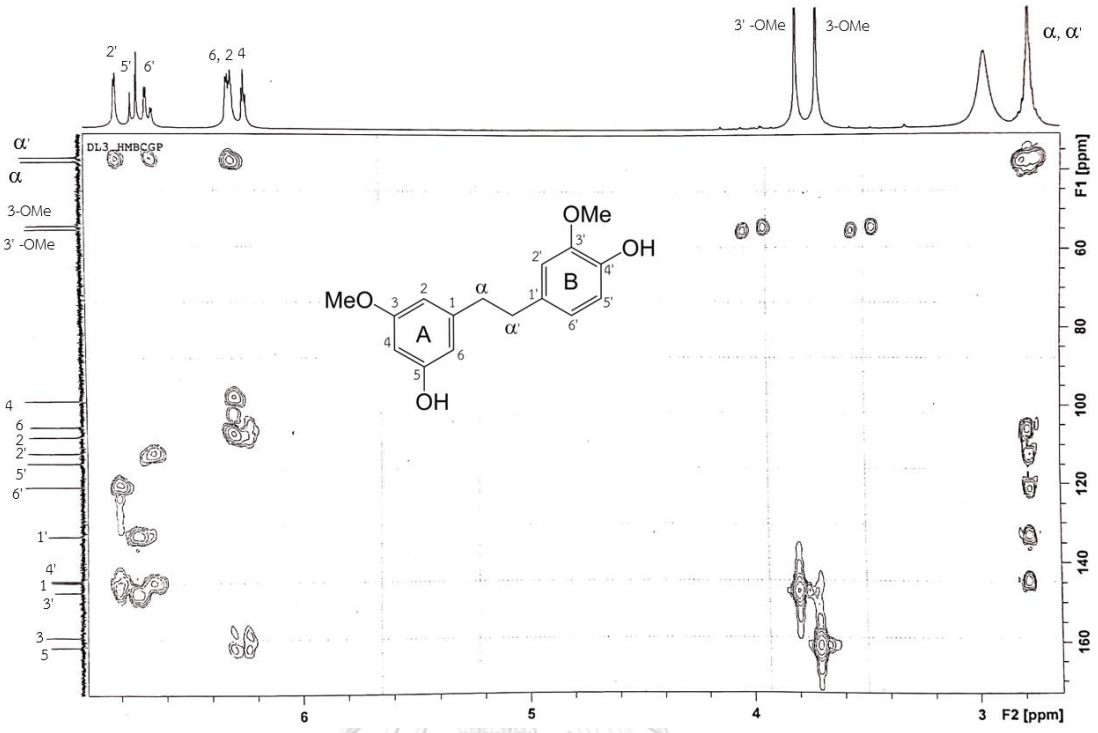
C.3 ^{13}C NMR (75 MHz) spectrum of compound 3 in acetone-d_6



