สารที่มีฤทธิ์ยับยั้งเอนไซม์แอลฟา-กลูโคซิเดสและเอนไซม์ไลเปสจากเอื้องเงินหลวง

นางสาวปรัชญาพร อินทองแก้ว

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาเภสัชศาสตรมหาบัณฑิต
สาขาวิชาเภสัชเวท ภาควิชาเภสัชเวทและเภสัชพฤกษศาสตร์
คณะเภสัชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2559

ALPHA-GLUCOSIDASE AND LIPASE INHIBITORS

FROM *DENDROBIUM FORMOSUM*

Miss Prachyaporn Inthongkaew

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Pharmacy Program in Pharmacognosy
Department of Pharmacognosy and Pharmaceutical Botany
Faculty of Pharmaceutical Sciences
Chulalongkorn University
Academic Year 2016

Thesis Title	ALPHA-GLUCOSIDASE AND LIPASE INHIBITORS FROM *DENDROBIUM FORMOSUM*
By	Miss Prachyaporn Inthongkaew
Field of Study	Pharmacognosy
Thesis Advisor	Associate Professor Boonchoo Sritularak, Ph.D.
Thesis Co-Advisor	Professor Kittisak Likhitwitayawuid, Ph.D.

Accepted by the Faculty of Pharmaceutical Sciences, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.....Dean of the Faculty of Pharmaceutical Sciences
(Assistant Professor Rungpetch Sakulbumrungsil, Ph.D.)

THESIS COMMITTEE

.....Chairman
(Associate Professor Rutt Suttisri, Ph.D.)

.....Thesis Advisor
(Associate Professor Boonchoo Sritularak, Ph.D.)

.....Thesis Co-Advisor
(Professor Kittisak Likhitwitayawuid, Ph.D.)

.....Examiner
(Chaisak Chansriniyom, Ph.D.)

.....External Examiner
(Associate Professor Supachoke Mangmool, Ph.D.)

ปรัชญาพร อินทองแก้ว : สารที่มีฤทธิ์ยับยั้งเอนไซม์แอลฟา-กลูโคซิเดสและเอนไซม์ไลเปสจากเอื้องเงินหลวง (ALPHA-GLUCOSIDASE AND LIPASE INHIBITORS FROM *DENDROBIUM FORMOSUM*) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ภก. ดร.บุญชู ศรีตุลารักษ์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ศ. ภก. ดร.กิตติศักดิ์ ลิขิตวิทยาวุฒิ, 185 หน้า.

การศึกษาทางพฤกษเคมีของสารสกัดหยาบด้วยเมทานอลจากต้นเอื้องเงินหลวง (วงศ์ Orchidaceae) สามารถแยกสารบริสุทธิ์ที่เคยมีรายงานมาแล้วได้ทั้งหมด 12 ชนิด ได้แก่ สารกลุ่ม phenanthrenes 2 ชนิด (confusarin, nudol), สารกลุ่ม dihydrophenanthrenes 5 ชนิด (hircinol, erianthridin, lusianthridin, coelonin, 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene), สารกลุ่ม dihydrophenanthrenequinones 1 ชนิด (5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone), สารกลุ่ม bibenzyls 3 ชนิด (gigantol, batatasin III, moscatilin) และสารกลุ่ม phenylpropanoids 1 ชนิด (dihydroconiferyl dihydro-*p*-coumarate) พิสูจน์โครงสร้างทางเคมีของสาร โดยการวิเคราะห์ข้อมูลสเปกโตรสโคปี (NMR และ HRS-ESI-MS) จากการศึกษาฤทธิ์ยับยั้งเอนไซม์แอลฟา-กลูโคซิเดส และเอนไซม์ไลเปสของสารบริสุทธิ์ทั้งหมดที่แยกได้พบว่า 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone มีฤทธิ์ยับยั้งเอนไซม์สูงที่สุด โดยมีค่าความเข้มข้นที่สามารถยับยั้งเอนไซม์แอลฟา-กลูโคซิเดสและเอนไซม์ไลเปสได้ 50% (IC_{50}) คือ 126.88 และ 69.45 ไมโครโมลาร์ ตามลำดับ เมื่อศึกษาข้อมูลจลนพลศาสตร์ของเอนไซม์โดยการเขียนรูปกราฟตามวิธีการของ Lineweaver-Burk plot พบว่า 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone เป็นตัวยับยั้งแบบไม่แข่งขันต่อเอนไซม์แอลฟา-กลูโคซิเดสและเอนไซม์ไลเปส

