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BIOACTIVE COMPOUNDS FROM *DENDROBIUM INFUNDIBULUM*

Miss Salinee Na Ranong

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Pharmacy Program in Pharmacognosy
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Thesis Title	BIOACTIVE COMPOUNDS FROM *DENDROBIUM INFUNDIBULUM*
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สาลินี ณ ระนอง : สารที่มีฤทธิ์ทางชีวภาพจากเอื้องตาเหิน (BIOACTIVE COMPOUNDS FROM *DENDROBIUM INFUNDIBULUM*) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ภก. ดร. บุญชู ศรีตุลารักษ์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ศ. ภก. ดร. กิตติศักดิ์ ลิขิตวิทยาวุฒิ, 206 หน้า.

การศึกษาทางพฤกษเคมีของสารสกัดเมทานอลของเอื้องตาเหิน (วงศ์ Orchidaceae) สามารถแยกสารบริสุทธิ์ได้ 9 ชนิด ได้แก่ สารใหม่ 2 ชนิด (dendroinfundin A และ dendroinfundin B) และสารที่เคยมีรายงานมาก่อน 7 ชนิด (ephemeranthol A, moscatilin, aloifol I, batatasin III, 3,3′-dihydroxy-4,5-dimethoxybibenzyl, 3,4′-dihydroxy-3′,4,5-trimethoxybibenzyl และ dendrosinen B) พิสูจน์โครงสร้างสารโดยอาศัยข้อมูลทางสเปกโทรสโกปี สารทั้งหมดถูกนำมาทดสอบฤทธิ์ในการยับยั้งเอนไซม์ไลเปสและเอนไซม์แอลฟา-กลูโคซิเดส พบว่า สารที่มีฤทธิ์ยับยั้งเอนไซม์ไลเปสได้อย่างอ่อน คือ dendrosinen B (IC_{50} = 295.0±37.9 μM) ซึ่งมีฤทธิ์ยังไม่ดีเมื่อเทียบกับ orlistat (IC_{50} = 31.4±0.6 nM) และสารที่มีฤทธิ์ยับยั้งเอนไซม์แอลฟากลูโคซิเดสได้ดี ได้แก่ batatasin III (IC_{50} = 148.8±8.4 μM) และ dendrosinen B (IC_{50} = 213.9±2.4 μM) ซึ่งมีฤทธิ์ที่แรงกว่า acarbose (IC_{50} = 809.1±22.2 μM)

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

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KEYWORDS: DENDROBIUM INFUNDIBULUM / ALPHA-GLUCOSIDASE INHIBITORY ACTIVITY / LIPASE INHIBITORY ACTIVITY / ORCHIDACEAE / DIHYDROPHENANTHRENES / BIBENZYLS

SALINEE NA RANONG: BIOACTIVE COMPOUNDS FROM *DENDROBIUM INFUNDIBULUM*. ADVISOR: ASSOC. PROF. BOONCHOO SRITULARAK, Ph.D., CO-ADVISOR: PROF. KITTISAK LIKHITWITAYAWUID, Ph.D., 206 pp.

Phytochemical study of the methanol extract from *Dendrobium infundibulum* (Orchidaceae) led to isolation of nine pure compounds including two new compounds (dendroinfundin A and dendroinfundin B) and seven known compounds (ephemeranthol A, moscatilin, aloifol I, batatasin III, 3,3′-dihydroxy-4,5-dimethoxybibenzyl, 3,4′-dihydroxy-3′,4,5-trimethoxybibenzyl and dendrosinen B). Their structures were determined from their spectroscopic data. All compounds were then examined for their lipase and alpha-glucosidase inhibitory activities. Dendrosinen B (IC_{50} = 295.0±37.9 μM) showed moderate inhibitory activity against lipase when compared with orlistat (IC_{50} = 31.4±0.6 nM). Strong anti alpha-glucosidase agents were batatasin III (IC_{50} = 148.8±8.4 μM) and dendrosinen B (IC_{50} = 213.9±2.4 μM), which were more potent than acarbose (IC_{50} = 809.1±22.2 μM).

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

Page

Page

Page

List of figures

List of tables

List of schemes

ABBREVIATIONS & SYMBOLS

Ac	=	Acetate
Ara	=	Arabinose
Acetone-d_6	=	Deuterated acetone
BHT	=	Butylated hydroxytoluene
br s	=	Broad singlet (for NMR spectra)
°C	=	Degree celsius
$CaCl_2$	=	Calcium chloride
CC	=	Column chromatography
$CDCl_3$	=	Deuterated chloroform
CH_2Cl_2	=	Dichloromethane
cm	=	Centimeter
^{13}C-NMR	=	Carbon-13 Nuclear Magnetic Resonance
d	=	Doublet (for NMR spectra)
dd	=	Doublet of doublets (for NMR spectra)
δ	=	Chemical shift
EtOAc	=	Ethyl acetate
FCC	=	Flash Column Chromatography
FT-IR	=	Fourier-transformed infrared spectroscopy
g	=	Gram
Glc	=	Glucose
HMBC	=	^{1}H-detected Heteronuclear Multiple Bond Correlation
^{1}H-NMR	=	Proton Nuclear Magnetic Resonance

HR-ESI-MS	=	High Resolution Electrospray Ionization Mass Spectrometry
HSQC	=	^{1}H-detected Heteronuclear Single Quantum Coherence
IC_{50}	=	Concentration exhibiting 50% inhibition
IR	=	Infrared
J	=	Coupling constant
Kg	=	Kilogram
L	=	Liter
λ_{max}	=	Wavelength at maximal absorption
$[M+Na]^{+}$	=	Sodium-adduct pseudo molecular ion
m	=	Multiplet (for NMR spectra)
Meo	=	Methoxy
MeOH	=	Methanol
MHz	=	Megahertz
mg	=	Milligram
µg	=	Microgram
mL	=	Milliliter
µL	=	Microliter
µM	=	Micromolar
mm	=	Millimeter
mM	=	Millimolar
nM	=	Nanomolar
MS	=	Mass spectrum
4-MU	=	4-methylumbelliferone

4-MUO	=	4-methylumbelliferyl oleate
m/z	=	Mass to charge ratio
N/A	=	Not available
NaCl	=	Sodium chloride
Na_2CO_3	=	Sodium carbonate
NMR	=	Nuclear Magnetic Resonance
NOESY	=	Nuclear Overhauser Effect Spectroscopy
OH	=	Hydroxy
*p*NPG	=	*p*-nitrophenyl-α-D-glucopyranoside
pH	=	Potential of Hydrogen ion
ppm	=	Part per million
Rha	=	Rhamnose
s	=	Singlet (for NMR spectra)
t	=	Triplet (for NMR spectra)
TLC	=	Thin Layer Chromatography
Tris-HCl	=	Tris Hydrochloride
U	=	Unit
UV-VIS	=	Ultraviolet and Visible spectroscopy
VLC	=	Vacuum Liquid Column Chromatography

CHAPTER I
INTRODUCTION

According to a World Health Organization report in 2016, the top ten leading causes of death were mostly from non-infectious diseases, especially in middle-income and high-income countries (World Health Organization, 2018). In Thailand, non-communicable diseases that are the major causes of mortality are cancer, ischemic heart disease, stroke and diabetes (Public Health Statistic, 2016).

Ischemic heart disease and stroke caused of abnormal adaptive immunity response triggered by certain disorders such as obesity (Sell *et al.*, 2012). Many groups of drugs, for example, norepinephrine-releasing agents, pancreatic and gastric lipase inhibitors, serotonin 2C receptor agonists, GABA modulators, dopamine and norepinephrine reuptake inhibitors, opioid antagonists and glucagon-like peptide-1 agonists, have been used to treat obesity (Apovian *et al.*, 2015). Obesity is the main cause of several non-communicable diseases, especially type-II diabetes, which has been treated by several types of drugs, including biguanides, sulfonylureas, meglitinides, thiazolidinediones, α-glucosidase inhibitors, dipeptidyl peptidase-4 inhibitors, bile acid sequestrants, dopamine-2 agonists, sodium glucose co-transporter type 2 inhibitors, glucagon-like peptide-1 receptor agonists and amylinomimetics (American Diabetes Association, 2018). Although there are a lot of drugs for the management of these diseases, problems still exist, due to diseases' complications and drugs' side effects. The issues might be resolved by developing new drugs with high potency and less side effects. The importance of drugs derived from plants have been recognized for years. Traditional use of *Dendrobium* plants in Chinese medicine as antidiabetic agents has stimulated the author's interest in doing research to find the active constituents.

Dendrobium is the largest genus in the family Orchidaceae with 800-1,400 species (Jin *et al.*, 2009). In Thailand, several species of *Dendrobium* have been identified as follows ("BGO Plant Database," 2011; Environment, 2014; Thongdonair *et al.*, 2013).

Dendrobium acerosum Lindl.	**กล้วยไม้มือนาง** Kluai mai mue nang
D. aciculare Lindl.	**เอื้องใบเข็ม** Ueang bai Khem
D. acinaciforme Roxb.	**เอื้องยอดสร้อย** Ueang yot soi
D. aduncum Wall. ex. Lindl.	N/A
D. albosanguineum Lindl.	**เอื้องตางัว** Ueang ta ngua
D. aloifolium (Blume) Rchb.f.	**เอื้องมณี** Ueang mani
D. alterum Seidenf.	**เอื้องเข็ม** Ueang khem
D. anceps Sw.	**หางปลา** Hang pla
D. angulatum Lindl.	**เอื้องมะลิน้อย** Ueang mali noi
D. anosmum Lindl.	**เอื้องสาย** Ueang sai
D. aphyllum (Roxb.) C.E.C.Fisch.	**เอื้องงวงช้าง** Ueang nguang chang
D. bellatulum Rolfe	**เอื้องแซะภู** Ueng sae phu
D. bensoniae Rchb.f.	**เอื้องสายดอกขาว** Ueang doe khao
D. bicameratum Lindl.	**เอื้องเข็ม** Ueang khem
D. bifarium Lindl.	N/A
D. bilobulatum Seidenf.	**กล้วยไม้ก้างปลา** Kluai mai kang pla
D. blumei Lindl.	**หวายนายบลูม** Wai nai blume
D. brevimentum Seidenf.	**เอื้องสายสีดอกใต้** Ueang sai si dok tai
D. brymerianum Rchb.f.	**เอื้องคำฝอย** Ueang kham foi
D. calicopis Ridl.	**เอื้องสายทะเลบันม่วง** Ueang sai ta lay bun muang
D. capillipes Rchb.f.	**เอื้องคำกิ่ว** Ueang kham kio
D. cariniferum Rchb.f.	**เอื้องกาจก** Ueang kachok
D. chittimae Seidenf.	**เอื้องจิตติมา** Ueang chittima
D. christyanum Rchb.f.	**เอื้องแซะภูกระดึง** Ueang sae phu kradueng

D. chrysanthum Lindl.	**เอื้องสายมรกต** Ueang sai morakot
D. chryseum Rolfe	**N/A**
D. chrysocrepis Par. & Rchb.f.	**N/A**
D. chrysotoxum Lindl.	**เอื้องคำ** Ueang kham
D. ciliatilabellum Seidenf.	**หวายเขาเขียว** Wai khao khiao
D. clavator Ridl.	**N/A**
D. compactum Rolfe ex Hackett	**เอื้องข้าวตอก** Ueang khao tok
D. compressum Lindl.	**หวายแบนตะนาวศรี** Wai baen tanao si
D. concinnum Miq.	**หางเปีย** Hang pia
D. confinale Kerr	**N/A**
D. cowenii O'Byrne & Vern.	**N/A**
D. crepidatum Lindl. & Paxton	**เอื้องสายน้ำเขียว** Ueang sai nam khiao
D. cretaceum Lindl.	**เอื้องสายน้ำนม** Ueang sai num nom
D. crocatum Hook.f.	**เอื้องนางนวล** Ueang nang nuan
D. cruentum Rchb.f.	**เอื้องนกแก้ว** Ueang nok kaeo
D. crumenatum Sw.	**หวายตะมอย** Wai tamoi
D. crystallinum Rchb.f.	**เอื้องนางฟ่อน** Ueang nang fon
D. cumulatum Lindl.	**เอื้องสายสี่ดอก** Ueang sai si dok
D. curviflorum Rolfe	**N/A**
D. cuspidatum Lindl.	**เอื้องข้าวตอกปากแหลม** Ueang khao tok pak lam
D. dantaniense Guillaumin	**เอื้องเข็ม** Ueang khem
D. delacourii Guillaumin	**เอื้องดอกมะขาม** Ueang dok ma kham
D. deltatum Seidenf.	**N/A**
D. denneanum Kerr	**N/A**

D. densiflorum Lindl.	**เอื้องมอนไข่** Ueang mon khai
D. denudans D.Don	**เอื้องสายจำปา** Ueang sai champa
D. devonianum Paxton	**เอื้องเมี่ยง** Ueang miang
D. dickasonii Williams	**เอื้องเคี้ยะ** Ueang khia
D. dixanthum Rchb.f.	**เอื้องเทียน** Ueang thian
D. dixonianum Rolfe ex Downie	**เอื้องข้าวตอกเหลือง** Ueang khao tok Lueang
D. draconis Rchb.f.	**เอื้องเงิน** Ueang ngoen
D. elliottianum O'Byrne	**หวายเจดีย์** Wai chedi
D. ellipsophyllum Tang & Wang	**เอื้องทอง** Ueang thong
D. eriiflorum Griff.	N/A
D. erostelle Seidenf.	N/A
D. erosum (Blume) Lindl.	N/A
D. eserre Seidenf.	N/A
D. exile Schltr.	**เอื้องเสี้ยน** Ueang sian
D. falconeri Hook.	**เอื้องสายวิสูตร** Ueang sai wisut
D. farmeri Paxton	**เอื้องมัจฉาณุ** Ueang matchanu
D. fimbriatum Hook.	**เอื้องคำน้อย** Ueang kham noi
*D. findlayanu*m Par. & Rchb.f.	**พวงหยก** Phuang yok
D. flexile Ridl.	N/A
D. formosum Roxb. ex Lindl.	**เอื้องเงินหลวง** Ueang ngoen luang
D. friedericksianum Rchb.f.	**เอื้องเหลืองจันทบูร** Ueang lueang chantabun
D. fuerstenbergianum Schltr.	**เอื้องแซะภูกระดึง** Ueang sae phukradueng
D. fychianum Bateman ex Rchb.f.	**หวายพม่า** Wai phama
D. garrettii Seidenf.	**หวายการ์เร็ต** Wai karet

D. gibsonii Paxton Lindl.	**เอื้องคำสาย** Ueang kham sai
D. grande Hook.f.	**เอื้องแผงใบใหญ่** Ueang pheang bai yai
D. gratiotissimum Rchb.f.	**เอื้องกิ่งดำ** Ueang king dam
D. gregulus Seidenf.	**เอื้องมะต่อม** Ueang ma tom
D. griffithianum Lindl.	**เอื้องมัจฉาณุ** Ueang matchanu
D. harveyanum Rchb.f.	**เอื้องคำฝอย** Ueang kham foi
D. hendersonii Hawkes & Heller	**หวายตะมอยน้อย** Wai tamoi noi
D. henryi Schltr.	**เอื้องสุริยัน** Ueang suriyan
D. hercoglossum Rchb.f.	**เอื้องดอกมะเขือ** Ueang dok ma kuea
D. heterocarpum Lindl.	**เอื้องสีตาล** Ueang si tan
D. hymenanthum Rchb.f.	**เอื้องน้อยกลีบบาง** Ueang noi klip bang
D. hymenopterum Hook.f.	**N/A**
D. incurvum Lindl.	**N/A**
D. indivisum (Blume) Miq. var. *indivisum*	**ตานเสี้ยนไม้** Tan sian mai
D. indivisum (Blume) Miq.	**N/A**
var. *lampangense* Rolfe	
D. indivisum (Blume) Miq.	**ก้างปลา** Kang pla
var. *pallidum* Seidenf.	
D. indragiriense Schltr.	**เอื้องอินทิรา** Ueang inthira
D. infundibulum Lindl.	**เอื้องตาเหิน** Ueang ta hoen
D. intricatum Gagnep.	**เอื้องชมพู** Ueang chomphu
D. jenkinsii Wall. ex Lindl.	**เอื้องผึ้งน้อย** Ueang phueng noi
D. kanburiense Seidenf.	**หวายเมืองกาญจน์** Wai muang kan
D. keithii Ridl.	**หางเปีย** Hang pia

D. kentrophyllum Hook.f.	**ก้างปลาใหญ่** Kang pla yai
D. kontumense Gagnep.	**เอื้องเงินวิลาศ** Ueang ngoen wilat
D. kratense Kerr	**เอื้องข้าวตอกปากจัก** Ueang khaw tok pak chuk
D. lagarum Seidenf.	N/A
D. lamellatum (Blume) Lindl.	**หวายแบนชวา** Wai ban chawa
D. lampongense Sm.	**หวายลำปอง** Wai lum pong
D. lamyaiae Seidenf.	**เอื้องครั่งแสดน้อย** Ueang krang sad noi
D. leonis (Lindl.) Rchb.f.	**เอื้องตะขาบใหญ่** Ueang ta khap yai
D. lindleyi Steud.	**เอื้องผึ้ง** Ueang phueng
D. linguella Rchb.f.	**เอื้องดอกมะเขือใต้** Ueang dok ma kuea tai
D. lituiflorum Lindl.	**เอื้องสายม่วง** Ueang sai muang
D. lueckelianum Fessel & Wolff	N/A
D. mannii Ridl.	**เอื้องหางปลา** Ueang hang pla
D. metachilinum Rchb.f.	**เอื้องทองใต้** Ueang tong tai
D. monticola Hunt & Summerh.	**เอื้องข้าวตอกมรกต** Ueang khaw tok morakot
D. moschatum (Buch.-Ham.) Sw.	**เอื้องจำปา** Ueang champa
D. mucronatum Seidenf.	N/A
D. nanocompactum Seidenf.	N/A
D. nathanielis Rchb.f.	**เกล็ดนิ่ม** Klet nim
D. nobile Lindl.	**เอื้องเก๊ากิ่ว** Ueang kao kio
D. ochreatum Lindl.	**เอื้องตะขาบ** Ueang ta khap
D. oligophyllum Gagnep.	**ข้าวตอกปราจีน** Khao tok prachin
D. pachyglossum Par.& Rchb.f	**เอื้องขนหมู** Ueang khon mu
D. pachyphyllum (Kuntze) Bakh.f.	**เอื้องน้อย** Ueang noi

D. palpebrae Lindl.	**เอื้องมัจฉา** Ueang matcha
D. pandaneti Ridl.	**เอื้องปักษาปากส้ม** Ueang paksa pak som
D. panduriferum Hook.f.	**หวายดินสอ** Wai dinsor
D. parciflorum Rchb.f. ex Lindl.	**เอื้องดอกขาวใบแบน** Ueang dok khao bai baen
D. parcum Rchb.f.	**เอื้องก้านกิ่ว** Ueang kan kio
D. parishii Rchb.f.	**เอื้องครั่ง** Ueang khrang
D. parvum Seidenf.	N/A
D. peguanum Lindl.	**หวายเปกู** Wai peku
D. pendulum Roxb.	**เอื้องไม้เท้าฤาษี** Ueang mai thao ruesi
D. perpaulum Seidenf.	**เอื้องข้าวตอกอินทนนท์** Ueang khao tok inthanon
D. planibulbe Lindl.	N/A
D. podagraria Hk. F.	N/A
D. polyanthum Wall. ex Lindl.	**เอื้องสายประสาท** Ueang sai prasat
D. porphyrochilum Lindl.	**เอื้องเฉวียน** Ueang chawian
D. porphyrophyllum Guillaumin	N/A
D. praecinctum Rchb.f.	**หวายภูหลวง** Wai phu luang
D. primulinum Lindl.	**เอื้องสายน้ำผึ้ง** Ueang sai num peung
D. proteranthum Seidenf.	**หวายน้อยภูหลวง** Wai noi phu luang
D. pulchellum Roxb. ex Lindl.	**เอื้องคำตาควาย** Ueang kham ta khwai
D. pychnostachyum Lindl.	**เศวตสอดสี** Sawet sot si
D. rhodopterygium Rchb.f.	N/A
D. rhodostele Ridl.	**เอื้องแมงเงาแดง** Ueang mang ngao dang
D. salaccense (Blume) Lindl.	**เอื้องใบไผ่** Ueang bai phai
D. sanguinolentum Lindl.	**เอื้องสายทะเลบัน** Ueang sai ta lay bun

D. scabrilingue Lindl.	**เอื้องแซะ** Ueang sae
D. schilhaueri Ormerod & Pedersen	**N/A**
D. secundum (Blume) Lindl.	**เอื้องแปรงสีฟัน** Ueang preang si fan
D. seidenfadenii Seng. & Bockem.	**N/A**
D. senile Par. & Rchb.f.	**เอื้องชะนี** Ueang chani
D. setifolium Ridl.	**เอื้องตุ้มหู** Ueang tomhu
D. signatum Rchb.f.	**เอื้องเค้ากิ่ว** Ueang khao kio
D. singaporense Hawkes & Heller	**N/A**
D. sinuatum (Lindl.) Lindl. ex Rchb.f.	**N/A**
D. sociale Sm.	**N/A**
D. strongylanthum Rchb.f.	**เอื้องเย้าลม** Ueang yao lom
D. stuartii Bailey	**N/A**
D. stuposum Lindl.	**เอื้องสาย** Ueang sai
D. subulatum (Blume) Lindl.	**N/A**
D. sukhakulii Hort.	**หวายสุขะกุล** Wai sukhakun
D. sulcatum Lindl.	**เอื้องจำปาน่าน** Ueang champa nan
D. superbiens Rchb.f.	**หวายคิง** Wai khing
D. sutepense Rolfe ex Downie	**เอื้องมะลิ** Ueang mali
D. terminale Par. & Rchb.f.	**เอื้องแผงโสภา** Ueang phaeng sopha
D. tetrodon Rchb.f. ex Lindl.	**เอื้องสายดอกเขียว** Ueang sai dok kheaw
D. thyrsiflorum Rchb.f ex Andr'e	**เอื้องมอนไข่ใบมน** Ueang mon khai bai mon
D. tortile Lindl.	**เอื้องไม้ตึง** Ueang mai tueng
D. trigonopus Rchb.f.	**เอื้องคำเหลี่ยม** Ueang kham liam
D. trinervium Ridl.	**เทียนลิง** Thian ling

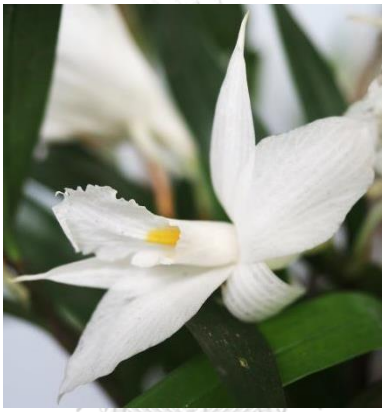
D. truncatum Lindl.	**N/A**
D. umbonatum Seidenf.	**N/A**
D. unicum Seidenf.	**เอื้องครั่งแสด** Ueang krang saet
D. uniflorum Griff.	**เอื้องทอง** Ueang thong
D. venustum Teijsm. & Binn	**ข้าวเหนียวลิง** Khao niao ling
D. villosulum Lindl.	**กล้วยหญ้านา** Kluai ya na
D. virgineum Rchb.f.	**เอื้องนางชี**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

Dendrobium orchids have diverse morphology and produce wide variety of secondary metabolites. Several plants in this genus have been studied for their chemical constituents and biological activities, but some have not yet been investigated for bioactive compounds, including *Dendrobium infundibulum* Lindl.

D. infundibulum is known as “Ueang ta hoen (เอื้องตาเหิน)” in Thai. It is an epiphytic orchid with 25-50 cm tall. Its pseudobulbs are 1-1.5 cm in diameter. The pseudobulds covered by leaf sheaths and light black hairs. The oblong-elliptic leaves were 6-8 cm long, 2-2.5 cm wide, shed when flowering. Flower arised near apex. They are 6-7 cm across and fragant. There are 1-3 flowers in an inflorescence. The seplas and petals are white. Petals are broadly ovate. Lips are with yellow orange marking. This plant is distributed in India, Myanmar, Laos, and Thailand. Its flowering period is in January to April (north, northeast and west) ("BGO Plant Database," 2011).

The methanol extract of *D. infundibulum* was evaluated for inhibitory activity against lipase and α-glucosidase. Although it could not inhibit α-glucosidase, but it exhibited 68.45% inhibitory activity against lipase at the concentration of 100 µg/mL. The interesting activity leaded to selection of this plant for the study. The objective of this study is to investigate the phytochemical profile and the inhibitory activity against lipase and α-glucosidase of this plant. The result of this research may provide useful information for studying the chemotaxonomy of *Dendrobium* species or developing new drugs.

a.



b.

Figure 1 *Dendrobium infundibulum* Lindl.

a. The flower of *Dendrobium infundibulum* Lindl.

b. The whole plant of *Dendrobium infundibulum* Lindl.

CHAPTER II
HISTORICAL

Several plants from different genera of the family Orchidaceae have been used in Traditional Chinese Medicine. Examples are Tianma (*Gastrodia elata*), Bai-Ji (*Bletilla striata*), Jin-Xian-Ma (*Anoectochilus* species), Shan-Ci-Gu (*Cremastra appendiculata*) and Shihu (*Dendrobium* species).

Shihu (Herba Dendrobii), which is composed of many *Dendrobium* species (five species which were listed in Chinese Pharmacopoeia were *D. chrysanthum*, *D. fimbriatum*, *D. loddigesii*, *D. nobile* and *D. officinale*), have been mainly used for treating the diseases related to thirst, fever, red tongue, atrophic gastritis and diabetes (Xu *et al.*, 2015; Zhang *et al.*, 2007c).

These medicinal uses of *Dendrobium* have attracted the interest of many reseachers in the area of natural product and phytomedicine. This chapter describes previously reported phytochemical studies on *Dendrobium* plants.

1. Chemical constituents of *Dendrobium*

The chemical constituents of *Dendrobium* can be categorized into five major classes: bibenzyls, phenathrenes, flavonoids, terpenes and miscellaneous compounds. The names of plants and their parts used for the isolation of pure compounds are listed in the following tables.

1.1 Bibenzyls

The bibenzyls are derivatives of stilbenes, which are derived from cinnamic acid (via the shikimate pathway) and three acetate units from malonyl coenzyme A (Gorham, 1989). Bibenzyls found in *Dendrobium* are summarized in **Table 1** and their structures are shown in **Figure 2.**

Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species

Compounds	Plants	Part	References
Aloifol I [**1**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2016
	D. sinense	Whole plant	Chen *et al.*, 2014
Amoenylin [**2**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999a
Aphyllal C [**3**]	*D. aphyllum*	Stem	Yang *et al.*, 2015
Aphyllal D [**4**]	*D. aphyllum*	Stem	Yang *et al.*, 2015
Aphyllal E [**5**]	*D. aphyllum*	Stem	Yang *et al.*, 2015
Aphyllone B [**6**]	*D. aphyllum*	Stem	Yang *et al.*, 2015
Batatasin [**7**]	*D. polyanthum*	Stem	Hu *et al.*, 2009
	D. plicatile	Stem	Yamaki *et al.*, 1996
Batatasin III [**8**]	*D. aphyllum*	Stem	Yang *et al.*, 2015
	D. cariniferum	Whole plant	Chen *et al.*, 2008a; Liu *et al.*, 2009a
	D. draconis	Stem	Sritularak *et al.*, 2011a
	D. fimbriatum	Stem	Xu *et al.*, 2014
	D. formosum	Whole plant	Inthongkaew *et al.*, 2017
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. hongdie	Whole plant	Chen *et al.*, 2015
	D. nobile	Stem	Zhou *et al.*, 2016
	D. rotundatum	Whole plant	Majumder *et al.*, 1992

Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Brittonin A [**9**]	*D. secundum*	Stem Whole plant	Sritularak *et al.*, 2011b Phechrmeekha *et al.*, 2012)
Chrysotobibenzyl [**10**]	*D. aurantiacum* var. *denneanum* *D. capillipes* *D. chrysototxum* *D. nobile* *D. pulchellum*	Stem Whole plant Whole plant Stem Stem	Yang *et al.*, 2006b Phechrmeekha *et al.*, 2012 Li *et al.*, 2011 Zhang *et al.*, 2007b Chanvorachote *et al.*, 2013
Chrysotoxin [**11**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.*, 2006b
Chrysotoxine [**12**]	*D. capillipes* *D. nobile* *D. pulchellum*	Whole plant Stem Stem	Phechrmeekha *et al.*, 2012 Zhang *et al.*, 2007b Chanvorachote *et al.*, 2013; Bhummaphan *et al.*, 2018
Crepidatin [**13**]	*D. aurantiacum* var. *denneanum*	Whole plant	Liu *et al.*, 2009b

Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Crepidatin [**13**]	*D. capillipes*	Whole plant	Phechrmeekha *et al.*, 2012
	D. chrysanthum	Stem	Yang *et al.*, 2006a
	D. crepidatum	Whole plant	Majumder *et al.*, 1989
	D. nobile	Stem	Zhang *et al.*, 2007b
	D. pulchellum	Stem	Chanvorachote *et al.*, 2013
Crepidatuol A [**14**]	*D. crepidatum*	Stem	Li *et al.*, 2013
Crepidatuol B [**15**]	*D. crepidatum*	Stem	Li *et al.*, 2013
	D. loddigesii	Stem	Lu *et al.*, 2014
Cumulatin [**16**]	*D. cumulatum*	Whole plant	Majumder *et al.*, 1993
Dencryol A [**17**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Dencryol B [**18**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Dendrobin A [**19**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Dendrocandin A [**20**]	*D. candidum*	Stem	Li *et al.*, 2008
Dendrocandin B [**21**]	*D. candidum*	Stem	Li *et al.*, 2008
	D. signatum	Whole plant	Mittraphab *et al.*, 201
Dendrocandin C [**22**]	*D. candidum*	Stem	Li *et al.*, 2009
Dendrocandin D [**23**]	*D. candidum*	Stem	Li *et al.*, 2009b
Dendrocandin E [**24**]	*D. candidum*	Stem	Li *et al.*, 2009b

Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Dendrocandin F or Dendrofalconerol A [**25**]	*D. candidum* *D. falconeri* *D. signatum* *D. tortile*	Stem Arial part Whole plant Whole plant	Li *et al.*, 2009c Sritularak *et al.*, 2009 Mittraphab *et al.*, 2016 Limpanit *et al.*, 2016
Dendrocandin G [**26**]	*D. candidum*	Stem	Li *et al.*, 2009c
Dendrocandin H [**27**]	*D. candidum*	Stem	Li *et al.*, 2009c
Dendrocandin I [**28**]	*D. candidum* *D. signatum*	Stem Whole plant	Li *et al.*, 2009c Mittraphab *et al.*, 2016
Dendrofalconerol B [**29**]	*D. falconeri*	Arial part	Sritularak *et al.*, 2009
Dendrophenol [**30**]	*D. candidum*	Stem	Li *et al.*, 2008
Dendrosinen A [**31**]	*D. sinense*	Whole plant	Chen *et al.*, 2014
Dendrosinen B [**32**]	*D. sinense*	Whole plant	Chen *et al.*, 2014
Dendrosinen C [**33**]	*D. sinense*	Whole plant	Chen *et al.*, 2014
Dendrosinen D [**34**]	*D. sinense*	Whole plant	Chen *et al.*, 2014
Dengraol A [**35**]	*D. gratiosissimum*	Stem	Zhang *et al.*, 2008a
Dengraol B [**36**]	*D. gratiosissimum*	Stem	Zhang *et al.*, 2008a
Densiflorol A [**37**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
Dendrosignatol [**38**]	*D. signatum*	Whole plant	Mittraphab *et al.*, 2016
Dendrowillol A [**39**]	*D. williamsonii*	Whole plant	Yang *et al.*, 2018

Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
3,3′-Dihydroxy-4,5-dimethoxybibenzyl (5,3′-Dihydroxy-3,4-Dimethoxybibenzyl) [**40**]	*D. williamsonii*	Whole plant	Rungwichaniwat *et al.*, 2014
	D. sinense	Whole plant	Chen *et al.*, 2014
3,4′-Dihydroxy-5-methoxybibenzyl [**41**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999a
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
3,4′-Dihydroxy-5,5′-dimethoxydihydrostilbene [**42**]	*D. nobile*	Stem	Hwang *et al.*, 2010
3,4-Dihydroxy-5,4′-dimethoxybibenzyl [**43**]	*D. candidum*	Stem	Li *et al.*, 2008
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. signatum	Whole plant	Mittraphab *et al.*, 2016
	D. tortile	Whole plant	Limpanit *et al.*, 2016
4,5-Dihydroxy-3,3′-dimethoxybibenzyl [**44**]	*D. nobile*	Stem	Ye *et al.*, 2002b
4,4′-Dihydroxy-3,5-dimethoxybibenzyl [**45**]	*D. candidum*	Stem	Li *et al.*, 2008
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al.*, 2014

Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Erianin [**46**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Gigantol [**47**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a; Yang *et al.*, 2015
	D. aurantiacum var. *denneanum*	Stem	Yang *et al.*, 2006b
		Whole plant	Liu *et al.*, 2009b
	D. brymerianum	Whole plant	Klongkumnuankarn *et al.*, 2015
	D. capillipes	Whole plant	Phechrmeekha *et al.*, 2012
	D. cariniferum	Whole plant	Liu *et al.*, 2009a
	D. chrysotoxum	Stem	Hu *et al.*, 2012; Wu *et al.*, 2017a
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. devonianum	Whole plant	Sun *et al.*, 2014
	D. draconis	Stem	Sritularak *et al.*, 2011a
	D. formosum	Whole plant	Inthongkaew *et al.*, 2017
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. loddigesii	Whole plant	Ito *et al.*, 2010
	D. nobile	Stem	Zhang *et al.*, 2007b
	D. officinale	Stem	Zhao *et al.*, 2018
	D. polyanthum	Stem	Hu *et al.*, 2009

Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Gigantol [**47**]	*D. trigonopus*	Stem	Hu *et al.*, 2008b
4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol [**48**]	*D. longicornu*	Stem	Hu *et al.*, 2008a
5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl [**49**]	*D. secundum*	Stem	Phechrmeekha *et al.*, 2012
4-Hydroxy-3,5,3′-trimethoxybibenzyl [**50**]	*D. nobile*	Stem	Ye *et al.*, 2002b
Isoamoenylin [**51**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999a
Longicornuol A [**52**]	*D. longicornu* *D. sinense*	Stem Whole plant	Hu *et al.*, 2008a Chen *et al.*, 2014
Loddigesiinol C [**53**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Loddigesiinol D [**54**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
3-O-Methylgigantol [**55**]	*D. candidum* *D. nobile* *D. plicatile*	Stem Stem Stem	Li *et al.*, 2008 Hwang *et al.*, 2010 Yamaki *et al.*, 1996

Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species (Cont.)

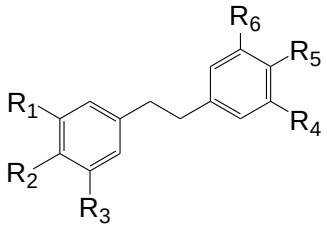
Compounds	Plants	Part	References
Moscatilin [**56**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999a
	D. aphyllum	Stem	Yang *et al.*, 2015
	D. aurantiacum var. denneanum	Whole plant, Stem	Yang *et al.*, 2006b; Liu *et al.*, 2009b
	D. brymerianum	Whole plant	Klongkumnuankarn *et al.*, 2015
	D. capillipes	Whole plant	Phechrmeekha *et al.*, 2012
	D. candidum	Stem	Li *et al.*, 2008
	D. chrysanthum	Stem	Yang *et al.*, 2006a
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al.*, 2014
	D. formosum	Whole plant	Inthongkaew *et al.*, 2017
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. loddigesii	Whole plant	Chen *et al.*, 1994; Ito *et al.*, 2010
	D. moscatum	Whole plant	Majumder *et al.*, 1987
	D. nobile	Stem	Miyazawa *et al.*, 1999; Zhang *et al.*, 2007b; Hwang *et al.*, 2010
	D. polyanthum	Stem	Hu *et al.*, 2009

Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Moscatilin [**56**]	*D. pulchellum*	Stem	Chanvorachote *et al.*, 2013
	D. secundum	Stem	Sritularak *et al.*, 2011b
Moscatilin diacetate [**57**]	*D. loddigesii*	Whole plant	Chen *et al.*, 1994
Nobilin D [**58**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Nobilin E [**59**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Trigonopol A [**60**]	*D. trigonopus*	Stem	Hu *et al.*, 2008b
	D. sinense	Whole plant	Chen *et al.*, 2014
Trigonopol B [**61**]	*D. trigonopus*	Stem	Hu *et al.*, 2008b
3,3′,4-Trihydroxy bibenzyl [**62**]	*D. longicornu*	Stem	Hu *et al.*, 2008a
3,3′,5-Trihydroxy bibenzyl [**63**]	*D. cariniferum*	Whole plant	Liu *et al.*, 2009a
3,5,4′-Trihydroxy bibenzyl [**64**]	*D. gratiosissimum*	Stem	Zhang *et al.*, 2008a
4,5,4′-Trihydroxy-3,3′-dimethoxy bibenzyl [**65**]	*D. secundum*	Stem	Sritularak *et al.*, 2011b; Phechrmeekha *et al.*, 2012
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al.*, 2014; Hlosrichok *et al.*, 2018

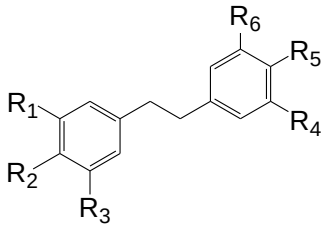
Table 1 Distribution of bibenzyl derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
3,4,3′-Trimethoxy-5,4′-dihydroxy bibenzyl or 3,4′-Dihydroxy-3′,4,5-trimethoxybibenzyl [**66**]	*D. sinense*	Whole plant	Chen *et al.*, 2014
Tristin [**67**]	*D. aphyllum*	Stem	Yang *et al.*, 2015
	D. brymerianum	Whole plant	Klongkumnuankarn *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. officinale	Stem	Zhao *et al.*, 2018
	D. trigonopus	Stem	Hu *et al.*, 2008b



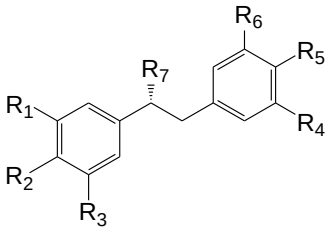
	R_1	R_2	R_3	R_4	R_5	R_6
[**1**] Aloifol I	OMe	OH	OMe	OH	H	H
[**2**] Amoenylin	OMe	OH	OMe	H	OMe	H
[**7**] Batatasin	OMe	H	H	OH	H	OH
[**8**] Batatasin III	OH	H	OMe	H	H	OH
[**9**] Brittonin A	OMe	OMe	OMe	OMe	OMe	OMe
[**10**] Chrysotobibenzyl	OMe	OMe	OMe	OMe	OMe	H
[**11**] Chrysotoxin	OMe	OH	OMe	OMe	OH	H
[**12**] Chrysotoxine	OMe	OMe	H	OMe	OH	OMe
[**13**] Crepidatin	OMe	OMe	OMe	OMe	OH	H
[**16**] Cumulatin	OMe	OMe	OH	OH	OMe	OMe
[**19**] Dendrobin A	OH	OH	OMe	H	H	OMe
[**32**] Dendrosinen B	OMe	OH	OH	H	H	OH
[**40**] 3,3′-Dihydroxy-4,5-dimethoxybibenzyl	OMe	OMe	OH	H	H	OH
[**41**] 3,4′-Dihydroxy-5-methoxybibenzyl	OH	H	OMe	H	OH	H
[**42**] 3,4′-Dihydroxy-5,5′-dimethoxydihydrostilbene	OH	H	OMe	OMe	OH	H

Figure 2 Structures of bibenzyl derivatives from *Dendrobium* species

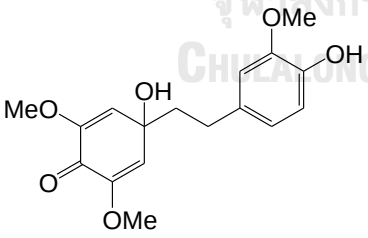


	R_1	R_2	R_3	R_4	R_5	R_6
[**44**] 4,5-Dihydroxy-3,3′-dimethoxybibenzyl	OMe	OH	OH	H	H	OMe
[**46**] Erianin	OMe	OMe	OMe	H	OMe	OH
[**47**] Gigantol	OMe	OH	H	OMe	H	OH
[**49**] 5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl	OMe	OMe	OH	OMe	OMe	OMe
[**50**] 4-Hydroxy-3,5,3′-trimethoxybibenzyl	OMe	OH	OMe	H	H	OMe
[**51**] Isoamoenylin	OMe	OMe	OMe	H	H	OH
[**56**] Moscatilin	OMe	OH	OMe	H	OH	OMe
[**57**] Moscatilin diacetate	OMe	OAc	OMe	H	OAc	OMe
[**62**] 3,3′,4-Trihydroxybibenzyl	OH	OH	H	H	H	OH
[**63**] 3,3′,5-Trihydroxybibenzyl	OH	H	OH	H	H	OH
[**64**] 3,5,4′-Trihydroxybibenzyl	OH	H	OH	H	OH	H
[**65**] 4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl	OMe	OH	OH	H	OH	OMe
[**66**] 3,4,3′-Trimethoxy-5,4′-dihydrobibenzyl	OMe	OMe	OH	H	OH	OMe
[**67**] Tristin	OH	H	OH	H	OH	OMe

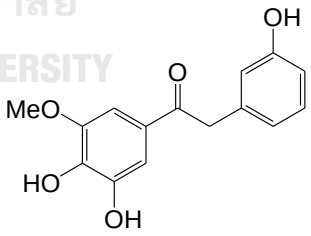
Figure 2 Structures of bibenzyl derivatives from *Dendrobium* species (Cont.)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**20**] Dendrocandin A	OH	OH	OMe	H	OMe	OH	OMe
[**30**] Dendrophenol	OMe	OH	OMe	OH	OH	H	H
[**43**] 3,4-Dihydroxy-5,4′-dimethoxybibenzyl	OH	OH	OMe	H	OMe	H	H
[**45**] 4,4′-Dihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	H	OH	H	H
[**53**] Loddigesiinol C	OMe	OH	OMe	H	OH	OMe	OMe
[**55**] 3-O-Methylgigantol	OMe	H	OH	OMe	OMe	H	H
[**4**] Aphyllal D	H	H	OH	H	OH	OMe	OH
[**5**] Aphyllal E	OMe	H	OH	H	OH	OMe	OH

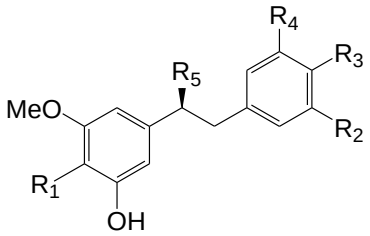


[**6**] Aphyllone B

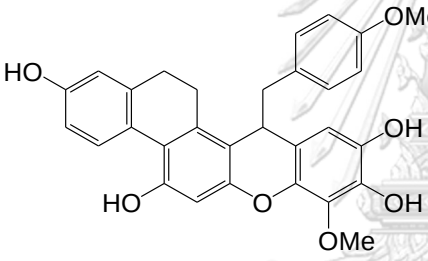


[**33**] Dendrosinen C

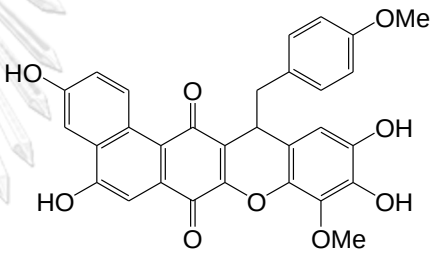
Figure 2 Structures of bibenzyl derivatives from *Dendrobium* species (Cont.)



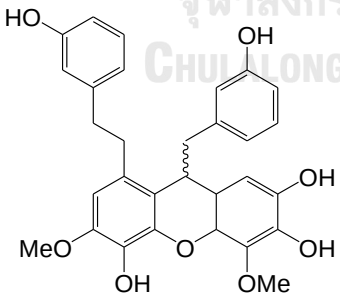
	R_1	R_2	R_3	R_4	R_5
[**22**] Dendrocandin C	OH	H	OH	H	OMe
[**23**] Dendrocandin D	OH	H	OH	H	OCH_2CH_3
[**24**] Dendrocandin E	OH	OH	OH	H	H
[**31**] Dendrosinen A	OMe	H	H	OH	H



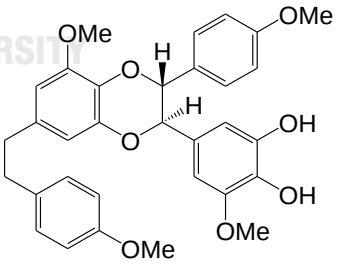
[**38**] Dendrosignatol



[**27**] Dendrocandin H

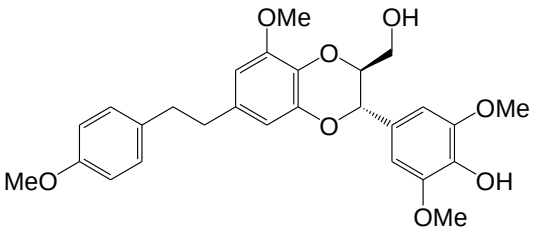


[**34**] Dendrosinen D

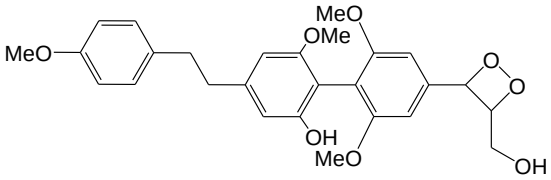


[**28**] Dendrocandin I

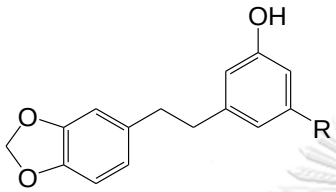
Figure 2 Structures of bibenzyl derivatives from *Dendrobium* species (Cont.)



[**21**] Dendrocandin B

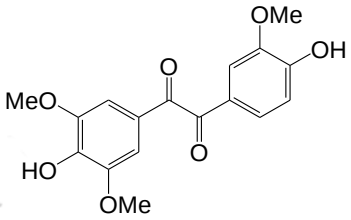


[**39**] Dendrowillol A

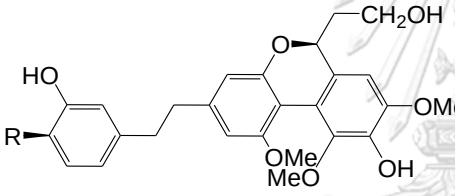


[**3**] Aphyllal C: R = OH

[**37**] Densiflorol A: R = OMe

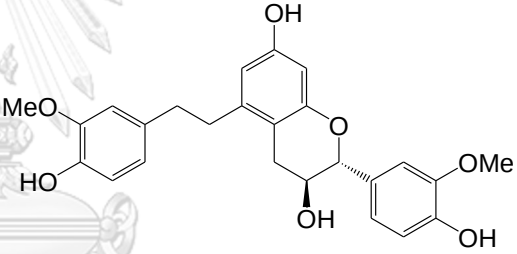


[**54**] Loddigesiinol D

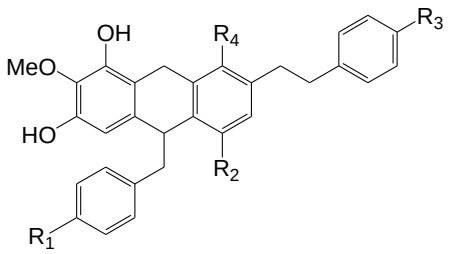


[**52**] Longicornuol A: R = H

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

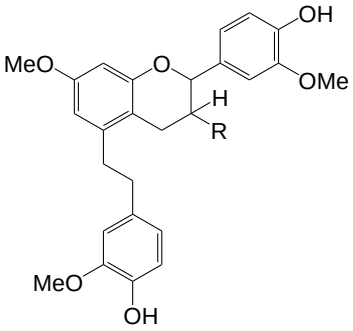


[**61**] Trigonopol B



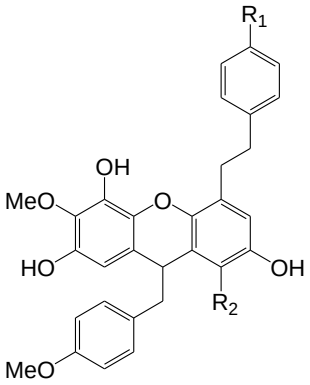
	R_1	R_2	R_3	R_4
[**17**] Dencryol A	OMe	OH	OH	H
[**18**] Dencryol B	OH	OMe	OMe	OH

Figure 2 Structures of bibenzyl derivatives from *Dendrobium* species (Cont.)



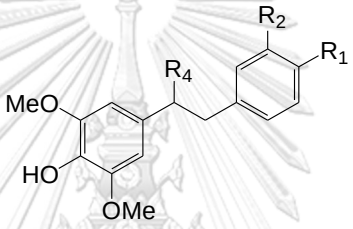
[**14**] Crepidatuol A: R = H

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



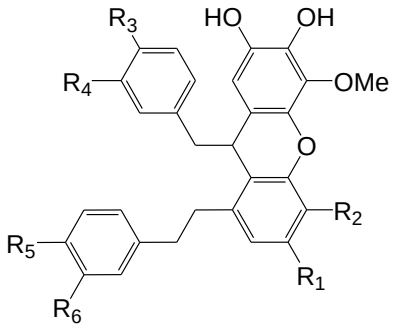
[**35**] Dengraol A: R_1 = OH, R_2 = H

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



	R_1	R_2	R_3
[**48**] 4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol	H	OH	OMe
[**58**] Nobilin D	OH	OMe	OH

Figure 2 Structures of bibenzyl derivatives from *Dendrobium* species (Cont.)



	R_1	R_2	R_3	R_4	R_5	R_6
[**25**] Dendrocandin F (Dendrofalconerol A)	OMe	OH	OMe	H	OMe	H
[**26**] Dendrocandin G	OMe	OH	OH	H	OMe	H
[**29**] Dendrofalconerol B	OH	H	OMe	H	OH	H
[**59**] Nobilin E	OMe	OH	H	OMe	H	OMe

Figure 2 Structures of bibenzyl derivatives from *Dendrobium* species (Cont.)

1.2 Phenanthrenes

Phenanthrene derivatives are derived from the general phenylpropanoid pathway, which begins from the synthesis of *trans*-cinnamic acid or its derivative *p*-coumaric acid from the aromatic amino acids phenylalanine or tyrosine (Dubrovina *et al.*, 2017). Previously reported phenanthrenes are listed in **Table 2**.

Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species

Compounds	Plants	Part	References
Amoenumin [**68**]	*D. amoenum*	Whole plant	Veerraju *et al.*, 1989
Aphyllone A [**69**]	*D. aphyllum*	Stem	Yang *et al.*, 2015
Bulbophyllanthrin [**70**]	*D. nobile*	Stem	Yang *et al.*, 2007
Crystalltone [**71**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Chrysotoxol A [**72**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Chrysotoxol B [**73**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Coelonin [**74**]	*D. amoenum*	Whole plant	Veerraju *et al.*, 1989
	D. aphyllum	Whole plant	Chen *et al.*, 2008a
	D. formosum	Whole plant	Inthongkaew *et al.*, 2017
	D. nobile	Stem	Yang *et al.*, 2007; Hwang *et al.*, 2010
Confusarin [**75**]	*D. formosum*	Whole plant	Inthongkaew *et al.*, 2017
	D. officinale	Stem	Zhao *et al.*, 2018
	D. noblie	Stem	Zhang *et al.*, 2008c

Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Cypripedin [**76**]	*D. densiflorum* *D. densiflorum*	Stem Whole plant	Fan *et al.*, 2001 Wattanathamsan *et al.*, 2018
Dehydroorchinol [**77**]	*D. nobile*	Stem	Kim *et al.*, 2015
Denbinobin [**78**]	*D. moniliforme* *D. nobile*	Stem Stem	Lin *et al.*, 2001 Yang *et al.*, 2007
Denbinobin B [**79**]	*D. sinense*	Whole plant	Chen *et al.*, 2013
Dendrocandin P1 [**80**]	*D. officinale*	Stem	Zhao *et al.*, 2018
Dendrocandin P2 [**81**]	*D. officinale*	Stem	Zhao *et al.*, 2018
Dendrochrysanene [**82**]	*D. chrysanthum*	Stem	Yang *et al.*, 2006a
Dendronone [**83**]	*D. cariniferum*	Whole plant	Chen *et al.*, 2008b
Densiflorol B [**84**]	*D. densiflorum* *D. chrysotoxum*	Stem Whole plant	Fan *et al.*, 2001 Li *et al.*, 2009d
Denthyrsinin [**85**]	*D. thyrsiforum*	Stem	Zhang *et al.*, 2005
Denthyrsinol [**86**]	*D. thyrsiforum*	Stem	Zhang *et al.*, 2005
Denthyrsinone [**87**]	*D. thyrsiforum*	Stem	Zhang *et al.*, 2005
9,10-Dihydromoscatin [**88**]	*D. polyanthum*	Stem	Hu *et al.*, 2009
9,10-Dihydrophenan-threne-2,4,7-triol [**89**]	*D. polyanthum*	Stem	Hu *et al.*, 2009

Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
2,2′-Dihydroxy-3,3′,4,4′,7,7-hexa methoxy-9,9′,10,10′-Tetrahydro-1,1′-biphenanthrene [**90**]	*D. nobile*	Stem	Yang *et al.*, 2007
4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [**91**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al.*, 2014
4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene [**92**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene [**93**]	*D. nobile*	Stem	Ye *et al.*, 2002b
2,5-Dihydroxy-3,4 dimethoxy phenanthrene [**94**]	*D. nobile*	Stem	Yang *et al.*, 2007
2,5-Dihydroxy-4,9-dimethoxy phenanthrene [**95**]	*D. nobile*	Stem	Zhang *et al.*, 2008c

Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
3,7-Dihydroxy-2,4-dimethoxy phenanthrene [**96**]	*D. chrysotoxum* *D. nobile*	Whole plant Stem	Li *et al.*, 2009d Zhang *et al.*, 2008c
4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene [**97**]	*D. nobile*	Stem	Yang *et al.*, 2007; Zhang *et al.*, 2007b
1,5-dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**98**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2016
2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene [**99**]	*D. plicatile*	Stem	Yamaki *et al.*, 1996
2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**100**]	*D. nobile*	Stem	Fan *et al.*, 2001; Yang *et al.*, 2007
2,6-Dihydroxy-1,5,7-trimethoxy phenanthrene [**101**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene [**102**]	*D. rotundatum*	Whole plant	Majumder *et al.*, 1992

Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
3,4-Dimethoxy-1-(methoxymethyl)-9,10-dihydrophenanthrene-2,7-diol [**103**]	*D. hainanense*	Aerial part	Zhang *et al.*, 2018
4,9-dimethoxy phenantrene-2,5-diol [**104**]	*D. chrysotoxum*	Whole plant	Li *et al.*, 2009d
5,7-dimethoxy phenantrene-2,6-diol [**105**]	*D. nobile*	Stem	Hwang *et al.*, 2010
Ephemeranthol A [**106**]	*D. nobile* *D. nobile* *D. officinale*	Whole plant Stem Stem	Hwang *et al.*, 2010 Yang *et al.*, 2007; Kim *et al.*, 2015; Zhou *et al.*, 2016 Zhao *et al.*, 2018
Ephemeranthol C [**107**]	*D. nobile*	Stem	Hwang *et al.*, 2010
Ephemeranthoquinone [**108**]	*D. plicatile*	Stem	Yamaki *et al.*, 1996
Epheranthol B [**109**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Erianthridin [**110**]	*D. formosum* *D. nobile* *D. plicatile*	Whole plant Stem Stem	Inthongkaew *et al.*, 2017 Yang *et al.*, 2007; Hwang *et al.*, 2010 Yamaki *et al.*, 1996

Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
2-Ethoxy-1-hydroxy-7-methoxy-5H-naphtho[8,1,2-cde]chromen-5-one [**111**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Fimbriatone [**112**]	*D. pulchellum*	Stem	Chanvorachote *et al.*, 2013
Fimbriol B [**113**]	*D. nobile*	Stem	Yang *et al.*, 2007; Hwang *et al.*, 2010
Flaccidin [**114**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999a
Flavanthridin [**115**]	*D. nobile*	Stem	Hwang *et al.*, 2010
Flavanthrin [**116**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
Flavanthrinin [**117**]	*D. brymerianum* *D. nobile* *D. venustum*	Whole plant Stem Whole plant	Klongkumnuankarn *et al.*, 2015 Zhang *et al.*, 2008c Sukphan *et al.*, 2014
Hircinol [**118**]	*D. aphyllum* *D. formosum* *D. moniliforme* *D. nobile* *D. thyrsiflorum*	Stem Whole plant Whole plant Stem Stem	Yang *et al.*, 2015 Inthongkaew *et al.*, 2017 Zhao *et al.*, 2016 Hwang *et al.*, 2010 Zhang *et al.*, 2005

Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene [**119**]	*D. nobile*	Stem	Yang *et al.*, 2007
5-Hydroxy-2,4-dimethoxy phenanthrene [**120**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene [**121**]	*D. nobile*	Stem	Yang *et al.*, 2007
3-Hydroxy-2,4,7-trimethoxy phenanthrene [**122**]	*D. nobile*	Stem	Yang *et al.*, 2007
Loddigesiinol A [**123**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Loddigesiinol B [**124**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Loddigesiinol G [**125**]	*D. loddigesii*	Stem	Lu *et al.*, 2014
Loddigesiinol H [**126**]	*D. loddigesii*	Stem	Lu *et al.*, 2014
Loddigesiinol I [**127**]	*D. loddigesii*	Stem	Lu *et al.*, 2014
Loddigesiinol J [**128**]	*D. loddigesii*	Stem	Lu *et al.*, 2014
Lusianthridin [**129**]	*D. aphyllum* *D. brymerianum* *D. formosum*	Whole plant Whole plant Whole plant	Chen *et al.*, 2008a Klongkumnuankarn *et al.*, 2015 Inthongkaew *et al.*, 2017

Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species (Cont.)

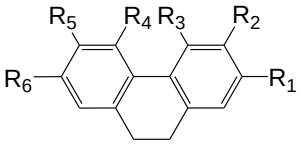
Compounds	Plants	Part	References
Lusianthridin [**129**]	*D. nobile*	Stem	Hwang *et al.*, 2010; Yang *et al.*, 2007
	D. plicatile	Stem	Yamaki *et al.*, 1996
	D. venustum	Whole plant	Sukphan *et al.*, 2014
7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol [**130**]	*D. draconis*	Stem	Sritularak *et al.*, 2011a
5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**131**]	*D. draconis*	Stem	Sritularak *et al.*, 2011a
	D. formosum	Whole plant	Inthongkaew *et al.*, 2017
Moniliformin [**132**]	*D. moniliforme*	Stem	Lin *et al.*, 2001
Moscatin [**133**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
	D. chrysanthum	Stem	Yang *et al.*, 2006a
	D. chrysotoxum	Whole plant	Li *et al.*, 2009d
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. loddigesii	Whole plant	Chen *et al.*, 1994
	D. polyanthum	Stem	Hu *et al.*, 2009
	D. thyrsiflorum	Stem	Zhang *et al.*, 2005
Nudol [**134**]	*D. formosum*	Whole plant	Inthongkaew *et al.*, 2017
	D. nobile	Stem	Yang *et al.*, 2007

Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Nudol [**134**]	*D. rotundatum*	Whole plant	Majumder *et al.*, 1992
Orchinol [**135**]	*D. officinale*	Stem	Zhao *et al.*, 2018
Plicatol A [**136**]	*D. nobile* *D. plicatile*	Stem Stem	Yang *et al.*, 2007 Honda *et al.*, 2000
Plicatol B [**137**]	*D. plicatile*	Stem	Honda *et al.*, 2000
Plicatol C [**138**]	*D. plicatile*	Stem	Honda *et al.*, 2000
Phoyunnanin C [**139**]	*D. venustum*	Whole plant	Sukphan *et al.*, 2014
Phoyunnanin E [**140**]	*D. venustum*	Whole plant	Sukphan *et al.*, 2014
Rotundatin [**141**]	*D. rotundatum*	Whole plant	Majumder *et al.*, 1992
(*S*)-2,4,5,9-Tetrahydroxy-9,10-dihydro phenanthrene [**142**]	*D. fimbriatum*	Stem	Xu *et al.*, 2014
2,4,5,9*S*-Tetrahydroxy-9,10-dihydro phenanthrene-4-*O*-β-D-glucopyranoside [**143**]	*D. primulinum*	Whole plant	Ye *et al.*, 2016
2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene [**144**]	*D. nobile*	Stem	Yang *et al.*, 2007
2,4,7-Trihydroxy-9,10-dimethoxyphenanthrene [**145**]	*D. officinale*	Stem	Zhao *et al.*, 2018
3,4,8-Trimethoxy phenanthrene-2,5-diol [**146**]	*D. nobile*	Stem	Hwang *et al.*, 2010

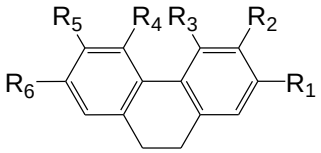
Table 2 Distribution of phenanthrenes and derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
2,5,7-Trimethoxy-4-methoxy-9,10-dihydro phenanthrene [**147**]	*D. longicornu* *D. formosum*	Stem Whole plant	Hu *et al.*, 2008a Inthongkaew *et al.*, 2017
1,5,7-Trimethoxy phenanthren-2-ol [**148**]	*D. nobile*	Stem	Kim *et al.*, 2015

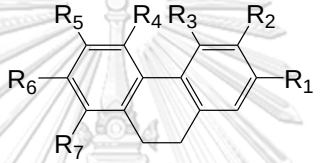


	R_1	R_2	R_3	R_4	R_5	R_6
[**74**] Coelonin	OH	H	OMe	H	H	OH
[**88**] 9,10-Dihydromoscatin	H	H	OH	OMe	H	OH
[**89**] 9,10-Dihydrophenanthrene-2,4,7-triol	OH	H	OH	H	H	OH
[**91**] 4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	OH	H	H
[**92**] 4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	OMe	H
[**93**] 4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene	H	OMe	OH	OH	H	OMe
[**96**] 3,7-Dihydroxy-2,4-dimethoxyphenanthrene	OMe	H	H	H	H	OH
[**97**] 4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	H	H
[**102**] 4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	H	OMe	OH
[**106**] Ephemeranthol A	OH	H	H	OH	OMe	OMe
[**107**] Ephemeranthol C	OH	OH	OMe	OH	H	H
[**110**] Erianthridin	OH	OMe	OMe	H	H	OH
[**115**] Flavanthridin	OH	H	H	OMe	OH	OMe
[**118**] Hircinol	OH	H	OMe	OH	H	H
[**121**] 3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene	OMe	OH	OMe	H	H	OMe

Figure 3 Structures of phenanthrene and derivatives from *Dendrobium* species

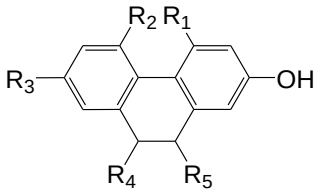


	R_1	R_2	R_3	R_4	R_5	R_6
[**129**] Lusianthridin	OMe	H	OH	H	H	OH
[**135**] Orchinol	OMe	H	OH	OH	H	H
[**145**] 2,4,7-Trihydroxy-9,10-Dimethoxyphenanthrene	OH	H	OH	H	H	OH

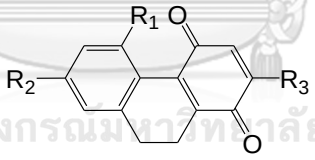


	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**98**] 1,5-dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene	OMe	H	OH	OMe	OMe	H	OH
[**100**] 2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene	OH	OMe	OMe	H	H	OMe	OH
[**103**] 3,4-Dimethoxy-1-(methoxymethyl)-9,10-dihydrophenanthrene-2,7-diol	OH	H	H	OMe	OMe	OH	EtOMe

Figure 3 Structures of phenanthrene and derivatives from *Dendrobium* species (Cont.)

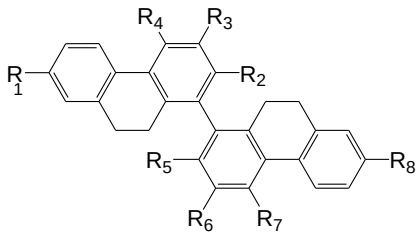


	R_1	R_2	R_3	R_4	R_5
[**119**] 2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene	OMe	H	OMe	H	H
[**130**] 7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol	OH	OH	OMe	H	H
[**147**] 2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene	OMe	OH	OH	H	H
[**138**] Plicatol C	H	OMe	OH	H	OMe
[**141**] Rotundatin	OMe	OH	H	OH	H
[**142**] (*S*)-2,4,5,9-Tetrahydroxy-9,10-dihydrophenanthrene	OH	OH	OH	H	OH

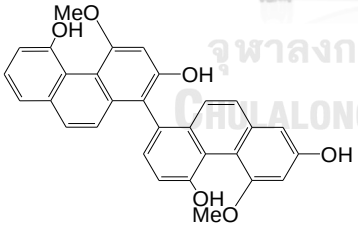


	R_1	R_2	R_3
[**83**] Dendronone	OH	OMe	H
[**84**] Densiferol B	H	OH	OMe
[**108**] Ephemeranthoquinone	H	OH	OMe
[**131**] 5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone	OMe	OH	H

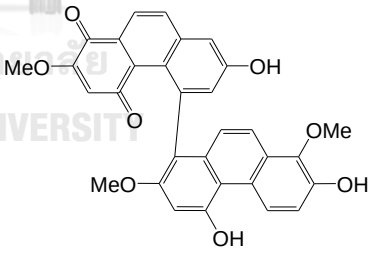
Figure 3 Structures of phenanthrene and derivatives from *Dendrobium* species (Cont.)



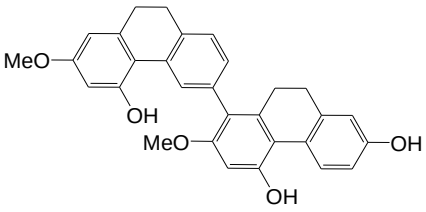
	R1	R2	R3	R4	R5	R6	R7	R8
[**90**] 2,2′-Dihydroxy-3,3′,4,4′,7,7′-hexamethoxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OMe	OH	OMe	OMe	OH	OMe	OMe	OMe
[**99**] 2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OH	OMe	H	OH	OMe	H	OH	OH
[**116**] Flavanthrin	OH	OH	H	OMe	OH	H	OMe	OH



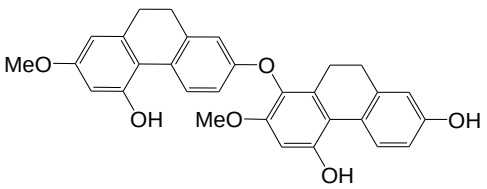
[**86**] Denthyrsinol



[**87**] Denthyrsinone

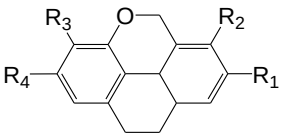


[**139**] Phoyunnanin C

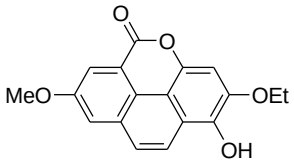


[**140**] Phoyunnanin E

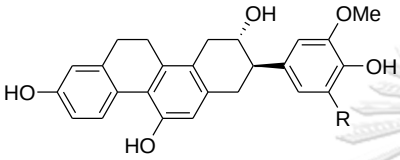
Figure 3 Structures of phenanthrene and derivatives from *Dendrobium* species (Cont.)



	R_1	R_2	R_3	R_4
[**68**] Amoenumin	OH	H	OH	OMe
[**114**] Flaccidin	OMe	OH	H	OH

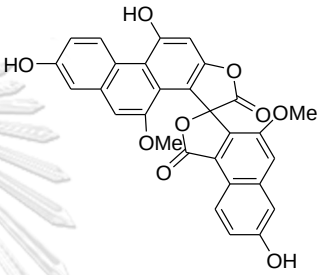


[**71**] Crystalltone

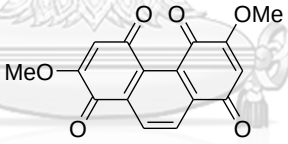


[**72**] Chrysotoxol A: R = H

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

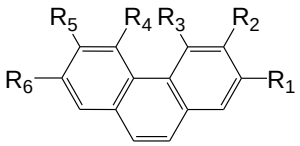


[**82**] Dendrochrysanene



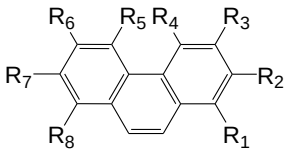
[**132**] Moniliformin

Figure 3 Structures of phenanthrene and derivatives from *Dendrobium* species (Cont.)



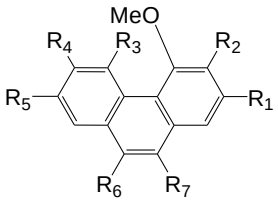
	R_1	R_2	R_3	R_4	R_5	R_6
[**70**] Bulbophyllanthrin	OMe	OH	OMe	OH	H	H
[**77**] Dehydroorchinol	OMe	H	OMe	H	H	OH
[**94**] 2,5-Dihydroxy-3,4-dimethoxyphenanthrene	H	H	OH	OMe	OMe	OH
[**105**] 5,7-dimethoxyphenanthrene-2,6-diol	OMe	OH	OMe	H	OH	H
[**109**] Epheranthol B	OMe	H	OH	OMe	H	H
[**113**] Fimbriol B	H	H	H	OH	OMe	OH
[**117**] Flavanthrinin	OH	H	H	OMe	H	H
[**120**] 5-Hydroxy-2,4-dimethoxyphenanthrene	OMe	H	OMe	OH	H	H
[**122**] 3-Hydroxy-2,4,7-trimethoxyphenanthrene	OMe	OH	OMe	H	H	OMe
[**133**] Moscatin	H	H	OH	OMe	H	OH
[**134**] Nudol	OH	OMe	OMe	H	H	OH
[**137**] Plicatol B	OH	H	OMe	OH	H	H

Figure 3 Structures of phenanthrene and derivatives from *Dendrobium* species (Cont.)

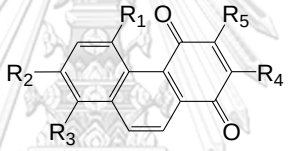


	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
[**75**] Confusarin	OMe	OH	H	H	OMe	OMe	OH	H
[**85**] Denthyrsinin	H	OMe	OH	OMe	H	H	OH	OMe
[**100**] 2,8-Dihydroxy-3,4,7-trimethoxy-9,10 phenanthrene	OH	OMe	H	H	OMe	OMe	OH	H
[**101**] 2,6-Dihydroxy-1,5,7-trimethoxy phenanthrene	OMe	OH	H	H	OMe	OH	OMe	H
[**104**] 4,9-Dimethoxy phenanthrene-2,5-diol	H	OH	H	OMe	OH	H	H	OMe
[**148**] 1,5,7-Trimethoxy phenanthren-2-ol	H	OMe	H	OMe	H	H	OH	OMe
[**146**] 3,4,8-Trimethoxy phenanthrene-2,5-diol	H	OH	OMe	OMe	OH	H	H	OMe

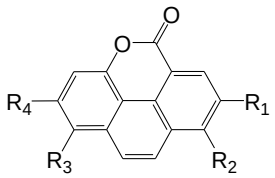
Figure 3 Structures of phenanthrene and derivatives from *Dendrobium* species (Cont.)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**95**] 2,5-Dihydroxy-4,9-dimethoxyphenanthrene	H	H	OMe	H	OH	H	OMe
[**123**] Loddigesiinol A	OH	H	OMe	H	H	OH	H
[**136**] Plicatol A	OH	H	OH	H	H	OMe	OMe
[**144**] 2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene	OH	OH	OH	H	H	OMe	H

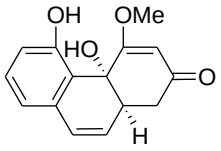


	R_1	R_2	R_3	R_4	R_5
[**76**] Cypripedin	H	OH	OMe	OMe	H
[**78**] Denbinobin	OH	OMe	H	H	OMe
[**79**] Denbinobin B	H	OH	H	OMe	OMe
[**84**] Densiflorol B	H	OH	H	OMe	H

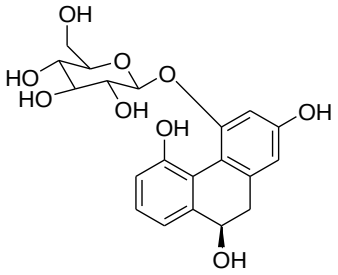


	R_1	R_2	R_3	R_4
[**111**] 2-Ethoxy-1-hydroxy-7-methoxy-5H-naphtho[8,1,2-cde]chromen-5-one	OMe	H	OH	OCH_2CH_3
[**112**] Fimbriatone	OH	OMe	H	OH

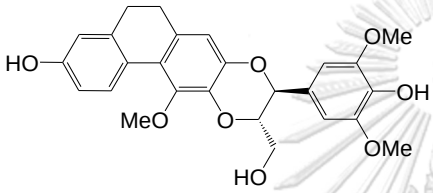
Figure 3 Structures of phenanthrene and derivatives from *Dendrobium* species (Cont.)



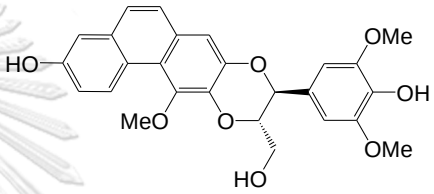
[**69**] Aphyllone A



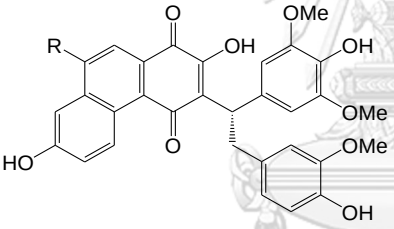
[**143**] 2,4,5,9*S*-Tetrahydroxy-9,10-dihydrophenanthrene-4-*O*-β-D-glucopyranoside



[**80**] Dendrocandin P1

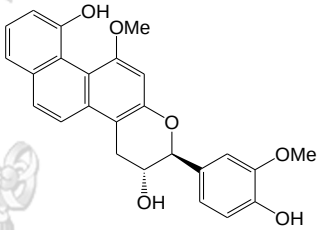


[**81**] Dendrocandin P2

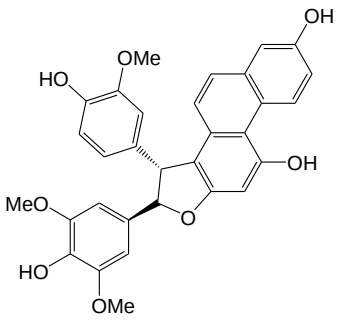


[**125**] Loddigesiinol G: R = H

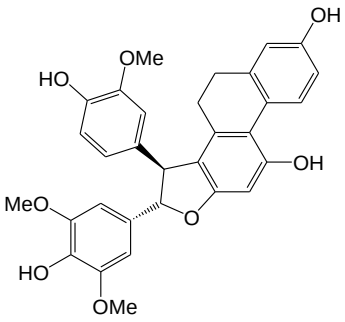
[**126**] Loddigesiinol H: R = OH



[**124**] Loddigesiinol B



[**127**] Loddigesiinol I



[**128**] Loddigesiinol J

Figure 3 Structures of phenanthrene and derivatives from *Dendrobium* species (Cont.)

1.3 Flavonoids

Flavonoids are biosynthesized through the combination of the phenylpropanoid and polyketide pathways. The phenylpropanoid pathway produces *p*-coumaroyl-CoA. The polyketide pathway elongates C2 chain by utilizing malonyl-CoA. The aromatic amino acids phenylalanine and tyrosine are the initiation of the phenylpropanoid pathway (Saito *et al.*, 2013). **Table 3** shows the flavonoid compounds found in *Dendrobium*.

Table 3 Distribution of flavonoid derivatives in *Dendrobium* species

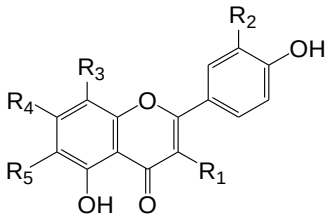
Compounds	Plant	Part	Reference
Apigenin [**149**]	*D. crystallinum* *D. williamsonii*	Stem Whole plant	Wang *et al.*, 2009 Rungwichaniwat *et al.*, 2014
6-*C*-(α-Arabinopyranosyl)-1-*C*-[(2-*O*-α-rhamnopyranosyl)-β-galactopyranosyl] apigenin [**150**]	*D. huoshanense*	Leaves and Stem	Chang *et al.*, 2010
Chrysoeriol [**151**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al.*, 2014
(2*S*)-Eriodictyol [**152**]	*D. ellipsophyllum* *D. tortile*	Whole plant Whole plant	Tanagornmeatar *et al.*, 2014 Limpanit *et al.*, 2016
6‴-Glucosyl-vitexin [**153**]	*D. crystallinum*	Stem	Wang *et al.*, 2009

Table 3 Distribution of flavonoid derivatives in *Dendrobium* species (Cont.)

Compounds	Plant	Part	Reference
Homoeriodictyol [**154**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
(2*S*)-Homoeriodictyol [**155**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al.*, 2014
5-Hydroxy-3-methoxy-flavone-7-*O*-[β-D-apiosyl-(1→6)]-β-D-glucoside [**156**]	*D. devonianum*	Whole plant	Sun *et al.*, 2014
Isoviolanthin [**157**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Luteolin [**158**]	*D. aurantiacum* var. *denneanum* *D. ellipsophyllum*	Whole plant Whole plant	Liu *et al.*, 2009b Tanagornmeatar *et al.*, 2014
Kaempferol [**159**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.*, 2006b
Kaempferol-3-O-α-L-rhamnopyranoside [**160**]	*D. secundum*	Whole plant	Phechrmeekha *et al.*, 2012
Kaempferol-3,7-O-di-α-L-rhamno pyranoside [**161**]	*D. secundum*	Whole plant	Phechrmeekha *et al.*, 2012
Kaempferol-3-O-α-L-rhamnopyranosyl-(1→2)-β-D-glucopyranoside [**162**]	*D. capillipes*	Whole plant	Phechrmeekha *et al.*, 2012

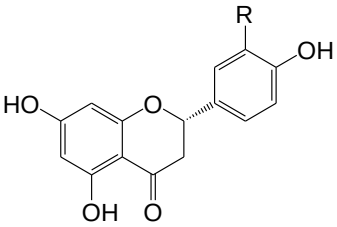
Table 3 Distribution of flavonoid derivatives in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1→2)-β-D-xylopyranoside (Lysimachiin) [**163**]	*D. capillipes*	Whole plant	Phechrmeekha *et al.*, 2012
Naringenin [**164**]	*D. aurantiacum var. denneanum*	Stem	Yang *et al.*, 2006b
Quercetin-3-*O*-α-L-rhamnopyranoside [**165**]	*D. secundum*	Stem	Phechrmeekha *et al.*, 2012
Quercetin-3-*O*-α-L-rhamnopyranosyl-(1→2)-β-D-xylopyranoside [**166**]	*D. capillipes*	Whole plant	Phechrmeekha *et al.*, 2012
6-*C*-[(2-*O*-α-Rhamnopyranosyl)-β-glucopyranosyl]-1-*C*-(α-arabinopyranosyl) apigenin [**167**]	*D. huoshanense*	Leaves and Stem	Chang *et al.*, 2010
6-*C*-(β-Xylopyranosyl)-1-*C*-[(2-*O*-α-rhamnopyranosyl)-β-glucopyranosyl] apigenin [**168**]	*D. huoshanense*	Leaves and Stem	Chang *et al.*, 2010

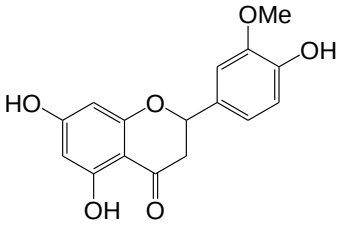


	R_1	R_2	R_3	R_4	R_5
[**149**] Apigenin	H	H	H	OH	H
[**150**] 6-C-(α-Arabinopyranosyl)-1-C-[(2-O-α-rhamnopyranosyl) -β-galactopyranosyl] apigenin	H	H	-Gal-Rha	OH	-Ara
[**151**] Chrysoeriol	H	OMe	H	OH	H
[**153**] 6‴-Glucosyl-vitexin	H	H	-Glc	OH	H
[**157**] Isoviolanthin	H	H	-Glc	OH	-Rha
[**158**] Luteolin	H	OH	H	OH	H
[**159**] Kaempferol	OH	H	H	OH	H
[**160**] Kaempferol-3-*O*-α-L-rhamnopyranoside	O-Rha	H	H	OH	H
[**161**] Kaempferol-3,7-*O*-di-α-L-rhamno pyranoside	O-Rha	H	H	O-Rha	H
[**162**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-glucopyranoside	O-Glc-Rha	H	H	OH	H
[**163**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside	O-Xyl-Rha	H	H	OH	H
[**167**] 6-*C*-[(2-*O*-α-Rhamnopyranosyl)-β-glucopyranosyl]-1-*C*-(α-arabinopyranosyl) apigenin	H	H	-Ara	OH	-Glc-Rha
[**168**] 6-*C*-(β-Xylopyranosyl)-1-*C*-[(2-*O*-α-rhamnosepyranosyl)-β-glucopyranosyl] apigenin	H	H	-Glc-	OH	-Xyl Rha

Figure 4 Structures of flavonoids and derivatives from *Dendrobium* species



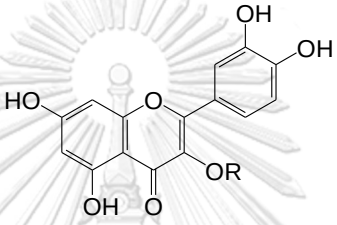
[**155**] (2*S*)- Homoeriodictyol: R = OMe



Homoeriodictyol [**154**]

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

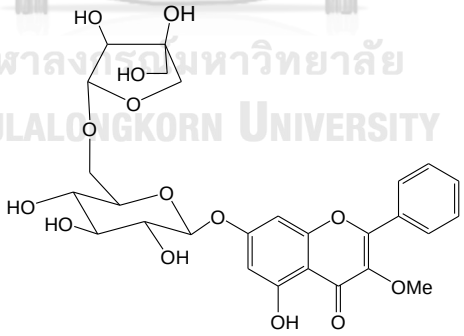
[**152**] (2*S*)-Eriodictyol; R = OH



R

[**165**] Quercetin-3-*O*-α-L-rhamnopyranoside O-Rha

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



[**156**] 5-Hydroxy-3-methoxy-flavone-7-*O*-[β-D-apiosyl-(1→6)]-β-D-glucoside

Figure 4 Structures of flavonoids and derivatives from *Dendrobium* species (Cont.)

1.4 Terpenes

Terpenoids could be biosynthesized via the mevalonate pathway and mevalonate-independent pathway through deoxyxylulose phosphate. They are derived from C_5 isoprene units. The basic structures are represented by $(C_5)_n$, which are hemiterpenes (C_5), monoterpenes (C_{10}), sesquiterpenes (C_{15}), diterpenes (C_{20}), sesterterpenes (C_{25}), triterpenes (C_{30}) and tetraterpenes (C_{40}). Terpenes which have been isolated from *Dendrobium* (sesquiterpines) are listed in **Table 4**.

Table 4 Distribution of terpene derivatives in *Dendrobium* species

Compounds	Plants	Part	References
Aduncin [**169**]	*D. aduncum*	Whole plant	Gawell *et al.*, 1976
Amoenin [**170**]	*D. amoenum*	Whole plant	Dahmen *et al.*, 1978; Majumder *et al.*, 1999a
Amotin [**171**]	*D. amoenum*	Whole plant	Dahmen *et al.*, 1978; Majumder *et al.*, 1999a
(−)-(1*R*,2*S*,3*R*,4*S*,5*R*, 6*S*,9*S*,11*R*)-11-Carboxymethyl dendrobine [**172**]	*D. nobile* *D. polyanthum*	Stem Stem	Meng *et al.*, 2017 Hu *et al.*, 2009
Corchoionoside C [**173**]	*D. polyanthum*	Stem	Hu *et al.*, 2009
Crystallinin [**174**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Dendrobane A [**175**]	*D. wardianum*	Stem	Fan *et al.*, 2013b
Dendrobine [**176**]	*D. nobile* *D. nobile*	Stem Stem	Wang *et al.*, 1985; Ye *et al.*, 2002b Meng *et al.*, 2017
Dendromoniliside A [**177**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003

Table 4 Distribution of terpene derivatives in *Dendrobium* species (Cont.)

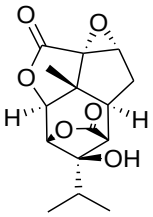
Compounds	Plants	Part	References
Dendromoniliside B [**178**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
Dendromoniliside C [**179**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
Dendromoniliside D [**180**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
Dendronobilin A [**181**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Dendronobilin B [**182**]	*D. crystallinum* *D. nobile*	Stem Stem	Wang *et al.*, 2009 Zhang *et al.*, 2007a ; Meng *et al.*, 2017
Dendronobilin C [**183**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Dendronobilin D [**184**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Dendronobilin E [**185**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Dendronobilin F [**186**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Dendronobilin G [**187**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Dendronobilin H [**188**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Dendronobilin I [**189**]	*D. nobile* *D. wardianum*	Stem Stem	Zhang *et al.*, 2007a Fan *et al.*, 2013b
Dendronobilin K [**190**]	*D. nobile*	Stem	Zhang *et al.*, 2008b
Dendronobilin L [**191**]	*D. nobile*	Stem	Zhang *et al.*, 2008b
Dendronobilin M [**192**]	*D. nobile*	Stem	Zhang *et al.*, 2008b ; Meng *et al.*, 2017
Dendronobilin N [**193**]	*D. nobile*	Stem	Zhang *et al.*, 2008b
Dendronobiloside A [**194**]	*D. nobile*	Stem	Ye *et al.*, 2002b; Zhao *et al.*, 2001

Table 4 Distribution of terpene derivatives in *Dendrobium* species (Cont.)

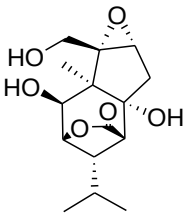
Compounds	Plants	Part	References
Dendronobiloside B [**195**]	*D. nobile*	Stem	Ye *et al.*, 2002b; Zhao *et al.*, 2001
Dendronobiloside C [**196**]	*D. nobile*	Stem	Ye *et al.*, 2002b
Dendronobiloside D [**197**]	*D. nobile*	Stem	Ye *et al.*, 2002b
Dendronobiloside E [**198**]	*D. nobile*	Stem	Ye *et al.*, 2002b
Dendrowardol A [**199**]	*D. wardianum*	Stem	Fan *et al.*, 2013a
Dendrowardol B [**200**]	*D. wardianum*	Stem	Fan *et al.*, 2013a
Dendrowardol C [**201**]	*D. wardianum*	Stem	Fan *et al.*, 2013b
Dendroside A [**202**]	*D. moniliforme* *D. nobile*	Stem Stem	Zhao *et al.*, 2003 Zhao *et al.*, 2001; Ye *et al.*, 2002b
Dendroside B [**203**]	*D. nobile*	Stem	Ye *et al.*, 2002a
Dendroside C [**204**]	*D. moniliforme* *D. nobile*	Stem Stem	Zhao *et al.*, 2003 Ye *et al.*, 2002a
Dendroside D [**205**]	*D. nobile*	Stem	Ye *et al.*, 2002a
Dendroside E [**206**]	*D. nobile*	Stem	Ye *et al.*, 2002a
Dendroside F [**207**]	*D. moniliforme* *D. nobile*	Stem Stem	Zhao *et al.*, 2003 Ye *et al.*, 2002a
Dendroside G [**208**]	*D. nobile*	Stem	Ye *et al.*, 2002a
α-Dihydropicrotoxinin [**209**]	*D. aduncum*	Whole plant	Gawell *et al.*, 1976

Table 4 Distribution of terpene derivatives in *Dendrobium* species (Cont.)

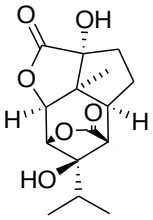
Compounds	Plants	Part	References
β-Dihydropicrotoxinin [**210**]	*D. aduncum*	Whole plant	Gawell *et al.*, 1976
Findlayanin [**211**]	*D. findlayanum* *D. nobile*	Whole plant Stem	Qin *et al.*, 2011 Meng *et al.*, 2017
3-Hydroxy-2-oxodendrobine [**212**]	*D. nobile*	Stem	Wang *et al.*, 1985
Oleanolic acid [**213**]	*D. devonianum*	Whole plant	Sun *et al.*, 2014
10β,12,14-Trihydroxy alloaromadendrane [**214**]	*D. wardianum*	Stem	Fan *et al.*, 2013a
Vomifoliol [**215**]	*D. devonianum*	Whole plant	Sun *et al.*, 2014
Wardianumine A [**216**]	*D. wardianum*	Whole plant	Zhang *et al.*, 2017



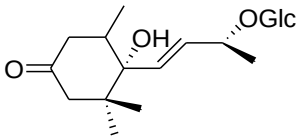
[**169**] Aduncin



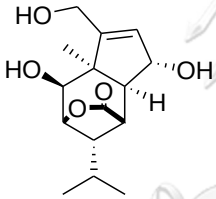
[**170**] Amoenin



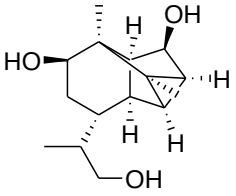
[**171**] Amotin



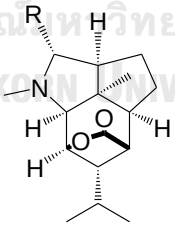
[**173**] Corchoionoside C



[**174**] Crystallinin



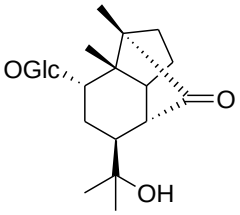
[**175**] Dendrobane A



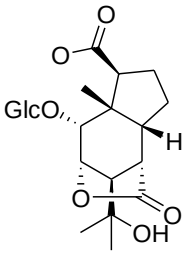
[**172**] (–)-(1*R*,2*S*,3*R*,4*S*,5*R*,6*S*,9*S*,11*R*)-11-Carboxymethyldendrobine: R = CH_2COOCH_3

[**176**] Dendrobine: R = H

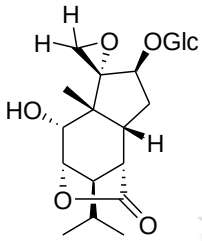
Figure 5 Structures of terpene and derivatives from *Dendrobium* species



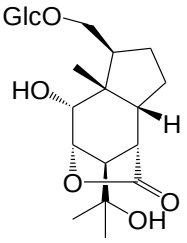
[**177**] Dendromoniliside A



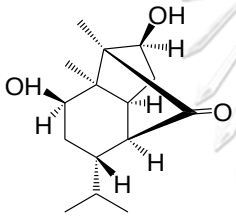
[**178**] Dendromoniliside B



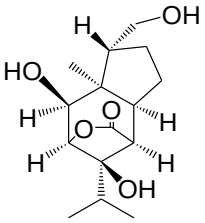
[**179**] Dendromoniliside C



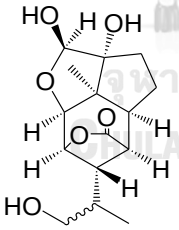
[**180**] Dendromoniliside D



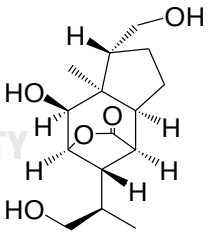
[**181**] Dendronobilin A



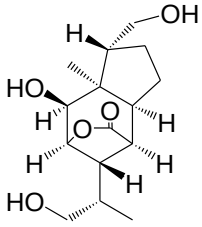
[**182**] Dendronobilin B



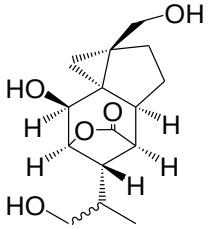
[**183**] Dendronobilin C



[**184**] Dendronobilin D

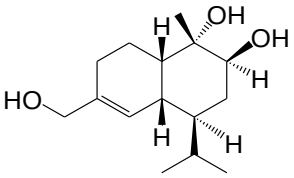


[**185**] Dendronobilin E

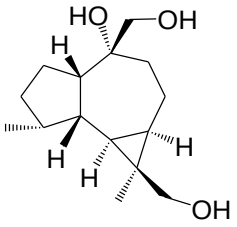


[**186**] Dendronobilin F

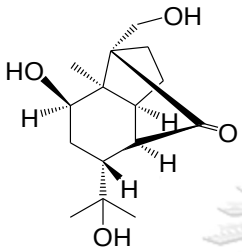
Figure 5 Structures of terpene and derivatives from *Dendrobium* species (Cont.)



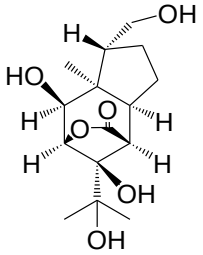
[**187**] Dendronobilin G



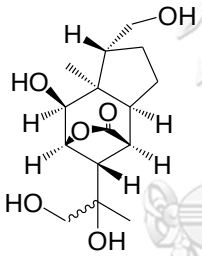
[**188**] Dendronobilin H



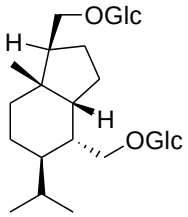
[**190**] Dendronobilin K



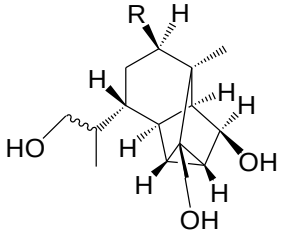
[**191**] Dendronobilin L



[**192**] Dendronobilin M



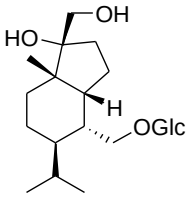
[**194**] Dendronobiloside A



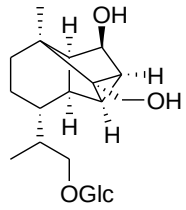
[**189**] Dendronobilin I: R = H

[**193**] Dendronobilin N: R = OH

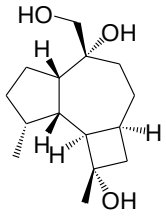
Figure 5 Structures of terpene and derivatives from *Dendrobium* species (Cont.)



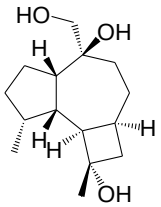
[**195**] Dendronobiloside B



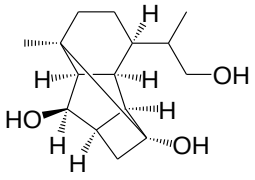
[**198**] Dendronobiloside E



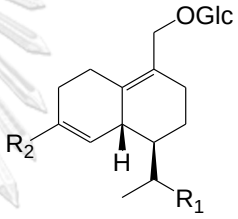
[**199**] Dendrowardol A



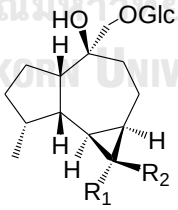
[**200**] Dendrowardol B



[**201**] Dendrowardol C

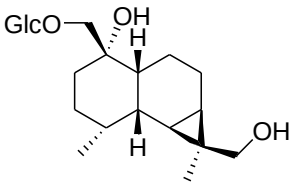


	R_1	R_2
[**196**] Dendronobiloside C	CH_3	CH_2OGlc
[**197**] Dendronobiloside D	CH_2OGlc	CH_3

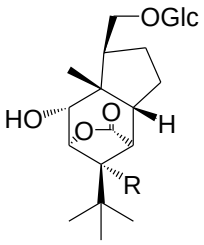


	R_1	R_2
[**202**] Dendroside A	CH_3	CH_2OH
[**203**] Dendroside B	CH_3	CH_2OGlc
[**204**] Dendroside C	CH_2OH	CH_3
[**205**] Dendroside D	CH_3	COOGlc

Figure 5 Structures of terpene and derivatives from *Dendrobium* species (Cont.)

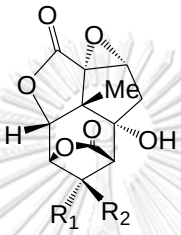


[**206**] Dendroside E

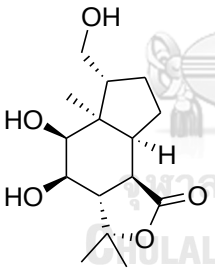


[**207**] Dendroside F: R = H

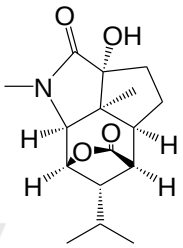
[**208**] Dendroside G: R = OH



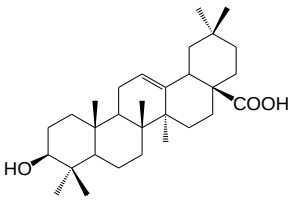
	R_1	R_2
[**209**] α-Dihydropicrotoxinin	$CH(CH_3)_2$	H
[**210**] β-Dihydropicrotoxinin	H	$CH(CH_3)_2$



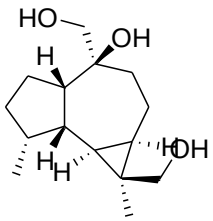
[**211**] Findlayanin



[**212**] 3-Hydroxy-2-oxodendrobine

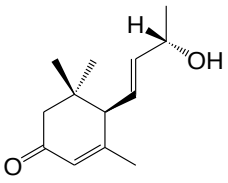


[**213**] Oleanolic acid

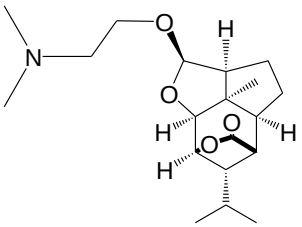


[**214**] 10β,12,14-Trihydroxy alloaromadendrane

Figure 5 Structures of terpene and derivatives from *Dendrobium* species (Cont.)



[**215**] Vomifoliol



[**216**] Wardianumine A

Figure 5 Structures of terpene and derivatives from *Dendrobium* species (Cont.)

1.5 Miscellaneous compounds

Miscellaneous compounds from *Dendrobium* include aliphatic compounds, benzoic acid derivatives, phenylpropanoids, fluorenones, coumarins, lignans and neolignans which are displayed in **Table 5**.

Table 5 Miscellaneous compounds found in *Dendrobium* species

Compounds	Plants	Part	References
Aliphatic acid derivatives			
Aliphalic acids [**217**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.*, 2001
Aliphatic alcohols [**218**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.*, 2001
Dimethyl malate [**219**]	*D. huoshanense*	Leaves and Stem	Chang *et al.*, 2010
Isopentyl butyrate [**220**]	*D. huoshanense*	Leaves and Stem	Chang *et al.*, 2010
3-Isopropyl-5-acetoxycyclohexene-1-one [**221**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2016
Malic acid [**222**]	*D. huoshanense*	Leaves and Stem	Chang *et al.*, 2001
(-)-Shikimic acid [**223**]	*D. fuscescens* *D. huoshanense* *D. pulchellum*	Whole plant Leaves and Stem Stem	Talapatra *et al.*, 1989 Chang *et al.*, 2010 Chanvorachote *et al.*, 2013

Table 5 Miscellaneous compounds found in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Benzoic acid derivatives and phenolic compounds			
Alkyl 4′-hydroxy-*trans*-cinnamates [**224**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.*, 2001
Alkyl *trans*-ferulates [**225**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.*, 2001
Antiarol [**226**]	*D. chrysotoxum*	stem	Hu *et al.*, 2012
Defuscin [**227**]	*D. aurantiacum* var. *denneanum* *D. fuscescens*	Stem Whole plant	Yang *et al.*, 2006b Talapatra *et al.*, 1989
Dibutyl phthalate [**228**]	*D. aphyllum* *D. longicornu*	Whole plant Whole plant	Chen *et al.*, 2008a Li *et al.*, 2009a
5,7-Dihydroxy-chromen-4-one [**229**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al.*, 2014
Diisobutyl phthalate [**230**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
cis-docosanoylferulate [**231**]	*D. tortile*	Whole plant	Limpanit *et al.*, 2016
trans-docosanoylferulate or *n*-Docosyl *trans*-ferulate [**232**]	*D. williamsonii* *D. longicornu*	Whole plant Whole plant	Rungwichaniwat *et al.*, 2014 Li *et al.*, 2009a

Table 5 Miscellaneous compounds found in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Bis(2-Ethylhexyl) phthalate [**233**]	*D. longicornu*	Whole plant	Li *et al.*, 2009a
Ethylhaematommate [**234**]	*D. longicornu*	Whole plant	Li *et al.*, 2009a
Ferulaldehyde [**235**]	*D. longicornu*	Whole plant	Li *et al.*, 2009a
Ferulic acid [**236**]	*D. secundum*	Stem	Sritularak *et al.*, 2011b
Gallic acid [**237**]	*D. longicornu* *D. williamsonii*	Whole plant Whole plant	Li *et al.*, 2009a Rungwichaniwat *et al.*, 2014
p-Hydroxy benzaldehyde [**238**]	*D. aurantiacum* var. *denneanum* *D. devonianum* *D. moniliforme* *D. tortile*	Whole plant Whole plant Whole plant Whole plant	Liu *et al.*, 2009b Sun *et al.*, 2014 Zhao *et al.*, 2016 Limpanit *et al.*, 2016
p-Hydroxybenzoic acid [**239**]	*D. devonianum*	Whole plant	Sun *et al.*, 2014
p-Hydroxyphenyl propionic acid [**240**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2016
p-Hydroxyphenyl propionic methyl ester [**241**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a

Table 5 Miscellaneous compounds found in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid [**242**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
n-Octacosyl ferulate [**243**]	*D. aurantiacum var. denneanum*	Stem	Yang *et al.*, 2006b
N-Phenylacetamide [**244**]	*D. huoshanense*	Leaves and Stem	Chang *et al.*, 2010
Phloretic acid [**245**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al.*, 2014
Protocatechuic acid [**246**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2016
Tetratriacontanyl-*trans*-*p*-coumarate [**247**]	*D. williamsonii*	Whole plant	Rungwichaniwat *et al.*, 2014
trans-Tetracosyl ferulate [**248**]	*D. tortile*	Whole plant	Limpanit *et al.*, 2016
Salicylic acid [**249**]	*D. huoshanense*	Leaves and Stem	Chang *et al.*, 2010
Salidrosol [**250**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Shashenoside I [**251**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
Syringin [**252**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
Syringic acid [**253**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Tetracosyl(Z)-*p*-coumarate [**254**]	*D. falconeri*	Whole plant	Sritularak *et al.*, 2009

Table 5 Miscellaneous compounds found in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Vanillic acid [**255**]	*D. devonianum* *D. moniliforme* *D. williamsonii*	Whole plant Whole plant Whole plant	Sun *et al.*, 2014 Zhao *et al.*, 2016 Rungwichaniwat *et al.*, 2014
Vanillin [**256**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2016
Vanilloside [**257**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
Coumarins Ayapin [**258**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
Coumarin [**259**]	*D. aurantiacum* var. *denneanum* *D. clavatum* var. *aurantiacum*	Whole plant Stem	Liu *et al.*, 2009b Chang *et al.*, 2001; Yang *et al.*, 2006b
Dendrocoumarin [**260**]	*D. nobile*	Whole plant	Zhou *et al.*, 2018
Denthyrsin [**261**]	*D. thyrsiflorum*	Stem	Zhang *et al.*, 2005
Dihydroconiferyl dihydro-*p*-coumarate [**262**]	*D. formosum* *D. moniliforme*	Whole plant Whole plant	Inthongkaew *et al.*, 2017 Zhao *et al.*, 2016
Itolide A [**263**]	*D. nobile*	Whole plant	Zhou *et al.*, 2018
Scoparone [**264**]	*D. densiflorum* *D. thyrsiforum*	Stem Stem	Fan *et al.*, 2001 Zhang *et al.*, 2005
Scopoletin [**265**]	*D. densiflorum*	Stem	Fan *et al.*, 2001

Table 5 Miscellaneous compounds found in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Lignans and neolignans			
Acanthoside B [**266**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
Dehydrodiconiferyl alcohol-4-*O*-β-D-glucoside [**267**]	*D. chrysanthum*	Stem	Ye *et al.*, 2004
Episyringaresinol [**268**]	*D. chrysotoxum* *D. longicornu*	Stem Stem	Hu *et al.*, 2012 Hu *et al.*, 2008a
(-)-(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 [**269**]	*D. auranticum* var *denneanum*	Stem	Li *et al.*, 2014
(-)-(8*S*,7′*E*)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-*O*-β-D-glucopyranoside [**270**]	*D. auranticum* var *denneanum*	Stem	Li *et al.*, 2014
(-)-(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 [**271**]	*D. auranticum* var *denneanum*	Stem	Li *et al.*, 2014

Table 5 Miscellaneous compounds found in *Dendrobium* species (Cont.)