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

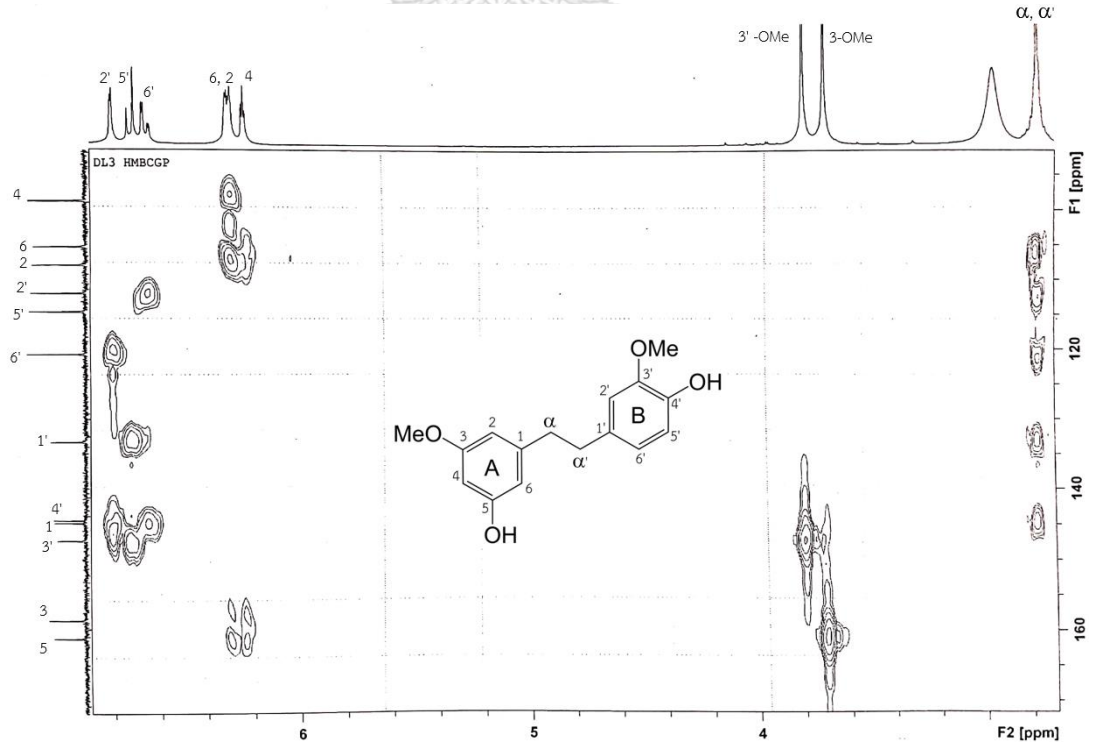


C.5 HMBC spectrum of compound 3 in acetone-d_6

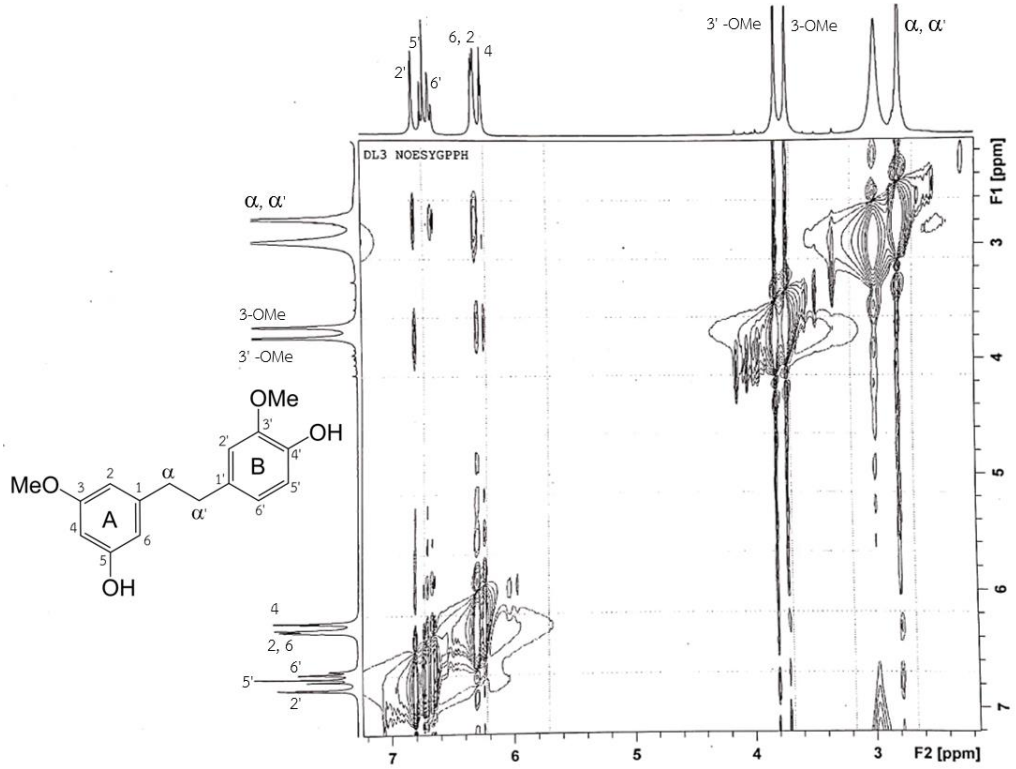


C.6 HMBC spectrum of compound 3 in acetone-d_6

(expansion from δ_C 92.5-172.5 (F1) and δ_H 2.70-6.90 (F2))

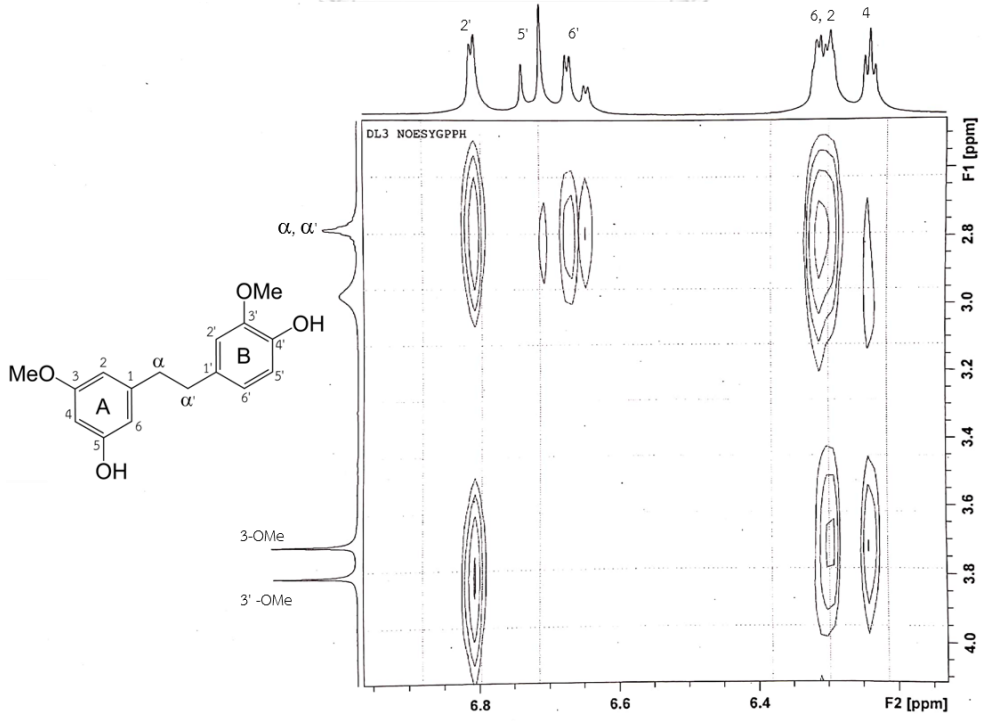


C.7 NOESY spectrum of compound 3 in acetone-d_6



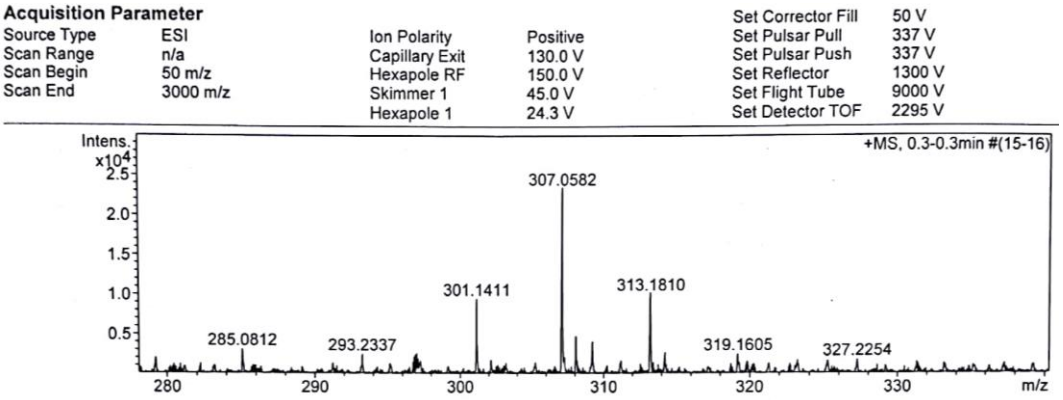
C.8 NOESY spectrum of compound 3 in acetone-d_6

(expansion from δ_H 2.45-4.12 (F1) and δ_H 6.13-6.95 (F2))