ภาควิชา	เภสัชเวทและเภสัชพฤกษศาสตร์	ลายมือชื่อนิสิต .....
สาขาวิชา	เภสัชเวท	ลายมือชื่อ อ.ที่ปรึกษาหลัก .....
ปีการศึกษา	2559	ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

5876115233 : MAJOR PHARMACOGNOSY
KEYWORDS: DENDROBIUM FORMOSUM / ALPHA-GLUCOSIDASE INHIBITORS / LIPASE INHIBITORS / BIBENZYLS / DIHYDROPHENANTHRENES

PRACHYAPORN INTHONGKAEW: ALPHA-GLUCOSIDASE AND LIPASE INHIBITORS FROM *DENDROBIUM FORMOSUM*. ADVISOR: ASSOC. PROF. BOONCHOO SRITULARAK, Ph.D., CO-ADVISOR: PROF. KITTISAK LIKHITWITAYAWUID, Ph.D., 185 pp.

Phytochemical investigation of the methanol extract from *Dendrobium formosum* (Orchidaceae) resulted in the isolation of twelve known compounds, which included two phenanthrenes (confusarin, nudol), five dihydrophenanthrenes (hircinol, erianthridin, lusianthridin, coelonin, 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene), a dihydrophenanthrenequinone (5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone), three bibenzyls (gigantol, batatasin III, moscatilin), and a phenylpropanoid (dihydroconiferyl dihydro-*p*-coumarate). These structures were determined by analysis of their NMR and HRS-ESI-MS data. The isolates were evaluated for **α**-glucosidase and lipase inhibitory activities. Among the isolates, 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone showed the highest **α**-glucosidase and lipase inhibitory effects with IC_{50} values of 126.88 μM and 69.45 μM, respectively. An enzyme kinetics study conducted by the Lineweaver-Burk plot method revealed that 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone was a non-competitive inhibitor of **α**-glucosidase and lipase enzymes.

Department:	Pharmacognosy and Pharmaceutical Botany	Student's Signature .....
		Advisor's Signature .....
Field of Study:	Pharmacognosy	Co-Advisor's Signature .....
Academic Year:	2016	

ACKNOWLEDGEMENTS

I wish to express my appreciation to my thesis advisor, Associate Professor Dr. Boonchoo Sritularak and my thesis co-advisor, Professor Dr. Kittisak Likhitwitayawuid, for their valuable advice, endless support, patience and encouragement throughout the course of this study.

I am grateful for all beneficial advice and assistance from the members of my thesis committee and wish to express my thanks to all staff members of the Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University, for assistance and facilities.

I also wish to express my thanks to all staffs of Department of Medical Sciences, Ministry of Public Health, for invaluable advice and support.

Finally, I would like to express my special gratitude to my family and friends for their love, understanding, supporting and encouragement.

CONTENTS

Page

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF SCHEMES

ABBREVIATIONS & SYMBOLS

Acetone-d_6	=	Deuterated acetone
α	=	Alpha
β	=	Beta
br s	=	Broad singlet (for NMR spectra)
°C	=	Degree celsius
CC	=	Column chromatography
$CDCl_3$	=	Deuterated chloroform
CH_2Cl_2	=	Dichloromethane
cm	=	Centimeter
^{13}C-NMR	=	Carbon-13 Nuclear Magnetic Resonance
1-D NMR	=	One-dimensional Nuclear Magnetic Resonance
2-D NMR	=	Two-dimensional Nuclear Magnetic Resonance
d	=	Doublet (for NMR spectra)
dd	=	Doublet of doublets (for NMR spectra)
δ	=	Chemical shift
DEPT	=	Distortionless Enhancement by Polarization Transfer
ESI-MS	=	Electrospray Ionization Mass Spectrometry
EtOAc	=	Ethyl acetate
FCC	=	Flash Column Chromatography
g	=	Gram
GF	=	Gel Filtration
Glc	=	Glucose