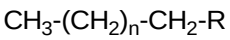
Compounds	Plants	Part	References
(-)-(7*S*,8*R*,7′*E*)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4′-oxyneolign-7′-ene-7,9,9′-triol-7,9′-bis-*O*-β-D-glucopyranoside [**272**]	*D. aurantiacum var. denneanum*	Stem	Xiong *et al.*, 2013
Liriodendrin [**273**]	*D. pulchellum*	Stem	Chanvorachote *et al.*, 2013
Lyoniresinol [**274**]	*D. chrysanthum* *D. nobile*	Stem Stem	Ye *et al.*, 2004 Zhang *et al.*, 2008c
(-)-Medioresinol [**275**]	*D. loddigesii* *D. nobile*	Whole plant Stem	Ito *et al.*, 2010 Zhang *et al.*, 2008c
(-)-Pinoresinol [**276**]	*D. loddigesii* *D. nobile*	Whole plant Stem	Ito *et al.*, 2010 Zhang *et al.*, 2008c
(-)-Syringaresinol [**277**]	*D. secundum* *D. devonianum*	Stem Whole plant	Sritularak *et al.*, 2011b Sun *et al.*, 2014
(+)-Syringaresinol [**278**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2016
(-)-Syringaresinol-4,4′-bis-*O*-β–D-glucopyranoside [**279**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013

Table 5 Miscellaneous compounds found in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Syringaresinol-4-*O*-D-monoglucopyranoside [**280**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
Fluorenones			
Denchrysan A [**281**]	*D. chrysotoxum*	Whole plant	Ye *et al.*, 2003
Denchrysan B [**282**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al.*, 2015
	D. chrysotoxum	Whole plant	Ye *et al.*, 2003
Dendroflorin [**283**]	*D. aurantiacum var. denneanum*	Stem	Yang *et al.*, 2006b
	D. brymerianum	Whole plant	Klongkumnuankarn *et al.*, 2015
	D. chrysotoxum	Stem	Hu *et al.*, 2012
Dengibsin [**284**]	*D. aurantiacum var. denneanum*	Stem	Yang *et al.*, 2006b
	D. chrysanthum	Stem	Yang *et al.*, 2006a
Nobilone [**285**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al.*, 2015
	D. nobile	Stem	Zhang *et al.*, 2007b

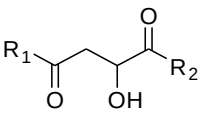
Table 5 Miscellaneous compounds found in *Dendrobium* species (Cont.)

Compounds	Plants	Part	References
Others			
Daucosterol [**286**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2016
Dehydrovomifoliol [**287**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
N-trans-feruloyl tyramine [**288**]	*D. devonianum*	Whole plant	Sun *et al.*, 2014
Palmarumycin JC2 [**289**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
4-(2-Hydroxypropyl)-2(5*H*)-furanone [**290**]	*D. tortile*	Whole plant	Limpanit *et al.*, 2016
Paprazine [**291**]	*D. devonianum*	Whole plant	Sun *et al.*, 2014
β-Sitosterol [**292**]	*D. polyanthum* *D. chrysotoxum*	Stem Stem	Hu *et al.*, 2009 Hu *et al.*, 2012
3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one (Tetrahydroanthracene) [**293**]	*D. polyanthum*	Stem	Hu *et al.*, 2009



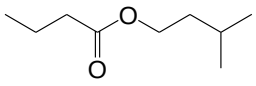
[**217**] Aliphatic acids: R = COOH, n = 19-31

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

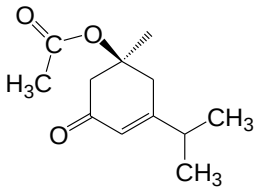


[**219**] Dimethyl malate: R_1 = R_2 =OMe

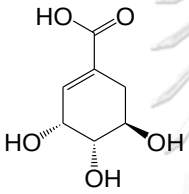
[**222**] Malic acid: R_1 = R_2 = OH



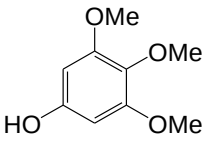
[**220**] Isopentyl butyrate



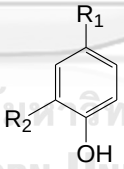
[**221**] 3-Isopropyl-5-acetoxycyclohexene-1-one



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

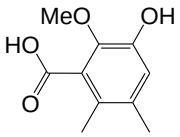


[**226**] Antiarol

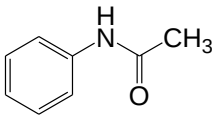


	R_1	R_2
[**238**] *p*-Hydroxybenzaldehyde	CHO	H
[**239**] *p*-Hydroxybenzoic acid	COOH	H
[**240**] *p*-Hydroxyphenylpropionic acid	$(CH_2)_2COOCH_3$	H
[**245**] Phloretic acid	$(CH_2)_2COOH$	OH
[**255**] Vanillic acid	COOH	OMe
[**256**] Vanillin	CHO	OMe

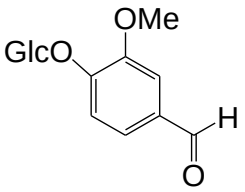
Figure 6 Miscellaneous compounds from *Dendrobium* species



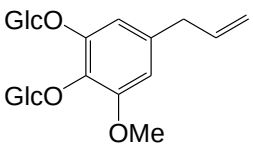
[**242**] 3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid



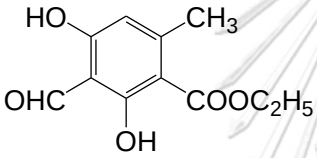
[**244**] *N*-phenylacetamide



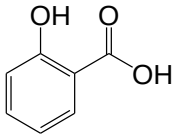
[**257**] Vanilloside



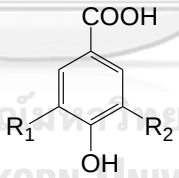
[**251**] Shashenoside I



[**234**] Ethylhaematommate

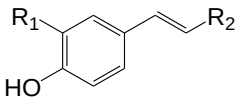


[**249**] Salicylic acid

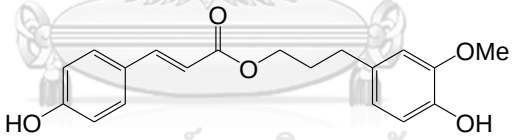


	R_1	R_2
[**237**] Gallic acid	OH	OH
[**253**] Syringic acid	OMe	OMe
[**246**] Protocatechuic acid	H	OH

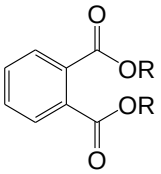
Figure 6 Miscellaneous compounds from *Dendrobium* species (Cont.)



	R_1	R_2
[**224**] Alkyl 4′-hydroxy-*trans*-cinnamates	H	$COOC_nH_{2n+1}$, n =22-32
[**225**] Alkyl *trans*-ferulates	OMe	$COOC_nH_{2n+1}$, n = 18-28, 30
[**227**] Defuscin	OMe	$COO(CH_2)_{27}CH_3$
[**232**] *trans*-docosanoylferulate	OMe	$COO(CH_2)_{21}CH_3$
[**235**] Ferulaldehyde	OMe	CHO
[**236**] Ferulic acid	OMe	COOH
[**243**] *n*-Octacosyl ferulate	OMe	$COO(CH_2)_{28}CH_3$
[**247**] Tetratriacontanyl-*trans*-*p*-coumarate	H	$COO(CH_2)_{33}CH_3$
[**248**] *trans*-Tetracosylferulate	OMe	$COO(CH_2)_{23}CH_3$



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

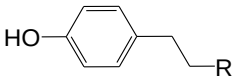


[**228**] Dibutyl phthalate; R = $CH_2CH_2CH_2CH_3$

[**230**] Diisobutyl phthalate; R = $CH_2CH(CH_3)_2$

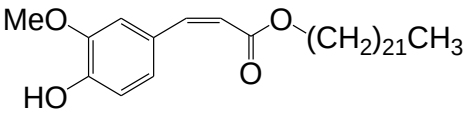
[**233**] Bis(2-ethylhexyl)phthalate; R=$CH_2CH(C_2H_5)(CH_2)_3CH_3$

Figure 6 Miscellaneous compounds from *Dendrobium* species (Cont.)

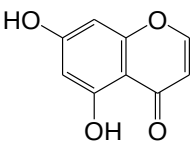


[**241**] *p*-Hydroxyphenyl propionic methyl ester: R = $COOCH_3$

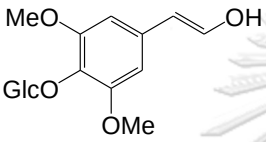
[**250**] Salidrosol: R = OH



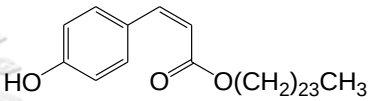
[**231**] *cis*-Docosanoylferulate



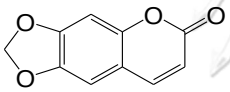
[**229**] 5,7-Dihydroxy-chromen-4-one



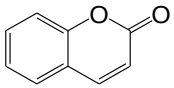
[**252**] Syringin



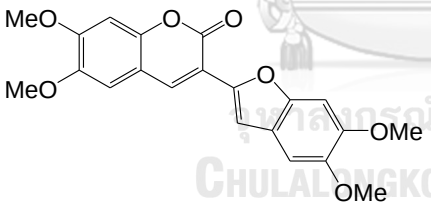
[**254**] Tetracosyl (*Z*)-*p*-coumarate



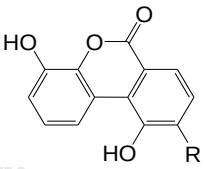
[**258**] Ayapin



[**259**] Coumarin

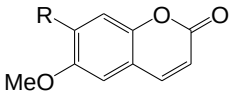


[**261**] Denthyrsin



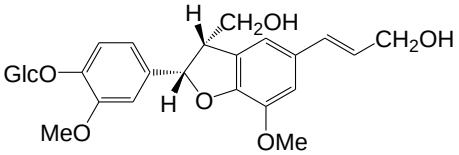
[**260**] Dendrocoumarin: R = OH

[**263**] Itolide A: R = H



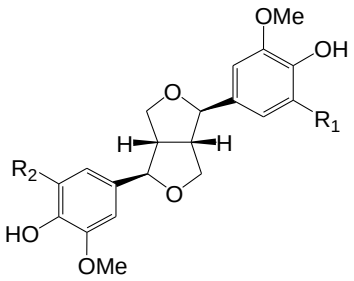
[**264**] Scoparone: R = OMe

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

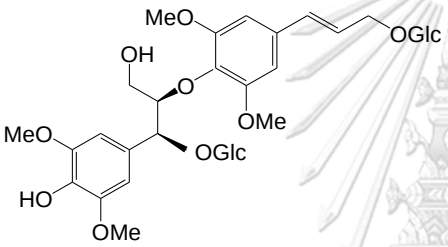


[**267**] Dehydrodiconiferyl alcohol-4-*O*-β-D-glucoside

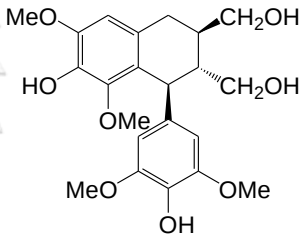
Figure 6 Miscellaneous compounds from *Dendrobium* species (Cont.)



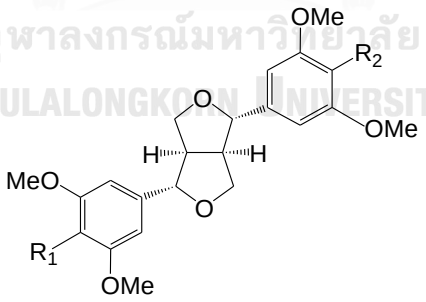
	R_1	R_2
[**268**] Episyringaresinol	OMe	OMe
[**275**] (-)-Medioresinol	H	OMe
[**276**] (-)-Pinoresinol	H	H



[**272**] (-)-(7*S*,8*R*,7′*E*)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-7,9,9′-triol-7,9′-bis-*O*-β-D-glucopyranoside

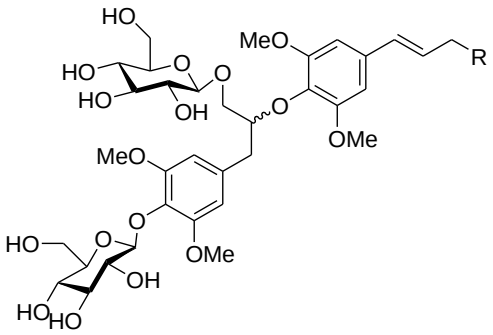


[**274**] Lyoniresinol



	R_1	R_2
[**266**] Acanthoside B	OGlc	OH
[**273**] Liriodendrin	OGlc	OGlc
[**278**] (+)-Syringaresinol	OH	OH

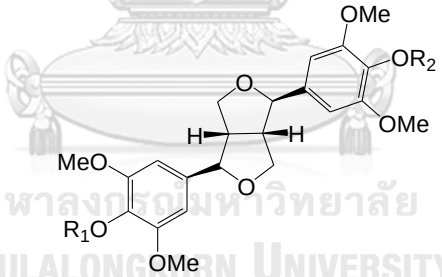
Figure 6 Miscellaneous compounds from *Dendrobium* species (Cont.)



[**269**] (-)-(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*

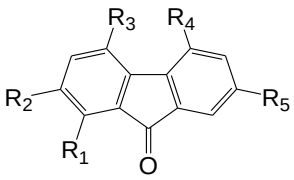
[**270**] (-)-(8*S*,7′*E*)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-*O*-β-D-glucopyranoside: R = OH; 8*S*

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

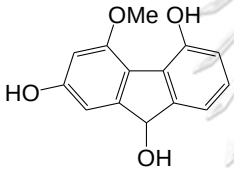


	R_1	R_2
[**277**] (-)-Syringaresinol	H	H
[**279**] (-)-Syringaresinol-4,4′-bis-*O*-β-D-glucopyranoside	Glc	Glc
[**280**] Syringaresinol-4-*O*-D-monoglucopyranoside	Glc	H

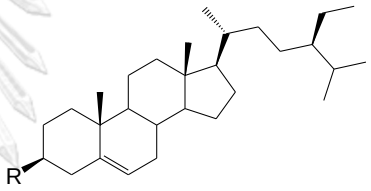
Figure 6 Miscellaneous compounds from *Dendrobium* species (Cont.)



	R_1	R_2	R_3	R_4	R_5
[**281**] Denchrysan A	H	OH	OH	OMe	OH
[**283**] Dendroflorin	OH	H	OH	OMe	OH
[**284**] Dengibsin	H	OH	OMe	OH	H
[**285**] Nobilone	H	OH	H	OMe	OH

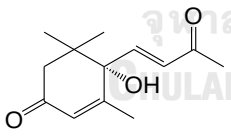


[**282**] Denchrysan B

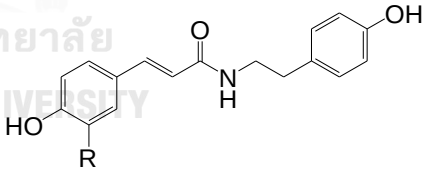


[**286**] Daucosterol: R = OGlc

[**292**] β-sitosterol: R = OH



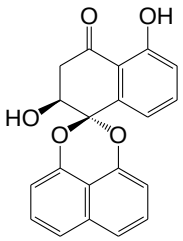
[**287**] Dehydrovomifoliol



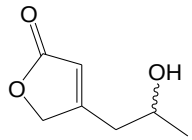
[**288**] *N-trans*-Feruloyl tyramine: R =OMe

[**291**] Paprazine: R = H

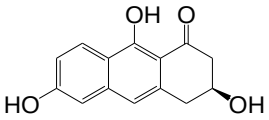
Figure 6 Miscellaneous compounds from *Dendrobium* species (Cont.)



[**289**] Palmarumycin JC2



[**290**] 4-(2-Hydroxypropyl)-2(5*H*)-furanone



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

Figure 6 Miscellaneous compounds from *Dendrobium* species (Cont.)

2. Biological activities of *Dendrobium* species

The secondary metabolites that were found in *Dendrobium* have been reported to posses many interesting biological activities, for example, cytotoxic activity, antioxidant activity, anti-platelet activity, anti-inflammatory activity, antifibrotic activity, immonomodulartory activity, neuroprotective activity, α-glucosidase inhibitory activity, antibacterial activity, antifungal activity, anti-viral, anti-malarial, anti-cataract activity and angiogenic activity (Teixeira da Silva *et al.*, 2017). Other activities which had also been reported were antimutagenic activity (Miyazawa *et al.*, 1999) and lipase inhibitory activity (Inthongkaew *et al.*, 2017).

2.1 Cytotoxic activity

Several types of cancer cell lines were used to examine the cytotoxic activity. Batatasin III which was isolated from *D. draconis* was reported to be cytotoxic agaist lung cancer cell (H460). It inhibited cell proliferation, migration and invasion by suppressing epithelial to mesenchymal transition and Focal Adhesion Kinase, Protein kinase B and Cell Division Cycle 42 pathway (Pinkhien *et al.*, 2017).

The compounds from *D. sinense* which showed activity against gastric cancer cells (SGC-7901) were aloifol I [**1**] (IC_{50} = 12.8±0.6), 3,4,3′-trimethoxy-5,4′-dihydroxybibenzyl [**66**] (IC_{50} = 16.7±0.4 μM) and 5,3′-dihydroxy-3,4-dimethoxybibenzyl [**40**] (IC_{50} = 7.8±0.05 μM) (Chen *et al.*, 2014).

Two compounds from *D. sinense*, compound [**40**] and longicornuol A [**52**], inhibited K562 cells (leukemia cell line) with IC_{50} value 15.7±0.2 μM and 10.3±0.1 μM, respectively. They also showed suppressing activity to hepatoma cell lines (BEL-7402) with IC_{50} 11.7±0.5 μM and 10.0±0.4 μM, respectively (Chen *et al.*, 2014). The other potent anti-leukemia agent were dengraol A [**35**] (IC_{50} = 2.1 μM) and dengraol B [**36**] (IC_{50} = 6.4 μM) from *D. gratiosissimum* which were examined with HL-60 cells (Zhang *et al.*, 2008a) and shashenoside I [**251**] from *D. aurantiacum* var. *denneanum* which exhibited the activity against MV4-11 cell with IC_{50} value 4.17 μM (Xiong *et al.*, 2013).

Crepidatin [**13**] and moscatilin [**56**] from *D. capillipes* exhibited the inhibitory activity to skin cancer cell (KB) with IC_{50} value 14.4 μM and 2.2 μM, repectively. They also showed the activity against lung cancer cell (NCI-H187) with IC_{50} value 13.7 μM and 10.5 μM, repectively (Phechrmeekha *et al.*, 2012).

2.2 Antioxidant activity

Many compounds from *Dendrobium* plants showed antioxidant activity. The DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging activity was extensively used to evaluate the antioxilant activity. Dendrocandin E [**24**] which was isolated from *D. candidum*, exhibited more potent antioxidant acitivity than vitamin C (Li *et al.*, 2009b). Gigantol [**47**] and 7-methoxy-9,10-dihydrophenanthrene-2,4,5-triol [**130**] which were isolated from *D. draconis* also revealed the DPPH scavenging activity but lesser potent than quercetin and Trolox® (Sritularak *et al.*, 2011a). Confusarin [**75**] and (-)-syringaresinol [**277**] from *D. nobile* showed lesser IC_{50} value than vitamin C and BHT (Zhang *et al.*, 2008c). Moscatilin [**56**], which isolated from *D. williamsonii* also exihibited more potent activity than vitamin C (Rungwichaniwat *et al.*, 2014).

2.3 Anti-platelet activity

Moscatilin [**56**] and moscatin [**133**] which isolated from *D. longicornu* showed the anti-platelet aggregation activity (Chen *et al.*, 1994). It complied with the activity against platelet aggregation of moscatilin [**56**] from *D. densiflorum*. *D. densiflorum* also give the other anti-platelet agent, e.g. gigantol [**47**], homoeriodictyol [**154**], scopoletin [**265**] and scoparone [**264**] (Fan *et al.*, 2001).

2.4 Anti-inflammatory activity

The inhibition of nitric oxide (NO) production was widely used to evaluate the anti-inflammatory activity. Two potent inhibitors against NO production from *D. chrysanthum* were loddigesiinol A [**123**] (IC_{50} = 2.6 μM), and loddigesiinol B [**124**] (IC_{50} = 10.9 μM) (Yang *et al.*, 2006a). Ephemeranthol A [**106**], coelonin [**74**], and lusianthridin [**129**], which were isolated from *D. nobile*, exhibited potent activity against NO production more potent than aminoguanidine with IC_{50} value 12.0±0.3 μM, 10.2±0.2 μM and 9.6±0.3 μM, respectively (Hwang *et al.*, 2010). Nobilin D [**58**],

nobilin E [**59**], and dendroflorin [**283**] from *D. nobile* were also shown to be anti-infalmmatory agents with IC_{50} value 15.3, 19.2 and 13.4 μM, respectively, which higher potency than resveratrol (Zhang *et al.*, 2007b).

2.5 Antifibrotic activity

The hepatoprotective effect of compounds from *D. nolie* was performed by monitoring the HSC-T6 cells proliferation. 2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene [**144**], denbinobin [**78**], coelonin [**74**] and fimbriol B [**113**] show appropiate antifibrotic activity with IC_{50} value at 9.0, 15.2, 13.4 and 11.0 μM, respectively (Yang *et al.*, 2007).

2.6 Immunomodulatory activity

Four sesquiterpene glycosides (dendroside D-G) from *D. nobile* expressed the immunomodulatory activity. Dendroside D [**205**] and dendroside G [**208**] increased T cell proliferation in murine lymphocyte after inducing by concanavalin A, while dendroside E [**206**] and dendroside F [**207**] responsed to both T cell and B cell proliferation after induced by concanavalin A and lipopolysaccharide, repectively (Ye *et al.*, 2002a).

2.7 Neuroprotective effect

The lignan and neolignan from *D. aurantiacum* var. *denneanum*, (-)-syringaresinol-4,4′-bis-*O*-β–D-glucopyranoside [**279**] and (-)-(7*S*,8*R*,7′*E*)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-7,9,9′-triol-7,9′-bis-*O*-β-D-glucopyranoside [**272**], showed neuroprotective effect against glutamate-induced neurotoxicity in PC12 cells (Xiong *et al.*, 2013).

2.8 lipase and α-glucosidase inhibitory activity

The phenanthrenes from *D. formosum*, 5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**131**] and confusarin [**75**], showed the activity against lipase with IC_{50} 69.45±10.14 μM and 154.61±8.58 μM, respectively, which were more potent than acarbose (IC_{50} = 745.9±88.4 μM). They also exhibited α-glucosidase inhibitory activity with IC_{50} value 126.88±0.66 μM and 189.78±11.1 μM, respectively,

which were much weaker than orlistat (IC_{50} = 0.013±0.004 μM) (Inthongkaew *et al.*, 2017).

The α-glucosidase inhibitors from *D. devonianum* were 5-hydroxy-3-methoxy-flavone-7-*O*-[β-D-apiosyl-(1→6)]-β-D-glucoside [**156**] and gigantol [**47**] which exibited higher % inihbition than acarbose at the concentration of 437.5 μM (Sun *et al.*, 2014).

The bibenzyl derivative, crepidatuol B [**15**] and phananthrene derivatives, Loddigesiinols G–J [**125**-**128**] from *D. loddigesii* showed potent α-glucosidase inhibitory activity with IC_{50} value 18.9, 16.7, 10.9, 2.7 and 3.2 μM, respectively (Lu *et al.*, 2014).

3,4-Dihydroxy-5,4′-dimethoxybibenzyl [**43**], *2(S)*-eriodictyol [**152**] and dendrofalconerol A [**25**], phenolic compounds from *D. tortile*, showed the activity against α-glucosidase with IC_{50} = 324.6±34.8 μM, 276.2±25.5 μM and 18.0±0.8 μM (Limpanit *et al.*, 2016).

CHAPTER III

EXPERIMENTAL

1. Materials

1.1 Plant material

The whole plants of *Dendrobium infundibulum* were purchased from Chatuchak market, Bangkok, in August 2015. Authentication was performed by Associate Professor Boonchoo Sritularak (Faculty of Pharmaceutical Sciences, Chulalongkorn University) by comparing with the Botanical Garden Organization Plant Database ("BGO Plant Database," 2011). A voucher specimen (BS-DI-082558) has been deposited at the Department of the Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University.

1.2 Chemical materials

Silica gel 60 F254 (E. Merck) precoated plate, silica gel 60 (No. 7734 for VLC) particle size 0.063-0.200 mm (E. Merck), silica gel 60 (No. 9385 for CC) particle size 0.040-0.063 mm (E. Merck) and Sephadex® LH-20 (GE Healthcare) were used as the stationary phase in chromatographic separation.

Organic solvents: acetone, dichloromethane, ethyl acetate, hexane and methanol were redistilled before use.

2. Experimental techniques

2.1 Analytical thin-layer chromatography (TLC)

Technique: One dimension ascending

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

Layer thickness: 0.2 mm

Distance: 5 cm

Temperature: Ambient Temperature (24-39°C)

Detection: Ultraviolet light at wavelengths of 254 and 365 nm.

2.2 Column Chromatography

2.2.1 Vacuum liquid chromatography (VLC)

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

Temperature: Ambient Temperature (24-39°C)

Packing method: Dry Packing

Loading method: 1. Dissolved the sample in a small amount of organic solvent, mixed with a proper quantity of the absorbent and triturated

2. Let the mixture dry in vacuum desiccator

3. Gradually placed the mixture on top of the column

Detection: 1. Examined every fraction by TLC with suitable mobile phase

2. Detected with ultraviolet light at wavelengths of 254 and 365 nm.

2.2.2 Flash column chromatography (FCC)

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

Temperature: Ambient Temperature (24-39°C)

Packing method: Appropriate organic solvent or solvent mixture was used as the eluent. Silica gel was suspended in the eluent, then poured into the column and left to set tightly

Loading method: 1. Dissolved the sample in a small amount of organic solvent, mixed with a suitable quantity of the absorbent and triturated

2. Let the mixture dry in vacuum desiccator

3. Gradually placed the mixture on the top of the colunm

Detection: 1. Examined every fractions by TLC with suitable mobile phase

2. Detected with ultraviolet light at wavelengths of 254 and 365 nm.

2.2.3 Gel filtration chromatography

Gel filter: Sephadex® LH-20 (GE Healthcare)

Temperature: Ambient Temperature (24-39°C)

Packing method: An appropriate organic solvent was used as the eluent. Gel filter was suspended in the eluent, poured into the column and left to set tightly overnight

Loading method: 1. Dissolved the sample in a small amount of organic solvent

2. gently pour the mixture on the top of the colunm

Detection: 1. Examined every fractions by TLC with proper mobile phase

2. Detected with ultraviolet light at wavelengths of 254 and 365 nm

2.3 Spectroscopy

2.3.1 Ultraviolet-Visible (UV-Vis) spectroscopy

UV spectra (in methanol) were obtained on a Shimadzu UV-160A UV/VIS spectrophotometer (Pharmaceutical Research Instrument Center, Faculty of Pharmaceutical Sciences, Chulalongkorn University).

2.3.2 Infrared (IR) spectroscopy

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

2.3.3 Mass spectrometry

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

2.3.4 Nuclear magnetic resonance (NMR) spectroscopy

The ^{1}H and ^{13}C NMR spectra were recorded on a Bruker Avance DPX-300 FT-NMR spectrometer (Faculty of Pharmaceutical Sciences, Chulalongkorn University) or

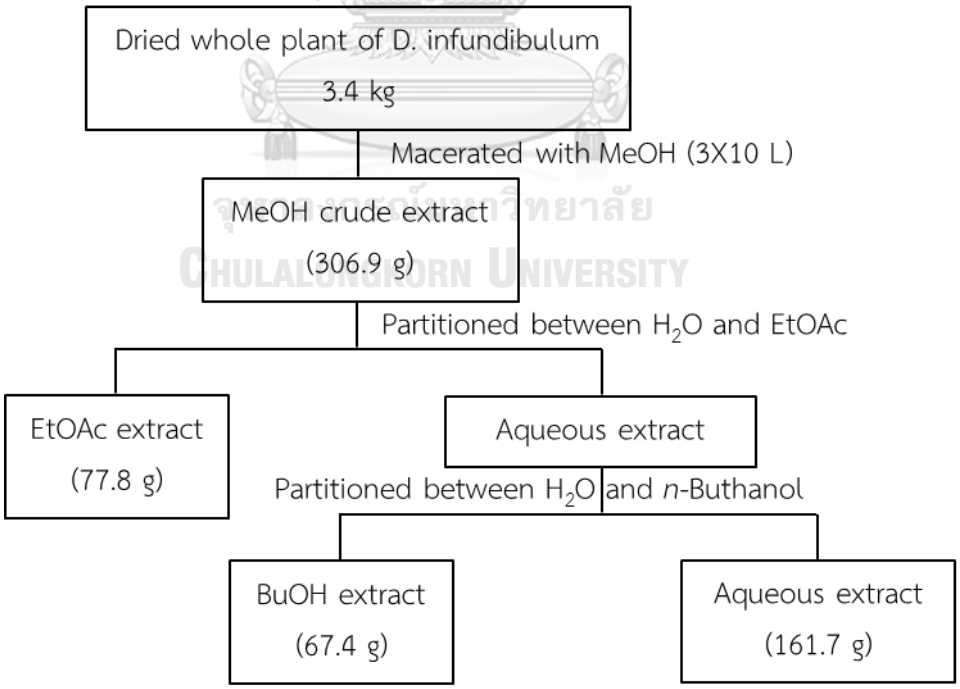
a Bruker Avance III HD 500 NMR spectrometer (Scientific and Technological Research Equipment Center, Chulalongkorn University)

The solvent for NMR spectra was deuterated acetone (acetone-d_6). The chemical shifts were reported in ppm scale using the chemical shift of the solvent as the reference signal.

3. Extraction and isolation

3.1 Extraction

The dried whole plants of *D. infundibulum* (3.4 kg) were ground and then macerated with methanol (3X10L) for 72 hours, three times. The organic solvent was evaporated under reduced pressure to give 306.9 g of crude methanol extract. This material was suspended in water and partitioned with EtOAc and then *n*-butanol to give an EtOAc extract (77.8 g), and *n*-butanol extract (67.4 g), and aqueous extract (161.7 g) **(Scheme 1).**

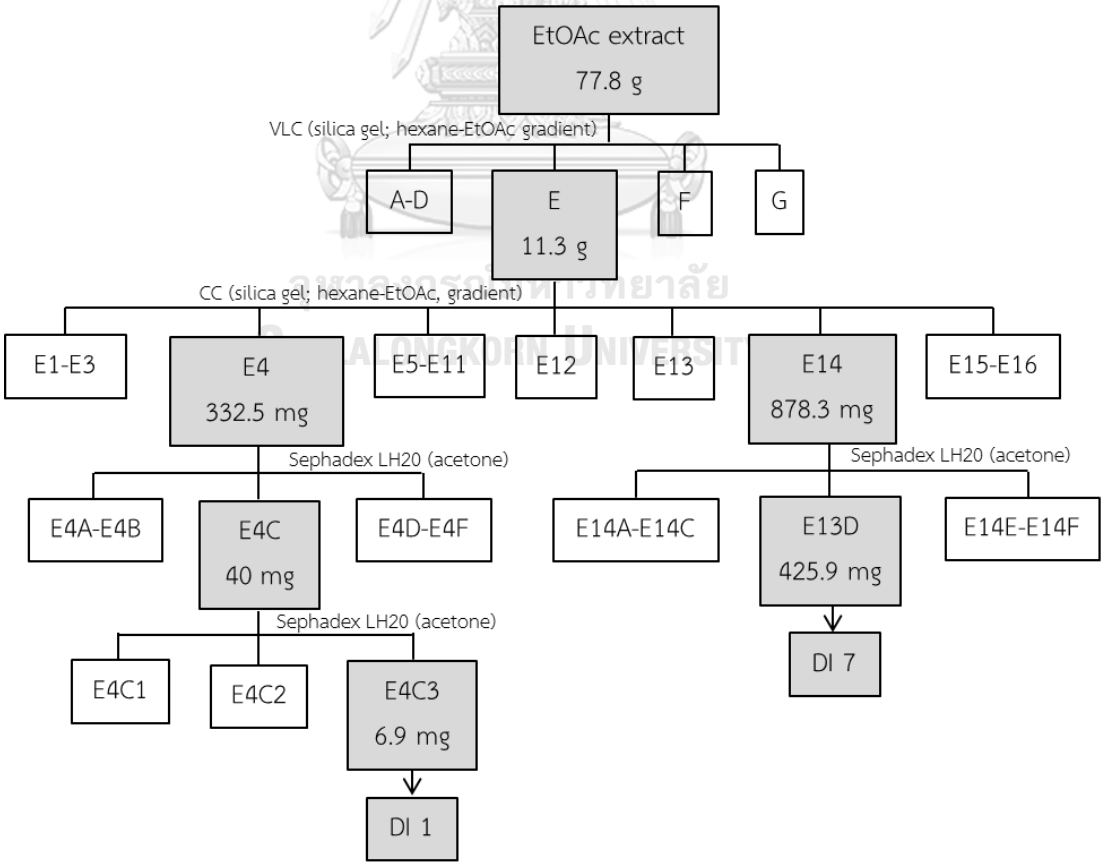


Scheme 1 Extraction of *Dendrobium Infundibulum*

All three extracts were tested for lipase and α-glucosidase inhibitory activities. The EtOAc extract showed the highest activity with 83.30% and 66.28% inhibition of lipase and α-glucosidase, respectively, at a concentration of 100 µg/mL. Therefore this extract was selected for further studies.

3.2 Separation and isolation

The EtOAc extract (77.8 g) was initially fractionated by vacuum liquid chromatography (VLC) as shown in **Scheme 2**. Silica gel (No. 7734, 600 g) was used as the stationary phase and a step gradient of hexane-EtOAc (from 1:0 to 0:1) was used as the mobile phase. The eluents were collected about 300 mL per fraction and examined by TLC (silica gel, hexane-EtOAc = 7:3). Then, fractions with similar TLC patterns were combined to give 7 fractions (A-G): A (33.8 g), B (8.1 g), C (9.4 g), D (2.6 g), E (11.3 g), F (7.2 g), and G (45.5 g).



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

3.2.1 Isolation of compound DI1 (Dendroinfundin A)

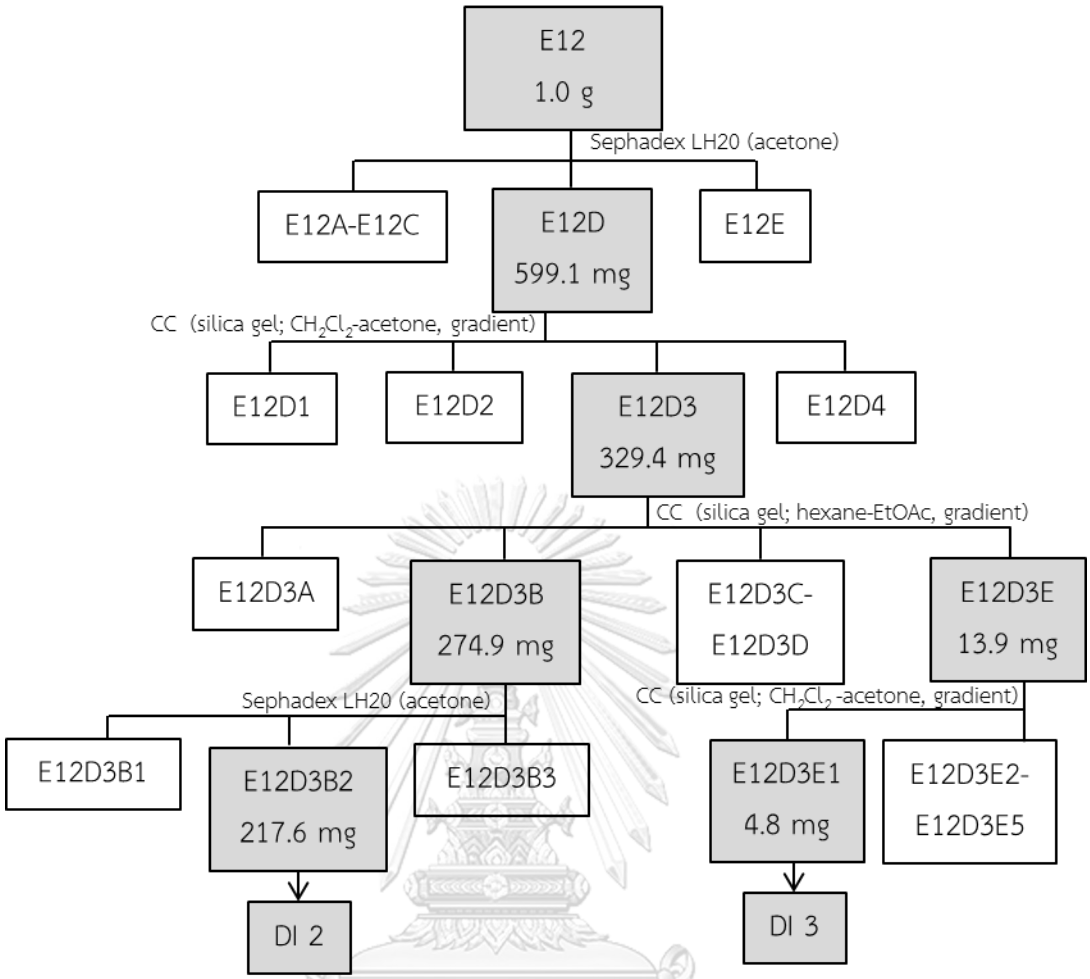
As shown in **Scheme 2**, fraction E (11.3 g) was further separated by flash column chromatography using silica gel (No. 9385) as the stationary phase with a gradient mixture of hexane-EtOAc (1:0 to 0:1) as the mobile phase to give 16 fractions (E1-E16). Then, fraction E4 (332.5 mg) was fractionated on a Sephadex LH-20 column eluated with acetone to afford 6 fractions (E4A-E4F). Fraction E4C (40 mg) was purified on a Sephadex LH-20 column eluated with acetone to give 3 fractions (E4C1-E4C3). Fraction E4C3, after drying gave compound **DI1** (6.9 mg), a white amorphous solid (R_f = 0.46, silica gel, hexane: EtOAc = 1:1).

3.2.2 Isolation of compounds DI2 (Ephemeranthol A) and DI3 (Dendroinfundin B)

Fraction E12 (1.0 g) was separated on a Sephadex LH-20 column eluated with acetone to give 5 fractions (E12A-E12E) (**Scheme 3**). Fraction E12D (599.1 mg) was further separated on a silica gel column gradient mixture of CH_2Cl_2-acetone (1:0 to 0:1) to obtain 4 fractions (E12D1-E12D4). Fraction E12D3 (329.4 mg) was seperated by using CC (silica gel, gradient mixture of CH_2Cl_2-acetone (1:0 to 0:1)) to give 5 fractions (E12D3A-E12D3E).

Fraction E12D3B (274.9 mg) was purified on a Sephadex LH-20 column eluated with acetone to give 3 fractions (E12D3B1-E12D3B3). Fraction E12D3B, after drying gave compound DI2 (217.6 mg) as a white amorphous solid (R_f = 0.46, silica gel, hexane: EtOAc, 7:3).

Fraction E12D3E (13.9 mg) was subjected to CC over silica gel, eluted with CH_2Cl_2-acetone gradient (from 1:0 to 0:1) to give 5 fractions (E12D3E1-E12D3E5). Fraction E12D3E1, after drying, yeilded compound DI3 (4.8 mg) as a brown amorphous solid (R_f = 0.48, silica gel 60 F254, hexane: EtOAc = 1:1).

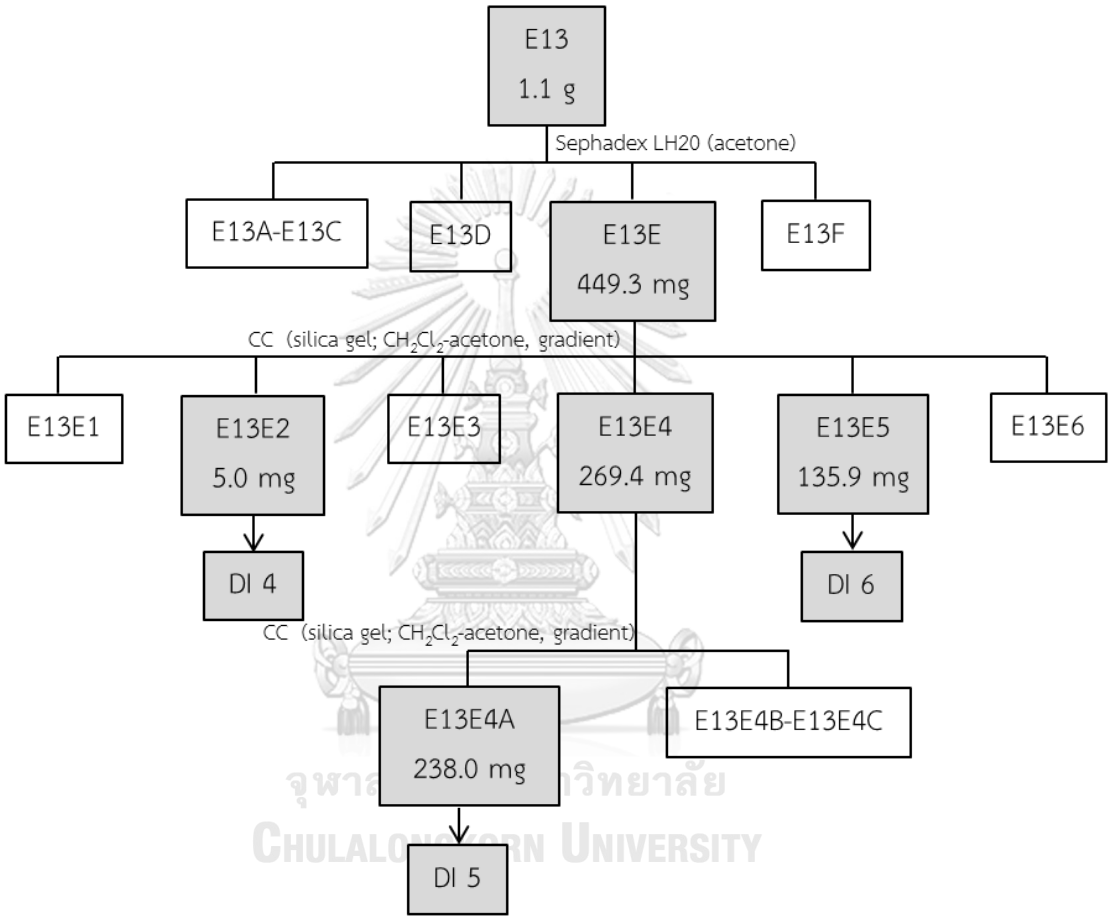


Scheme 3 Separation of fraction E12 of *Dendrobium Infundibulum*

3.2.4 Isolation of compounds DI4 (Moscatilin), DI5 (Aloifol I) and DI6 (Batatasin III)

As shown in **Scheme 4**, fraction E13 (1.1 g) was separated on Sephadex LH-20 column eluted with acetone to give 6 fractions (E13A-E13F). Fraction E13E (449.3 mg) was further separated using a silica gel column (CH_2Cl_2-acetone, gradient from 1:0 to 0:1) to give 6 fractions (E13E1-E13E6). Compounds DI4 (5.0 mg) and DI6 (135.9 mg) were obtained from fraction E13E2 and E12E5 (R_f = 0.46 and 0.34, respectively, silica gel 60 F254, CH_2Cl_2-acetone = 1:1). Compounds DI4 was orangish-brown amorphous solid, while DI6 was brown amorphous solid.

Finally, fraction E13E4 (269.4 mg) was purified by CC using silica gel and a gradient mixture of CH_2Cl_2-acetone (1:0 to 0:1) to afford 3 fractions (E13E4A-E13E4C). Fraction E13E4A, after drying, yeilded compound DI5 (238 mg) as a reddish-brown amorphous solid (R_f = 0.40, silica gel, hexane: EtOAc 1:1).



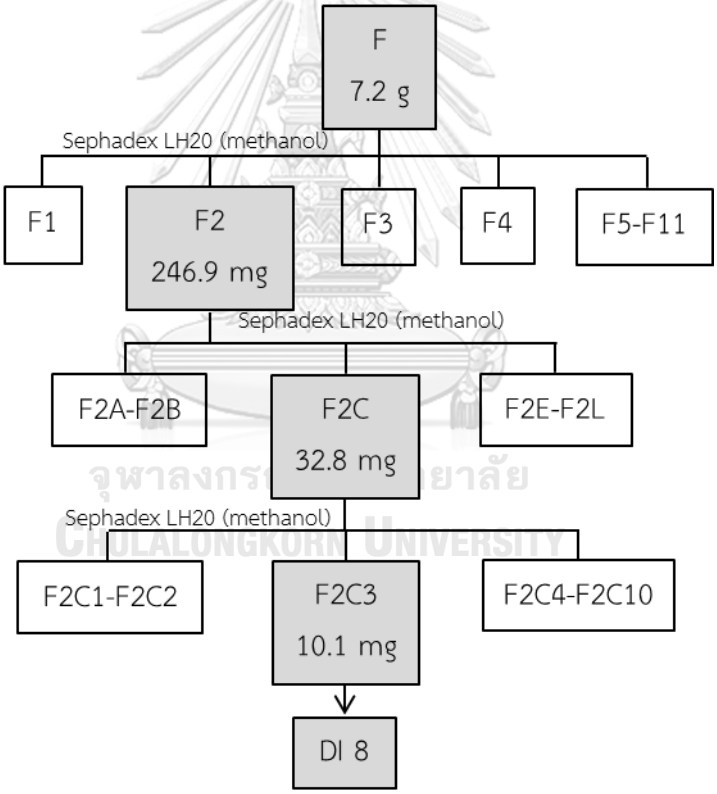
Scheme 4 Separation of fraction E13 of *Dendrobium Infundibulum*

3.2.6 Isolation of compound DI7 (3,3′-Dihydroxy-4,5-dimethoxybibenzyl)

Fraction E14 (878.3 mg) was separated on a Sephadex LH-20 column eluted with acetone to give 6 fractions (E14A-E14F). After removal of the solvent, fraction E14D (425.9 mg) yeilded compound DI7 as a dark brown amorphous solid (R_f = 0.24, silica gel 60 F254, hexane: EtOAc = 7:3) (**Scheme 2**).

3.2.7 Isolation of compound DI8 (3,4′-Dihydroxy-3′,4,5-trimethoxybibenzyl)

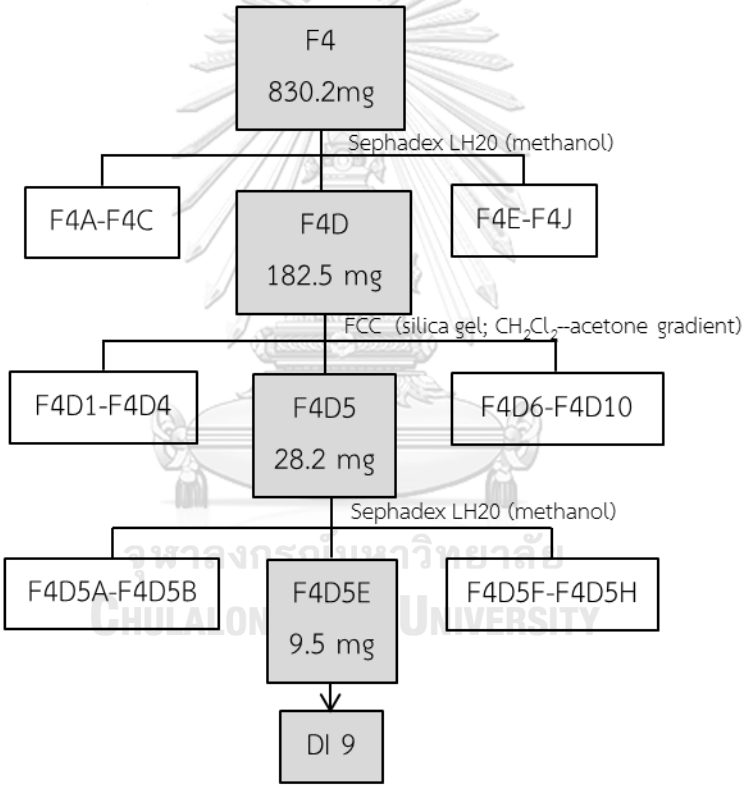
Fraction F (7.2 g) was separated on Sephadex LH-20 column eluted with methanol to give 11 fractions (F1-F11). Fraction F2 (246.9 mg) was separated on a Sephadex LH-20 column eluted with methanol to afford 12 fractions (F2A-F2L). Fraction F2C (32.8 mg) was further purified by Sephadex LH-20 column eluted with methanol to give 10 fractions (F2C1-F2C10) (**Scheme 5**). Fraction F2C3, after drying, afford compound DI8 (10.1 mg) as a dark brown amorphous solid. Its R_f value (when applied on silica gel and developed with mixture of hexane-EtOAc ratio 1:1) was 0.50.



Scheme 5 Separation of fraction F of *Dendrobium Infundibulum*

3.2.8 Isolation of compound DI9 (Dendrosinen B)

As shown in **Scheme 6**, fraction F4 (830.2 mg) was separated on a Sephadex LH-20 column eluted with methanol to give 10 fractions (F4A-F4J). Fraction F4D (182.5 mg) was further separated by CC (silica gel, CH_2Cl_2-acetone, gradient from 1:0 to 0:1) to give 10 fractions (F4D1-F4D10). Fraction F4D5 (28.2 mg) was purified by Sephadex LH-20 column eluted with methanol to give 8 fractions (F4D5A-F4D5H). Fraction F4D5E, upon drying, gave compound DI9 (9.5 mg) as a brown amorphous solid (R_f = 0.36, silica gel, hexane: EtOAc - 1:1).



Scheme 6 Separation of fraction 4 of *Dendrobium Infundibulum* (DI9)

4. Physical and spectral data of isolated compounds

4.1 Compound DI1 (Dendroinfundin A)

Compound DI1 was obtained as a white amorphous solid, soluble in acetone (6.9 mg, 0.00020% based on dried weight of whole plant).

UV: λ_{max} nm (log ε), in methanol 222 (4.36), 273 (4.07); **Figure 9**

FT-IR: ν cm^{-1} (KBr): 3358, 2922, 1658, 1468; **Figure 8**

HR-ESI-MS: $[M+Na]^+$ ion at *m/z* 309.1047 ($C_{17}H_{18}O_4Na$); **Figure 7**

^{1}H-NMR: δ ppm, 500 MHz, in acetone-d_6; **Figure 10, Table 6**

^{13}C-NMR: δ ppm, 125 MHz, in acetone-d_6; **Figure 11, Table 6**

4.2 Compound DI2 (Ephemeranthol A)

Compound DI2 was obtained as a white amorphous solid, soluble in acetone (218 mg, 0.00641% based on dried weight of whole plant).

HR-ESI-MS: $[M+Na]^+$ ion at *m/z* 295.0965 ($C_{17}H_{18}O_4Na$); **Figure 19**

^{1}H-NMR: δ ppm, 300 MHz, in acetone-d_6; **Figure 20, Table 7**

^{13}C-NMR: δ ppm, 75 MHz, in acetone-d_6; **Figure 20, Table 7**

4.3 Compound DI3 (Dendroinfundin B)

Compound DI3 was obtained as a dark brown amorphous solid, soluble in acetone (4.8 mg, 0.00014% based on dried weight of whole plant).