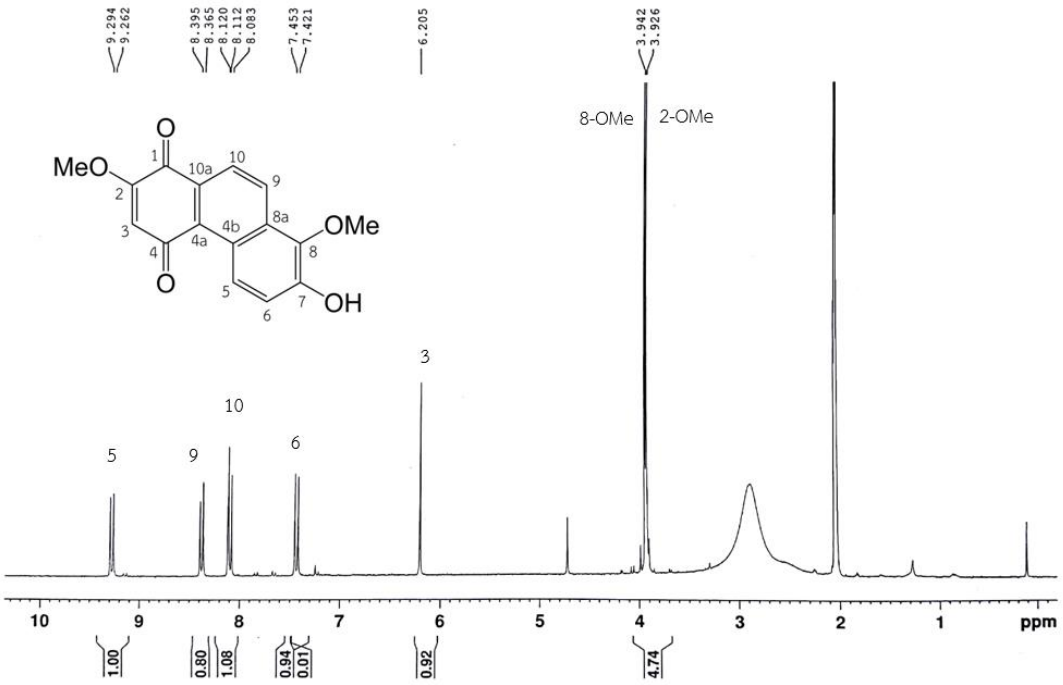


Appendix D: The spectral data of compound 4

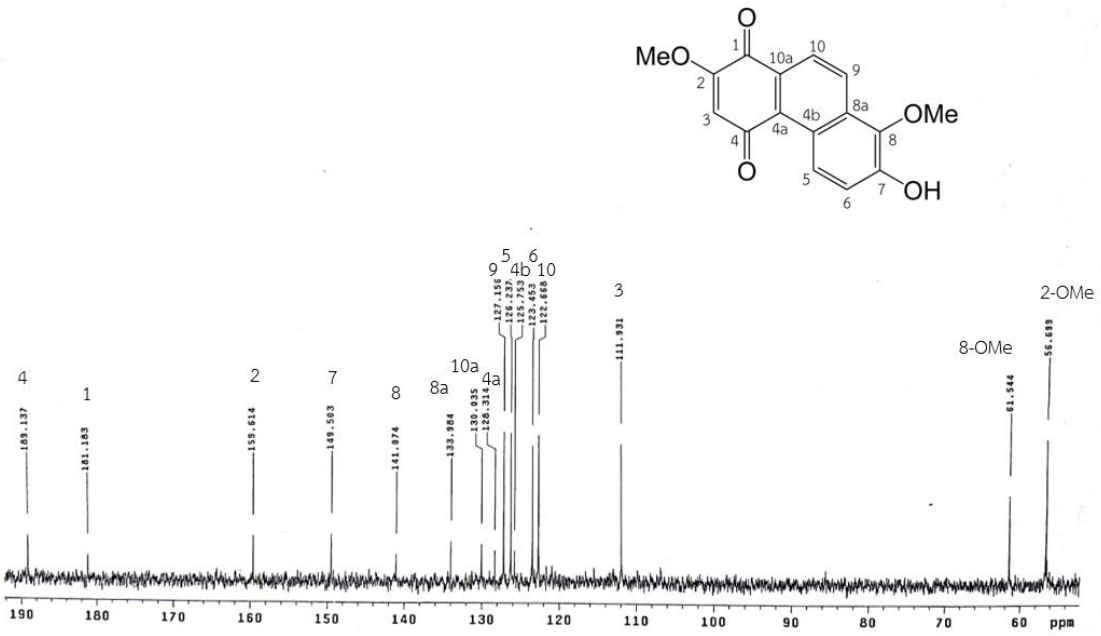
D.1 Mass spectrum of compound 4



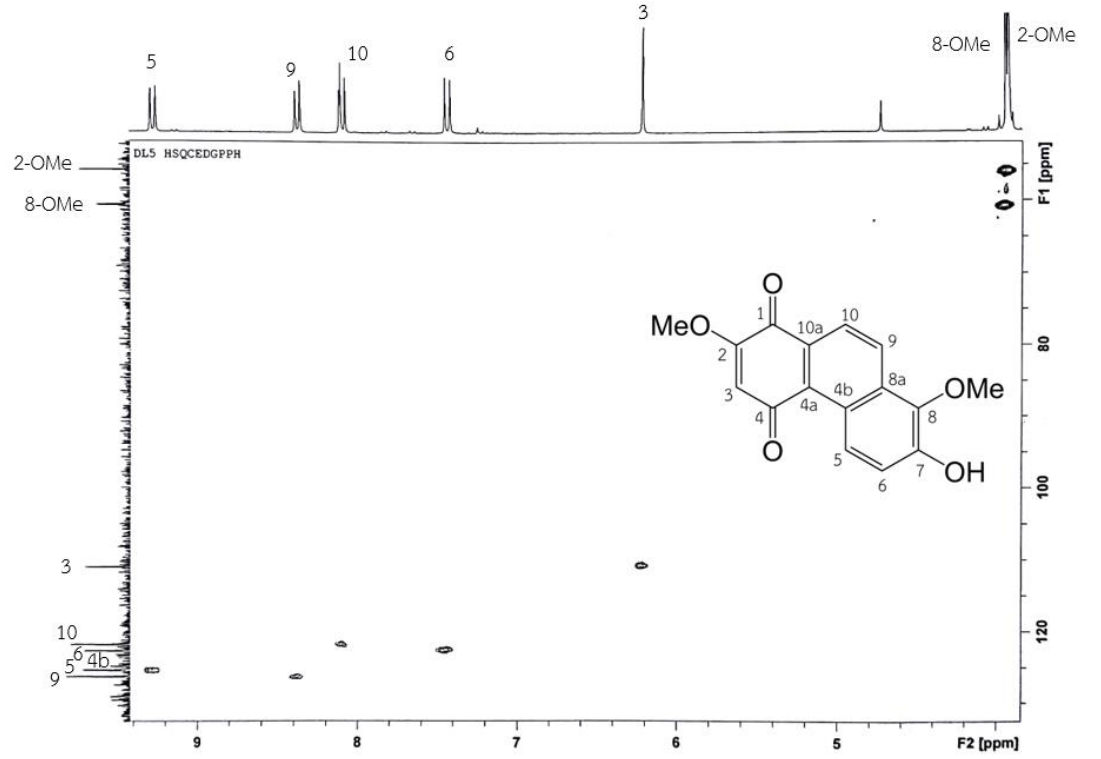
D.2 ^{1}H NMR (300 MHz) spectrum of compound 4 in acetone-d_6



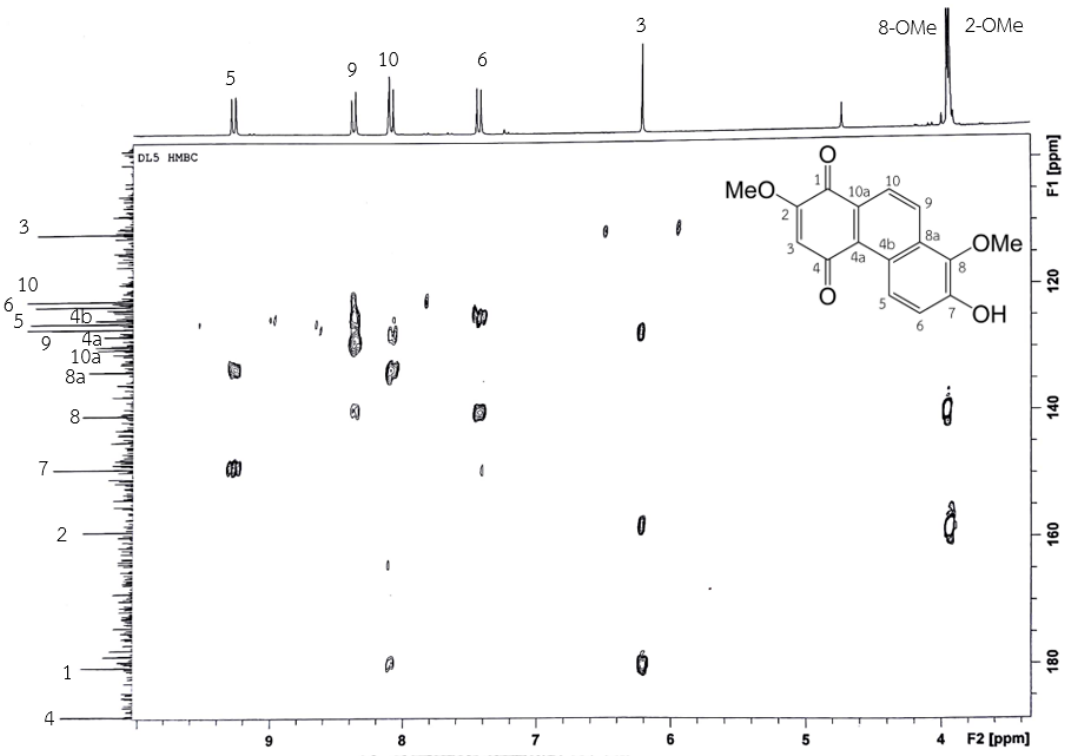
D.3 ^{13}C NMR (75 MHz) spectrum of compound 4 in acetone-d_6