UV: λ_{max} nm (log ε), in methanol 223 (4.56), 273 (4.15), 303 (3.84); **Figure 27**

FT-IR : ν cm^{-1} (KBr): 3358, 2922, 1658, 1468; **Figure 26**

HR-ESI-MS: $[M+Na]^+$ ion at *m/z* 325.1051 ($C_{17}H_{18}O_5Na$); **Figure 25**

^{1}H-NMR: δ ppm, 500 MHz, in acetone-d_6; **Figure 28, Table 8**

^{13}C-NMR: δ ppm, 125 MHz, in acetone-d_6; **Figure 29, Table 8**

4.4 Compound DI4 (Moscatilin)

Compound DI4 was obtained as a orangish-brown amorphous solid, soluble in acetone (5 mg, 0.00015% based on dried weight of whole plant).

HR-ESI-MS: $[M+Na]^+$ ion at *m/z* 327.1219 ($C_{17}H_{20}O_5Na$); **Figure 38**

^{1}H-NMR: δ ppm, 300 MHz, in acetone-d_6; **Figure 39, Table 9**

^{13}C-NMR: δ ppm, 75 MHz, in acetone-d_6; **Figure 40, Table 9**

4.5 Compound DI5 (Aloifol I)

Compound DI5 was obtained as a reddish-brown solid, soluble in acetone (238 mg, 0.00700% based on dried weight of whole plant).

HR-ESI-MS: $[M+Na]^+$ ion at *m/z* 297.1107 ($C_{16}H_{18}O_4Na$); **Figure 45**

^{1}H-NMR: δ ppm, 300 MHz, in acetone-d_6; **Figure 46, Table 10**

^{13}C-NMR: δ ppm, 75 MHz, in acetone-d_6; **Figure 47, Table 10**

4.6 Compound DI6 (Batatasin III)

Compound DI6 was obtained as a brown amorphous solid, soluble in acetone (135.9 mg, 0.003997% based on dried weight of whole plant).

HR-ESI-MS: $[M+Na]^+$ ion at *m/z* 267.1051 ($C_{15}H_{16}O_3Na$); **Figure 52**

^{1}H-NMR: δ ppm, 300 MHz, in acetone-d_6; **Figure 53, Table 11**

^{13}C-NMR: δ ppm, 75 MHz, in acetone-d_6; **Figure 54, Table 11**

4.7 Compound DI7 (3,3′-Dihydroxy-4,5-dimethoxybibenzyl)

Compound DI7 was obtained as a dark brown amorphous soilid, soluble in acetone (425.9 mg, 0.01253% based on dried weight of whole plant).

HR-ESI-MS: $[M+Na]^+$ ion at *m/z* 297.1107 ($C_{16}H_{18}O_4Na$); **Figure 60**

^{1}H-NMR: δ ppm, 300 MHz, in acetone-d_6; **Figure 61, Table 12**

^{13}C-NMR: δ ppm, 75 MHz, in acetone-d_6; **Figure 62, Table 12**

4.8 Compound DI8 (3,4′-Dihydroxy-3′,4,5-trimethoxybibenzyl)

Compound DI8 was obtained as a dark brown amorphous solid, soluble in acetone (10.1 mg, 0.000296% based on dried weight of whole plant).

HR-ESI-MS: $[M+Na]^+$ ion at *m/z* 327.1210 ($C_{17}H_{20}O_5Na$); **Figure 68**

^{1}H-NMR: δ ppm, 300 MHz, in acetone-d_6; **Figure 69, Table 13**

^{13}C-NMR: δ ppm, 75 MHz, in acetone-d_6; **Figure 70, Table 13**

4.9 Compound DI9 (Dendrosinen B)

Compound DI9 was obtained as a brown amorphous solid, soluble in acetone (9.5 mg, 0.00028% based on dried weight of whole plant).

HR-ESI-MS: $[M+Na]^+$ ion at *m/z* 283.0911 ($C_{15}H_{16}O_4Na$); **Figure 76**

^{1}H-NMR: δ ppm, 300 MHz, in acetone-d_6; **Figure 77, Table 14**

^{13}C-NMR: δ ppm, 75 MHz, in acetone-d_6; **Figure 78, Table 14**

5. Assays for lipase and α-glucosidase inhibitory activities

5.1 Lipase inhibitory activity assay

5.1.1 Materials and instruments

- Pancreatic lipase enzyme (Sigma-Aldrich)
- 4-Methylumbelliferyl oleate (4-MUO) (Sigma-Aldrich)
- Orlistat (Sigma-Aldrich)
- Tris-HCl (Sigma-Aldrich)
- Sodium chloride (Merk)
- Calcium carbonate (Riedel-De Haen)
- Sodium citrate (Merck)
- Wallac 1420 Victor2 Microplate Reader (PerkinElmer)
- Transsonic 570/H Ultrasonic bath (Elma)

- Vortex Genie2 mixer (Scientific Industries)

5.1.2 Determination of lipase inhibitory activity

The lipase inhibitory activity was determined by measuring the amount of 4-methylumbelliferone (4-MU) released from the reaction between lipase and 4-methylumbelliferyl oleate (4-MUO). This enzyme assay method was adopted from two previous studies (Sergent *et al.*, 2012; Podsedek *et al.*, 2014). Tris-HCl buffer (pH 8.0) consisting of 13 mM Tris-HCl, 150 mM NaCl and 1.3 mM $CaCl_2$ was used to prepare the enzyme and substrate solutions. In 96-well plate, 25 µL of sample, 50 µL of 0.5 mM 4-MUO and 25 µL of 0.5 mg/mL pancreatic lipase were mixed and incubated at room temperature for 30 min. Then, 100 µL of 0.1 mM sodium citrate (pH 4.2) was added to terminate the reaction.

The sample was replaced by 20% DMSO as a negative control. The final concentration of DMSO in each well was controlled at 5%. Orlistat was used as a positive control and treated under the same condition as the sample.

Fluorescence of 4-MU was measured using a microplate reader with excitation and emission wavelengths of 355 and 460 nm, respectively. The percentage of lipase enzyme inhibition was calculated from the following formula:

$$\% \text{ inhibition} = \frac{(F_{control} - F_{control\ blank}) - (F_{sample} - F_{sample\ blank})}{(F_{control} - F_{control\ blank})} \text{ X } 100$$

Where $F_{control}$ and $F_{control\ blank}$ are the fluorescence value of the negative control with and without enzyme, respectively; F_{sample} and $F_{sample\ blank}$ are the fluorescence value of sample with and without enzyme, respectively.

After the screening test, the compounds could inhibit more than 50% of the enzyme activity at the concentration of 100 µg/mL were examined to determine the IC_{50} values. The experiment was performed in triplicate.

5.2 α-Glucosidase enzyme inhibitory activity assay

5.2.1 Materials and instruments

- α-Glucosidase enzyme (Sigma-Aldrich)
- *p*-Nitrophenyl-α-D-glucopyranoside (*p*NPG) (Sigma-Aldrich)
- Acarbose (Sigma-Aldrich)
- Monobasic potassium phosphate: KH_2PO_4 (Carlo Erba)
- Dibasic potassium phosphate: K_2HPO_4 (Carlo Erba)
- Sodium carbonate (Sigma-Aldrich)
- Wallac 1420 Victor2 Microplate Reader (PerkinElmer)
- Transsonic 570/H Ultrasonic bath (Elma)
- Vortex Genie2 mixer (Scientific Industries)

5.2.2 Determination of α-glucosidase inhibitory activity

The assay to determine of α-glucosidase inhibitory activity was adapted from prior research (Kang *et al.*, 2010) by monitoring the *p*-nitrophenol released from the interaction between α-glucosidase and *p*-nitrophenyl-α-D-glucopyranoside (*p*NPG). The enzyme and substrate were diluted in 0.1 M phosphate buffer (pH 6.8). In the assay, 40 µL of buffer, 10 µL of sample and 50 µL of 0.1 U/mL α-glucosidase were mixed in a 96-well plate and pre-incubated at 37 °C for 10 min. Then, 50 µL of 2 mM *p*NPG was added and the mixture was further incubated at 37 °C for 20 min. Finally, 100 µL of 0.1 mM Na_2CO_3 solution was added to stop the reaction.

The sample was replaced by 50% DMSO as a negative control and acarbose as a positive control. The final concentration of DMSO in each well was about 3.3%. The negative and positive controls were treated under the same condition as the sample.

The absorbance was then measured at 405 nm using a microplate reader. The percentage of α-glucosidase inhibition was calculated by the following formula:

$$\%\ \text{inhibiton} = \frac{(\mathrm{A_{control}} - \mathrm{A_{control\ blank}}) - (\mathrm{A_{sample}} - \mathrm{A_{sample\ blank}})}{(\mathrm{A_{control}} - \mathrm{A_{control\ blank}})}\ \mathrm{X}\ 100$$

Where $A_{control}$ and $A_{control\ blank}$ are the absorbance of the negative control with and without enzyme, respectively; A_{sample} and $A_{sample\ blank}$ are the absorbance of sample with and without enzyme, respectively.

The compounds were further analyzed for IC_{50} value if they showed $\geq$ 50% inhibition of the enzyme at the concentration of 100 µg/mL. The experiment to obtain the IC_{50} value experiment was performed in triplicate.

CHAPTER IV
RESULTS AND DISCUSSION

The whole plants of *Dendrobium infundibulum* were extracted with methanol to give methanol extract, which suspended in water and partitioned with EtOAc and n-butanol. All extracts were then examined for inhibitory activity against the enzymes lipase and α-glucosidase. The EtOAc extract, which showed the most potent lipase and α-glucosidase inhibitory activities, was selected for further separation using several chromatographic techniques to give 9 compounds.

1. Structure determination of isolated compounds

1.1 Structure determination of compound DI1

Compound DI1 was obtained as a white amorphous solid. The HR-ESI mass spectrum (**Figure 7**) presented an $[M+Na]^+$ ion peak at *m/z* 309.1047 (calcd. for $C_{17}H_{18}O_4Na$, 309.1102), suggesting the molecular formula $C_{17}H_{18}O_4$.

Its IR spectrum showed absorption bands of hydroxy group at 3358 cm^{-1}, aromatic rings at 2292 and 1659 cm^{-1} and methylene groups at 1468 cm^{-1} (**Figure 8**). The UV spectrum (**Figure 9**) presented maximal absorptions at 222 nm and 273 nm, implying that it was a dihydrophenanthrene (Lin *et al.*, 2013).

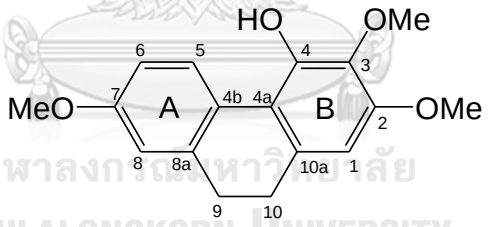
The ^{1}H NMR spectrum (**Figure 10**) exhibited four aromatic proton signals at δ 6.48-8.31 and three methoxy signals at δ 3.79, 3.80 and 3.85. An ABM splitting system of protons on ring A consisted of a double doublets at δ 6.78 (1H, *J* = 9.5, 2.5 Hz, H-6) and two doublets at δ 6.77 (1H, *J* = 2.5 Hz, H-8), and 8.31 (1H, *J* = 9.5 Hz, H-5). The siglet proton signal at δ 6.48 represented a proton with no coupling on ring B.

The number of signals in the ^{13}C-NMR spectrum (**Figure 11**) corresponded to the number of carbon atoms in the molecular formula. Nine proton signals were assigned to nine carbon atoms by the HSQC spectrum (**Figures 12-14**). It also revealed eight quaternary carbons.

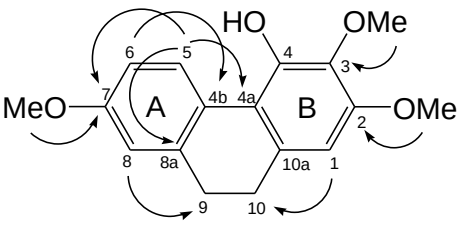
The positions of aromatic protons and methoxy groups were assigned by the correlations in HMBC spectrum (**Figures 15-17**). On ring A, the H-5 was assigned based on the correlations of C-4a (δ 115.5), C-7 (δ 158.7) and C-8a (δ 139.7). The H-6 and H-8 were assigned by the correlations to C-4b (δ 126.9) and C-9 (δ 30.9), respectively. The H-1 of ring B was assigned by the correlation of C-10 (δ 31.0). The methoxy protons at δ 3.85, 3.80 and 3.79 showed correlations to C-2 (δ 151.6), C-3 (δ 135.7) and C-7 (δ 158.7), respectively.

The NOESY spectrum (**Figure 18**) was used to confirm the positions of aromatic protons and methoxy groups. The 2-OMe substitution was confirmed by its correlations to H-1. The 7-OMe substitution was confirmed by its correlations to H-6 and H-8. The 3-OMe substitution was confirmed by the HMBC correlations from C-3 to 3-OMe protons and H-1.

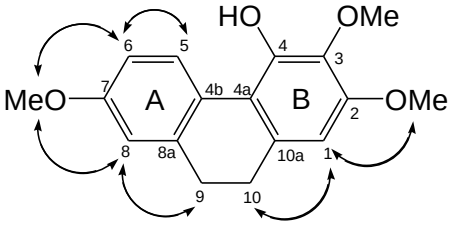
Based on the above spectral evidence, DI1 was characterized as 4-hydroxy-2,3,7-trimethoxydihydrophenanthrene and has been named dendroinfundin A.



Dendroinfundin A [**294**]



HMBC correlations (H⟶C)



NOESY correlations (H⟷H)

Table 6 NMR spectral data of compound DI1 (500 MHz, in acetone-d_6)

Position	Compound DI1	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
1	6.48 (*s*)	104.3
2	-	151.6
3	-	135.7
4	-	148.4
4a	-	115.5
4b	-	126.9
5	8.31 (*d*, *J* = 9.5 Hz)	129.6
6	6.78 (*d*, *J* = 9.5, 2.5 Hz)	112.0
7	-	158.7
8	6.77 (*d*, *J* = 2.5 Hz)	113.7
8a	-	139.7
9	2.69 (*m*)	30.9
10	2.69 (*m*)	31.0
10a	-	134.6
2-OMe	3.85 (*s*)	56.1
3-OMe	3.80 (*s*)	60.9
7-OMe	3.79 (*s*)	55.4

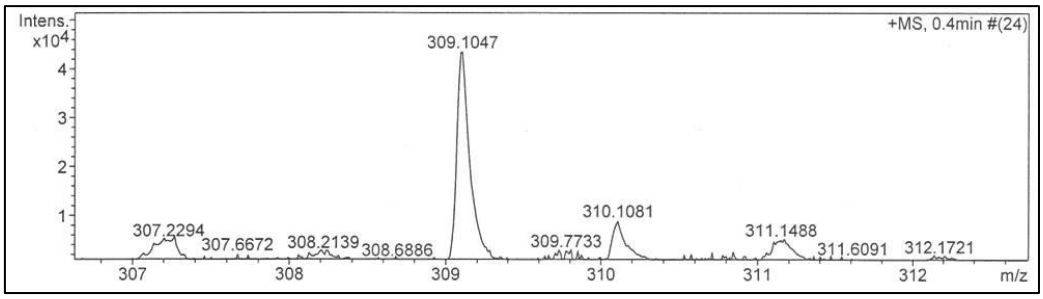


Figure 7 Mass spectrum of compound DI1

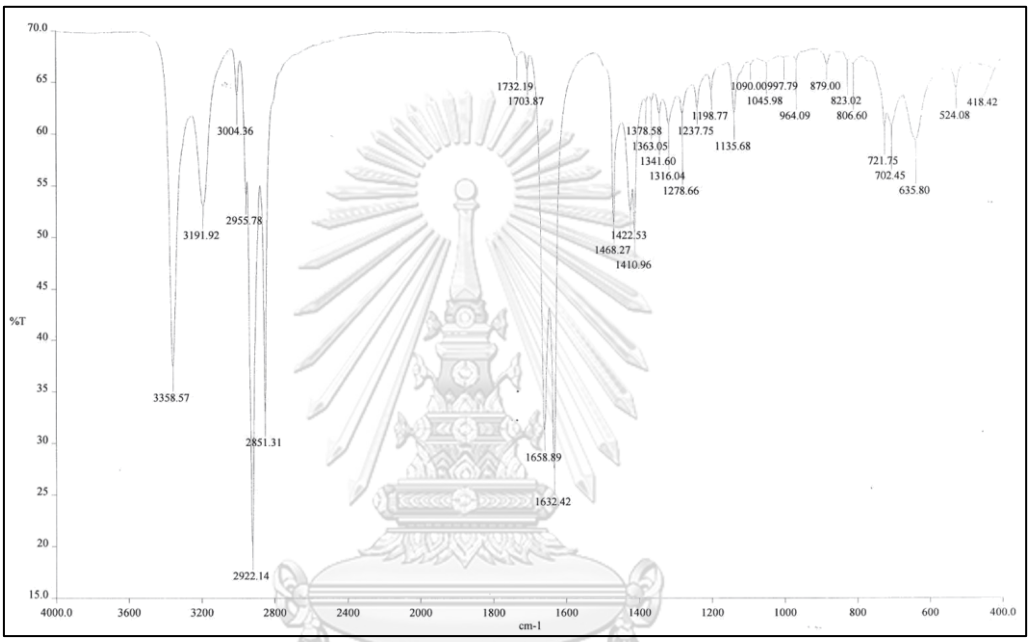


Figure 8 IR spectrum of compound DI1

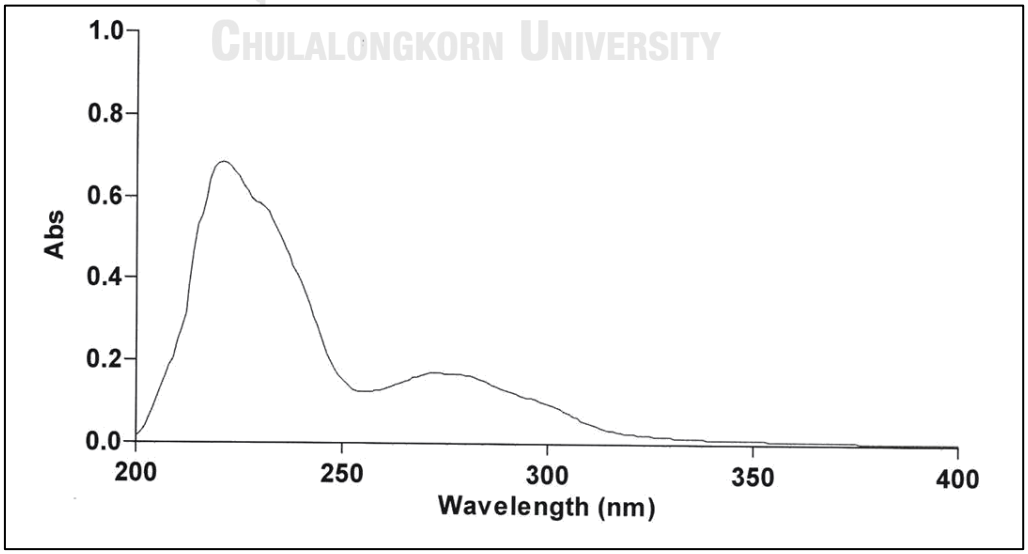


Figure 9 UV spectrum of compound DI1

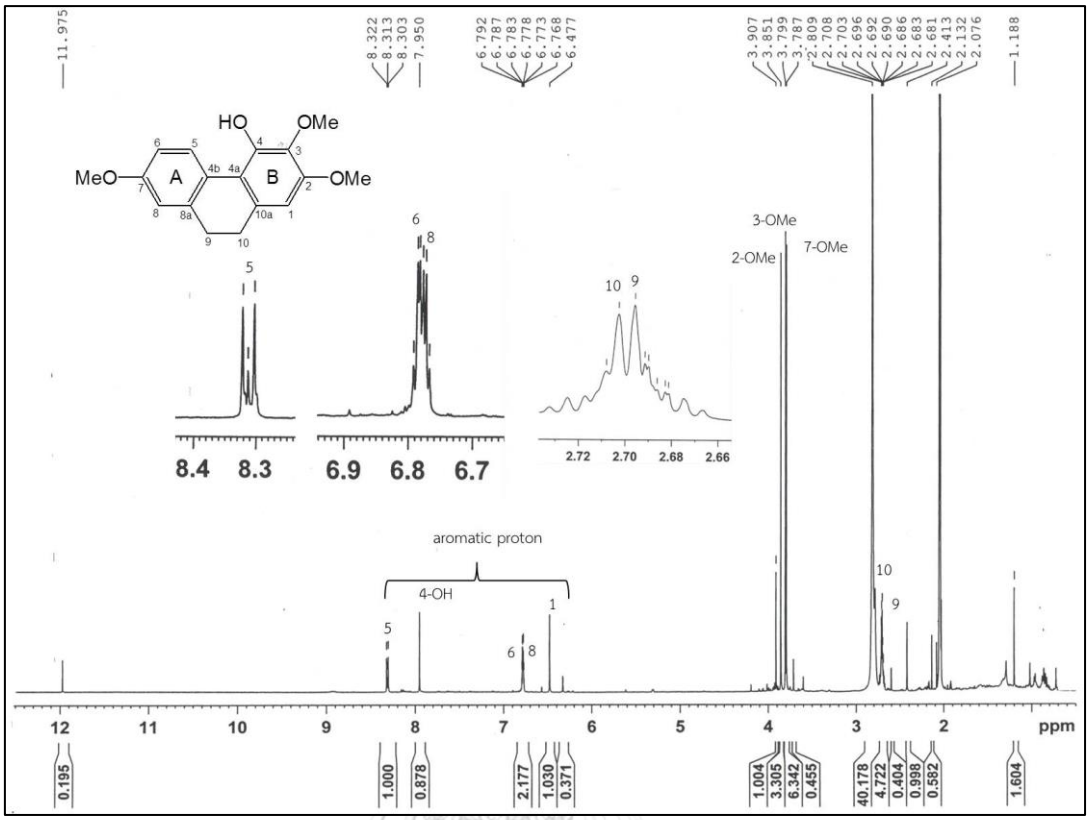


Figure 10 ^{1}H-NMR spectrum of compound DI1

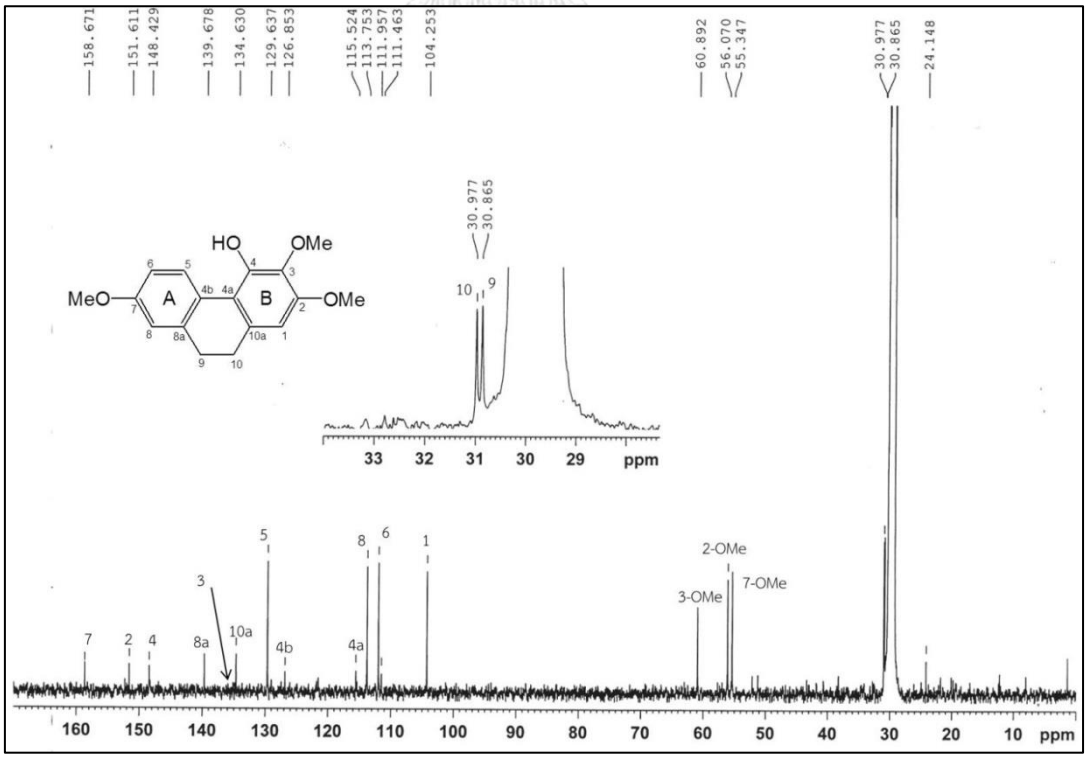


Figure 11 ^{13}C-NMR spectrum of compound DI1

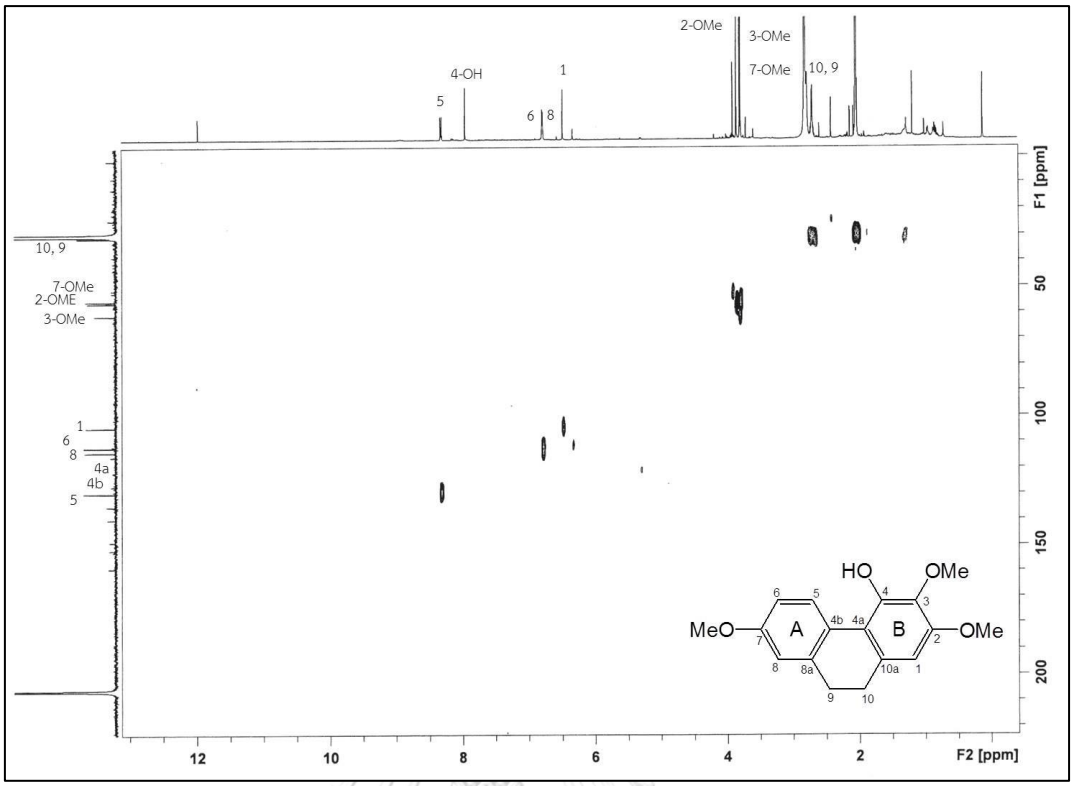


Figure 12 HSQC spectrum of compound DI1

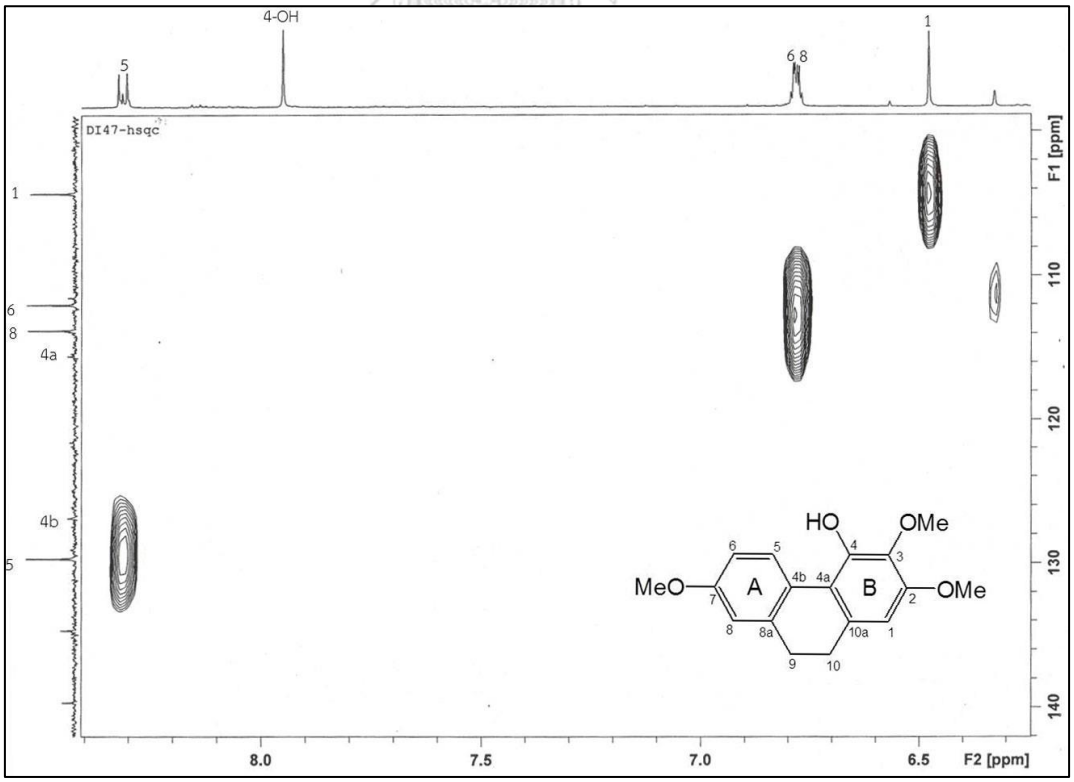


Figure 13 HSQC spectrum of compound DI1 (enlarge1)

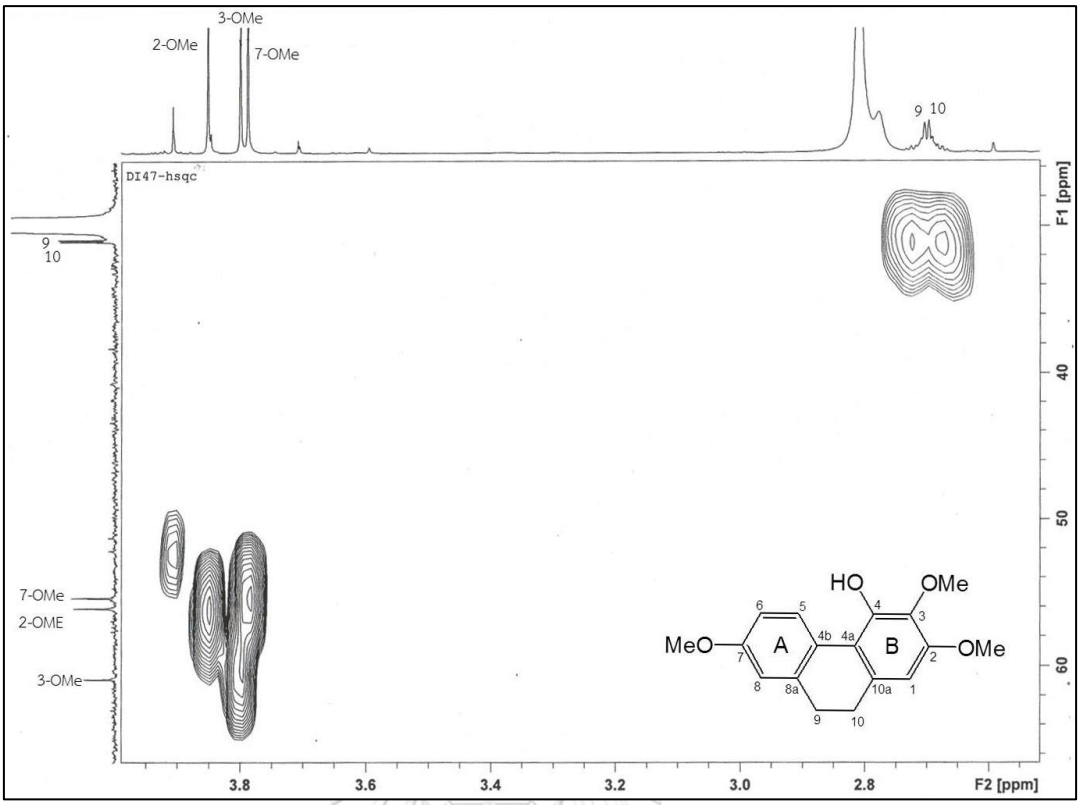


Figure 14 HSQC spectrum of compound DI1 (enlarge2)

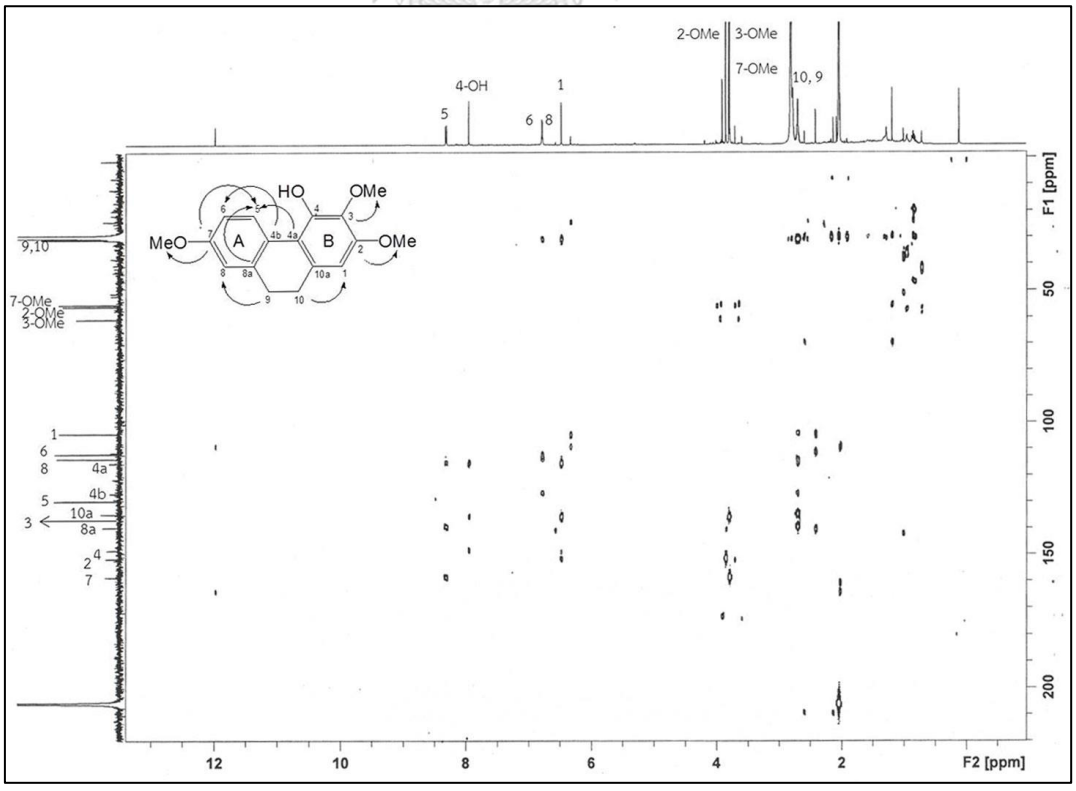


Figure 15 HBMC spectrum of compound DI1

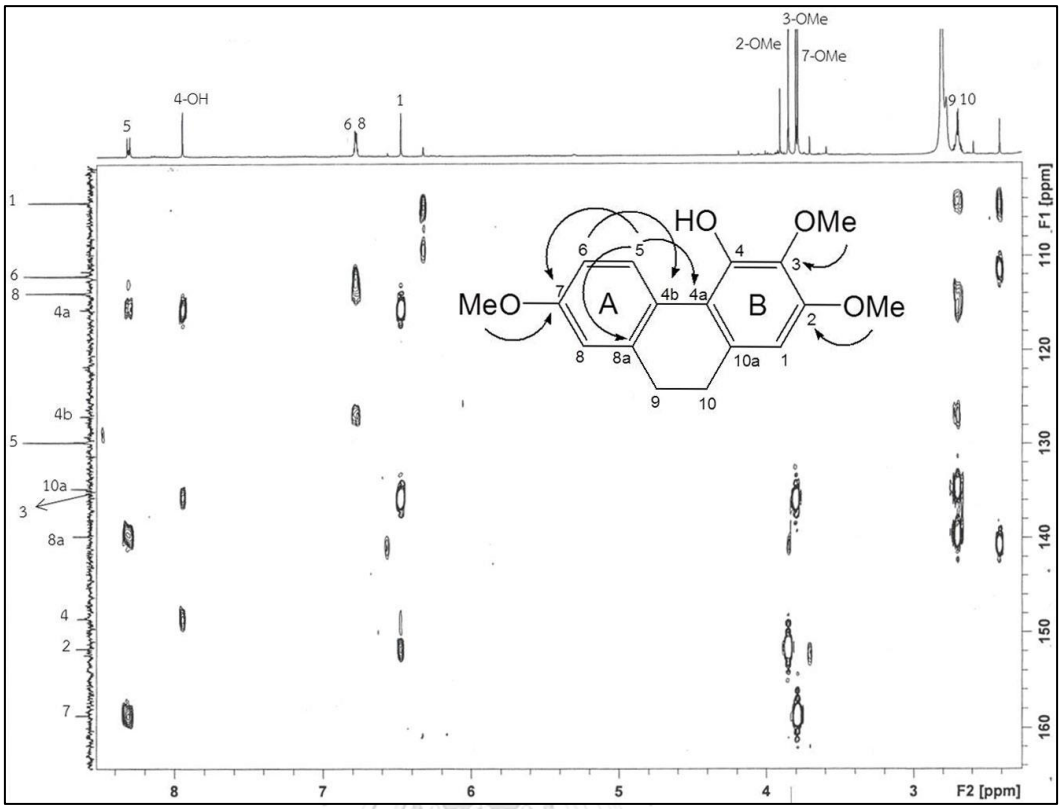


Figure 16 HBMC spectrum of compound DI1 (enlarge 1)

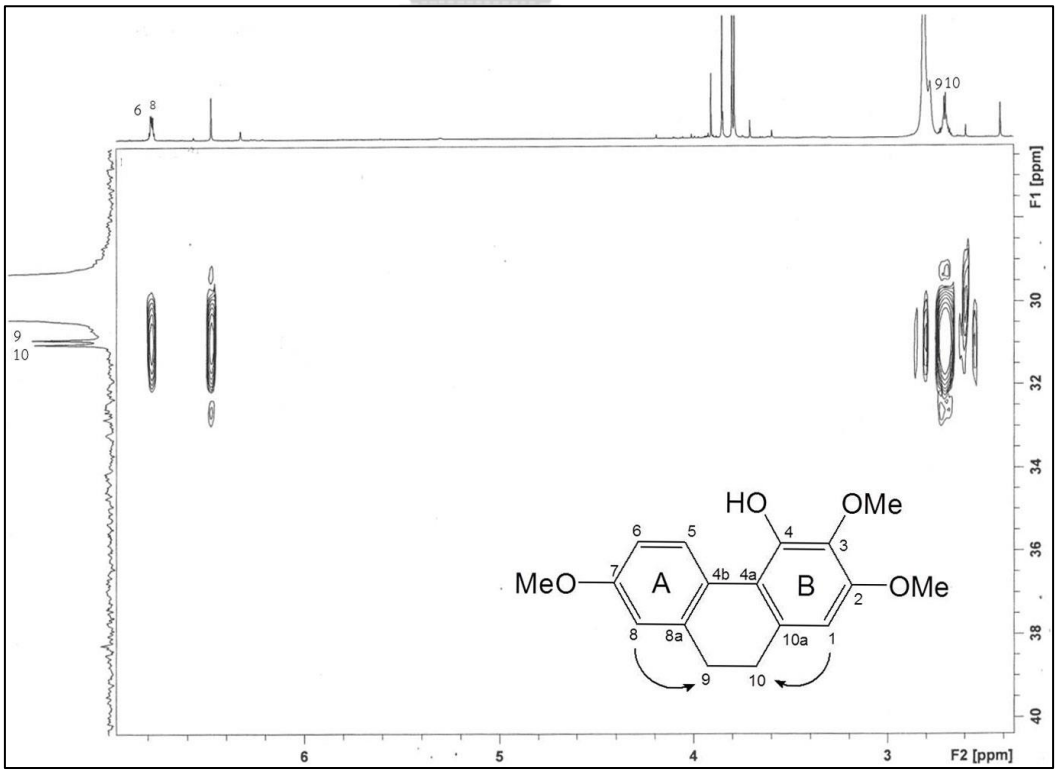


Figure 17 HBMC spectrum of compound DI1 (enlarge 2)

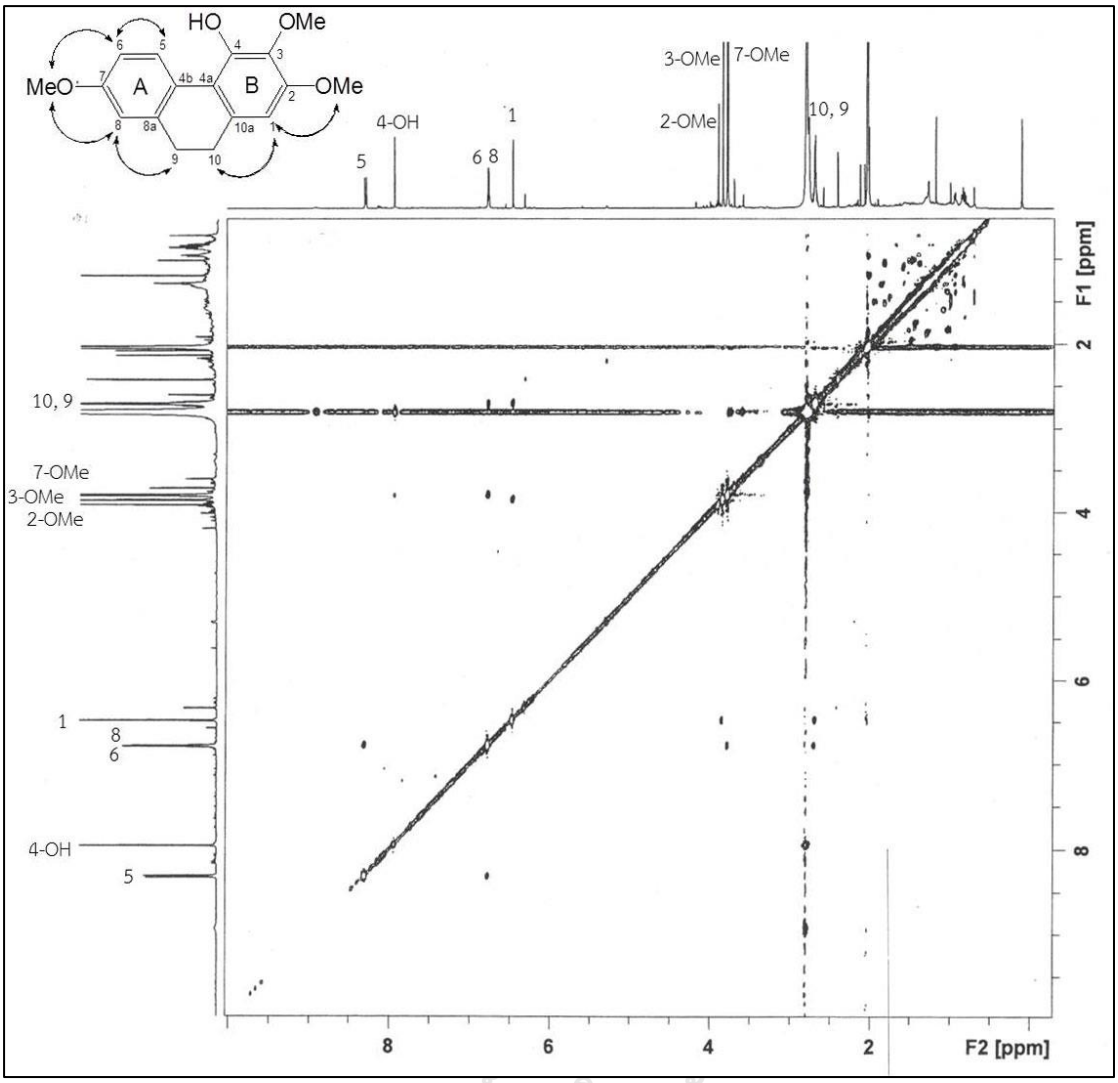


Figure 18 NOESY spectrum of compound DI1

1.2 Structure determination of compound DI2

Compound DI2 was obtained as a white amorphous solid. Its HR-ESI-MS (**Figure 19**) showed a sodium-adduct molecular ion $[M+Na]^+$ peak at *m/z* 295.0965 (calcd. for $C_{16}H_{16}O_4Na$; 295.0946), suggesting the molecular formula $C_{16}H_{16}O_4$. It had one carbon atom and two hydrogen atoms less than compound DI1 implying that a hydroxy group substituted instead of a methoxy group.

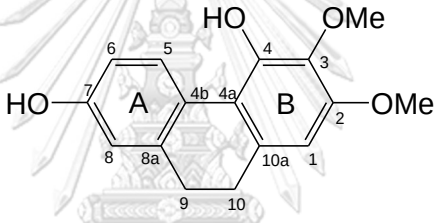
Its patterns of ^{1}H NMR (**Figure 20**) and ^{13}C NMR (**Figure 21**) spectrum were similar to compound DI1, only a methoxy signal was disappeared in both ^{1}H NMR and ^{13}C NMR spectrum. The HSQC spectrums were used to assign a linkage of proton to carbon (**Figure 22**).

The aromatic protons and methoxy groups were assigned by the correlations in HMBC spectrum (**Figure 23**). On ring A, the signal at δ 8.24 (1H, *d*, *J* = 9.3 Hz) was assigned as H-5 based on the correlations to C-7 (δ 156.2), C-4a (δ115.7) and C-8a (δ 139.7). The H-6 (δ 6.72, *dd*, *J* = 9.3, 2.7 Hz) was assigned by the correlation peak to C-4b (δ 125.7). The H-8 (δ 6.70, *d*, *J* = 2.7 Hz) was assigned by the correlations of C-7 (δ 156.2) and C-9 (δ 30.7). The H-1 (δ 6.70, *s*) of ring B was assigned by the correlation of C-2 (δ 151.3), C-3 (δ 135.8), C-4a (δ 115.7) and C-10 (δ 31.0). The proton at δ 7.93 (*s*) showed correlations to C-3, C-4 (δ 148.2) and C-4a, indicated the position of 4-OH. The methoxy protons at δ 3.83 and 3.79 showed correlations to C-2 (δ 151.3) and C-3 (δ 135.8), respectively.

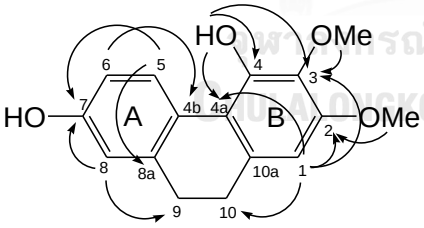
The NOESY spectrum (**Figure 24**) was used to confirm the positions of aromatic protons and methoxy groups. The 2-OMe substitution was confirmed by correlations of H-1 to H-10 (δ 2.66) and protons of 2-OMe. The position of H-5 was confirmed by the correlations to 4-OH and H-5. The cross peak of H-8 and H-9 indicated the close position between these two protons. The 3-OMe substitution was confirmed by no crosspeak to any proton.

From the data mentioned above and through comparison with previously reported NMR data (**Table 7**), compound DI2 was identified as ephemeranthol A

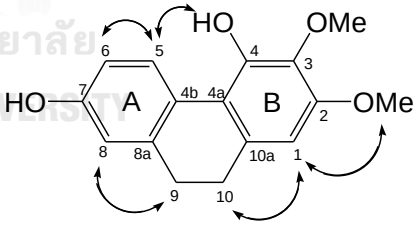
[**111**]. It has been isolated from *Ephemerantha lonchophylla* (Tezuka et al., 1991), *Dendrobium nobile* (Yang *et al.*, 2007; Hwang *et al.*, 2010; Kim *et al.*, 2015; Zhou *et al.*, 2016), *Flickingeria fimbriata* (Wu *et al.*, 2017b) and *Dendrobium officinale* (Zhao *et al.*, 2018). Its biological activities which were reported are anti-inflammatory activity (inhibited nitric oxide production with the IC_{50} 12.0±0.3 μM) (Hwang *et al.*, 2010), by inhibition of NF-ΚB activation and phosphorylation of MAP kinases in the macrophages (Kim *et al.*, 2015), antifibrotic activity by inhibition of hepatic (HSC-T6) cell proliferation (IC_{50} 79.2 μM) (Yang *et al.*, 2007) and cytotoxic activity against leukemia cells (HL-60; IC_{50} 39.35±1.58 μM and THP-1; IC_{50} 36.34±2.21 μM) (Zhao *et al.*, 2018).