D.4 HSQC spectrum of compound 4 in acetone-d_6

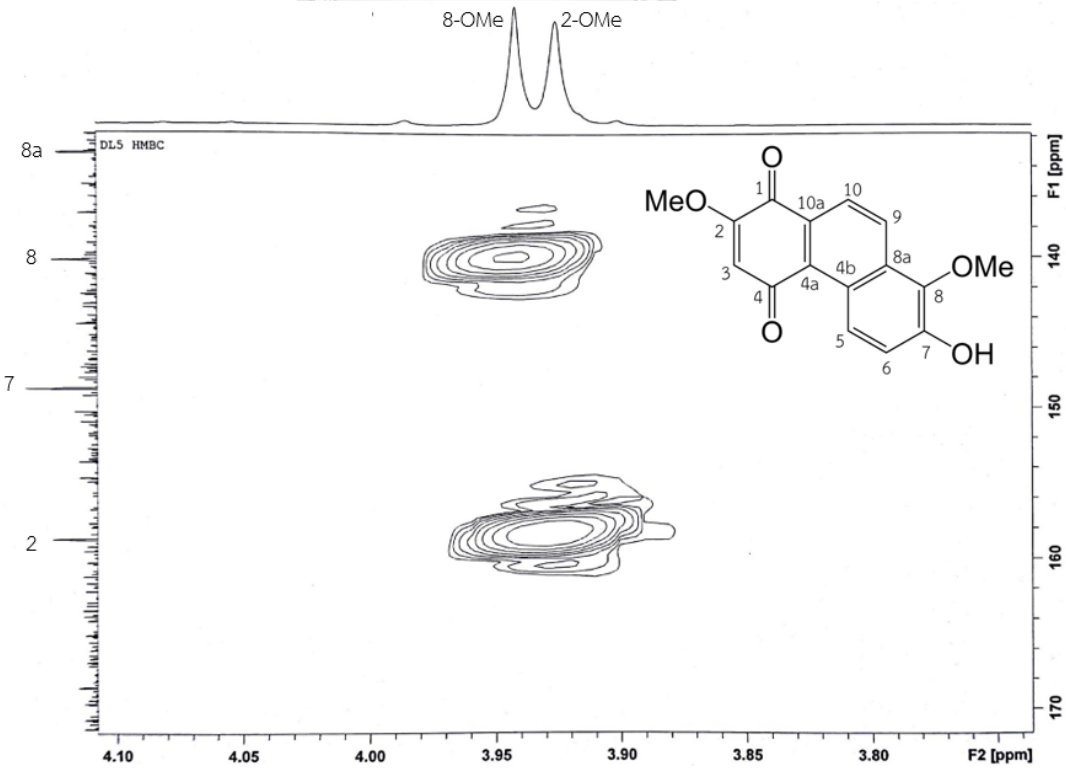


D.5 HMBC spectrum of compound 4 in acetone-d_6

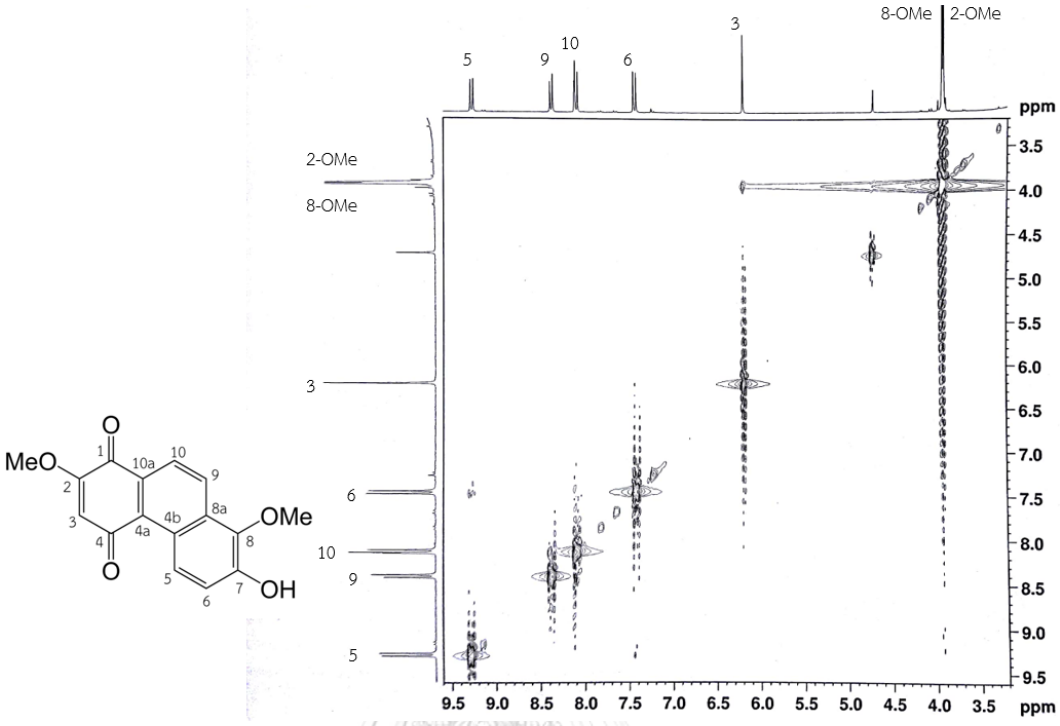


D.6 HMBC spectrum of compound 4 in acetone-d_6

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

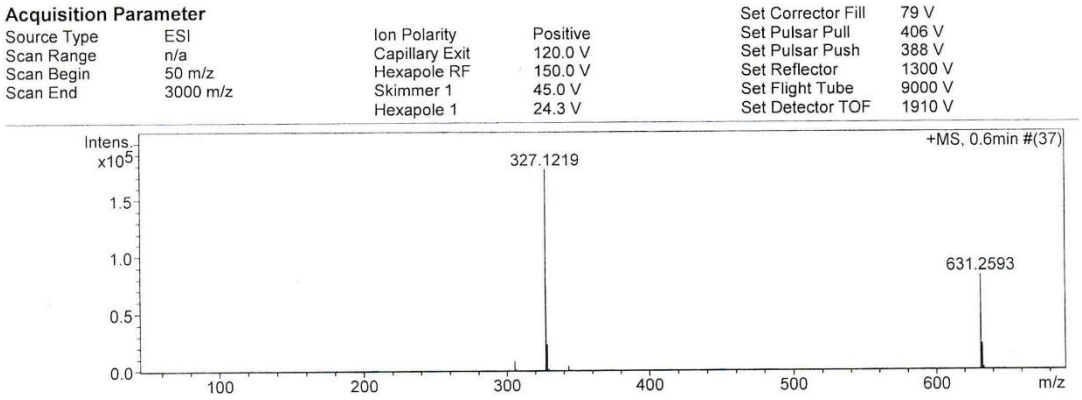


D.7 NOESY spectrum of compound 4 in acetone-d_6

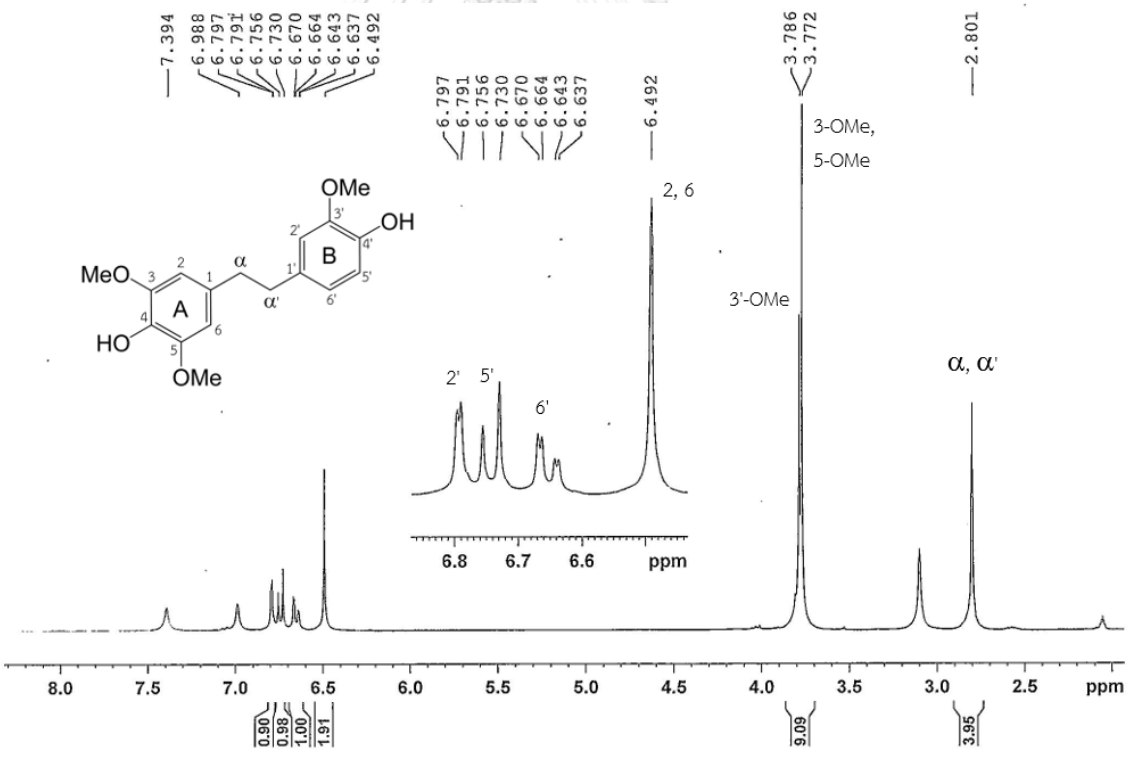


Appendix E: The spectral data of compound 5

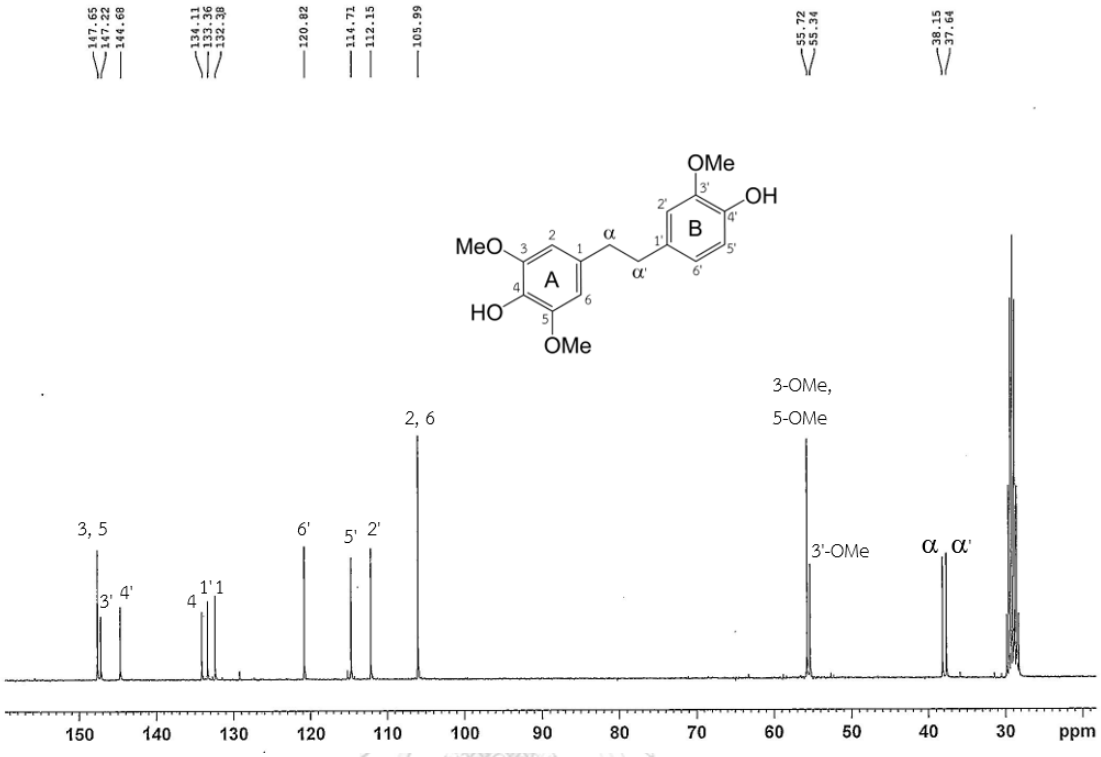
E.1 Mass spectrum of compound 5



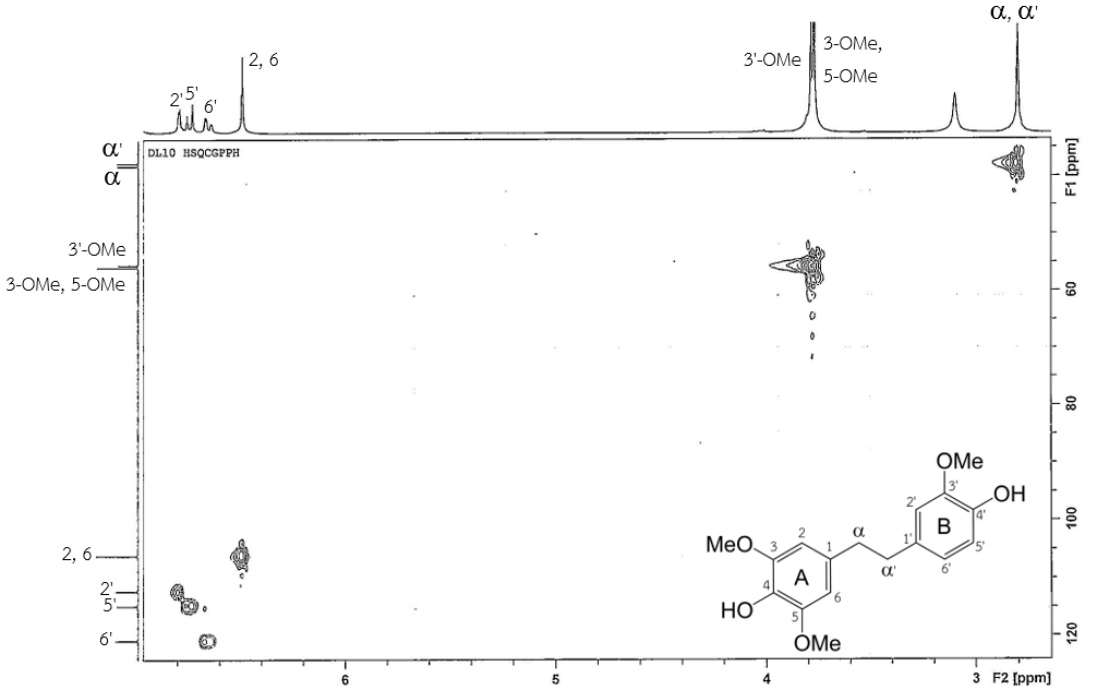
E.2 ^{1}H NMR (300 MHz) spectrum of compound 5 in acetone-d_6



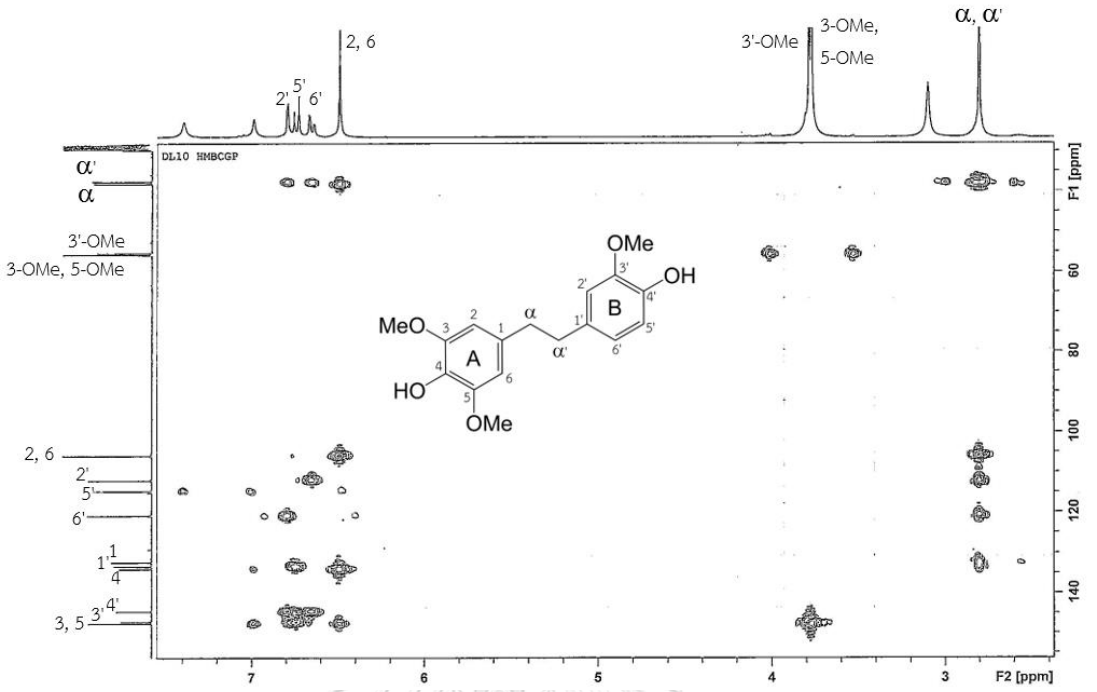
E.3 ^{13}C NMR (75 MHz) spectrum of compound 5 in acetone-d_6