Ephemeranthol A [**106**]



HMBC correlations (H→C)



NOESY correlations (H↔H)

Table 7 NMR spectral data of compound DI2 (300 MHz, in acetone-d_6) and ephemeranthol A (400 MHz, in $CDCl_3$)

Position	Compound DI2		Ephemeranthol A*
	δ_H in ppm (mult., *J* in Hz)	**δ_C in ppm**	**δ_H in ppm (mult., *J* in Hz)**
1	6.45 (*s*)	104.3	6.39 (*s*)
2	-	151.3	-
3	-	135.8	-
4	-	148.2	-
4a	-	115.7	-
4b	-	125.7	-
5	8.24 (*d*, *J* =9.3 Hz)	129.7	8.22 (*d*, *J* =8.5 Hz)
6	6.72 (*dd*, *J* =9.3, 2.7 Hz)	113.5	6.74 (*dd*, *J* =8.5, 3.0 Hz)
7	-	156.2	-
8	6.70 (*d*, *J* =2.7 Hz)	115.1	6.71 (*d*, *J* =3.0 Hz)
8a	-	139.7	-
9	2.66 (*m*)	30.7	2.74 (*m*)
10	2.66 (*m*)	31.0	2.74 (*m*)
10a	-	134.4	-
2-OMe	3.83 (*s*)	56.0	3.89 (*s*)
3-OMe	3.79 (*s*)	60.8	3.93 (*s*)

*Tezuka et al., 1991

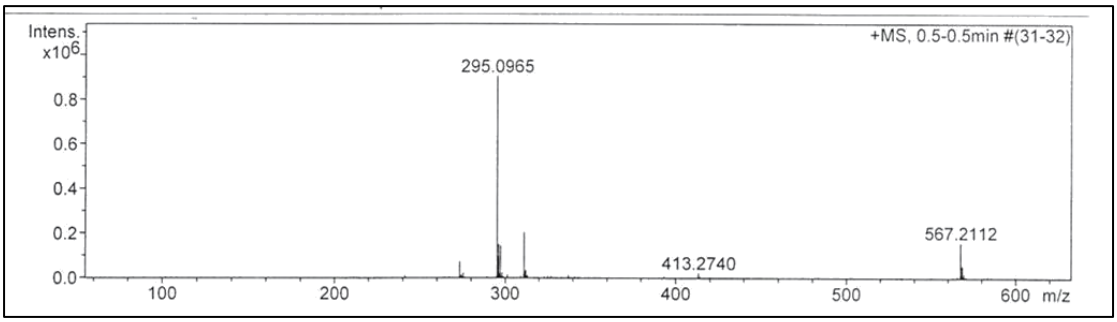


Figure 19 Mass spectrum of compound DI2

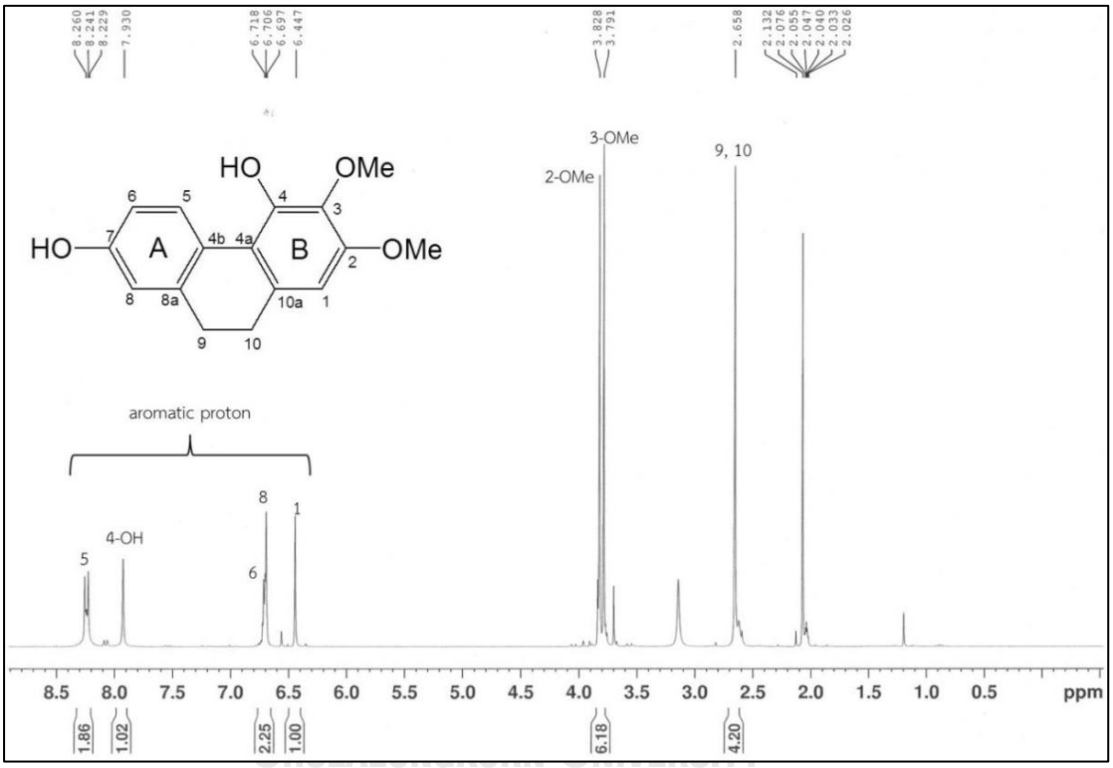


Figure 20 ^{1}H-NMR spectrum of compound DI2

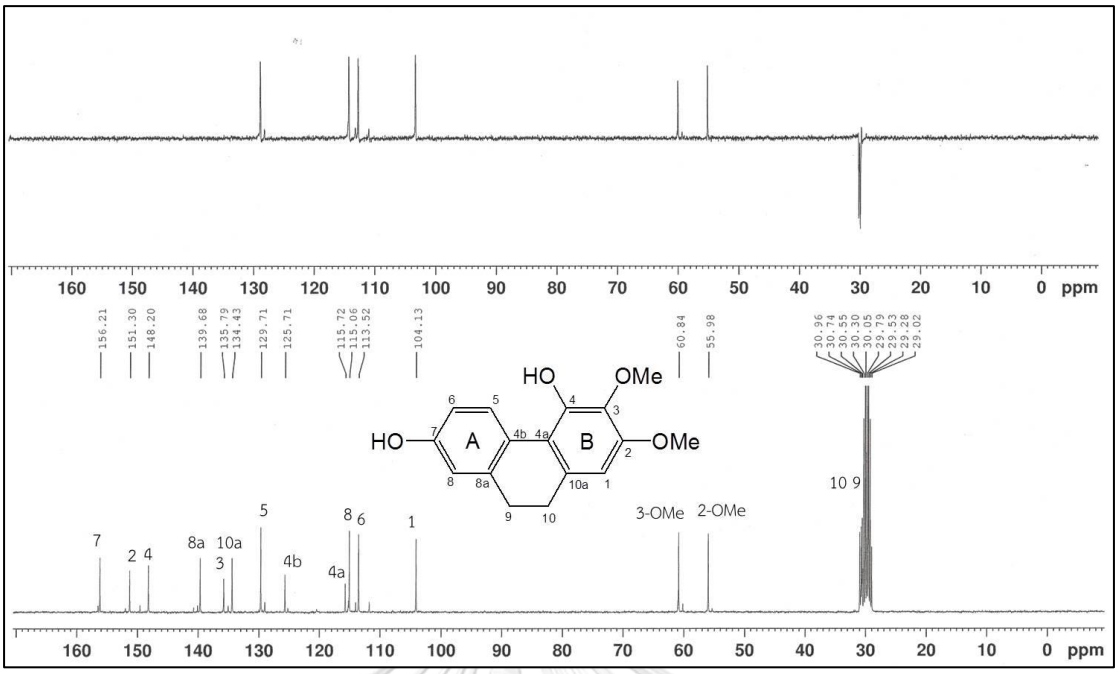


Figure 21 ^{13}C-NMR spectrum of compound DI2

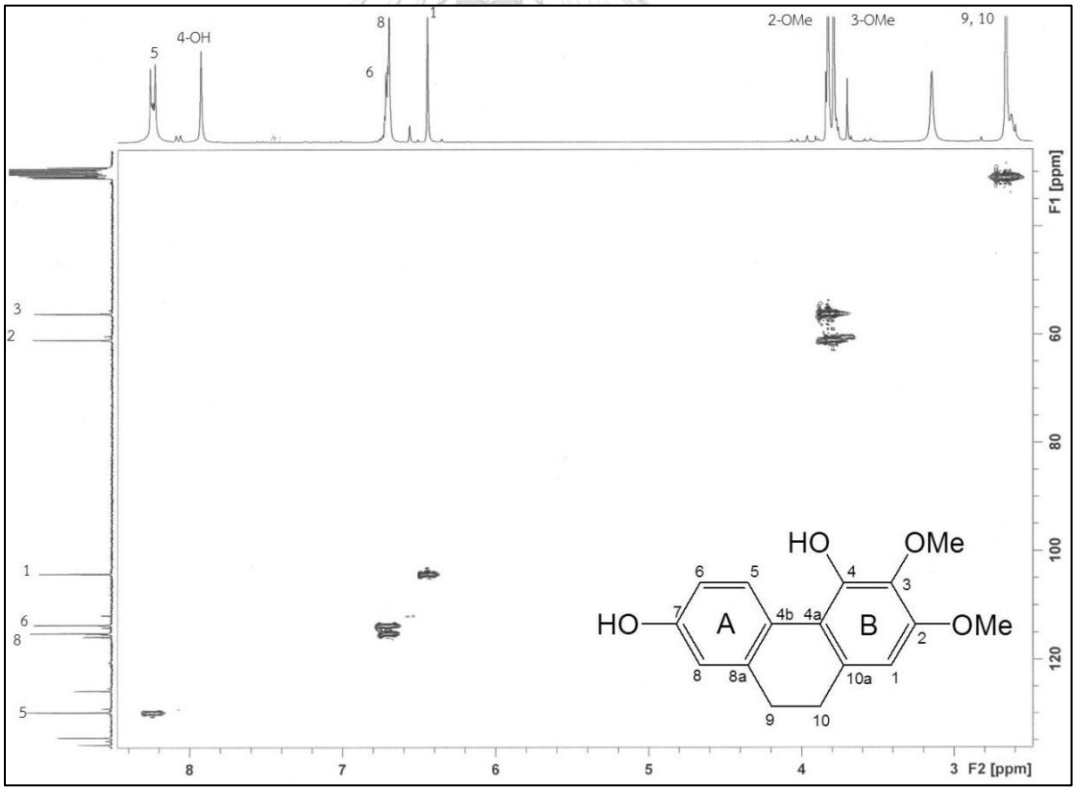


Figure 22 HSQC spectrum of compound DI2

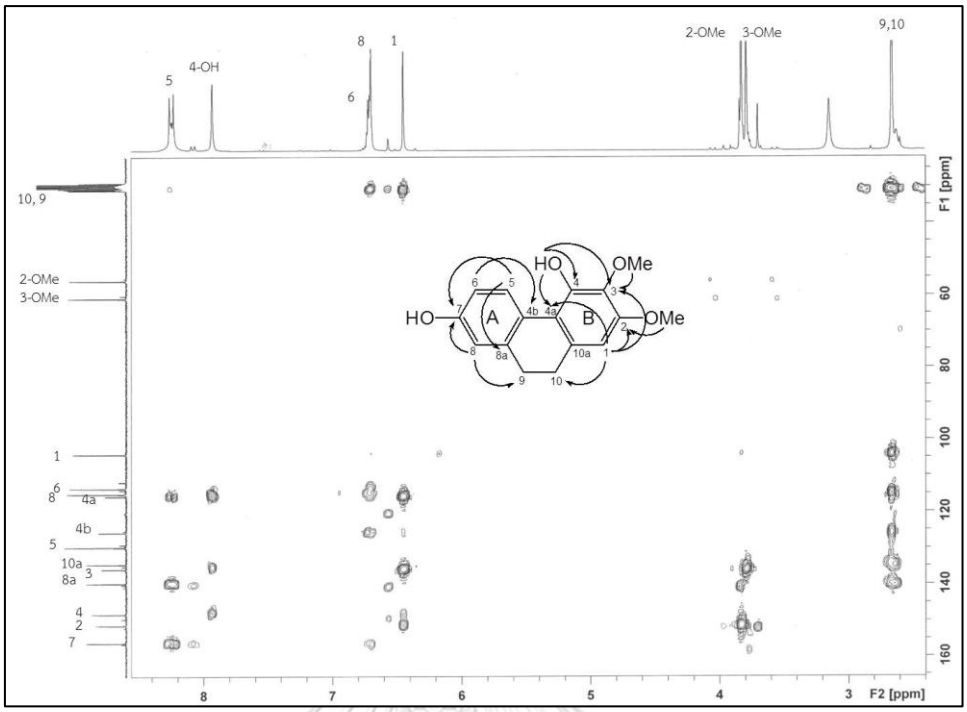


Figure 23 HMBC spectrum of compound DI2

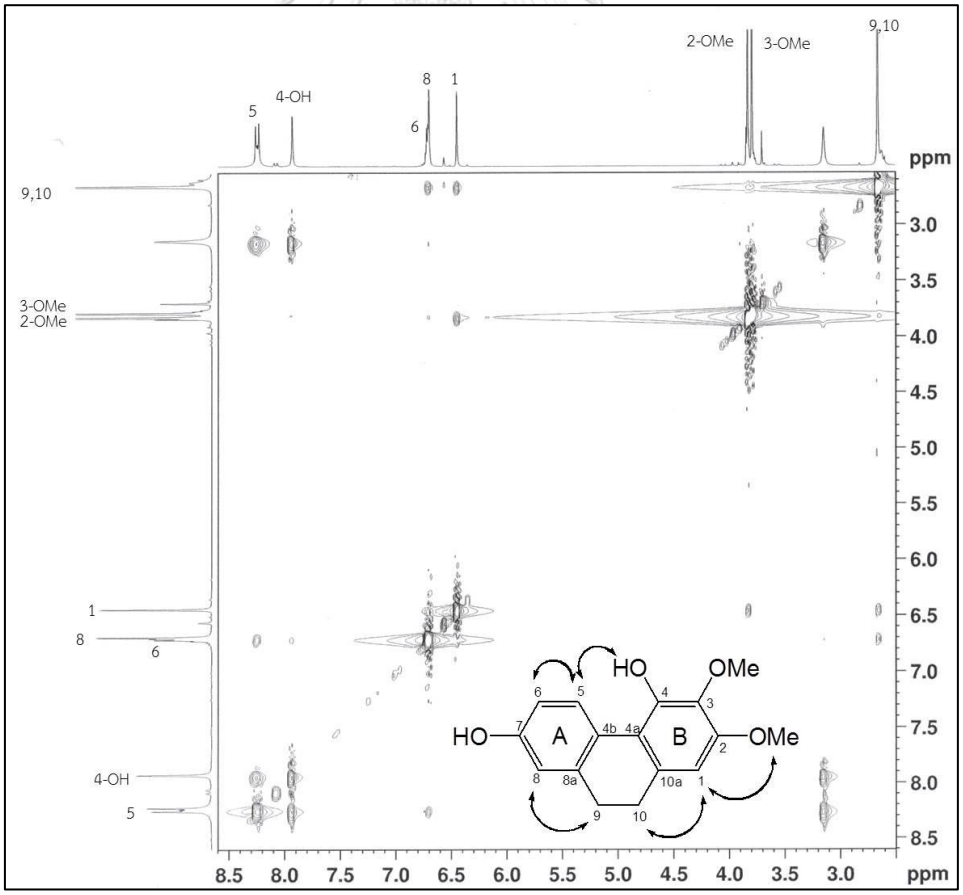


Figure 24 NOESY spectrum of compound DI2

1.3 Structure determination of compound DI3

Compound DI3 was isolated as a dark brown amorphous soilid. Its HR-ESI-MS (**Figure 25**) presented a sodium-adduct molecular ion $[M+Na]^+$ peak at *m/z* 325.1051, (calcd. for $C_{17}H_{18}O_4Na$; 325.1051), suggesting the molecular formula $C_{17}H_{18}O_5$. It had one oxygen atom more than compound DI1 implying that there was a hydroxy group substituted instead of an aromatic proton.

Its IR spectrum showed absorption bands of hydroxy group at 3358 cm^{-1}, aromatic rings at 2292 and 1659 cm^{-1} and methylene groups at 1468 cm^{-1} (**Figure 26**). The UV spectrum (**Figure 27**) presented maximal absorptions at 222 nm and 273 nm, implying that it was a dihydrophenanthrene (Lin *et al.*, 2013).

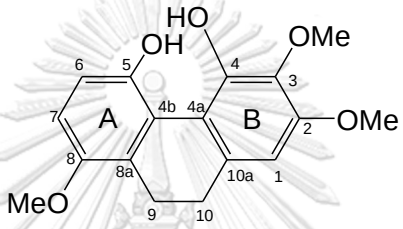
The ^{1}H NMR (**Figure 28**) spectrum showed the similar structure of ring B to that of DI1. It was confirmed by the HMBC correlations from H-1 (1H, s, δ 6.63) to C-10 (δ 31.2). The assignments of C-2 (δ 152.6) and C-3 (δ 136.6) were obtained from the HMBC correlations between 2-OMe protons and C-2, and between 3-OMe (3H, s, δ 3.81) protons and C-3, together with the NOESY interaction between 2-OMe protons (3H, s, δ 3.88) and H-1.

The number of signals in the ^{13}C-NMR spectrum (**Figure 29**) corresponded to the number of carbon atoms in the molecular formula. Eight proton signals were assigned to nine carbon atoms by the HSQC spectrum (**Figures 30-31**). It also revealed nine quaternary carbons, which wxihibited five substititions on the phenanthrene nucleus.

The positions of aromatic protons and substitutes were showed by the HMBC spectrum (**Figures 32-35**). On ring A, the signal at δ 6.84 was assigned as H-7 based on the correlations to C-8a (δ 128.8). The H-6 was assigned by the correlation peak to C-4b (δ 123.4). The H-1 of ring B was assigned by the correlation to C-2 (δ 152.6), C-4a (δ 115.4), C-10 (δ 31.2) and C-10a (δ 136.8). The methoxy protons at δ 3.88, 3.81 and 3.78 showed correlations to C-2 (δ 151.3), C-3 (δ 135.8) and C-8 (δ 56.7), respectively.

The NOESY spectrum (**Figures 36-37**) was used to confirm the position of aromatic protons and methoxy groups. The 2-OMe substitution was confirmed by correlations of H-1 to H-10 (δ 2.56) and protons of 2-OMe. The position of 7-OMe was confirmed by the correlations to H-7 and H-9. The 3-OMe substitution was confirmed by no crosspeak to any proton.

On the basis of the above spectroscopic studies, DI3 was thus characterized as 4,5-dihydroxy-2,3,8-trimethoxydihydrophenanthrene, and has been given the trivial name dendroinfundin B.



Dendroinfundin B [**295**]

HMBC correlations (C→H) NOESY correlations (H↔H)

Table 8 NMR spectral data of compound DI3 (500 MHz, in acetone-d_6)

Position	Compound DI3	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
1	6.63 (*s*)	105.2
2	-	152.6
3	-	136.6
4	-	147.3
4a	-	115.4
4b	-	123.4
5	-	148.6
6	6.81 (*d*, *J* = 9.0 Hz)	117.3
7	6.84 (*d*, *J* = 9.0 HZ)	112.2
8	-	150.5
8a	-	128.8
9	2.66 (*m*)	23.1
10	2.56 (*m*)	31.2
10a	-	136.8
2-OMe	3.88 (*s*)	56.2
3-OMe	3.81 (*s*)	60.8
8-OMe	3.78 (*s*)	56.7

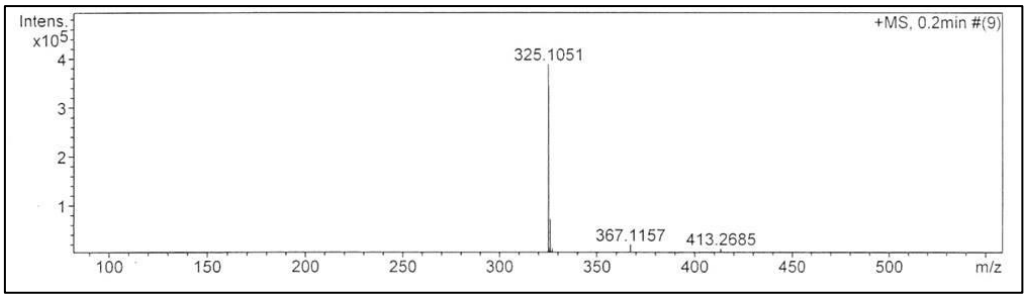


Figure 25 Mass spectrum of compound DI3

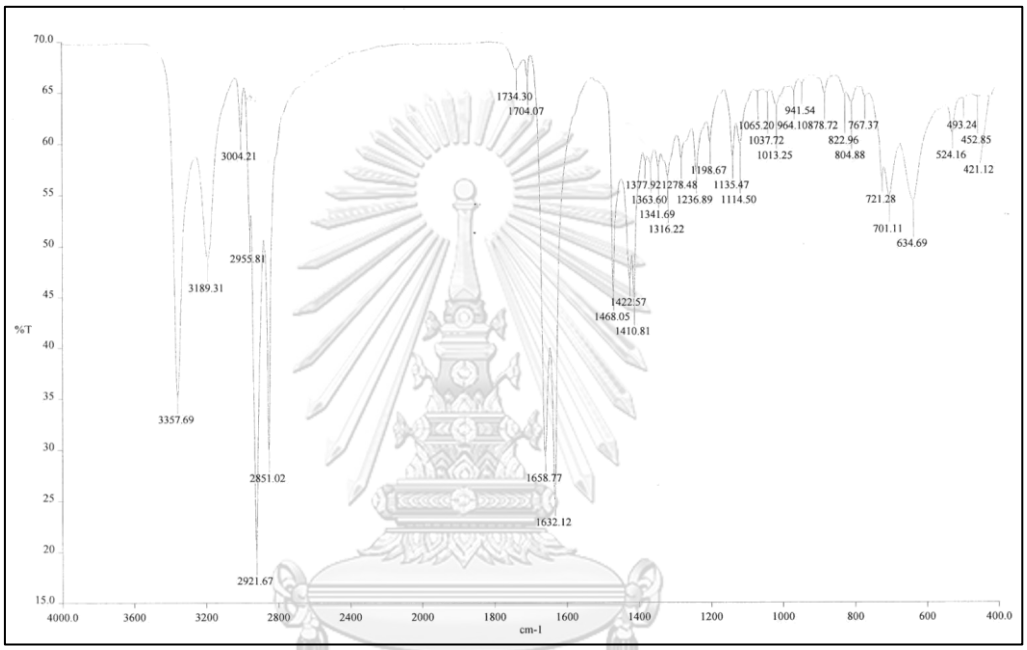


Figure 26 IR spectrum of compound DI3

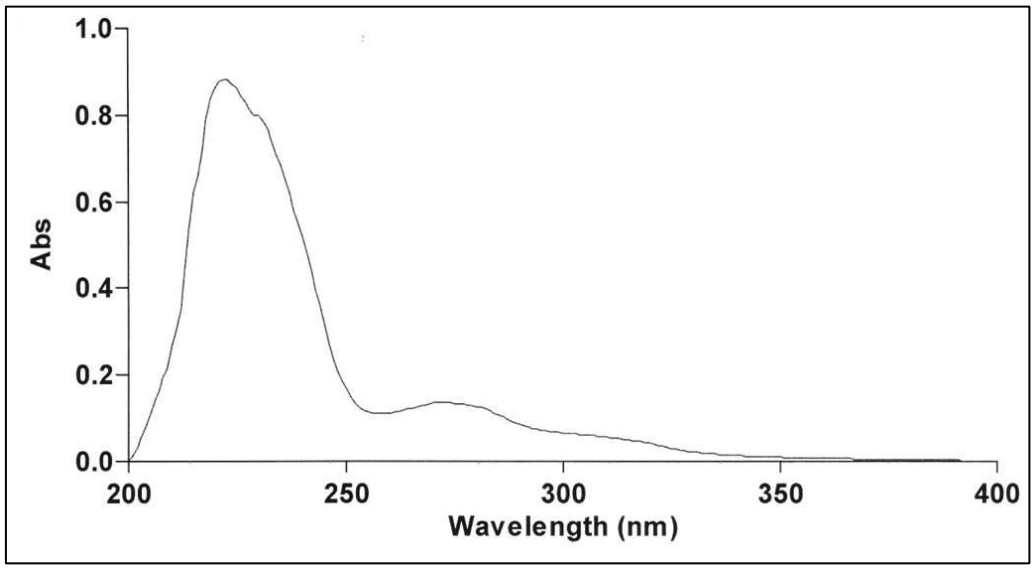


Figure 27 UV spectrum of compound DI3

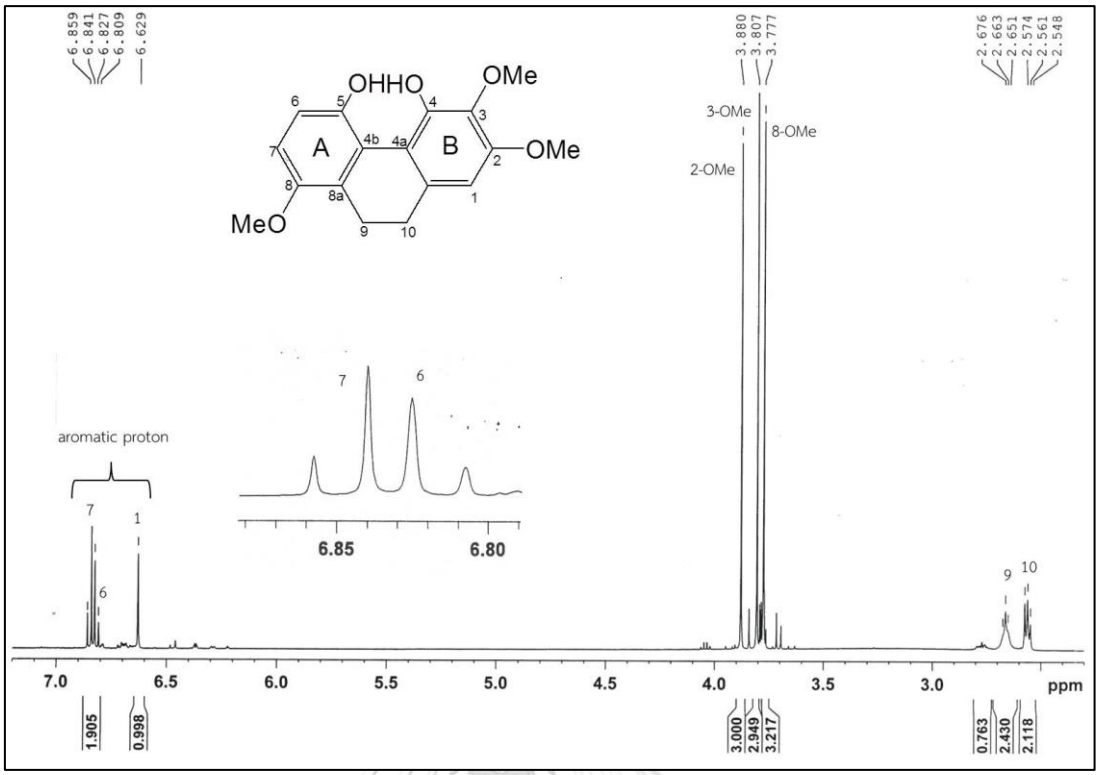


Figure 28 ^{1}H-NMR spectrum of compound DI3

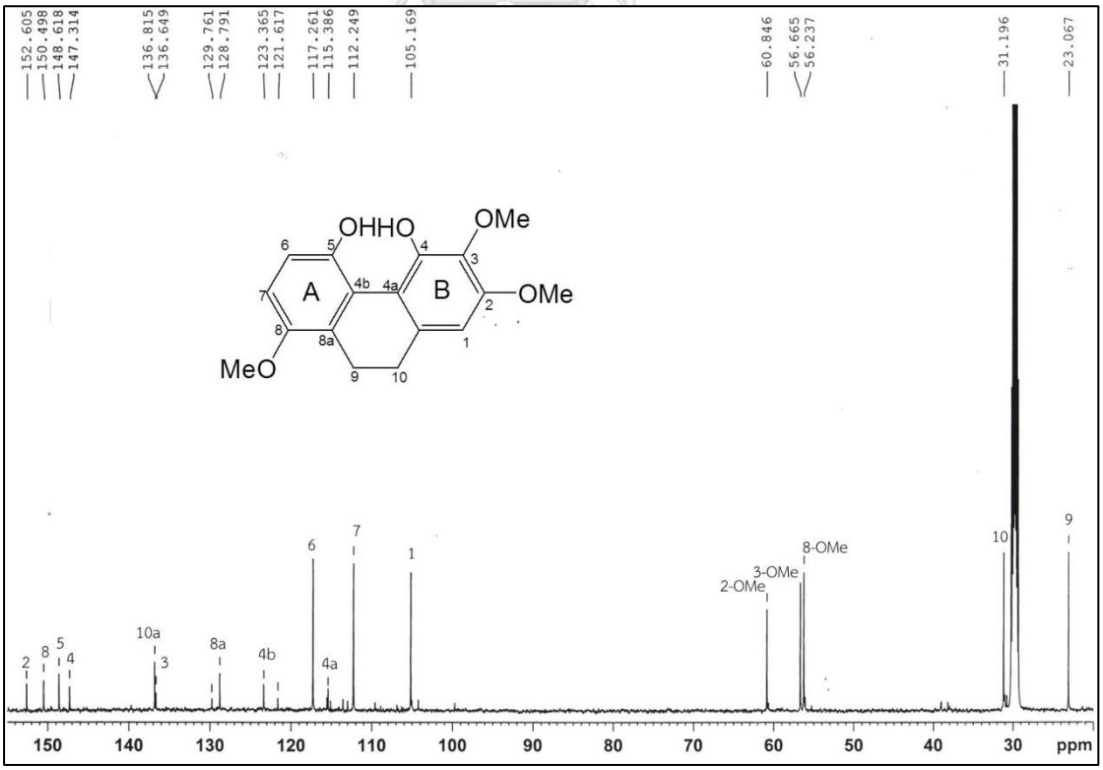


Figure 29 ^{13}C-NMR spectrum of compound DI3

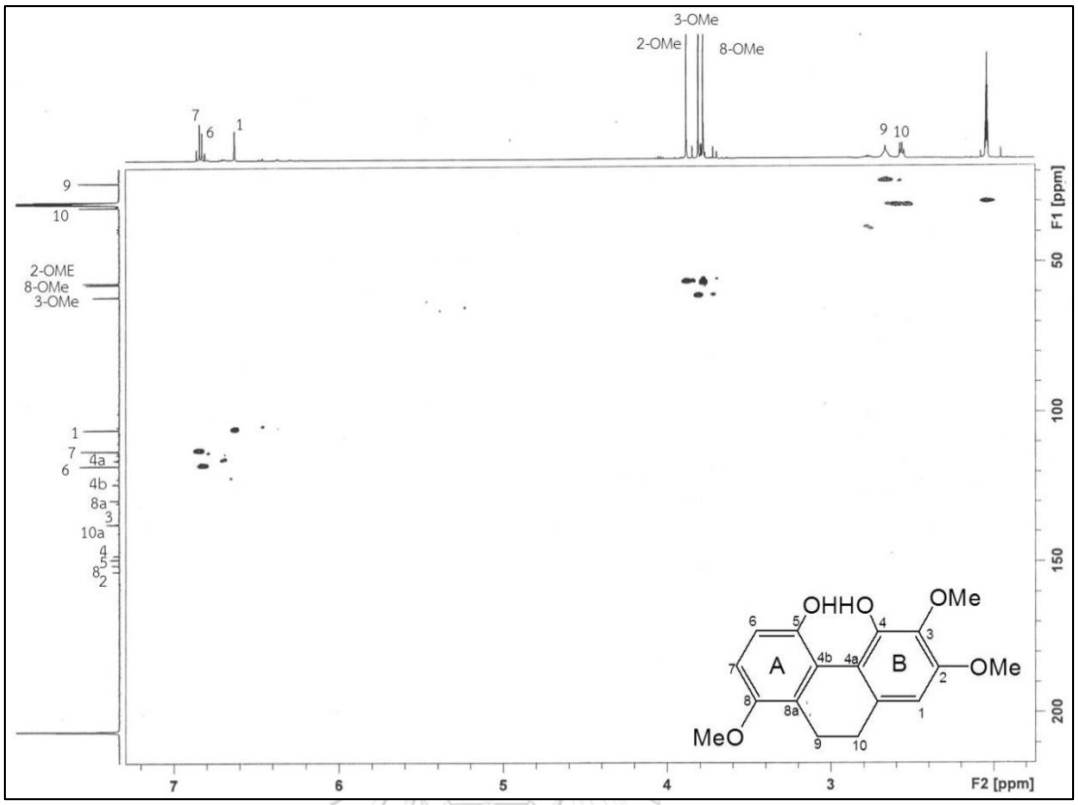


Figure 30 HSQC spectrum of compound DI3

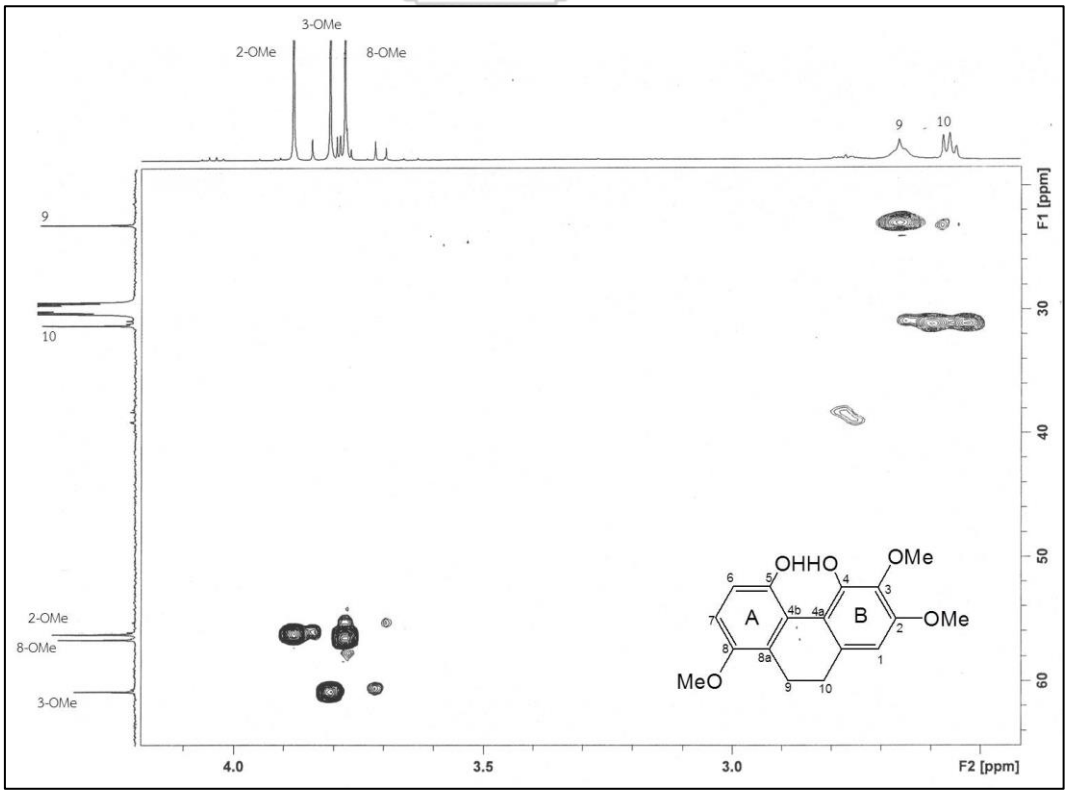


Figure 31 HSQC spectrum of compound DI3 (enlarge)

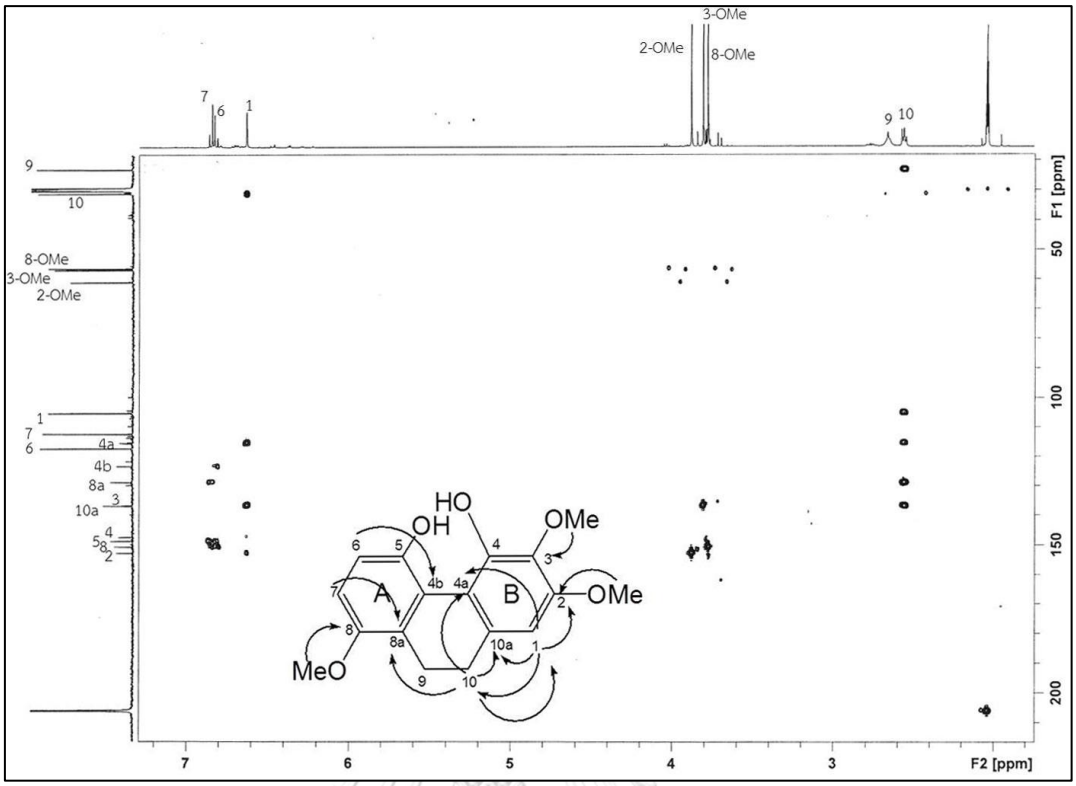


Figure 32 HMBC spectrum of compound DI3

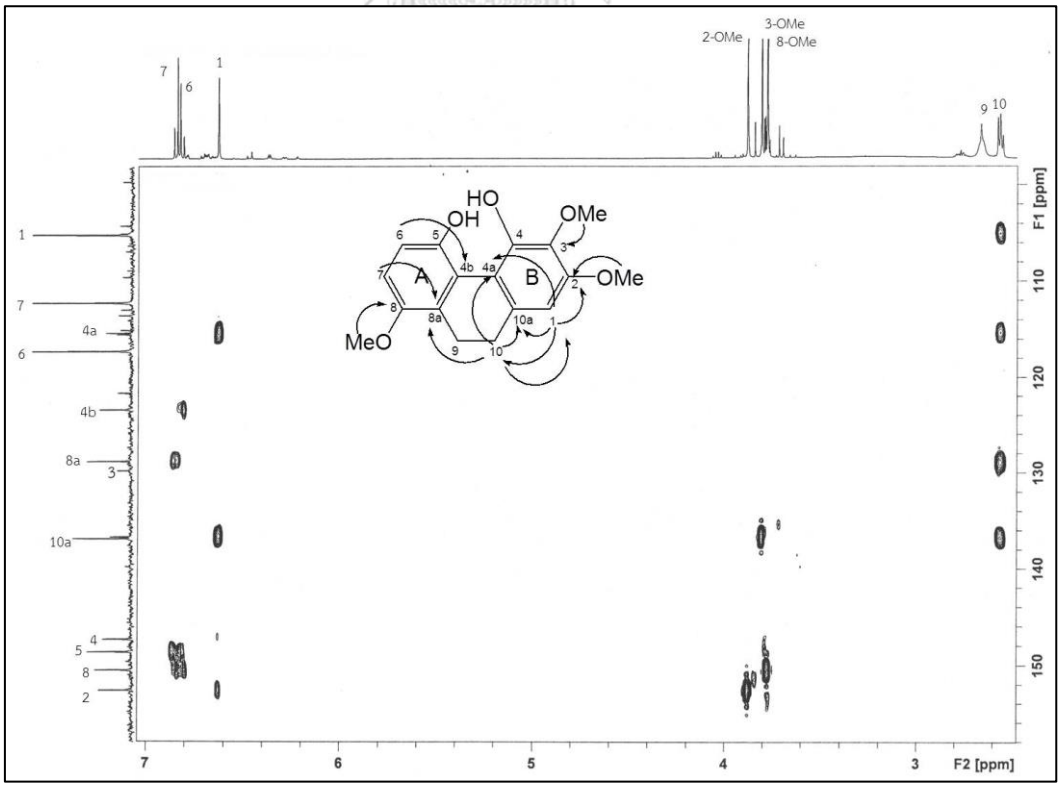


Figure 33 HMBC spectrum of compound DI3 (enlarge 1)

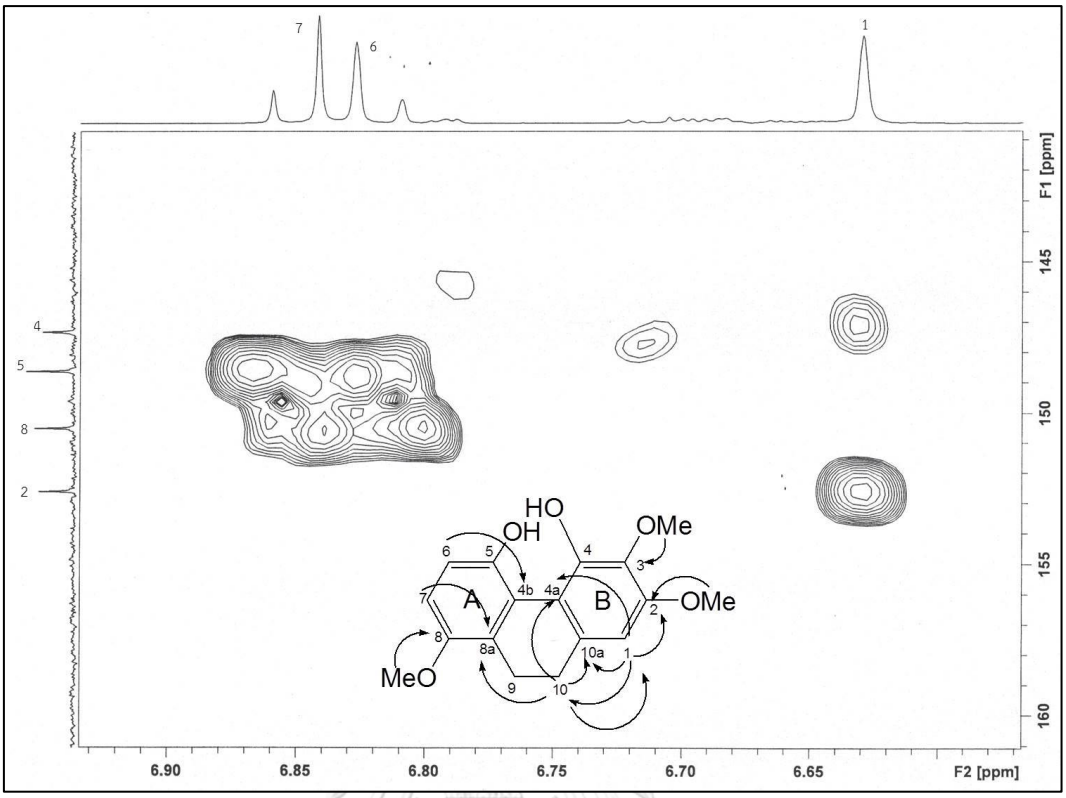


Figure 34 HMBC spectrum of compound DI3 (enlarge 2)

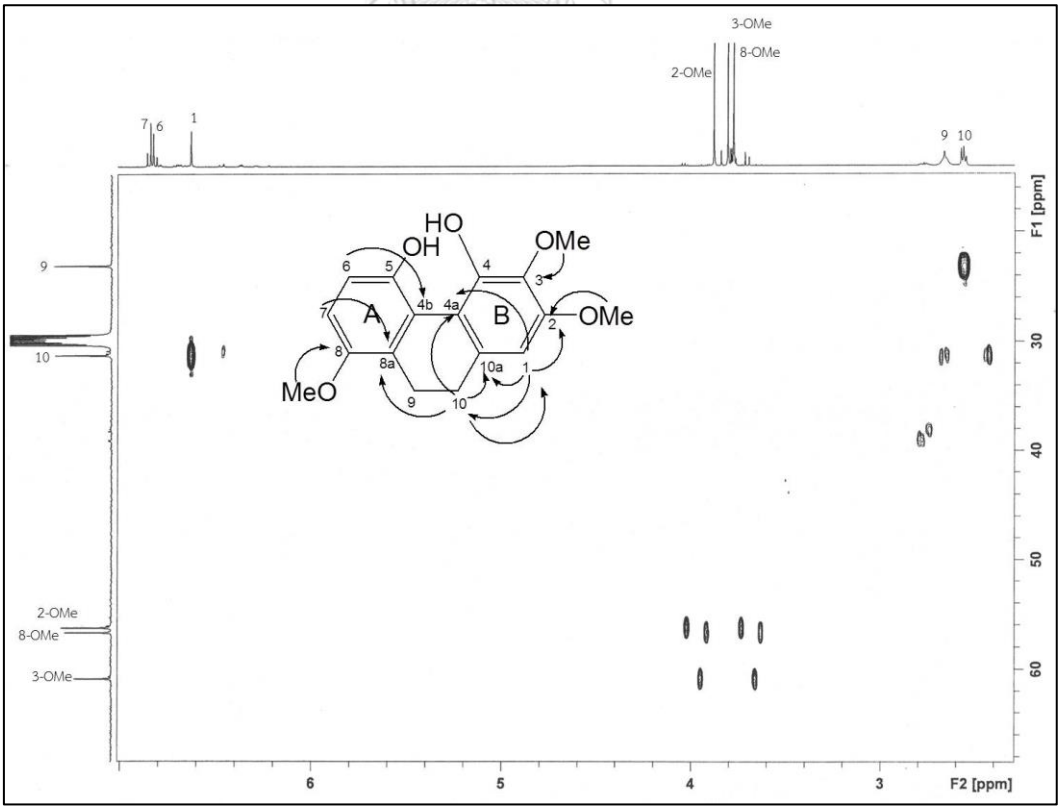


Figure 35 HMBC spectrum of compound DI3 (enlarge 3)

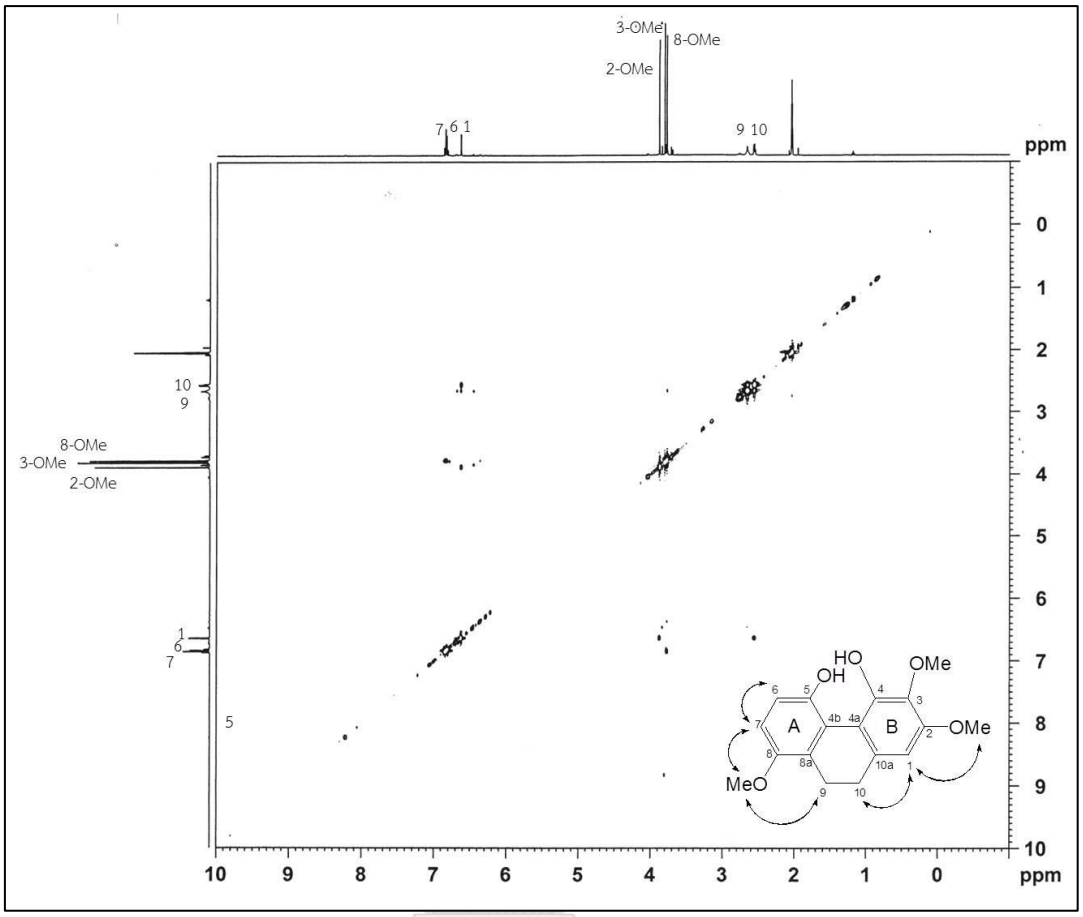


Figure 36 NOESY spectrum of compound DI3

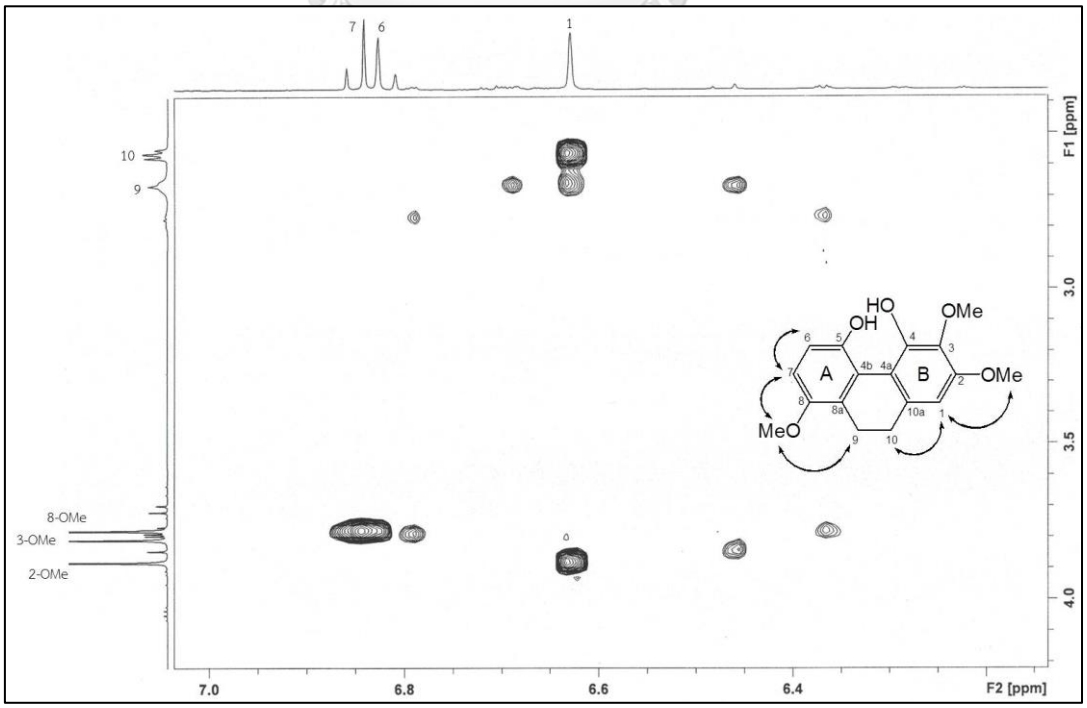


Figure 37 NOESY spectrum of compound DI3 (enlarge)

1.4 Structure determination of compound DI4

Compound DI4 was isolated as a orangish-brown amorphous solid. Its HR-ESI-MS (**Figure 38**) presented a sodium-adduct molecular ion $[M+Na]^+$ peak at *m/z* 327.1219, (calcd. for $C_{17}H_{20}O_5Na$; 327.1208), suggesting the molecular formula $C_{17}H_{20}O_5$.

The ^{1}H-NMR (**Figure 39**) and ^{13}C NMR spectrum (**Figure 40**) showed the aromatic, methoxy and methylene signals, suggested that compound DI4 was a bibenzyl.

The ^{1}H-NMR spectrum presented four aromatic signals at δ 6.38-6.86, three methoxy signals at δ 3.86 (9H, *s*) and a methylene signals at δ 2.84 (4H, *s*, H-α, H-α'). The symmetry of substitutes on ring A were showed by high intensity signal at δ 6.38 (2H, *s*, H-2, H-6) on ^{1}H NMR spectrum. This symmetry were also showed by high intensity signals at δ 146.9 (C-3 and C-5) and δ 105.23 (C-2 and C-6) on ^{13}C NMR spectrum. The splitting pattern of protons on ring B consisted of a doublets at δ 6.86 (1H, *J* = 8.1 Hz, H-5′), a double doublets at δ 6.71 (1H, *J* = 8.1, 1.2 Hz, H-6′) and a singlet at δ 6.64 (H-2′), indicated two different substitutes on ring B.

The HSQC spectrum (**Figure 41**) was used to find the correlations between protons and carbons with a single bond. It also revealed seven quaternary carbons, suggested five substitutions on bibenzyl nucleus.

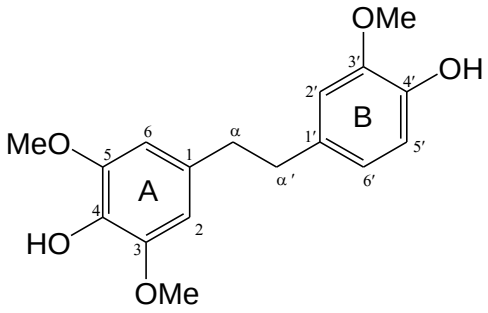
The positions of aromatic protons and methoxy groups were assigned by the correlations in HMBC spectrum (**Figure 42**). Regarding a symmetry of ring A, two methoxy groups should be located on the meta-substitution position of each other. The H-2 and H-6 were assigned based on the correlations to C-α (δ 38.5), C-3 (δ 146.9) and C-5 (δ 146.9).

On ring B, The H-5′ was assigned by the correlations to C-4′ (δ 143.8) and C-3′ (δ 146.3), respectively. The H-6′ was assigned by the correlations to C-2′ (δ 111.3), C-4′ (δ 143.8) and C-α' (δ 37.9). The H-2′ was assigned by the correlations to C-4′,

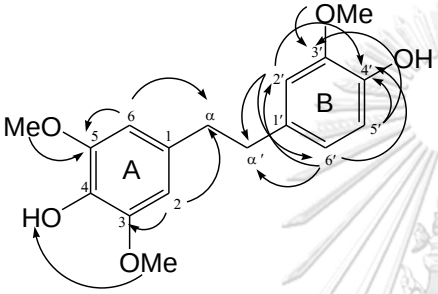
C-6′ (δ 121.1) and C-α'. Three methoxy proton signals revealed the correlations to C-3, C-5 and C-3′, respectively.