E.4 HSQC spectrum of compound 5 in acetone-d_6

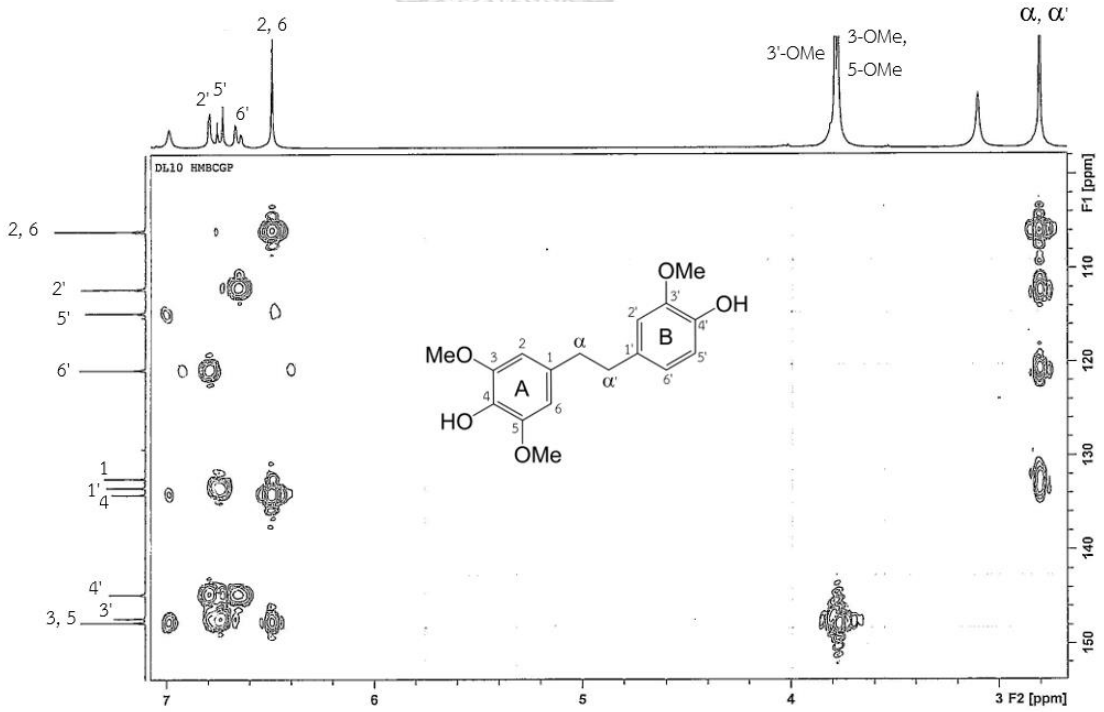


E.5 HMBC spectrum of compound 5 in acetone-d_6



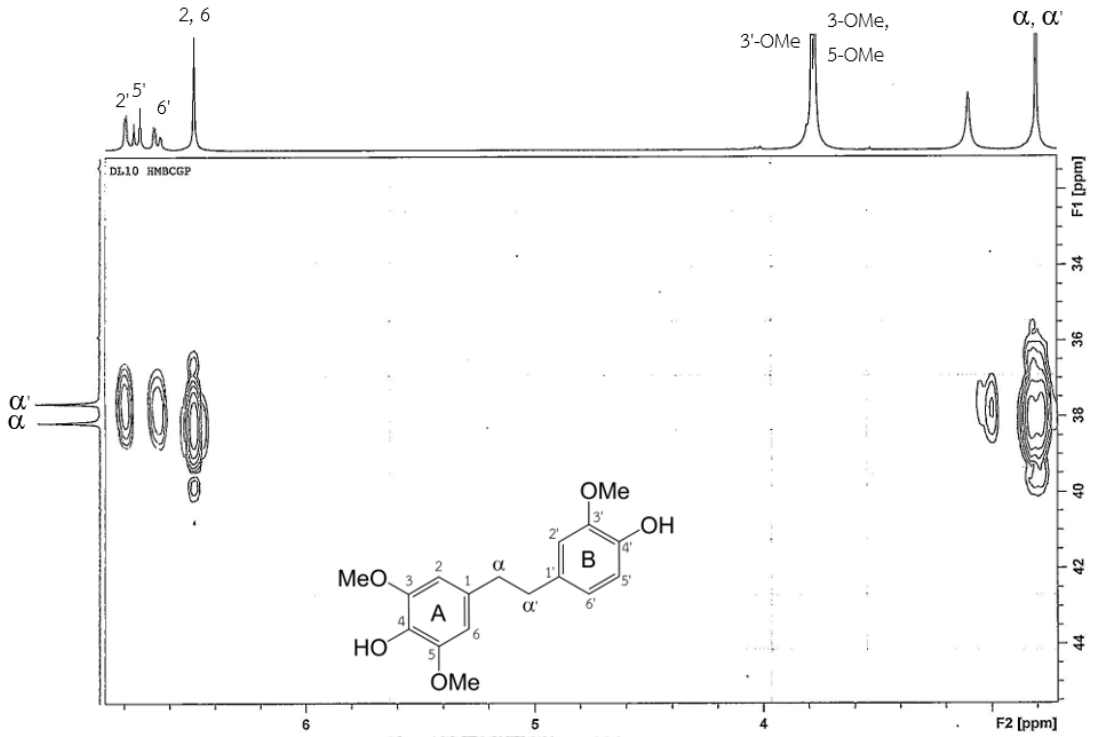
E.6 HMBC spectrum of compound 5 in acetone-d_6

(expansion from δ_C 98.0-151.0 (F1) and δ_H 2.70-7.10 (F2))