The NOESY spectrum (**Figures 43-44**) was used to confirm the positions of aromatic protons and methoxy groups. On ring A, the 3-OMe (5-OMe) substitution was confirmed by correlations of H-2 (H-6) and protons of 3-OMe (5-OMe). On ring B, the 3′-OMe substitution was confirmed by its correlations to H-2′.

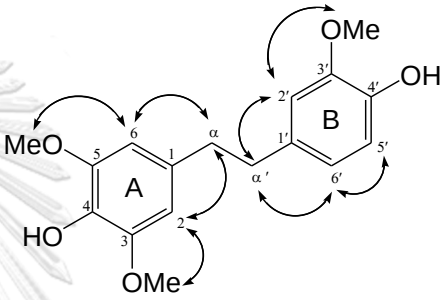
From the above data, and through comparison of its ^{1}H-NMR and ^{13}C-NMR spectra (**Table 9**) with the previously reported data (Majumder *et al.*, 1987), DI4 was identified as moscatilin [**59**]. This compound was first found in *Dendrobium moscatum* and then also found in many plants of *Dendrobium* species, for example, *D. capillipes* (Phechrmeekha *et al.*, 2012), *D. densiflorum* (Fan *et al.*, 2001), *D. loddigesii* (Chen *et al.*, 1994), and *D. secundum* (Sritularak *et al.*, 2011b). it showed many biological activities such as cytotoxic activity against cervical cancer cell (IC_{50} = 2.2 μM) (Phechrmeekha *et al.*, 2012), antiplatele aggregation (IC_{50} = 61.8 μM) (Chen *et al.*, 1994), anti-infalmmatory activity (IC_{50} = 10.2$\pm$0.2 μM) (Hwang *et al.*, 2010) and anioxidant activity (IC_{50} = 15.87$\pm$1.48 μM) (Sritularak *et al.*, 2011b).



Moscatilin [**56**]



HMBC correlations (C→H)



NOESY correlations (H↔H)

Table 9 NMR spectral data of compound DI4 (300 MHz, in acetone-d_6) and Moscatilin (100 MHz, in $CDCl_3$)

Position	Compound DI4		Moscatilin*	
	δ_H in ppm (mult., *J* in Hz)	**δ_C in ppm**	**δ_H in ppm (mult., *J* in Hz)**	**δ_C in ppm**
1	-	132. 9	-	132.8
2	6.38 (*br s*)	105.2	6.30 (*s*)	105.2
3	-	146.9	-	146.8
4	-	133.7	-	133.5
5	-	146.9	-	146.8
6	6.38 (*br s*)	105.2	6.30 (*s*)	105.2
α	2.84 (br s)	38.5	2.79 (s)	38.3
α′	2.84 (br s)	37.9	2.79 (s)	37.8
1′	-	132.9	-	132.8
2′	6.64 (*br s*)	111.3	6.60 (*d*, *J* = 2.0 Hz)	111.2
3′	-	146.3	-	146.1
4′	-	143.8	-	143.7
5′	6.86 (*d*, *J* = 8.1 Hz)	114.2	6.77 (*d*, *J* = 8.0 Hz)	114.1
6′	6.71 (*dd*, *J* = 8.1, 1.2 Hz)	121.1	6.74 (*dd*, *J* = 8.0, 2.0 Hz)	121.0
3-OMe	3.86 (s)	56.3	3.81 (s)	56.2
5-OMe	3.86 (s)	56.3	3.81(s)	56.2
3′-OMe	3.86 (s)	55.9	3.81(s)	55.8

*Majumder *et al.*, 1987

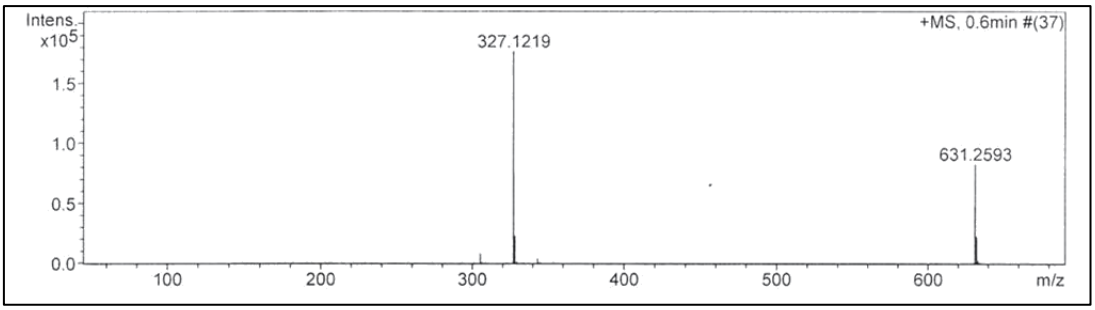


Figure 38 Mass spectrum of compound DI4

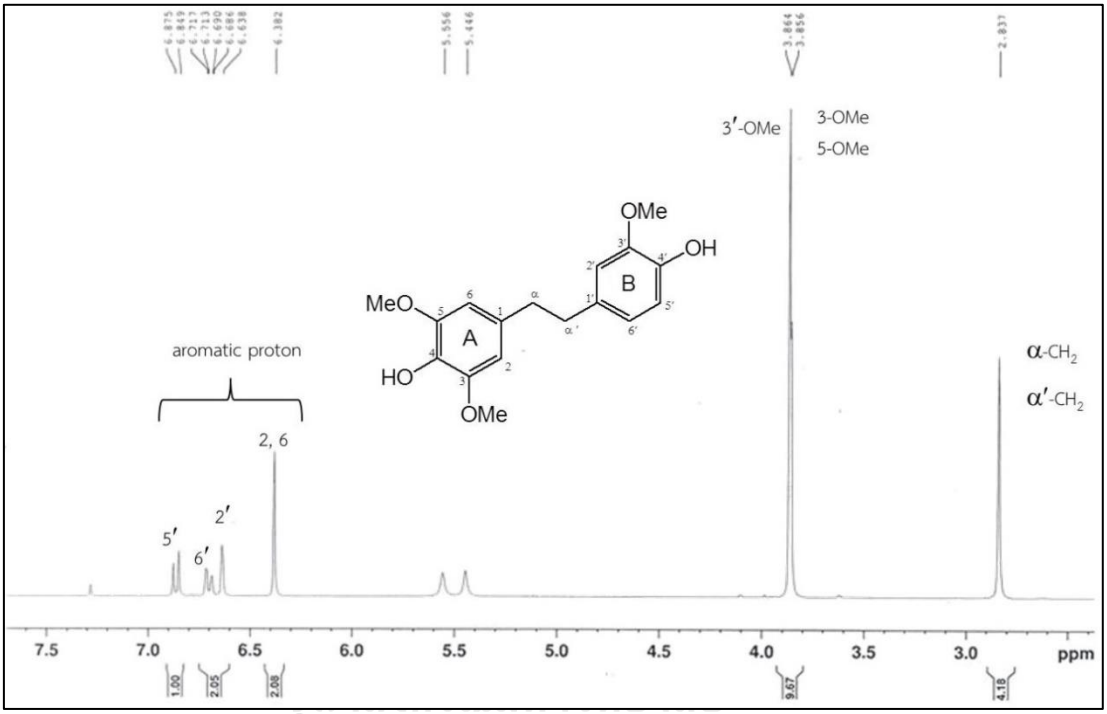


Figure 39 ^{1}H-NMR spectrum of compound DI4

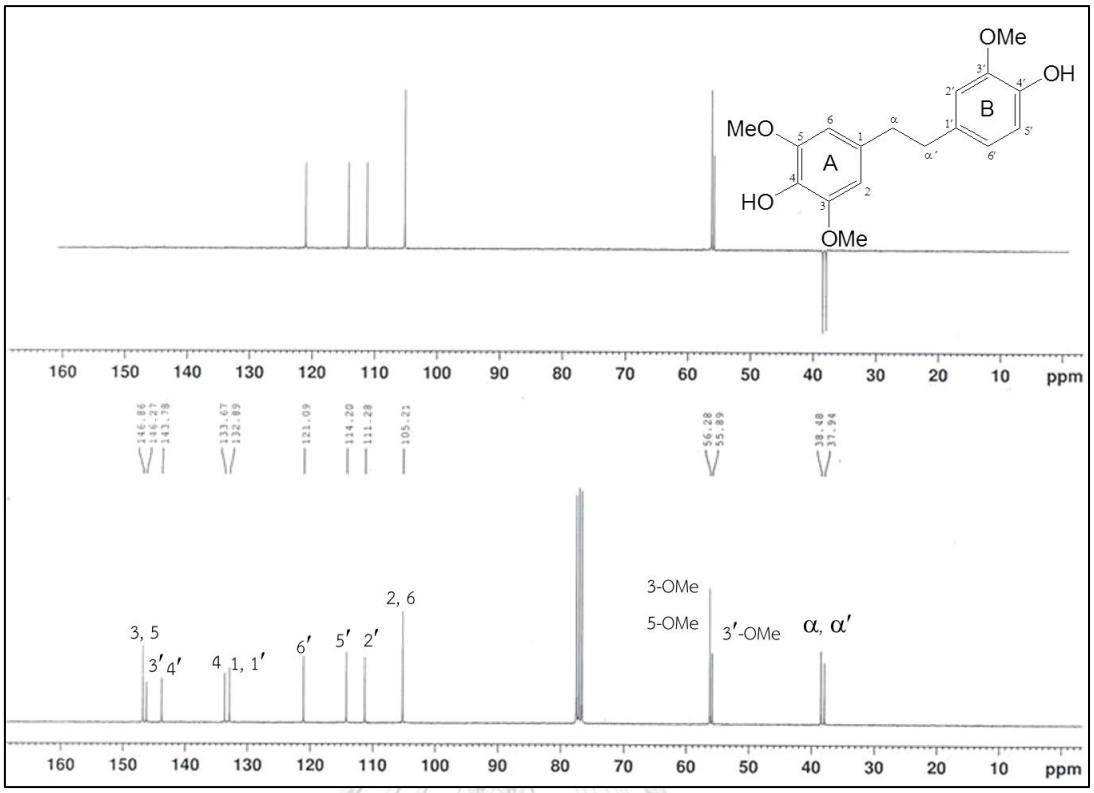


Figure 40 ^{13}C-NMR spectrum of compound DI4

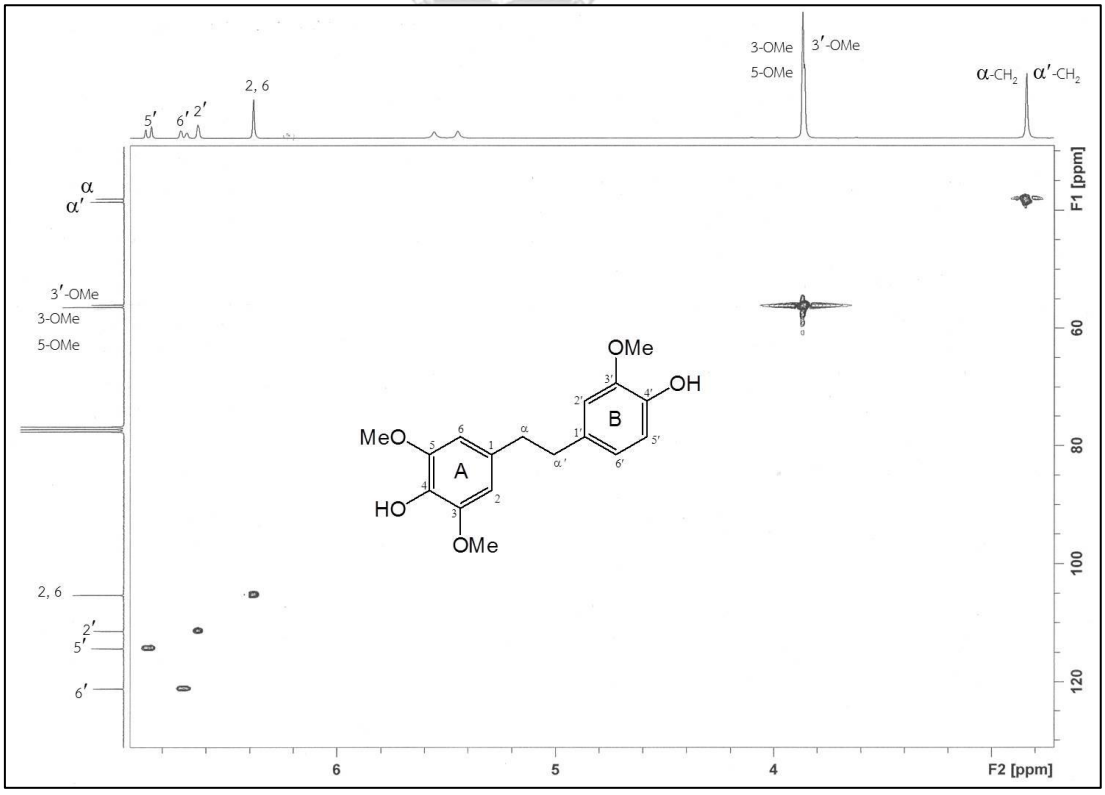


Figure 41 HSQC spectrum of compound DI4

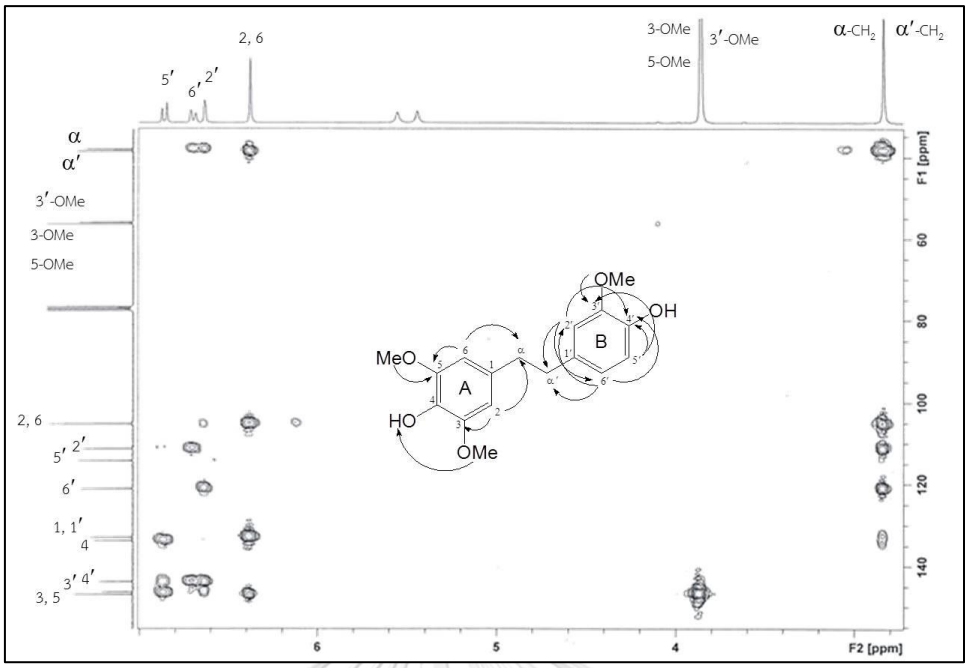


Figure 42 HMBC spectrum of compound DI4

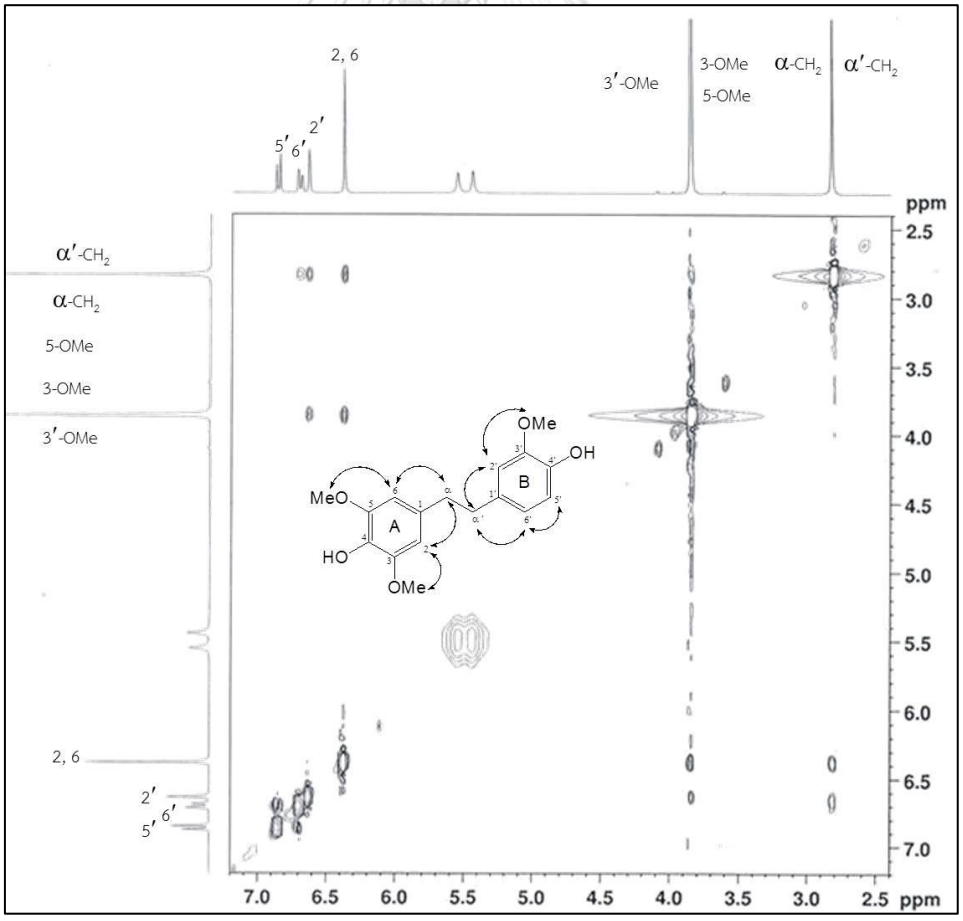


Figure 43 NOESY spectrum of compound DI4

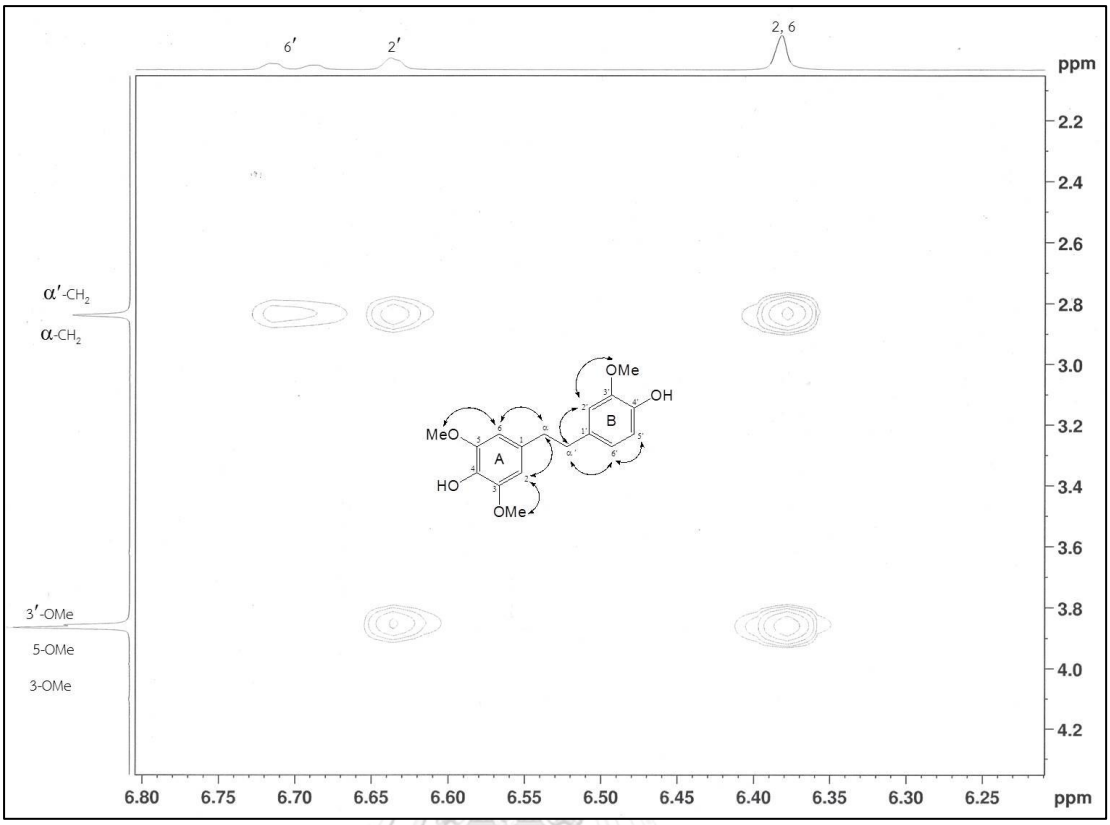


Figure 44 NOESY spectrum of compound DI4 (enlarge)

1.5 Structure determination of compound DI5

Compound DI5 was isolated as a reddish-brown amorphous solid. Its HR-ESI-MS (**Figure 45**) presented a sodium-adduct molecular ion $[M+Na]^+$ peak at *m/z* 297.1107, (calcd. for $C_{16}H_{18}O_4Na$; 297.1103), suggesting the molecular formula $C_{16}H_{18}O_4$. It showed a carbon atom, two hydrogen atoms and an oxygen atom less than compound DI4 implied the disappearence of a methoxy group.

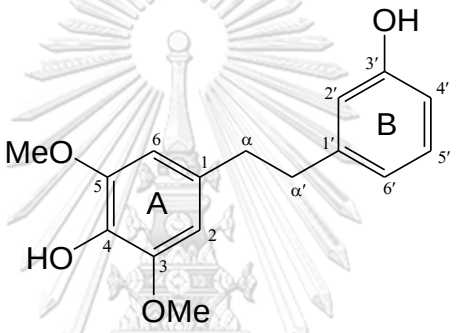
Its ^{1}H NMR (**Figure 46**) and ^{13}C NMR (**Figure 47**) spectrum were similar to compound DI4. There were two different points between proton and carbon signals of compounds DI4 and DI5. The first one was the disappearance of a methoxy signal in both ^{1}H NMR and ^{13}C NMR spectrum. The second one was the addition of a proton signal of ring B at δ 6.63 (H-4′, *dd*, *J* = 8.1, 2.1 Hz).

The symmetry of substitutes on ring A were showed by high intensity signal at δ 6.48 (2H, *s*, H-2, H-6) on ^{1}H NMR spectrum. This symmetry were also showed by double peaks at δ 148.5 (C-3 and C-5) and δ 106.9 (C-2 and C-6) on ^{13}C NMR spectrum. The splitting pattern of protons on ring B consisted of a triplets at δ 7.07 (1H, *J* = 8.1 Hz, H-5′), a double doublets at δ 6.63 (*J* = 8.1, 2.1 Hz, H-4′) and two broad doublets at δ 6.68 (*J* = 2.1 Hz, H-2′) and 6.66 (*J* = 8.1 Hz, H-6′), suggested a hydroxy substitution at C-3′

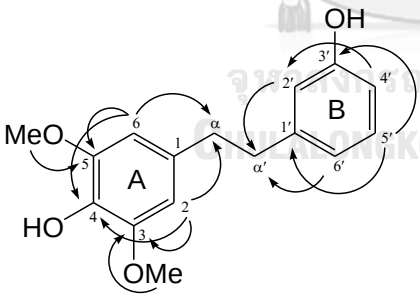
The HSQC spectrums were used to assign a linkage of proton to carbon (**Figure 48**). The positions of aromatic protons and methoxy groups were assigned by the correlations in HMBC spectrum (**Figure 49**). The equivalent protons on ring A, H-2 and H-6, were assigned based on the correlations to C-α (δ 38.6), C-3 (C-5) and C-4 (δ 135.1). On ring B, The H-5′ was assigned by the correlations to C-1′ (δ 144.4) and C-3′ (δ 158.2). The H-4′ was assigned by the correlations to C-2′ (δ 120.5). Two methoxy proton signals (δ 3.76, *s*, 6H) revealed the correlations to C-3 and C-5.

The positions of aromatic protons and methoxy groups were comfirmed by NOESY spectrum (**Figures 50-51**). On ring A, the 3-OMe (5-OMe) substitution was confirmed by their correlations of H-2 (H-6).

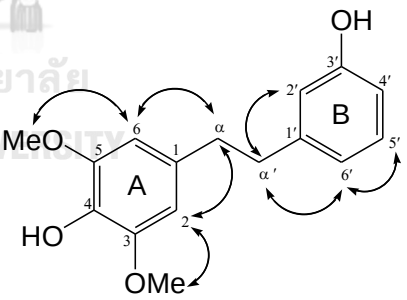
From the above data, and through comparison of its ^{1}H-NMR and ^{13}C-NMR spectra (**Table 10**) with the previously reported data (Juneja *et al.*, 1987) DI5 was identified as aloifol I [**1**], which were firstly found in *Cymbidium aloifolium*. This compound was also found in other plants in the family Orchidaceae e.g. *Liparis regnieri (*Ren *et al., 2016)*, *Bulbophyllum emarginatum* (Zhao *et al.*, 2015), *B. protractum* (Majumder *et al.*, 1997), *Dendrobium sinense* (Chen *et al.*, 2014), *D. moniliforme* (Ye *et al.*, 2016) and *D. williamsonii* (Yang *et al.*, 2018). It showed cytotoxic activity againt gastric cancer cells (SCG-7901) with an IC_{50} of 12.8±0.6 μM (Chen *et al.*, 2014).



Aloifol I [**1**]



HMBC correlations (C⟶H)



NOESY correlations (H⟷H)

Table 10 NMR spectral data of compound DI5 (300 MHz, in acetone-d_6) and aloifol I (400 MHz, in $CDCl_3$)

Position	Compound DI5		Aloifol I*	
	δ_H in ppm (mult., *J* in Hz)	**δ_C in ppm**	**δ_H in ppm (mult., *J* in Hz)**	**δ_C in ppm**
1	-	133.1	-	132.8
2	6.48 (*s*)	106.9	6.27 (*s*)	105.4
3	-	148.5	-	146.8
4	-	135.1	-	132.9
5	-	148.5	-	146.8
6	6.48 (*s*)	106.9	6.27 (*s*)	105.4
α	2.79 (*s*)	38.6	2.75 (*s*)	36.7
α′	2.79 (*s*)	38.8	2.75 (*s*)	37.7
1′	-	144.4	-	143.3
2′	6.68 (*br d*, *J* = 2.1 Hz)	120.5	6.62 (*dd*, *J* = 9.0, 2.5 Hz)	120.5
3′	-	158.2	-	155.9
4′	6.63 (*dd*, *J* = 8.1, 2.1 Hz)	113.5	6.62 (*dd*, *J* = 9.0, 2.5 Hz)	112.9
5′	7.07 (*t*, *J* = 8.1 Hz)	130.0	7.03 (*t*)	129.2
6′	6.66 (*br d*, *J* = 8.1 Hz)	116.3	6.62 (*dd*, *J* = 9.0, 2.5 Hz)	115.2
3-OMe	3.76 (*s*)	56.6	3.72 (*s*)	56.2
5-OMe	3.76 (*s*)	56.6	3.72 (*s*)	56.2

*Juneja *et al.*, 1987

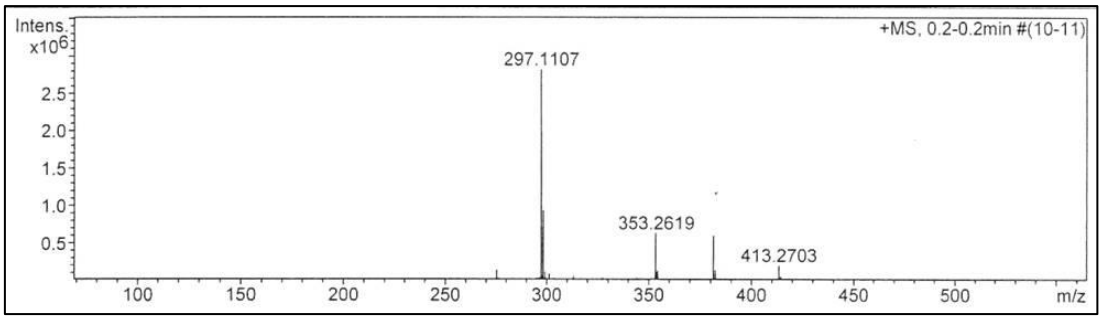


Figure 45 Mass spectrum of compound DI5

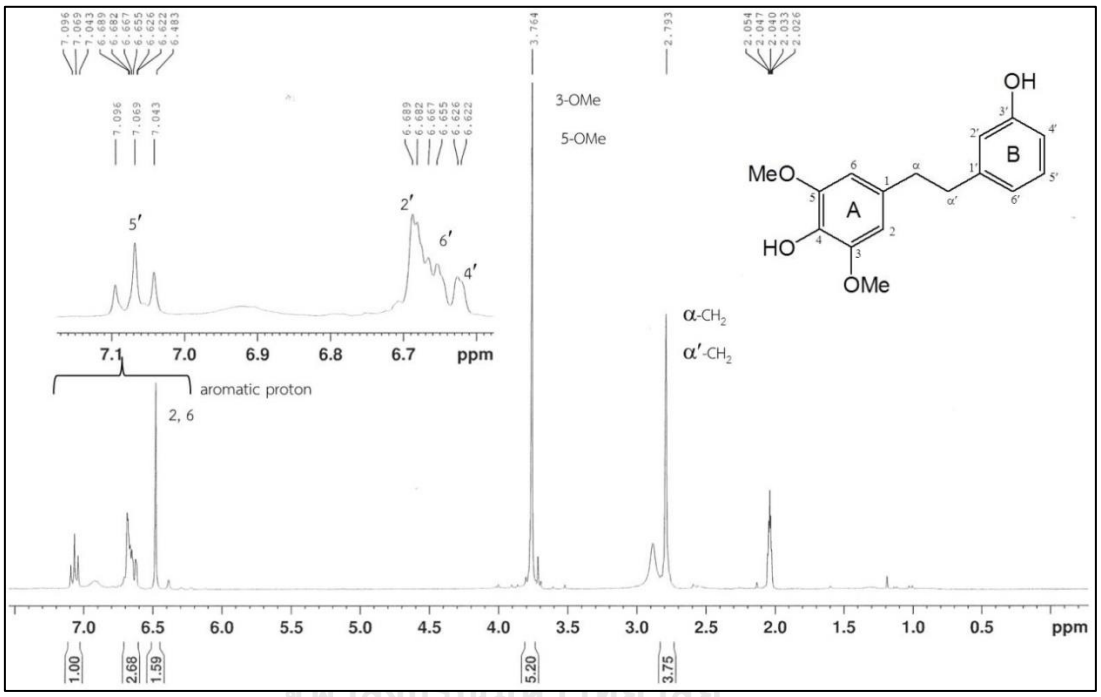


Figure 46 ^{1}H-NMR spectrum of compound DI5

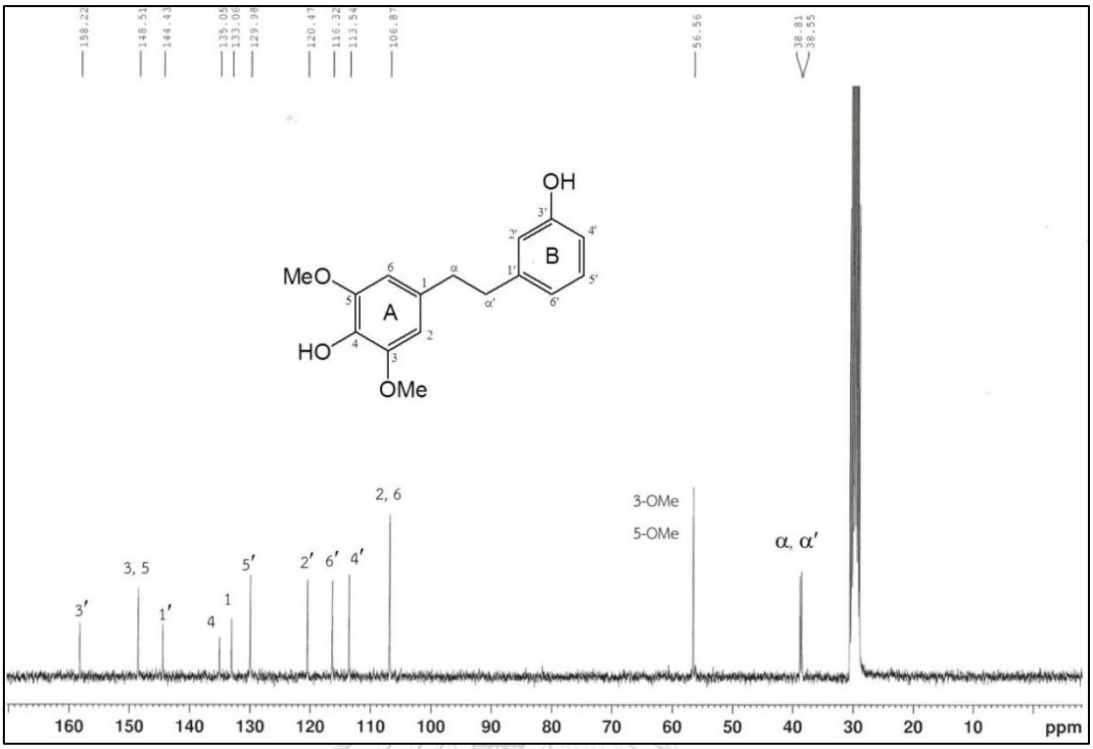


Figure 47 ^{13}C-NMR spectrum of compound DI5

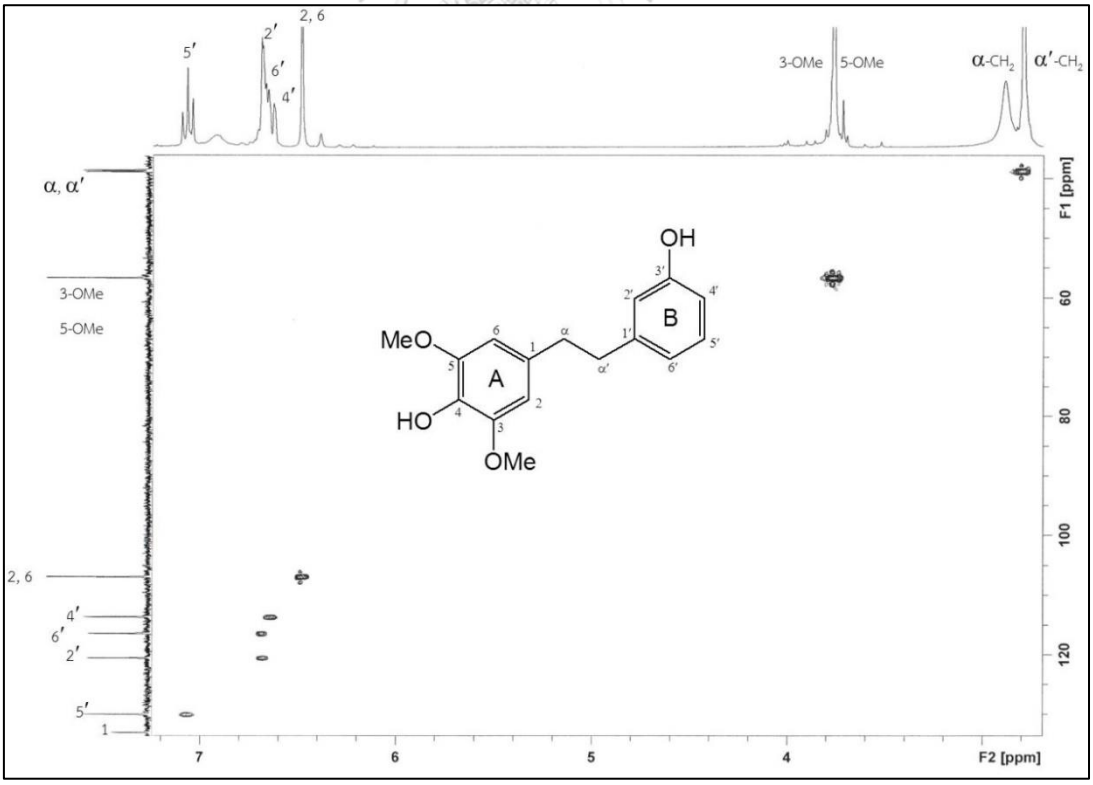


Figure 48 HSQC spectrum of compound DI5

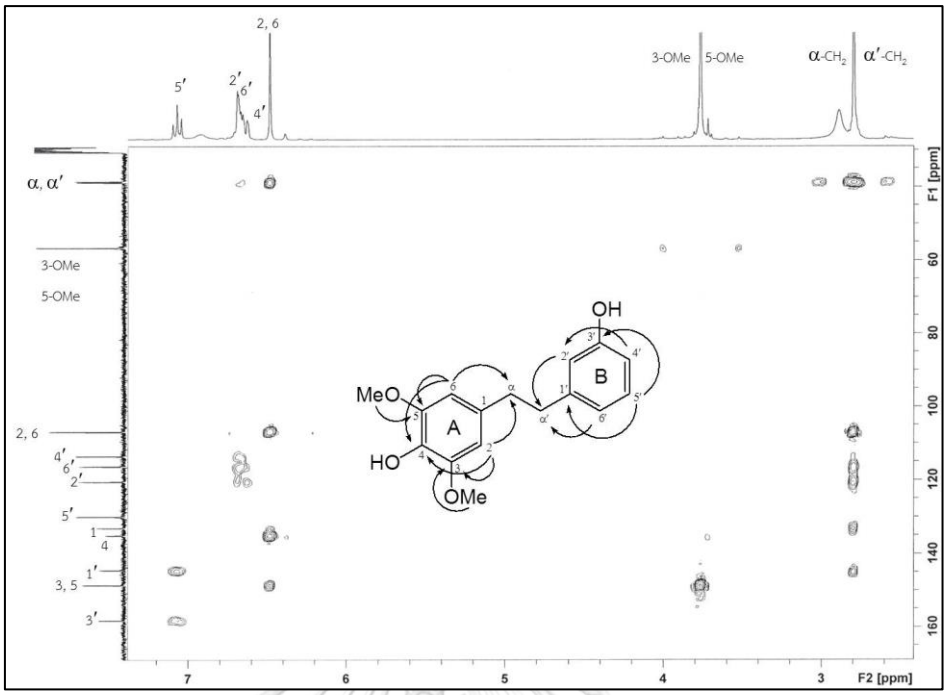


Figure 49 HMBC spectrum of compound DI5

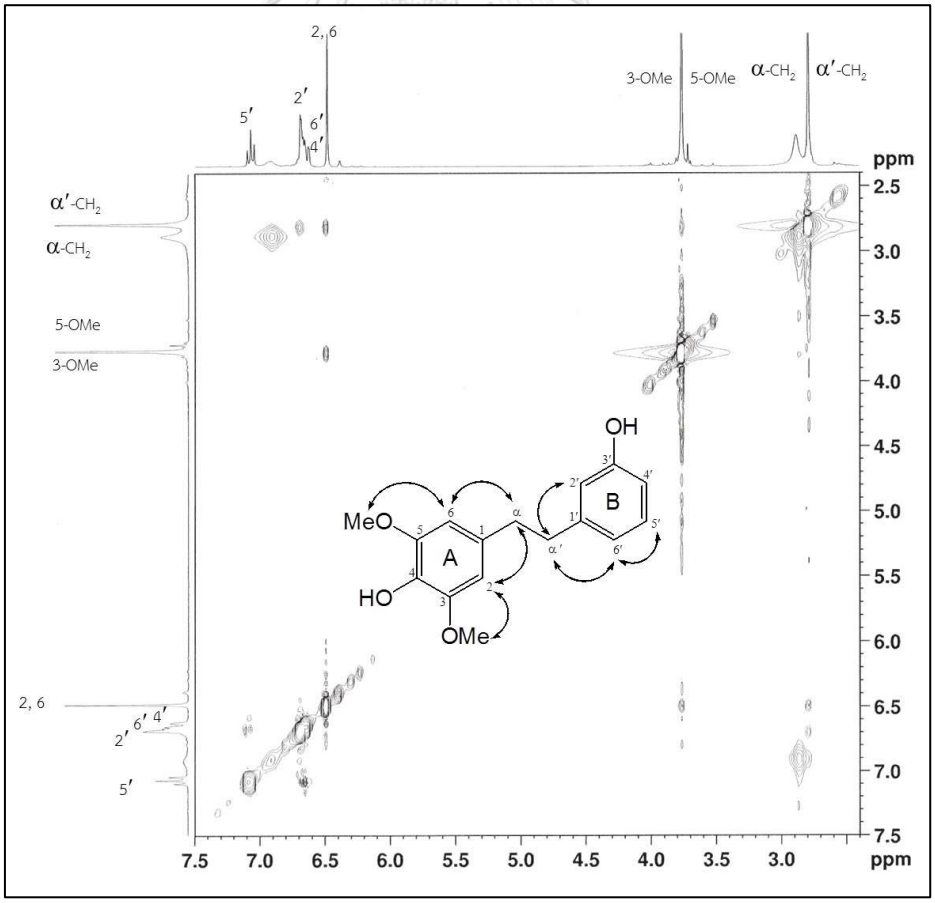


Figure 50 NOESY spectrum of compound DI5

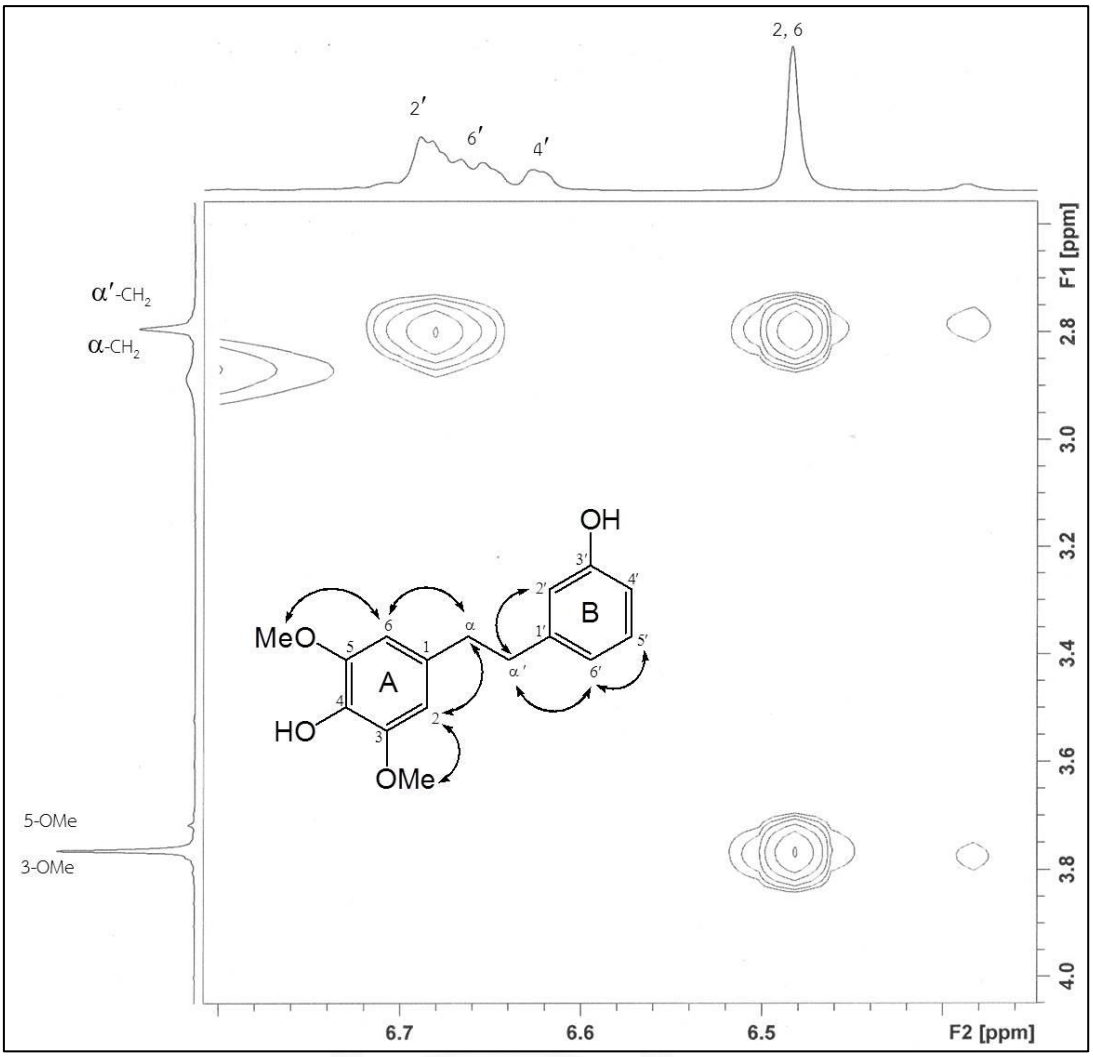


Figure 51 NOESY spectrum of compound DI5 (enlarge)

1.6 Structure determination of compound DI6

Compound DI6 was isolated as a brown amorphous solid. Its HR-ESI-MS (**Figure 52**) presented a sodium-adduct molecular ion $[M+Na]^+$ peak at *m/z* 267.1051, (calcd. for $C_{15}H_{16}O_3Na$; 267.0997), suggesting the molecular formula $C_{15}H_{16}O_3$.

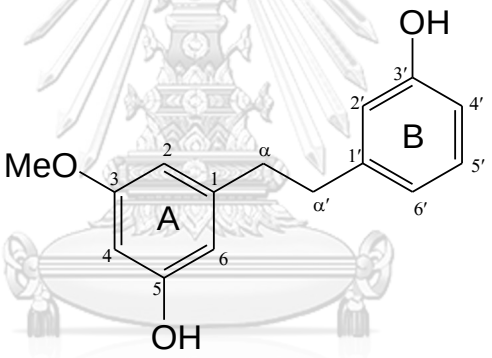
The ^{1}H NMR spectrum (**Figure 53**) showed seven aromatic signals. The ^{1}H NMR of four aromatic signals of ring B were similar to compound DI5, which were aromatic protons of ring B. The splitting pattern of those protons consisted of a triplets at δ 7.08 (1H, *J* = 7.8 Hz, H-5′), a double doublets at δ 6.66 (*J* = 7.8, 1.8 Hz, H-4′) and two broad doublets at δ 6.73 (*J* = 1.8 Hz, H-2′) and 6.70 (*J* = 7.8 Hz, H-6′), implied a hydroxy substitution on ring B at C-3′. The other aromatic proton signals of on ring A were three meta-coupled protons resonated at δ 6.26 (*t*, *J* = 2.1 Hz, H-4), 6.31 (*br s*, H-2) and 6.35 (*br s*, H-6), indicated two different meta-substitution on this ring.

The number of signals in the ^{13}C-NMR spectrum (**Figure 54**) corresponded to the number of carbon atoms in the molecular formula. The protons were assigned to the carbon atoms by the HSQC spectrum (**Figure 55**). It also revealed five quaternary carbons, affirmed number of substitutions.

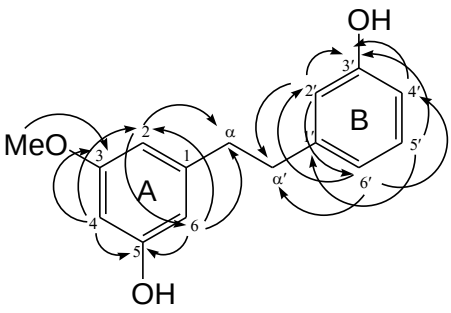
The aromatic protons and methoxy groups were assigned the positions by the correlations in HMBC spectrum (**Figures 56-58**). On ring A, the H-6 was assigned based on the correlations to C-2 (δ 106.2), C-5 (δ 159.1) and C-α (δ 38.4). The H-2 was assigned based on the correlation to C-6 (δ 108.7) and C-α. The H-4 was assigned based on the correlations to C-2, C-3 (δ 161.7) and C-5. On ring B, The H-5′ was assigned by the correlations to C-1′ (δ 144.2) and C-3′ (δ 158.0). The H-2′ was assigned by the correlations to C-6′ (δ 120.3), C-3′ and C-α′ (δ 38.1). The H-6′ was assigned by the correlations to C-2′, C-4′ (δ 113.5) and C-α′. The H-4′ was assigned by the correlations to C-3′. Two methoxy proton signals (δ 3.69, *s*, 6H) revealed the correlations to C-3 and C-5.

The positions of aromatic protons and methoxy groups were comfirmed by NOESY spectrum (**Figure 59**). On ring A, the 3-OMe substitution was confirmed by its correlations of H-2 and H-4.

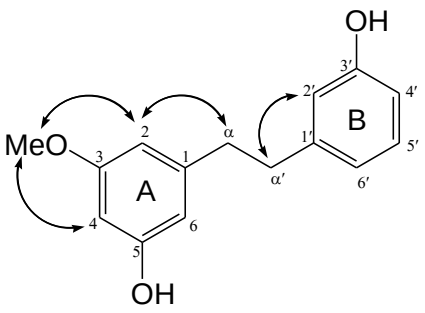
All of the spectral data were identical with those (**Table 11**) of batatasin III [**8**], a compound previously reported in *Sunipia scariosa* (Yang *et al.*, 2014a). This compound was also found in many plants in Orchidaceae such as *Coelogyne ovalis* (Sachdev *et al.*, 1986), *Cirrhopetalum andersonii* (Majumder *et al.*, 1991), *Bulbophyllum reptans* (Majumder *et al.*, 1999b), and *Dendrobium gratiosissimum* (Zhang *et al.*, 2008a). Its interesting biological activities are broad-spectrum antifungal activitiy (Zhou *et al.*, 2016) and cytotoxic activity by inhibiting cell proliferation, migration and invasion though suppressing EMT and FAK/AKT/CDC42 pathway of lung cancer cell (H460) (Pinkhien *et al.*, 2017).



Batatasin III [**8**]



HMBC correlations (C⟶H)



NOESY correlations (H⟷H)

Table 11 NMR spectral data of compound DI6 (300 MHz, in acetone-d_6) and Batatasin III (500 MHz, in $CDOD_3$)

Position	Compound DI6		Batatasin III*	
	δ_H in ppm (mult., *J* in Hz)	**δ_C in ppm**	**δ_H in ppm (mult., *J* in Hz)**	**δ_C in ppm**
1	-	145.0	-	144.1
2	6.31 (*br s*)	106.2	6.24 (*dd*, *J* = 2.0, 2.2 Hz)	107.6
3	-	161.7	-	158.0
4	6.26 (*t*, *J* = 2.1 Hz)	99.7	6.20 (*dd*, *J* = 2.0, 2.2 Hz)	98.5
5	-	159.1	-	160.8
6	6.35 (*br s*)	108.7	6.24 (*dd*, *J* = 2.0, 2.2 Hz)	105.6
α	2.79 (*m*)	38.4	2.79 (*m*)	37.5
α′	2.79 (*m*)	38.1	2.79 (*m*)	37.8
1′	-	144.2	-	143.3
2′	6.73 (*br d*, *J* = 1.8 Hz)	116.1	6.63 (*m*)	115.0
3′	-	158.0	-	156.9
4′	6.66 (*dd*, *J* = 7.8, 1.8 Hz)	113.5	6.63 (*m*)	112.4
5′	7.08 (*t*, *J* = 7.8 Hz)	130.0	7.08 (*dd*, *J* = 7.5, 8.0 Hz)	128.9
6′	6.70 (*br d*, *J* = 7.8 Hz)	120.3	6.63 (*m*)	119.5
3-OMe	3.69 (*s*)	55.2	3.70 (*s*)	54.1

*Yang *et al.*, 2014b

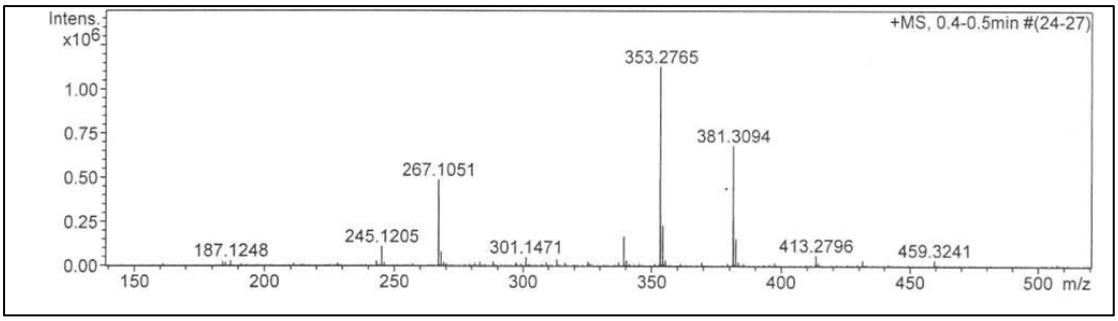


Figure 52 Mass spectrum of compound DI6

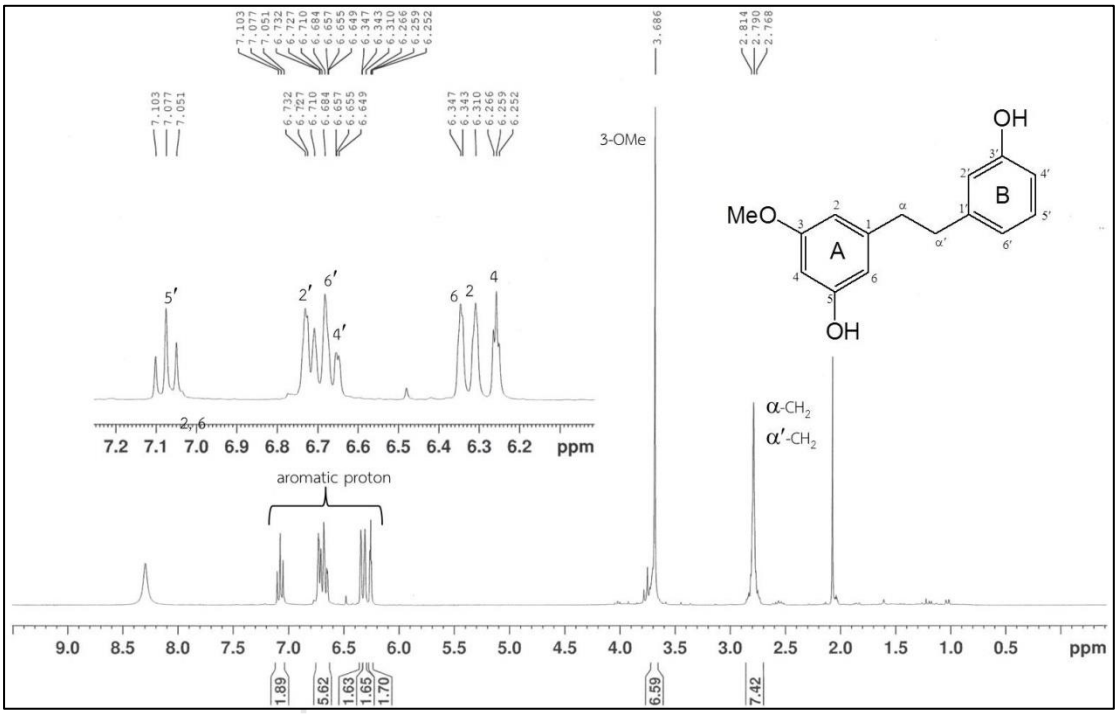


Figure 53 ^{1}H-NMR spectrum of compound DI6

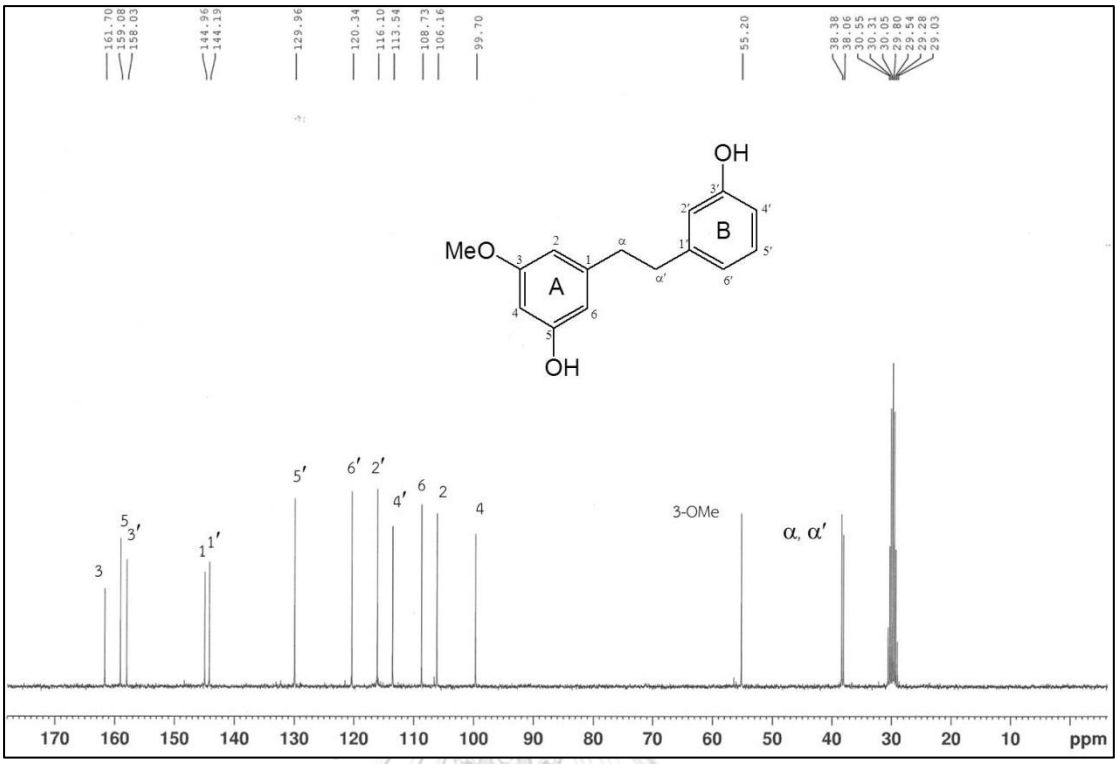


Figure 54 ^{13}C-NMR spectrum of compound DI6

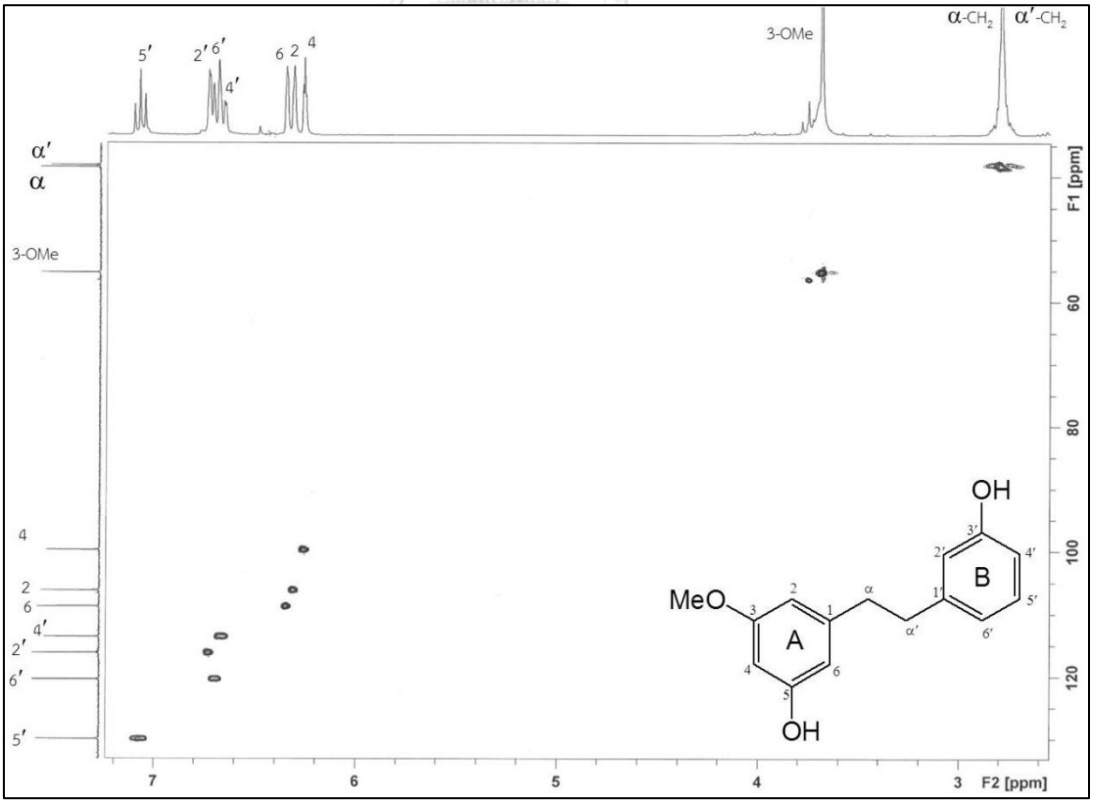


Figure 55 HSQC spectrum of compound DI6

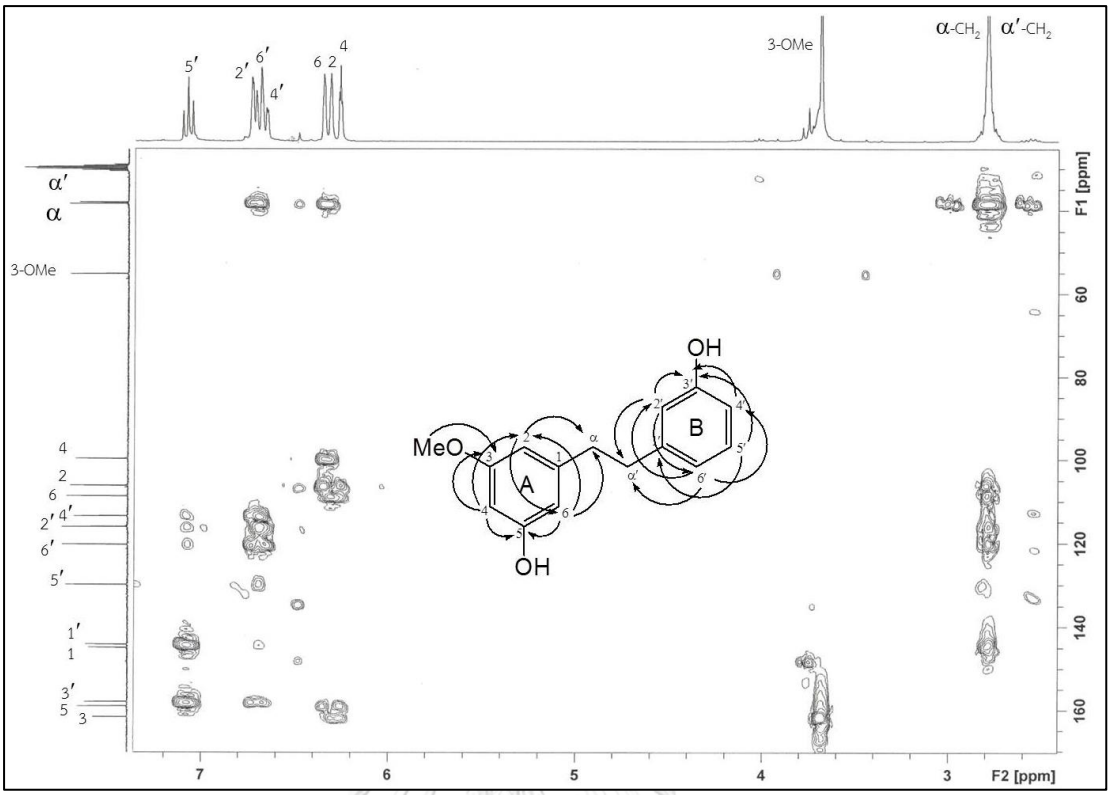


Figure 56 HMBC spectrum of compound DI6

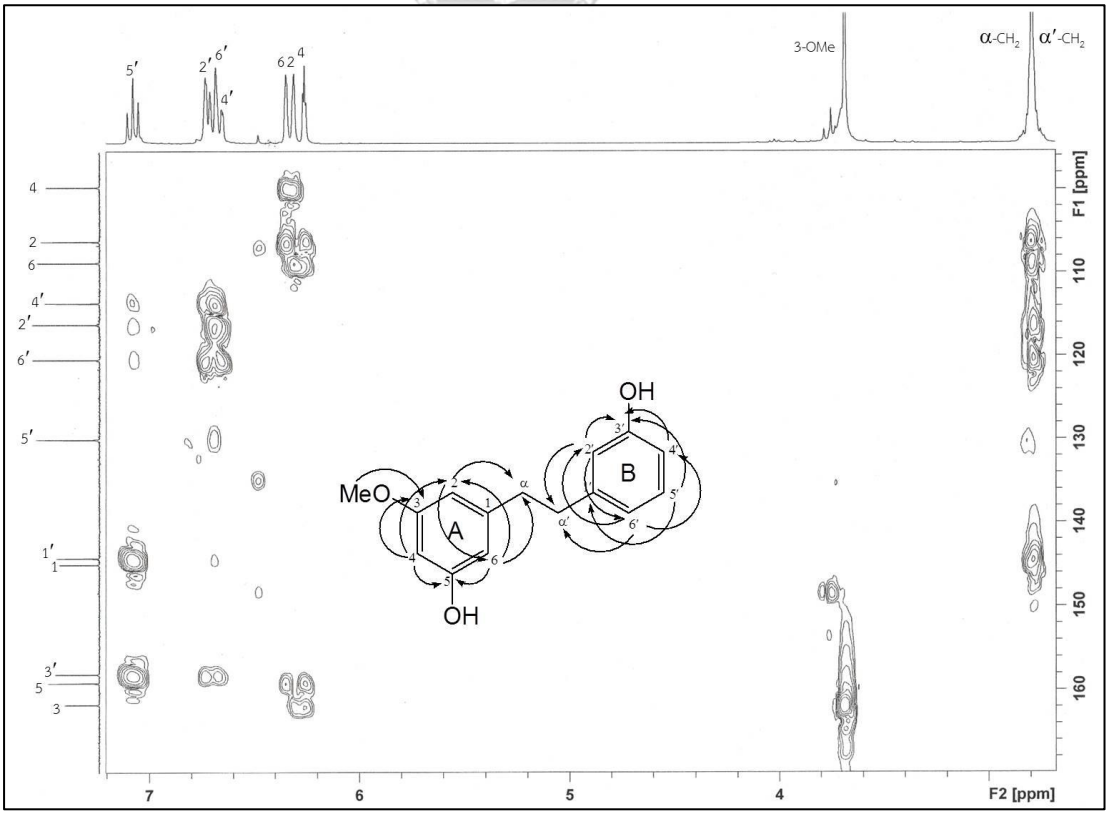


Figure 57 HMBC spectrum of compound DI6 (enlarge 1)

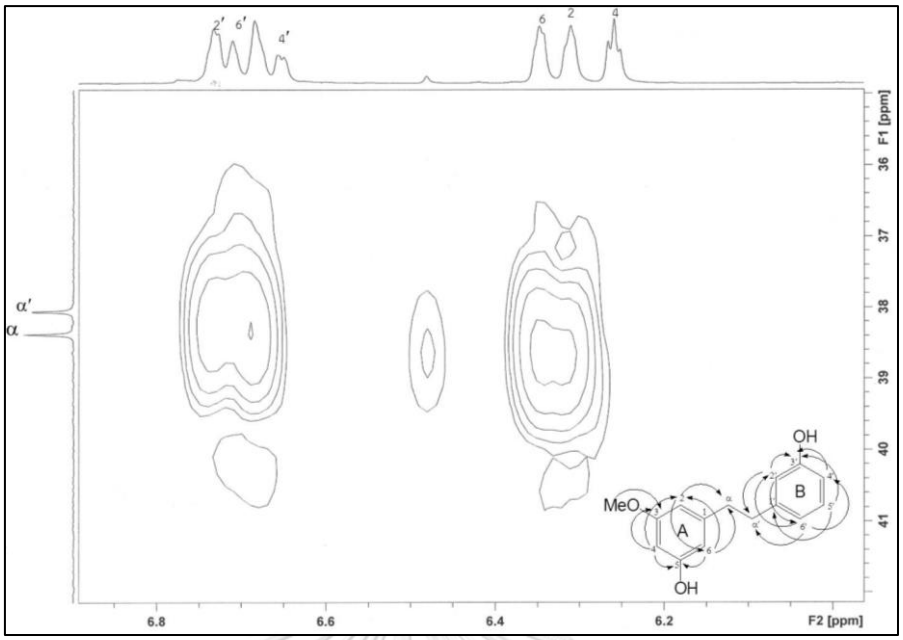


Figure 58 HMBC spectrum of compound DI6 (enlarge 2)

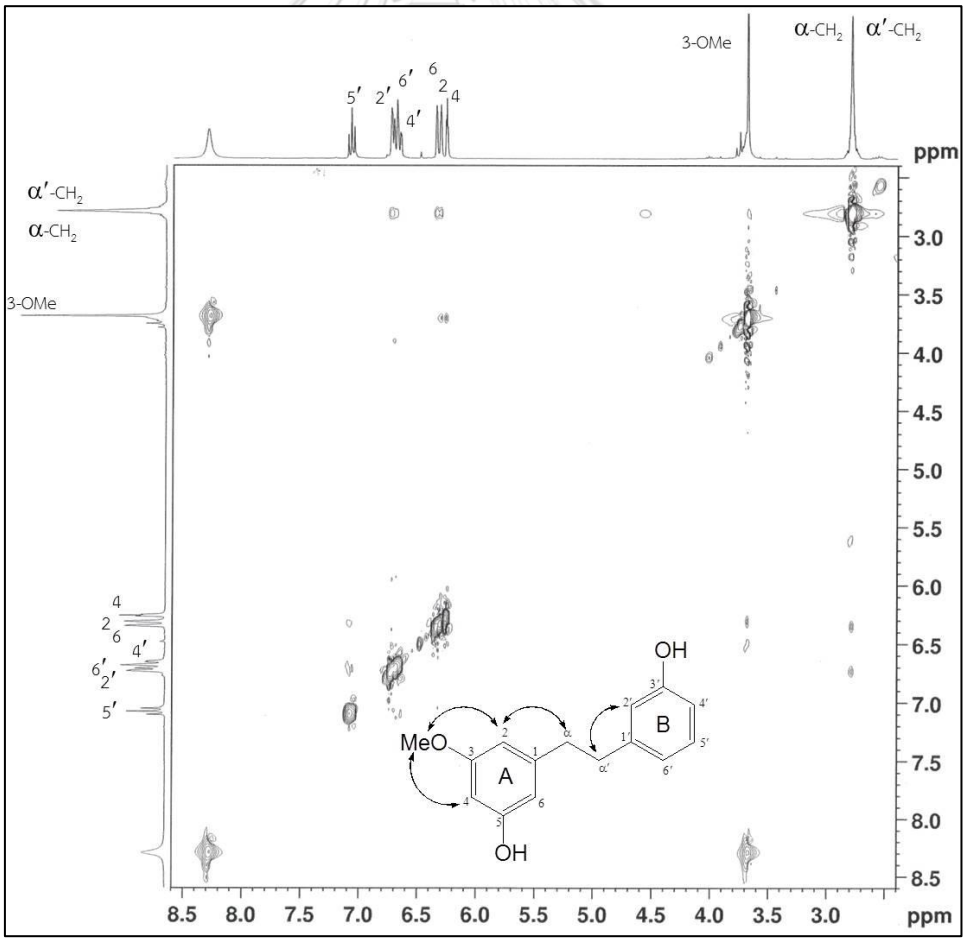


Figure 59 NOESY spectrum of compound DI6

1.7 Structure determination of compound DI7

Compound DI7 was isolated as a dark brown amorphous solid. Its HR-ESI-MS (**Figure 60**) presented a sodium-adduct molecular ion $[M+Na]^+$ peak at *m/z* 297.1107, (calcd. for $C_{16}H_{18}O_4Na$; 297.1103), suggesting the molecular formula $C_{16}H_{18}O_4$. The number carbons corresponded to the number of signals in ^{13}C NMR spectrum (**Figure 62**). The degree of unsaturation, which was calculated by the molecular formula, implied that there were two aromatic rings in the skeleton.

Compound DI7 showed the same molecular formula as compound DI5. The ^1H-NMR spectrum (**Figure 61**) also exhibited six aromatic protons at δ 6.39-7.10, two singlet signals of methoxy groups at δ 3.75 (3H, 4-OMe) and 3.78 (3H, 5-OMe) and multiplet signals of methylene groups at δ 2.80 (4H, H-α, H-α'). Two methine protons of ring A appeared as broad singlets at δ 6.39 (1H, *s*, H-6) and 6.45 (1H, *s*, H-2).

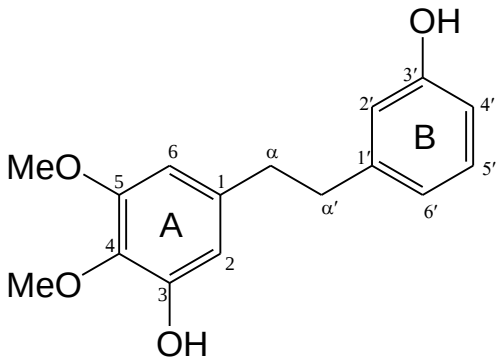
The 3-OH substitution of ring B was showed by the splitting pattern of protons which consisted of a triplets at δ 7.10 (1H, *J* = 7.8 Hz, H-5′), a double doublets at δ 6.68 (*J* = 7.8, 1.5 Hz, H-4′) and a broad doublets at δ 6.72 (*J* = 7.8 Hz, H-6′) and a broad singlet at δ 6.76 (H-2′).

The HSQC spectrums were used to assign a single bond between proton and carbon (**Figure 63**). They also revealed six quaternary carbons which indicated four substitutions, consisted of two methoxy groups and two hydroxy groups. The positions of aromatic protons and methoxy groups were assigned by the correlations in HMBC spectrum (**Figure 64**). The H-2, protons of ring A was assigned based on correlations to C-3 (δ 150.1), C-6 (δ 104.1) C-4 (δ 134.5) and C-α (δ 37.6). The H-6 was assigned by the correlations to C-2 (δ 108.7), C-4, C-5 (δ 153) and C-α (δ 37.6). On ring B, The H-5′ was assigned by the correlations to C-1′ (δ 143.5) and C-3′ (δ 157.3). The H-2′ was assigned by the correlations to C-3′ and C-6′ (δ 119.7). The H-6′ was assigned by the correlations to C-2′ (δ 115.4), C-4′ (δ 112.8) and C-α' (δ 37.6).

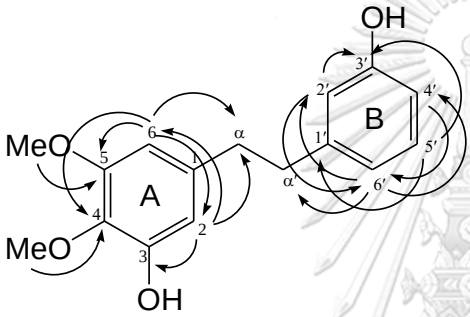
The H-4′ was assigned by the correlations to C-6′ (δ 119.7). Two methoxy proton signals (δ 3.75 and 3.78, *s*, 6H) revealed the correlations to C-4 and C-5.

The positions of aromatic protons and methoxy groups were comfirmed by NOESY spectrum (**Figures 66-67**). On ring A, the 5-OMe substitution was confirmed by correlations of H-6 to protons of 5-OMe. The 4-OMe substitution was confirmed by no correlation to any proton. The position of H-2′ was ensured by correlation of H2′ to H-α′.

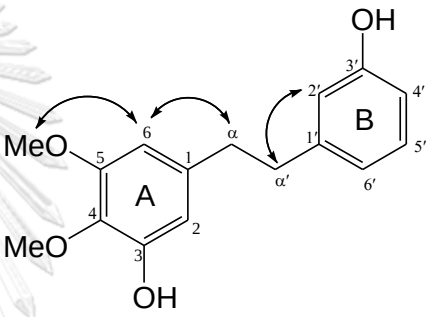
On the basis of the above spectroscopic data and comparison of the NMR data (**Table 12**), DI7 was characterized as 3,3′-dihydroxy-4,5-dimethoxybibenzyl, which was first isolated from the leaves of *Empertrum nigrum* (Arriaga-Giner *et al.*, 1993). The assignments of C-1, C-4 and C-1′ in this structure were revised by the 2D NMR data. It was also found in the whole plant of *Dendrobium williamsonii* (Rungwichaniwat *et al.*, 2014), and *D. sinense* (Chen *et al.*, 2014). It showed cytotoxic activity against gastic cancer (SCG-7901), hepatocelluar carcinoma (BEL-7402) and leukemia cells (K562) (Chen *et al.*, 2014).



3,3′-Dihydroxy-4,5-dimethoxybibenzyl [**42**]



HMBC correlations (C⟶H)



NOESY correlations (H⟷H)

Table 12 NMR spectral data of compound DI7 (300 MHz, in acetone-d_6) and 3,3′-Dihydroxy-4,5-dimethoxybibenzyl (300 MHz, in $CDOD_3$)

Position	Compound DI7		3,3′-Dihydroxy-4,5-dimethoxybibenzyl*	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
1	-	137.8	-	143.3
2	6.45 (*br s*)	108.7	6.47 (*d*, *J* = 1.9 Hz)	108.0
3	-	150.1	-	148.6
4	-	134.5	-	138.0
5	-	153.0	-	152.0
6	6.39 (*br s*)	104.1	6.25 (*d*, *J* = 1.9 Hz)	104.3
α	2.80 (*m*)	37.6	2.81 (*m*)	37.5
α′	2.80 (*m*)	37.6	2.81 (*m*)	37.4
1′	-	143.5	-	133.5
2′	6.76 (*br s*)	115.4	6.67 (*m*)	115.3
3′	-	157.3	-	155.8
4′	6.68 (*dd*, *J* = 7.8, 1.5 Hz)	112.8	6.67 (*m*)	112.8
5′	7.10 (*t*, *J* = 7.8 Hz)	129.3	7.15 (*dd*, *J* = 8.7, 7.5 Hz)	129.2
6′	6.72 (*br d*, *J* = 7.8 Hz)	119.7	6.76 (*dt*, 7.5, 1.1)	120.3
4-OMe	3.75 (*s*)	59.9	3.87 (*s*)	60.8
5-OMe	3.78 (*s*)	55.3	3.81 (*s*)	55.6

*Arriaga-Giner *et al.*, 1993

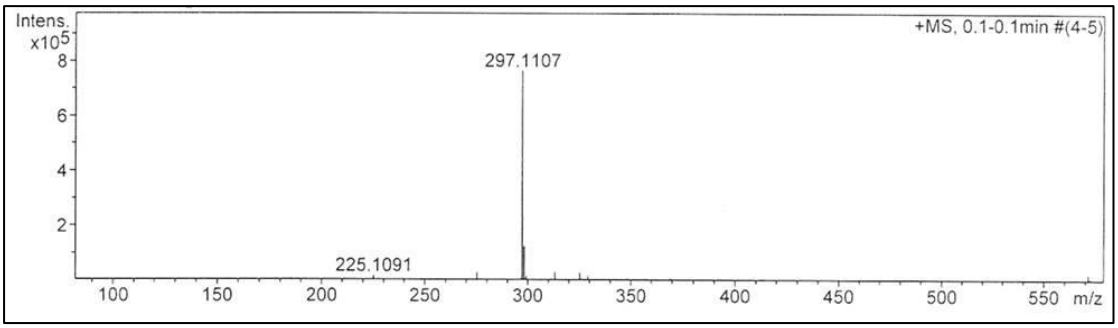


Figure 60 Mass spectrum of compound DI7

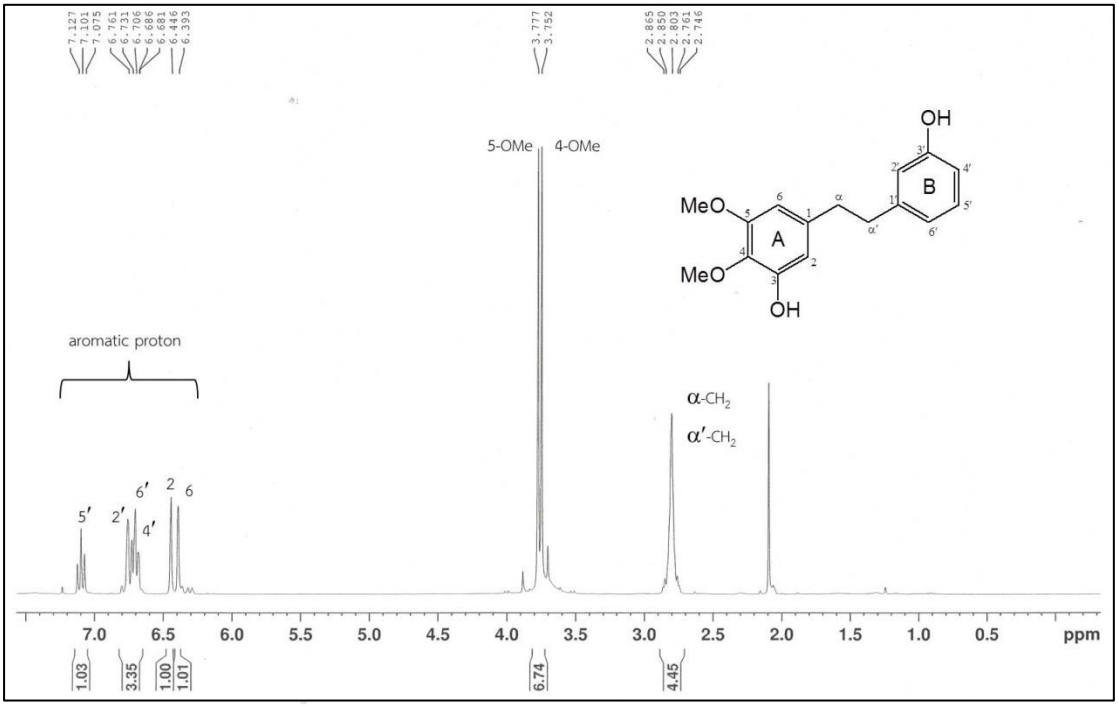


Figure 61 ^{1}H-NMR spectrum of compound DI7

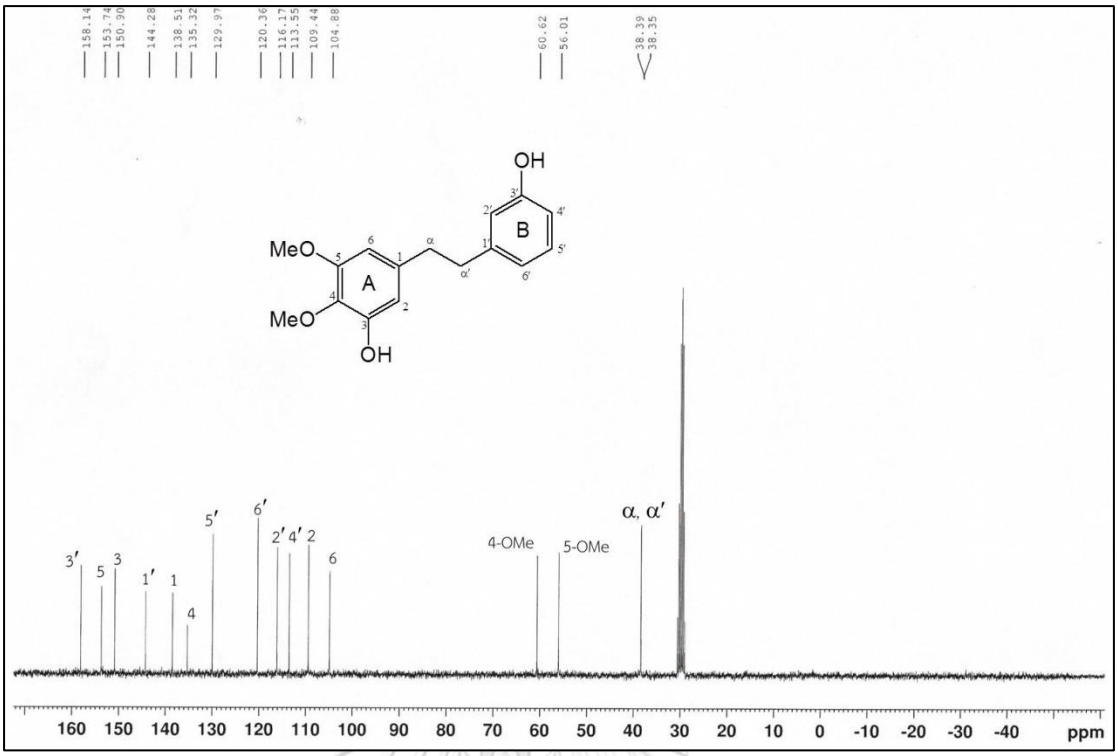


Figure 62 ^{13}C-NMR spectrum of compound DI7

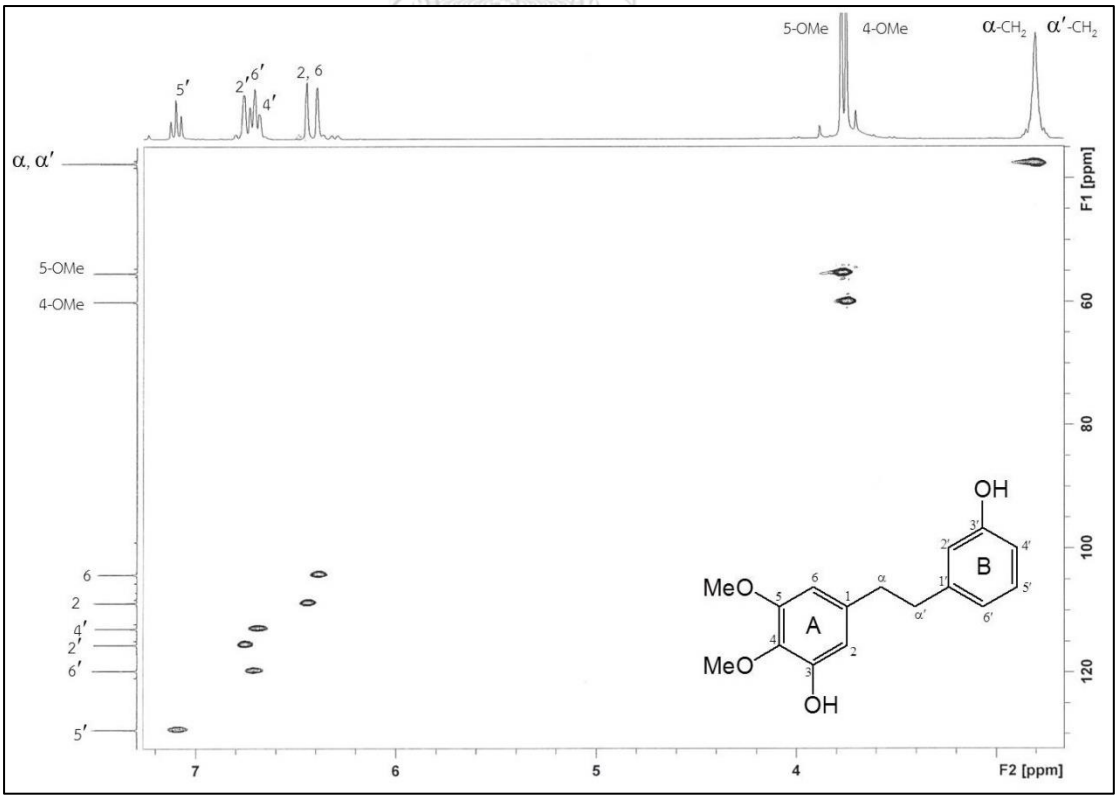


Figure 63 HSQC spectrum of compound DI7

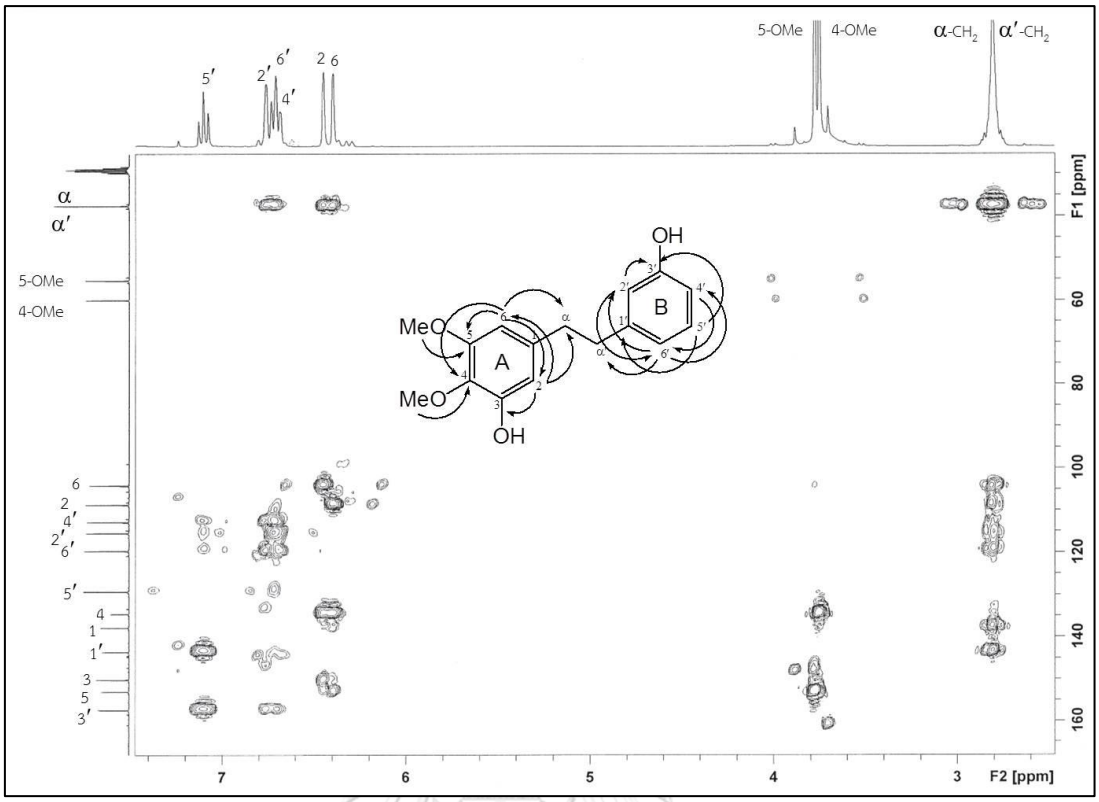


Figure 64 HMBC spetrum of compound DI7

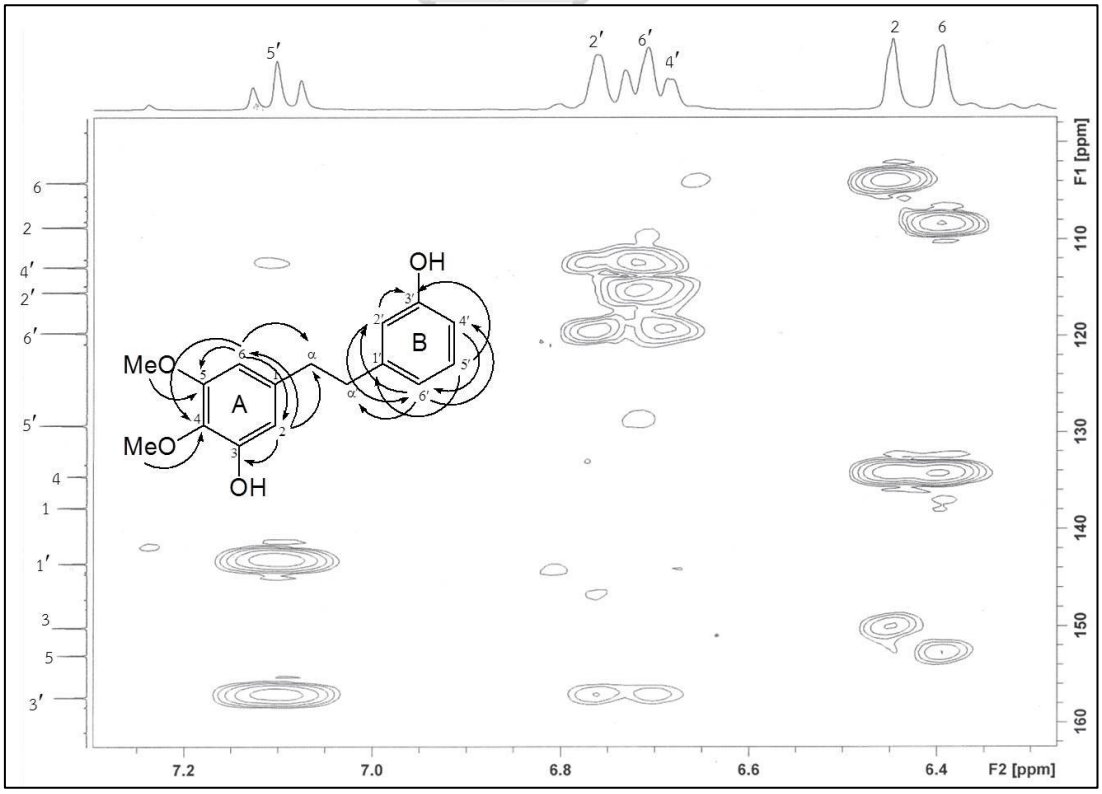


Figure 65 HMBC spetrum of compound DI7 (enlarge)

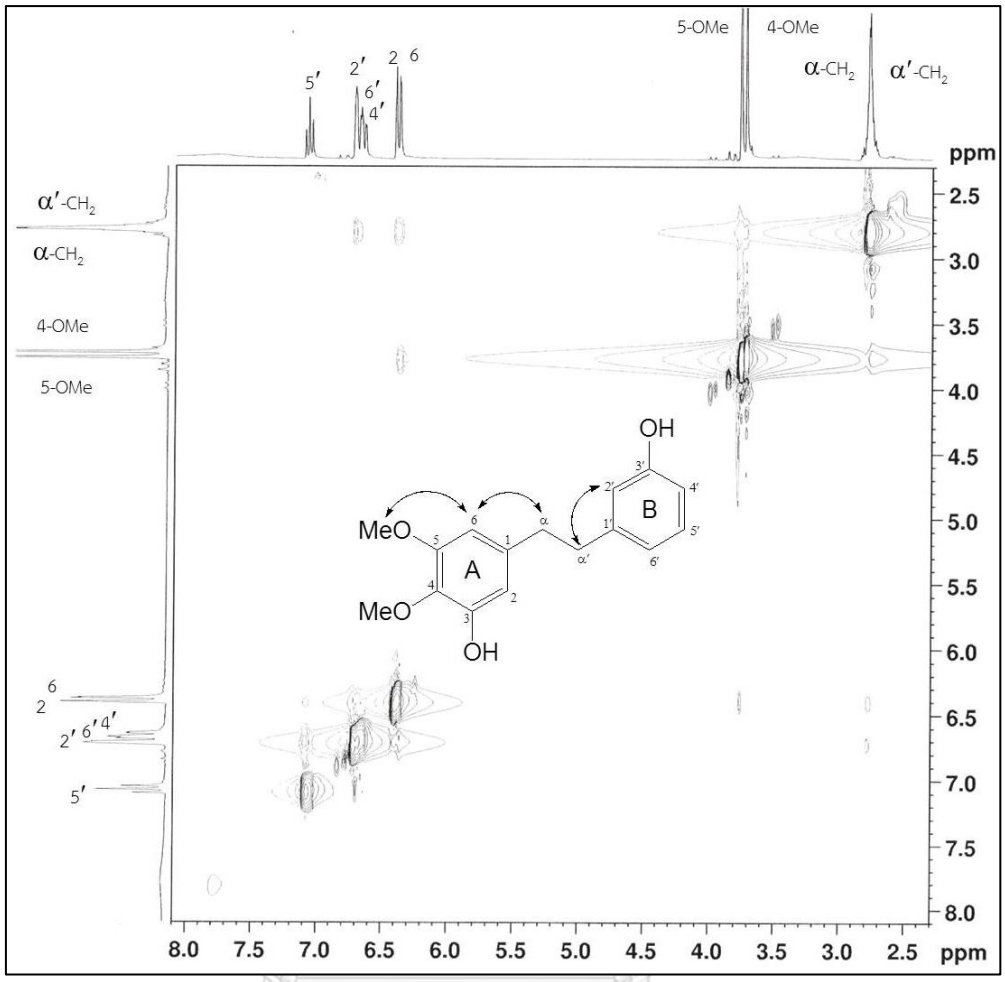


Figure 66 NOESY spectrum of compound DI7

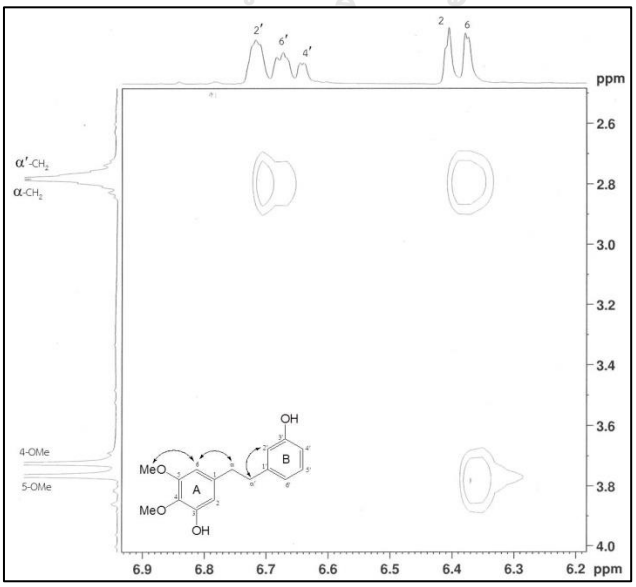


Figure 67 NOESY spectrum of compound DI7 (enlarge)

1.8 Structure determination of compound DI8

Compound DI8 was isolated as a dark brown amorphous solid. Its HR-ESI-MS (**Figure 68**) showed a sodium-adduct molecular ion $[M+Na]^+$ peak at *m/z* 327.1210, (calcd. for $C_{17}H_{20}O_5Na$; 327.1208), suggesting the molecular formula $C_{17}H_{20}O_5$. This formula was supported by twelve signals of aromatic carbons, three signals of methoxy carbons and two signals of methylene carbons in the ^{13}C-NMR spectrum (**Figure 70**). It implied the bibenzyl skeleton of this compound.

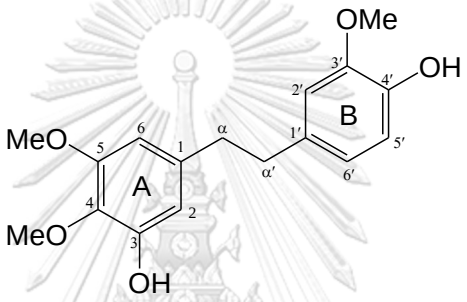
The ^{1}H-NMR spectrum (**Figure 69**) also exhibited five aromatic protons at δ 6.39-81, two singlet signals of methoxy groups at δ 3.74 (3H, 4-OMe), 3.79 (3H, 5-OMe) and δ 3.81 (3H, 3′-OMe) and singlet signals of methylene groups at δ 2.80 (2H, H-α') and δ 2.81 (2H, H-α). Two methine protons of ring A appeared as broad singlets (same as compound **DI7**) at δ 6.41 (1H, *s*, H-2) and 6.39 (1H, *s*, H-6). The splitting pattern of protons on ring B, similar to DI5, consisted of two doublets at δ 6.81 (1H, *J* = 1.5 Hz, H-2′) and δ 6.74 (1H, *J* = 7.8 Hz, H-5′) and a double doublets at δ 6.68 (1H, *J* = 7.8, 1.5 Hz, H-6′), indicated two different substitutions on ring B.

The HSQC spectrums were used to assign a linkage of proton to carbon (**Figure 71**). The numbers of quaternary carbons suggested five substitutes (3xOMe and 2xOH). The positions of aromatic protons and methoxy groups were assigned by the correlations in HMBC spectrum (**Figures 72-73**). The H-2 protons of ring A was assigned based on correlations C-6 (δ 105.0), C-4 (δ 135.4) and C-α (δ 38.2). The H-6 was assigned by the correlations to C-2 (δ 109.6), C-4, C-5 (δ 151.0) and C-α. On ring B, The H-2′ was assigned by the correlations to C-3′ (δ 148.0), C-4′ (δ 145.6), C-6′ (δ121.6) and C-α' (δ 39.0). The H-5′ was assigned by the correlations to C-1′ (δ 134.1) and C-3′ (δ 148.0). The H-6′ was assigned by the correlations to C-2′ (δ 112.9), C-4′ and C-α'. Three methoxy proton signals revealed the correlations to C-4, C-5 and C-3′.

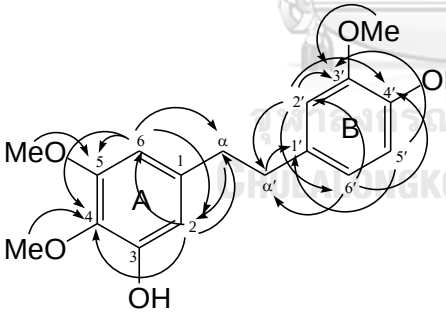
The positions of aromatic protons and methoxy groups were comfirmed by NOESY spectrum (**Figures 74-75**). On ring A, the location of 5-OMe was confirmed by

correlations of H-6 and protons of 5-OMe. The crosspeak between H-6′ and H-α′ was used to affirm the close position of these protons. The 3′-OMe substitution was confirmed by correlations of H-2′ to H-α′ and protons of 3′-OMe.

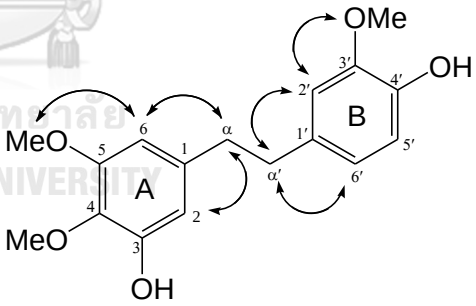
From the above data, and through comparison (**Table 13**) with previously reported data (Deciga-Campos *et al.*, 2007), DI8 was identified as 3,4′-dihydroxy-3′,4,5-trimethoxybibenzyl (DTB), which was previously found in *Scaphyglottis livida*. It was also found in *D. sinense* and shown to be cytotoxic against gastric cancer cell (SGC-7901).