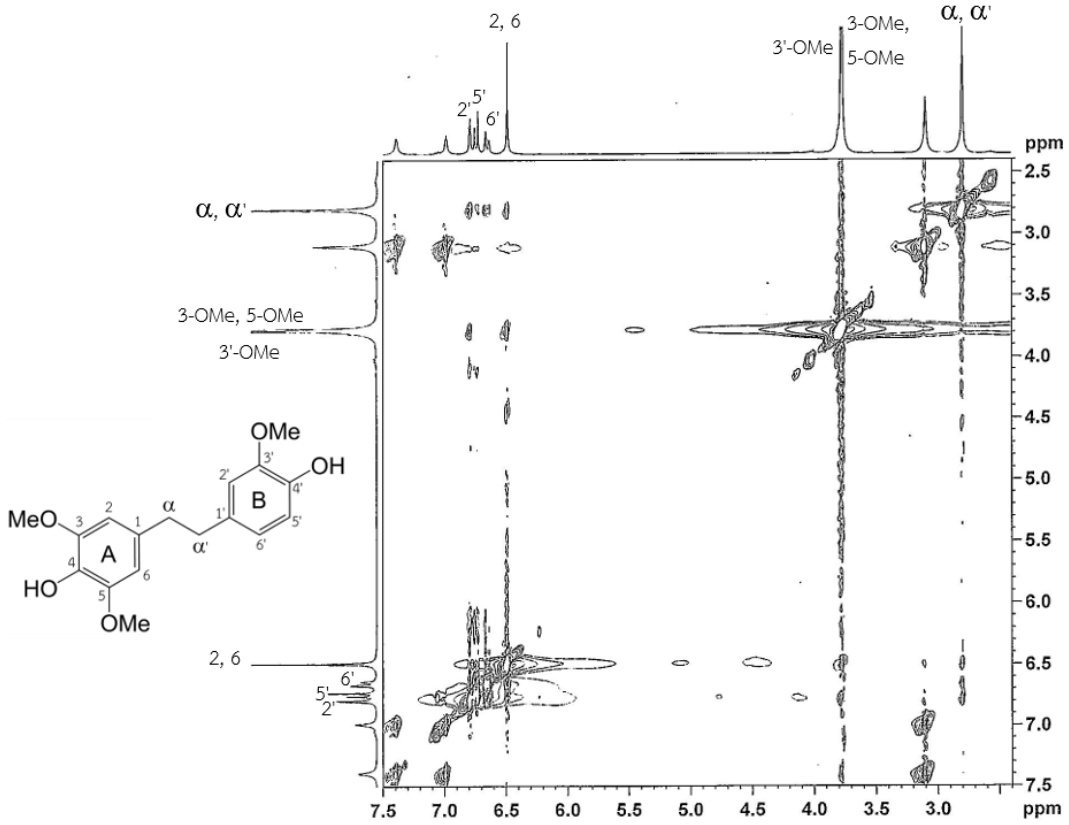


E.7 HMBC spectrum of compound 5 in acetone-d_6

(expansion from δ_C 31.3-45.5 (F1) and δ_H 2.70-6.90 (F2))

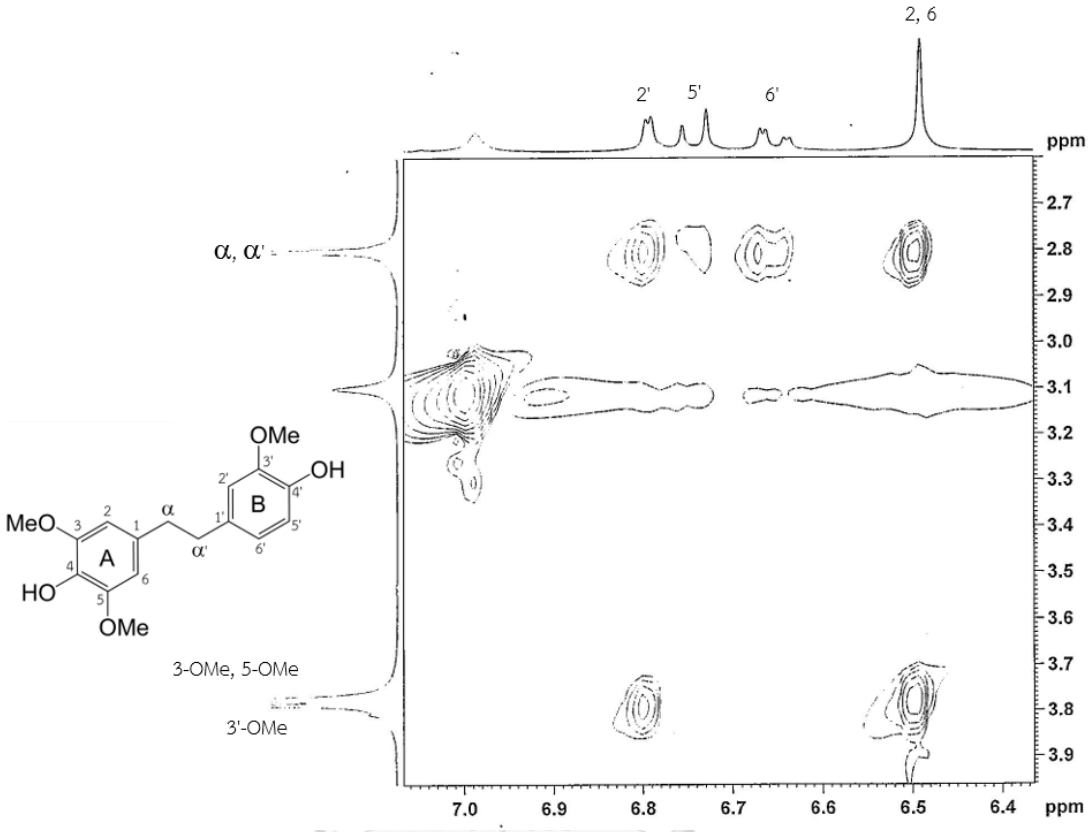


E.8 NOESY spectrum of compound 5 in acetone-d_6



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

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



VITA

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PUBLICATION	Chanpokapaiboon, K., Khoonrit, P., Yusakul, G., Juengwatanatrakul, T., Putalun, W., Tanaka, H., Sakamoto, S. and Morimoto, S. A Recombinant Fab Antibody Against Kwakhurin as a Tool for Sensitive Indirect Competitive ELISA. Curr Pharm Biotechnol. 2018;19(14):1170-6.
AWARD RECEIVED	Chulalongkorn University Graduate Scholarship to Commemorate the 72nd Anniversary of His Majesty King Bhumibala Aduladeja.