3,4′-Dihydroxy-3′,4,5-trimethoxybibenzyl [**66**]



HMBC correlations (C⟶H)



NOESY correlations (H⟷H)

Table 13 NMR spectral data of compound DI8 (300 MHz, in acetone-d_6) and 3,4′-dihydroxy-3′,4,5-trimethoxybibenzyl (500 MHz, in $CDCl_3$)

Position	Compound DI8		3,4,3′-Trimethoxy-5,4′-dihydroxybibenzyl
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)
1	-	138.7	-
2	6.41 (*br s*)	109.6	6.46 (*d*, *J* = 1.8 Hz)
3	-	151.0	-
4	-	135.4	-
5	-	153.8	-
6	6.39 (*d*, *J* = 2.1 Hz)	105.0	6.23 (*d*, *J* = 1.5 Hz)
α	2.81 (*s*)	38.2	2.80 (*s*)
α′	2.80 (*s*)	39.0	2.80 (*s*)
1′	-	134.1	-
2′	6.81 (*d*, *J* = 1.5 Hz)	112.9	6.63 (*d*, *J* = 2.1 Hz)
3′	-	148.0	-
4′	-	145.6	-
5′	6.74 (*d*, *J* = 7.8 Hz)	115.5	6.83 (*d*, *J* = 7.8 Hz)
6′	6.68 (*dd*, *J* = 7.8, 1.5 Hz)	121.6	-
3-OH	-	-	5.75 (*br s*)
4-OH	-	-	5.51 (*br s*)
4-OMe	3.74 (*s*)	60.6	3.81 (*s*)
5-OMe	3.79 (*s*)	56.1	3.85 (*s*)
3′-OMe	3.81 (*s*)	56.1	3.87 (*s*)

*Deciga-Campos *et al.*, 2007

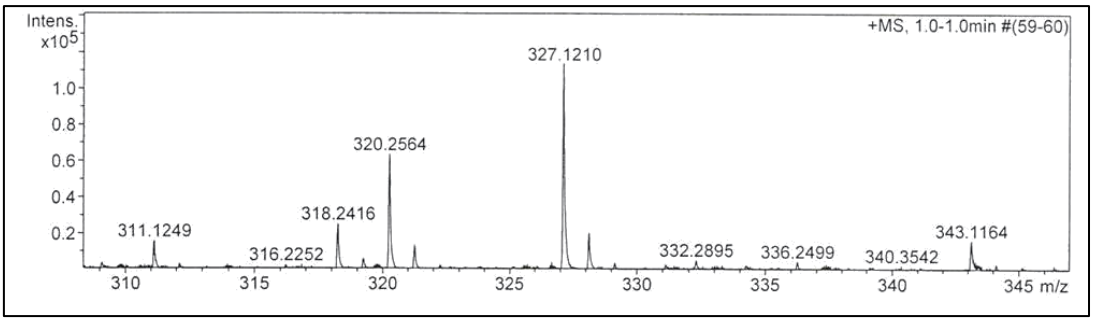


Figure 68 Mass spectrum of compound DI8

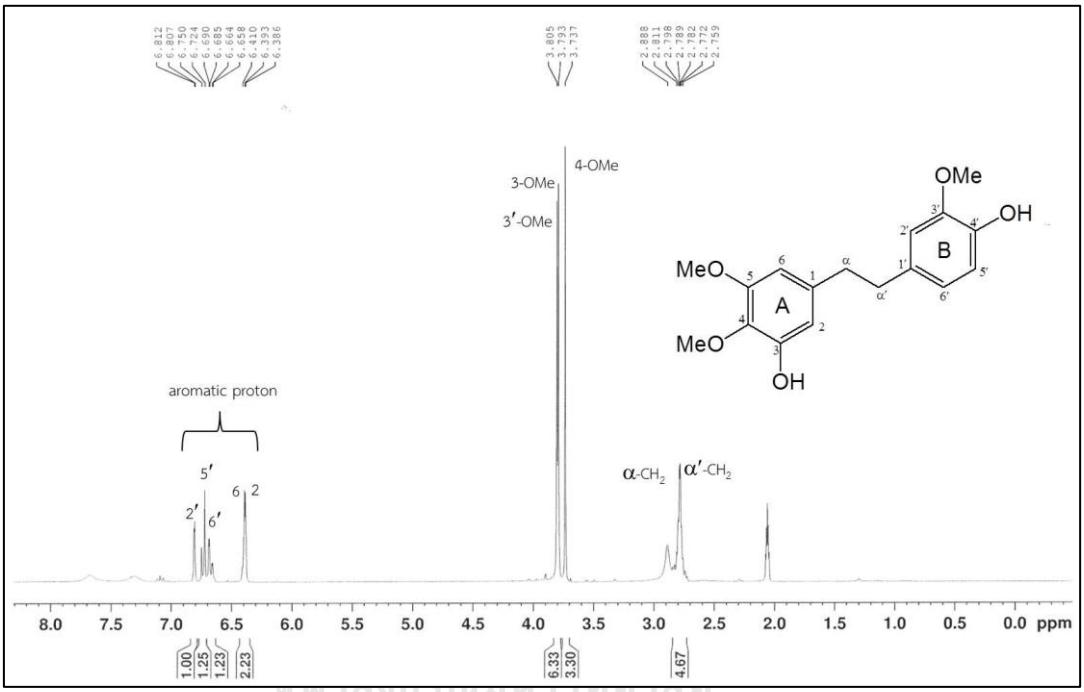


Figure 69 ^{1}H-NMR spectrum of compound DI8

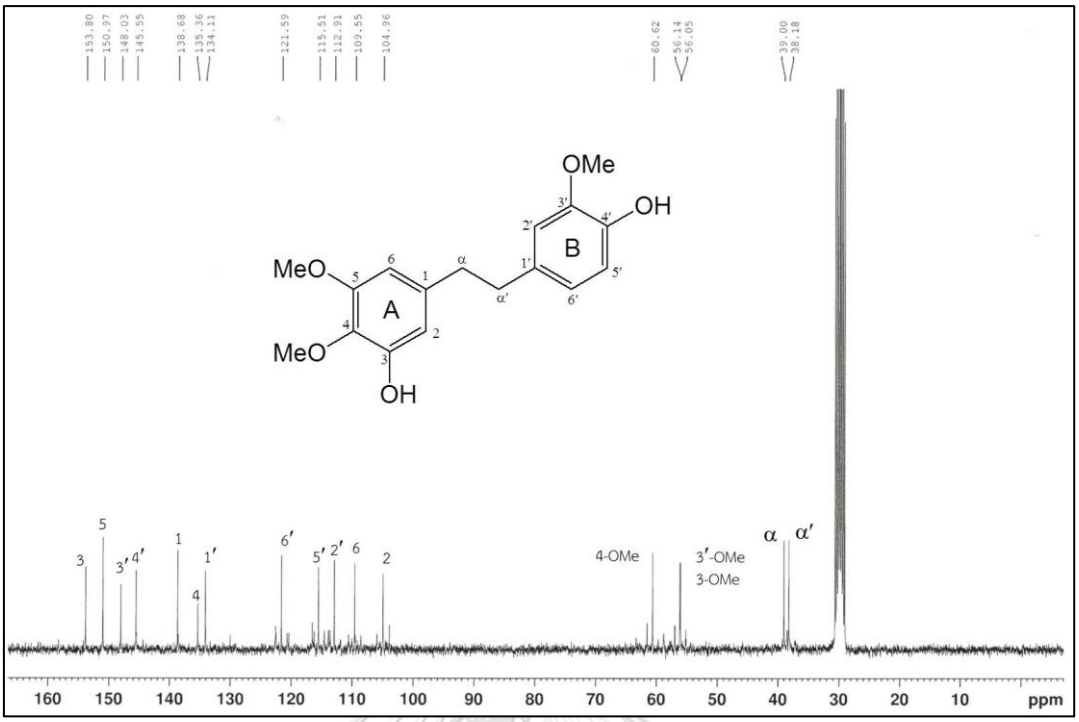


Figure 70 ^{13}C-NMR spectrum of compound DI8

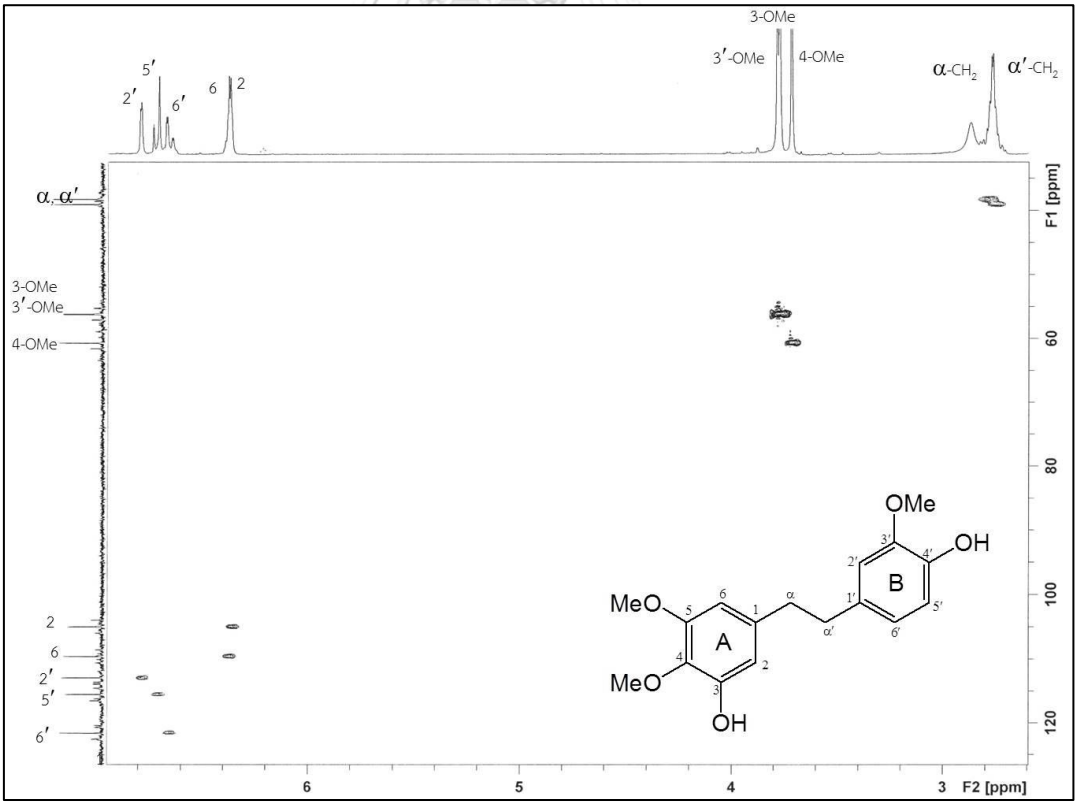


Figure 71 HSQC spectrum of compound DI8

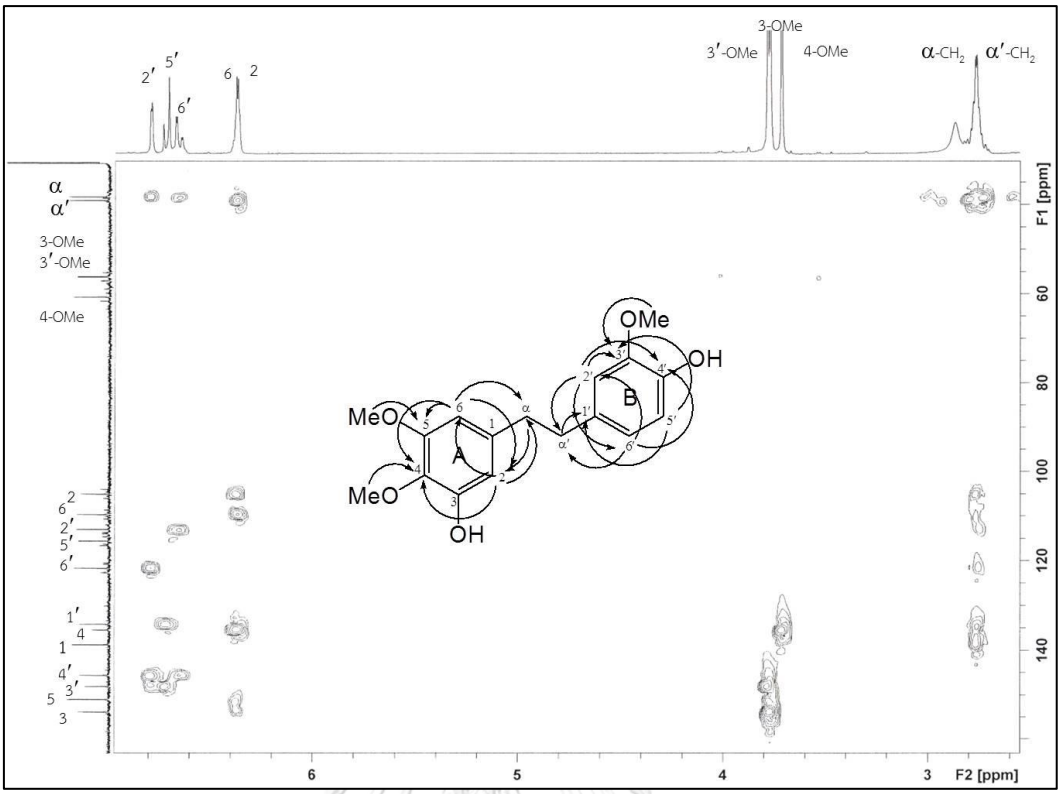


Figure 72 HMBC spectrum of compound DI8

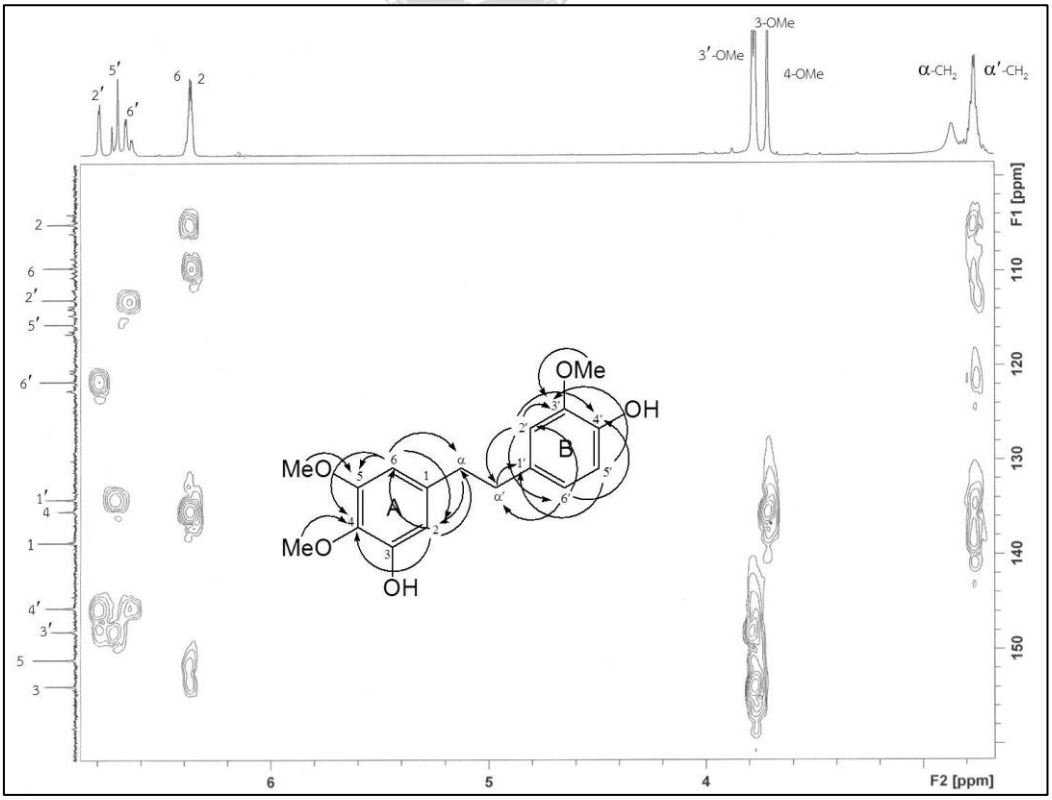


Figure 73 HMBC spectrum of compound DI8 (enlarge)

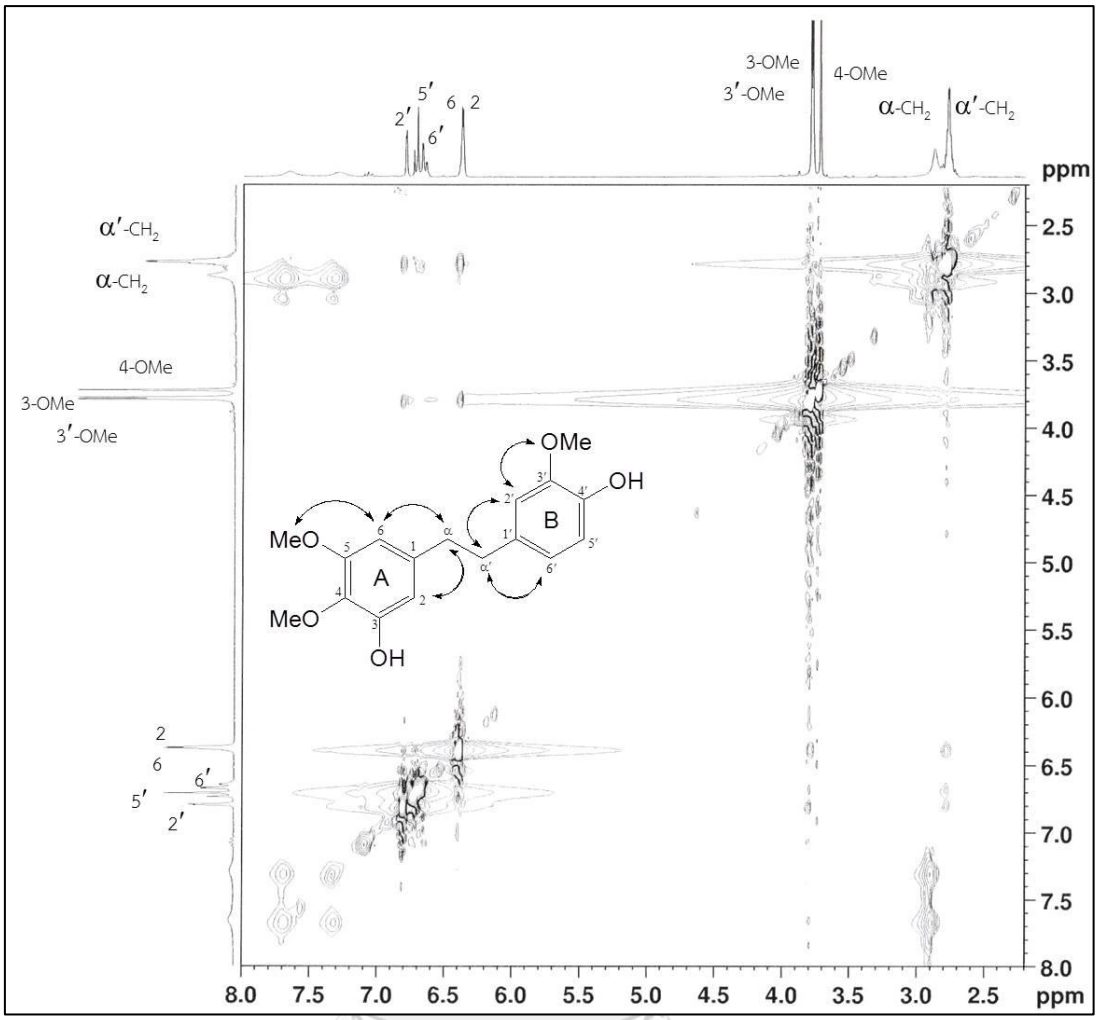


Figure 74 NOESY spectrum of compound DI8

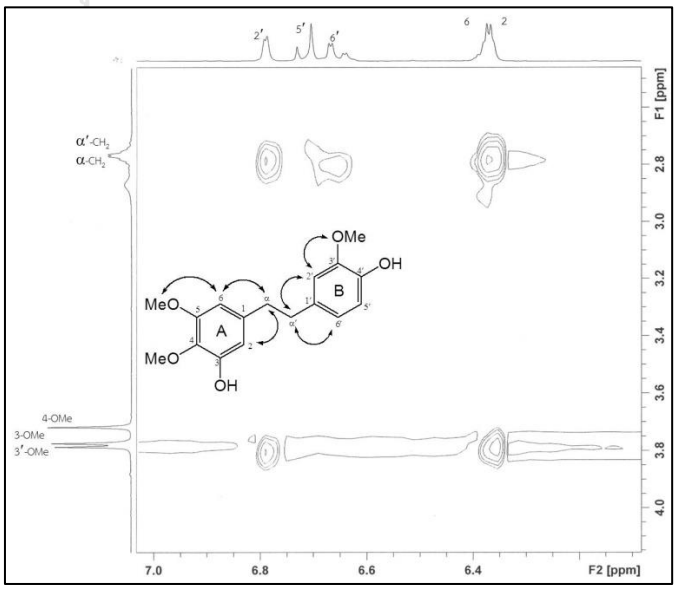


Figure 75 NOESY spectrum of compound DI8 (enlarge)

1.9 Structure determination of compound DI9

Compound DI9 was isolated as a brown amorphous solid. Its HR-ESI-MS (**Figure 76**) presented a sodium-adduct molecular ion $[M+Na]^+$ peak at *m/z* 283.0911, (calcd. for $C_{15}H_{16}O_4Na$; 283.0946), suggesting the molecular formula $C_{15}H_{16}O_4$.

The ^{1}H-NMR (**Figure 77**) and ^{13}C NMR spectrum (**Figure 78**) showed the aromatic, methoxy and methylene signals, suggested that compound DI9 was a bibenzyl. From the molecular formula, It had one carbon atom and two hydrogen atoms less than compound DI4 implying a substitution of a hydroxy group instead of a methoxy group.

The ^{1}H-NMR spectrum presented six aromatic signals at δ 6.35-7.06, a methoxy signals at δ 3.75 (3H, *s*) and two methylene signals at δ 2.76 (2H, *s*, H-α) and δ 2.77 (2H, *s*, H-α'). Two methine protons of ring A appeared as doublets at δ 6.35 (1H, *J* = 1.5 Hz, H-2) and 6.37 (1H, *J* = 1.5 Hz, H-6), suggested that there was no symmetrical substitution. The numbers of carbon signals in ^{13}C spectrum also comply with the molecular formula.

The splitting pattern of protons on ring B consisted of a triplet at δ 7.06 (1H, *J* = 7.8 Hz, H-5$'$), two doublets at δ 6.69 (1H, *J* = 1.5 Hz, H-2$'$) and 6.66 (1H, *J* = 7.8 Hz, H-6$'$) and a double doublet at δ 6.63 (1H, *J* = 7.8, 1.5 Hz, H-4$'$), indicated a substitution on this ring.

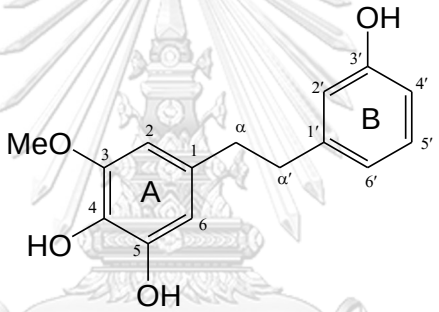
The HSQC spectrum (**Figures 79-80**) was used to find the correlations between protons and carbons with a single bond. It also revealed six quaternary carbons, suggested four substutites, a methoxy group and three hydroxy groups.

The positions of aromatic protons and methoxy groups were assigned by the correlations in HMBC spectrum (**Figure 81**). On ring A, the H-2 was assigned based on correlations to C-4 (δ 132.7), C-6 (δ 109.6) and C-α (δ 38.4). The H-6 was assigned by the correlations to C-2 (δ 104.5), C-5 (δ 146.1) and C-α (δ 38.4). On ring B, The H-5$'$ was assigned by the correlations to C-1$'$ (δ 144.5) and C-3$'$ (δ 158.2). The H-2$'$ was assigned by the correlations to C-6$'$ (δ 120.4). The H-6$'$ was assigned by the

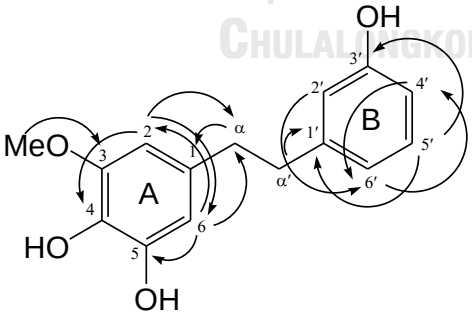
correlations to C-4′ (δ 113.5). The H-4′ was assigned by the correlations to C-6′. The methoxy proton signal (δ 3.75, *s*, 3H) revealed the correlations to C-3 (δ 148.7).

The NOESY spectrum (**Figures 82-83**) was used to confirm the positions of aromatic protons and methoxy groups. On ring A, the correlation of H-6 to H-α and correlations of H-2 to H-α and 3-OMe protons, were used to confirm the position of 3-OMe. The crosspeak between H-2′ and H-α′ affirmed the close position of these protons.

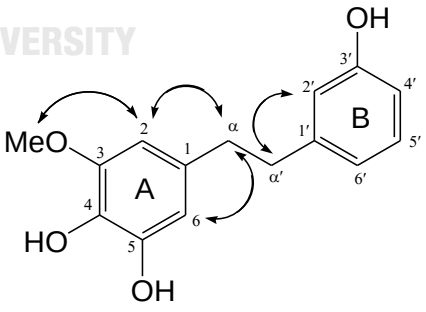
From the above data, and through comparison of its ^{1}H-NMR and ^{13}C-NMR spectra with the previously reported data (Chen *et al.*, 2014) (**Table 14**), DI9 was identified as dendrosinen B, which was first found in *Dendrobium sinense*.



Dendrosinen B [**32**]



HMBC correlations (C⟶H)



NOESY correlations (H⟷H)

Table 14 NMR spectral data of compound DI9 (300 MHz, in acetone-d_6) and Dendrosinen B (500 MHz, in $CDCl_3$)

Position	Compound DI9		Dendrosinen B*	
	δ_H in ppm (mult., *J* in Hz)	**δ_C in ppm**	**δ_H in ppm (mult., *J* in Hz)**	**δ_C in ppm**
1	-	133.6	-	134.0
2	6.35 (*d*, *J* = 1.5 Hz)	104.5	6.24 (*d*, *J* = 1.8 Hz)	105.0
3	-	148.7	-	149.4
4	-	132.7	-	133.1
5	-	146.1	-	146.2
6	6.37 (*d*, *J* = 1.5 Hz)	109.6	6.30 (*d*, *J* = 1.9 Hz)	109.9
α	2.76 (*m*)	38.4	2.72 (*m*)	38.8
α′	2.77 (*m*)	38.8	2.76 (*m*)	39.2
1′	-	144.5	-	144.8
2′	6.69 (*d*, *J* = 1.5 Hz)	116.2	6.59 (*t*, *J* = 1.6 Hz)	116.4
3′	-	158.2	-	158.2
4′	6.63 (*dd*, *J* = 7.8, 1.5 Hz)	113.5	6.57 (*dd*, *J* = 7.8, 1.6 Hz)	113.6
5′	7.06 (*t*, *J* = 7.8 Hz)	130.0	7.06 (*t*, *J* = 7.6 Hz)	130.2
6′	6.66 (*br d*, *J* = 7.8 Hz)	120.4	6.63 (*d*, *J* = 7.4 Hz)	120.9
3-OMe	3.75 (*s*)	56.3	3.76 (*s*)	56.5

*Chen *et al.*, 2014

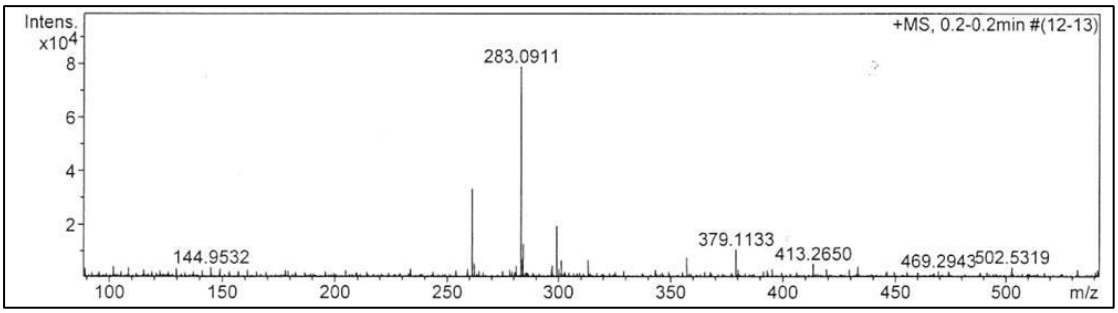


Figure 76 Mass spectrum of compound DI9

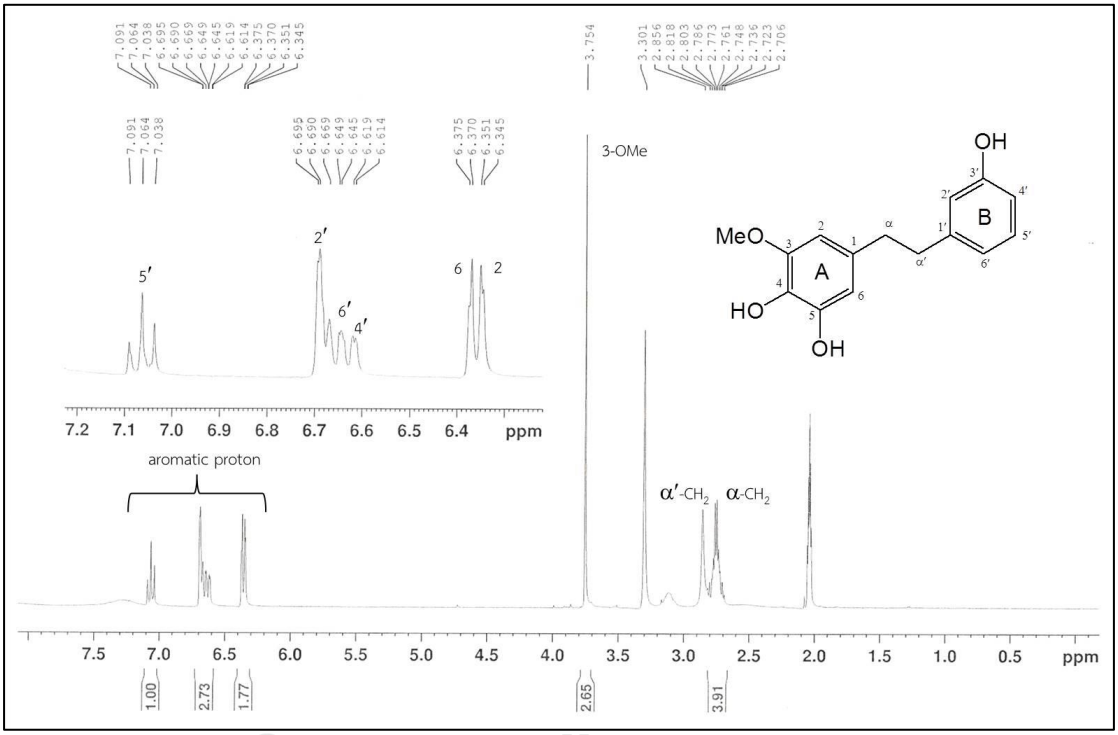


Figure 77 ^{1}H-NMR spectrum of compound DI9

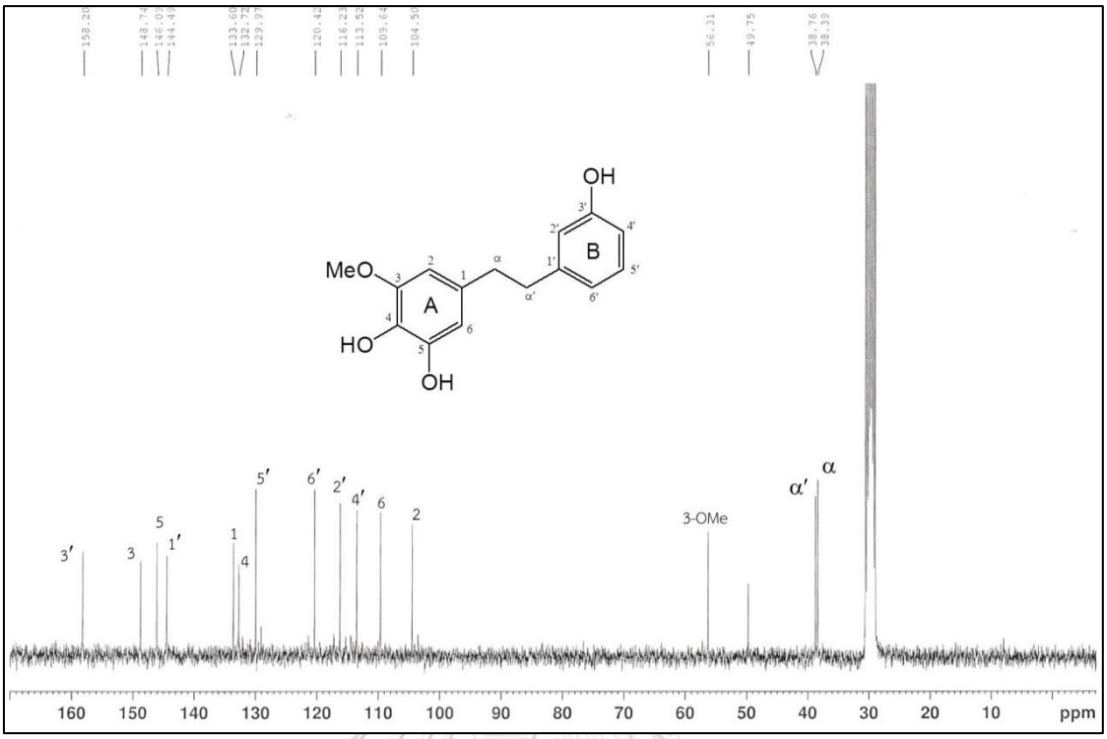


Figure 78 ^{13}C-NMR spectrum of compound DI9

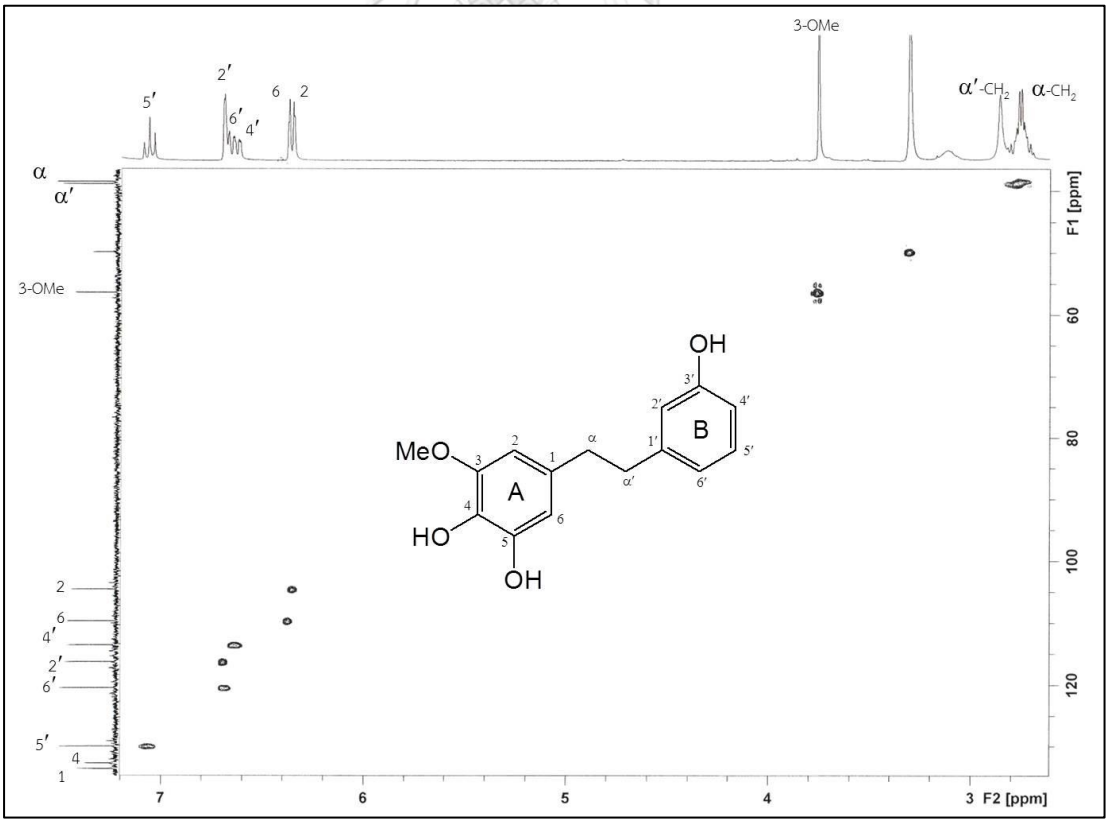


Figure 79 HSQC spectrum of compound DI9

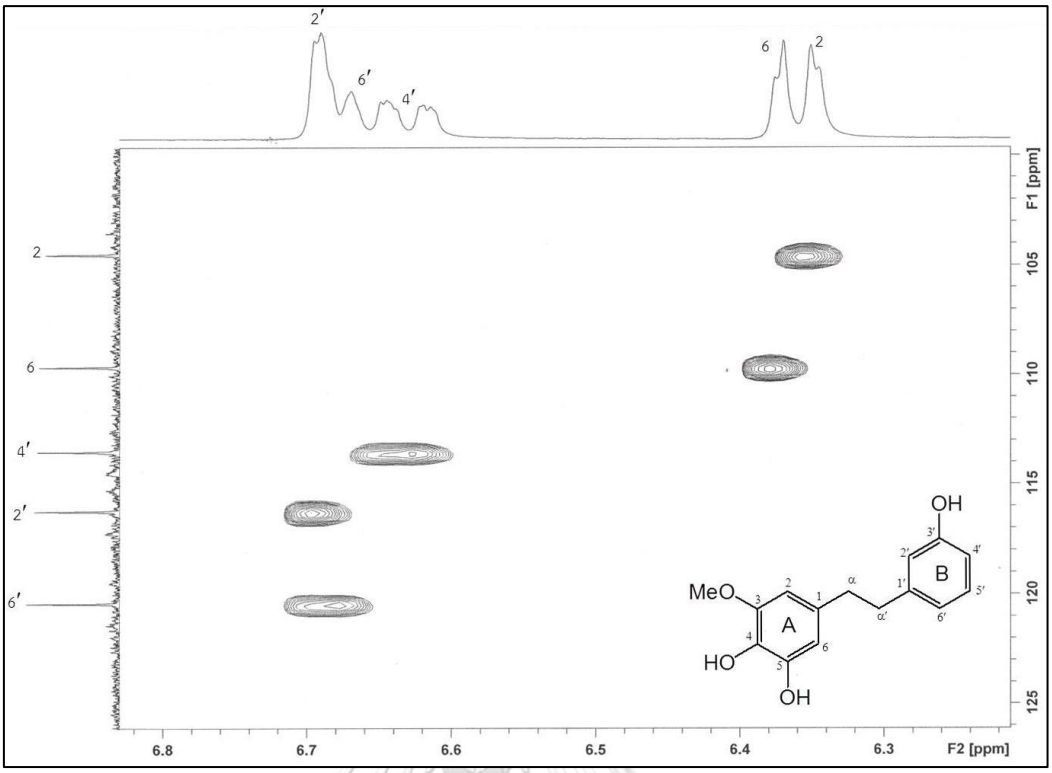


Figure 80 HSQC spectrum of compound DI9 (enlarge)

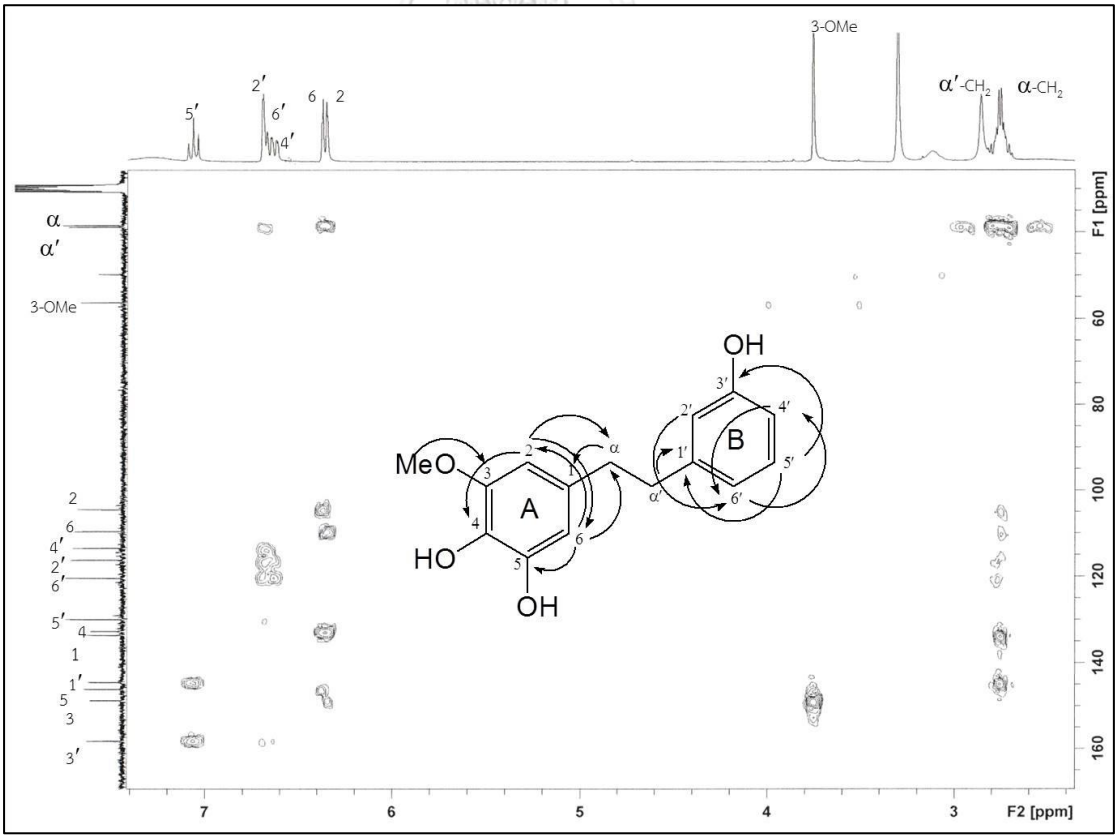


Figure 81 HMBC spectrum of compound DI9

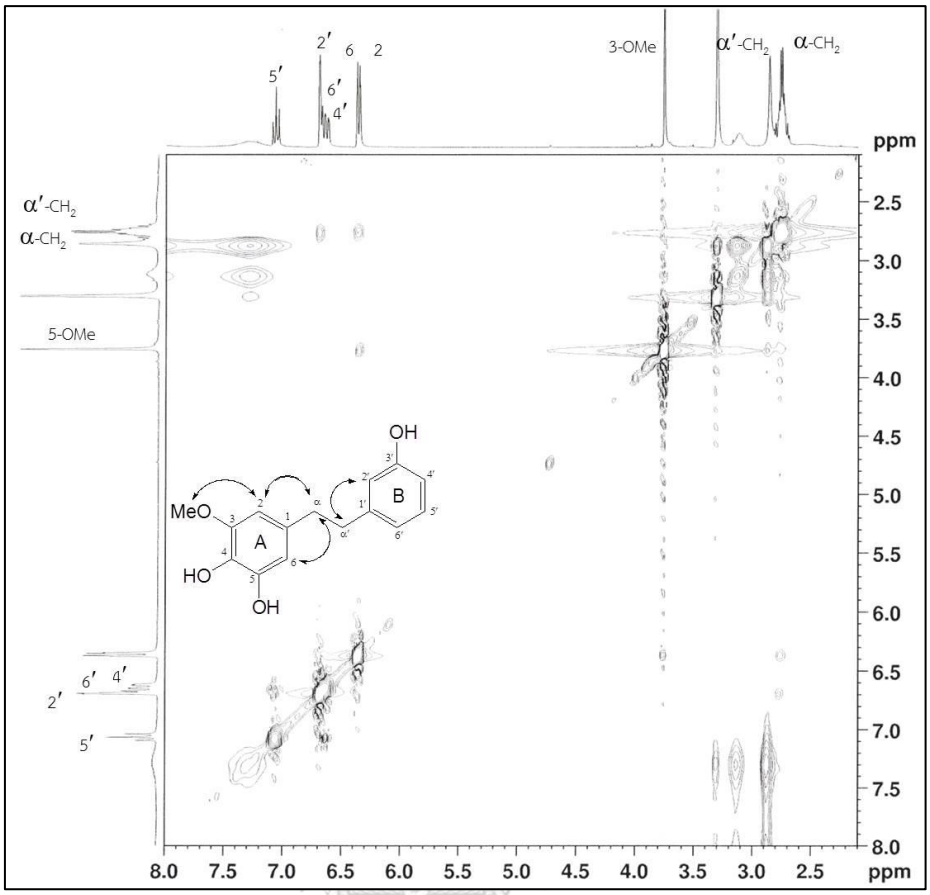


Figure 82 NOESY spectrum of compound DI9

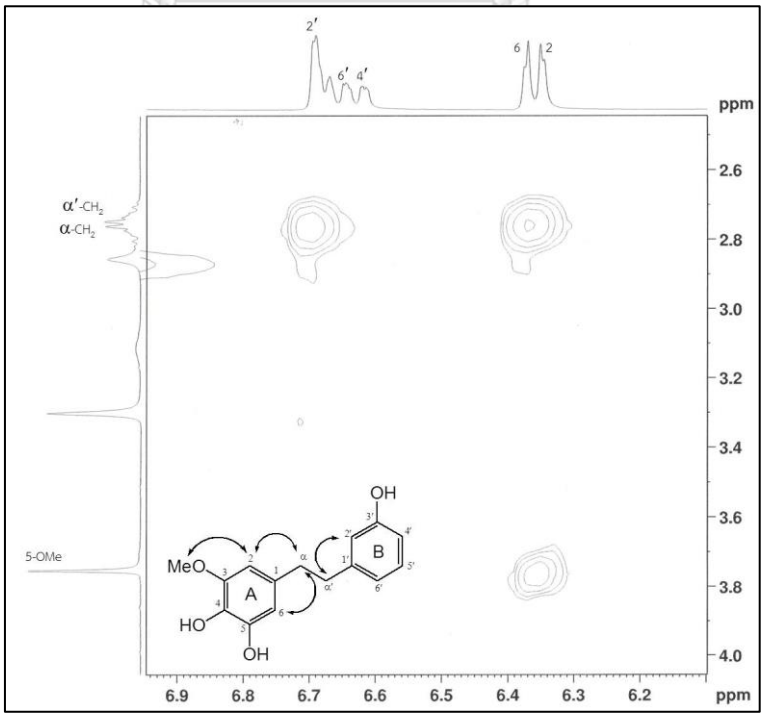
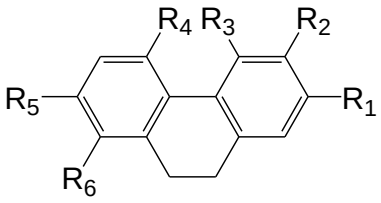
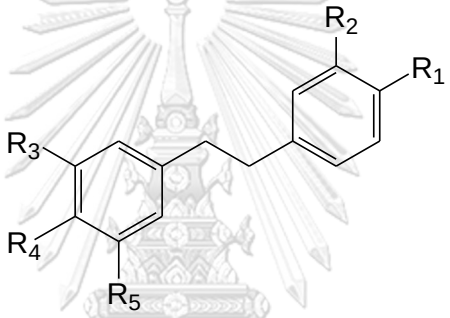


Figure 83 NOESY spectrum of compound DI9 (enlarge)



	R_1	R_2	R_3
Dendroinfundin A [**DI1**]	H	OMe	H
Ephemerathol A [**DI2**]	H	OH	H
Dendroinfundin B [**DI3**]	OH	H	OMe



	R_1	R_2	R_3	R_4
Moscatilin [**DI5**]	OH	OMe	OH	OMe
Aloifol I [**DI4**]	H	OH	OH	OMe
Batatasin [**DI6**]	H	OH	H	OH
3,3′-Dihydroxy-4,5-dimethoxybibenzyl [**DI7**]	H	OH	OMe	OH
3,4′-Dihydroxy-3′,4,5-trimethoxybibenzyl [**DI8**]	OH	OMe	OMe	OH
Dendrosinen B [**DI9**]	H	OH	OH	OH

Figure 84 Pure compounds isolated from *Dendrobium infundibulum*

2. Lipase and α-glucosidase inhibitory activities

The MeOH extract was initially examined for the lipase and α-glucosidase inhibitory activities. It showed 68.45% inhibition of lipase at 100 μg/mL but no inhibitory activity against α-glucosidase. Then it was partitioned to afford an EtOAc extract, a BuOH extract and a aqueous extract. All extracts were examined for those two activities. Potent lipase inhibitory activity was found for the EtOAc extract and the BuOH extract. The EtOAc extract was also active against α-glucosidase and was selected for further studies (**Table 15)**.

Table 15 Screening test for lipase and α-glucosidase inhibitory activities of all extracts at concentration 100 μg/mL

Extracts	**% Lipase inhibition**	**% α-glucosidase inhibition**
Methanol	68.45	No activity
Ethyl acetate	83.30	66.28
Butanol	72.30	No activity
Aqueous	No activity	No activity
Positive control	95.06 (Orlistat)	85.75 (Acarbose)

The EtOAc extract was further separated by quick column chromatography to give 7 fractions (A-G). All fractions were tested for lipase and α-glucosidase inhibitory activities. They all showed lipase inhibitory effect and nearly all of them (except fractions A and G) were also able to inhibit α-glucosidase enzyme.

Table 16 Lipase and α-glucosidase inhibitory activities of fractions obtained from ethyl acetate extract (at concentration 100 μg/mL)

Fractions	% Lipase inhibitory activitiy	% α-glucosidase inhibitory activity
A	50.68	No activity
B	79.37	101.70
C	85.75	99.43
D	88.58	117.89
E	92.86	83.85
F	86.23	96.88
G	78.03	No activity
Positive control	96.73 (Orlistat)	85.75 (Acarbose)

Fractions E and F were further studied because of their potent inhibitory activity on both enzymes. Seven compounds i.e. dendroinfundin A, ephemeranthol A, dendroinfundin B, aloifol I, moscatilin, batatasin III and 3,3′-dihydroxy-4,5-dimethoxybibenzyl were obtained from fraction E, and two compounds i.e. 3,4,3′-trimethoxy-5,4′-dihydroxybibenzyl (DTB) and dendrosinen B were obtained from fraction F. The IC_{50} values of these compounds are shown in **Table 17**.

Table 17 IC_{50} value for lipase and α-glucosidase inhibitory activities of compounds isolated from *Dendrobium infundibulum*

Sample	Lipase inhibitory activity (IC_{50})	α-glucosidase inhibitory activity (IC_{50})
Dendroinfundin A [**DI1, 305**]	No activity	No activity
Ephemeranthol A [**DI2, 111**]	No activity	No activity
Dendroinfundin B [**DI3, 306**]	No activity	No activity
Moscatilin [**DI4, 59**]	No activity	No activity
Aloifol I [**DI5, 1**]	No activity	No activity
Batatasin III [**DI6, 8**]	No activity	148.8±8.4 μM
3,3′-Dihydroxy-4,5-dimethoxybibenzyl [**DI7, 42**]	No activity	No activity
3,4,3′-Trimethoxy-5,4′-dihydroxybibenzyl [**DI8, 69**]	No activity	No activity
Dendrosinen B [**DI9, 34**]	295.0±37.9 μM	213.9±2.4 μM
Positive control	31.4±0.6 nM (Orlistat)	809.1±22.2 μM (Acarbose)

Batatasin III (IC_{50} = 148.8±8.4 μM) and dendrosinen B (IC_{50} = 213.9±2.4 μM exhibited more potent inhibitory against α-glucosidase than acarbose. Dendrosinen B (IC_{50} = 295.0±37.9 μM) also showed weak lipase inhibitory activity compared to orlistat.

CHAPTER V
CONCLUSION

The MeOH extract prepared from the whole plant of *Dendrobium infundibulum* was partitioned to afford EtOAc, BuOH and aqueous extracts after removal of the solvent. Then extracts were examined for lipase and α-glucosidase inhibitory activities. The EtOAc extract was selected for further separation using several chromotographic techniques to give nine pure compounds: dendroinfundin A, ephemeranthol A, dendroinfundin B, aloifol I, moscatilin, batatasin III and 3,3′-dihydroxy-4,5-dimethoxybibenzyl, 3,4′-Dihydroxy-3′,4,5-trimethoxybibenzyl (DTB) and dendrosinen B. The results of bioactivitiy evaluation indicated that batatasin III and dendrosinen B showed more potent α-glucosidase inhibitory activity than acarbose. Dendrosinen B also had weak lipase inhibitory activity. Batatasin III and dendrosinen B might provide lead structures for the development of new drugs that are useful as anti α-glucosidase agents.

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APPENDIX

VITA

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Poster presentation

Salinee Na Ranong, Kittisak Likhitwitayawuid and Boonchoo Sritularak. alpha-glucosidase inhibitors from Dendrobium infundibulum. Proceedings of the 10th Annual Northeast Pharmacy Research Conference of 2018 "Research and Development towards Wealth, Security and Sustainability" at Faculty of Pharmaceutical Sciences, Khon Kaen University, Thailand on 17-18 March 2018. (PSP-P-P002)

Publications

Warisada Sila-on, Salinee Na-Ranong, Sirilak Rakrod, Sarote Ornlaor and Zongporn Joungmunkong. (2016). Development and validation of RP-HPLC method for determination of acetazolamide, furosemide and phenytoin extemporaneous suspensions. Asian Journal of Pharmaceutical Sciences 11 : 138–139.

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