HMBC	=	^{1}H-detected Heteronuclear Multiple Bond Correlation
HR-ESI-MS	=	High Resolution Electrospray Ionization Mass Spectroscopy
^{1}H-NMR	=	Proton Nuclear Magnetic Resonance
HSQC	=	^{1}H-detected Heteronuclear Single Quantum Coherence
Hz	=	Hertz
IC_{50}	=	Concentration exhibiting 50% inhibition
IR	=	Infrared
J	=	Coupling constant
Kg	=	Kilogram
L	=	Liter
λmax	=	Wavelength at maximal absorption
$[M]^{+}$	=	Molecular ion
$[M+Na]^{+}$	=	Sodium-adduct molecular ion
$[M-H]^{-}$	=	Pseudomolecular ion
m	=	Multiplet (for NMR spectra)
MeOH	=	Methanol
mg	=	Milligram
µg	=	Microgram
min	=	Minute
mL	=	Milliliter
µL	=	Microliter
µM	=	Micromolar
mm	=	Millimeter

mM	=	Millimolar
MS	=	Mass spectrum
MW	=	Molecular weight
m/z	=	Mass to charge ratio
nm	=	Nanometer
NMR	=	Nuclear Magnetic Resonance
NOESY	=	Nuclear Overhauser Effect Spectroscopy
ppm	=	Part per million
Rha	=	Rhamnose
s	=	Singlet (for NMR spectra)
t	=	Triplet (for NMR spectra)
TLC	=	Thin Layer Chromatography
UV-VIS	=	Ultraviolet and Visible spectrophotometry
VLC	=	Vacuum Liquid Column Chromatography

CHAPTER I
INTRODUCTION

Diabetes mellitus (DM) is a metabolic disease characterized by high blood glucose level (hyperglycemia) which is resulted from a defect in insulin secretion and/or insulin action. Sustained hyperglycemia leads to diabetic complications such as diabetic nephropathy, diabetic retinopathy, diabetic neuropathy, cardiovascular disease and stroke, which causes morbidity and mortality among those affected (American Diabetes Association, 2010)

The two major types of diabetes are type 1 and type 2 diabetes. Type 1 diabetes is characterized by a specific destruction of the pancreatic β cells commonly associated with immune-mediated damage. Type 2 diabetes display a gradual change in glucose homeostasis due to insulin resistance and/or decreased insulin secretion. Besides, there are minor types of diabetes such as gestational diabetes (GDM) and specific types of diabetes due to other causes. GDM is diabetes that is first diagnosed in the second or third trimester of pregnancy that is not clearly either pre-existing type 1 or type 2 diabetes. Specific types of diabetes are due to other causes such as exocrine pancreas disease (such as cystic fibrosis) and drug- or chemical-induced diabetes (such as with glucocorticoid use, in the treatment of HIV/AIDS, or after organ transplantation), monogenic diabetes syndromes (such as neonatal diabetes and maturity-onset diabetes of the young [MODY]) (American Diabetes Association, 2017)

Treatment of diabetic as well as oral antidiabetic drugs can be classified by mechanism of action such as (Grant *et al.*, 2015)

Insulin secretagogues : Sulfonylureas (glibenclamide, gliclazide, glipizide)

: Rapid-acting prandial insulin releasers (repaglinide, nateglinide)

Insulin sensitisers : Biguanides (metformin)

: Thiazolidinediones (pioglitazone, rosiglitazone)

α-Glucosidase inhibitors : Acarbose, voglibose, miglitol

DPP-4 inhibitors : Sitagliptin, linagliptin, Alogliptin

GLP-1 receptor agonists : Exenatide, liraglutide, albiglutide

SGLT2 inhibitors : Canagliflozin, dapagliflozin, empagliflozin

α-Glucosidase is an enzyme that secrete from intestinal chorionic epithelium, which is association for degradation of carbohydrates. This enzyme can delay the carbohydrates digestion and absorption by blocking the activity of glucosidase competitively (Yin *et al.*, 2014).

α-Glucosidase inhibitors derived from medicinal plants such as terpenes, alkaloids, quinines, flavonoids, phenols, phenylpropanoids, steroids and other types of compounds (Yin *et al*., 2014) includes isolated compounds from *Dendrobium spp.* For example *D. loddigesii* (Lu *et al.*, 2014), *D. devonianum* (Sun *et al.*, 2014) and *D. totile* (Limpanit *et al.*, 2016).

An alternative approach to prevent postprandial hyperglycemia involves the use drugs that function as competitive inhibitors of small intestinal brush-border alpha-glucosidases. By inhibiting these enzymes the digestion of nonabsorbable, poly- and oligosaccharides (starch, sucrose) is prevented and thus the formation of absorbable monosaccharides (glucose, fructose) is delayed (De Ruiter, 2003).

Type 2 diabetes can also be caused by progressive β-cells dysfuction from excessive accumulation of lipids in the pancrease, which might damage to pancreatic β-cells and could effect to insulin resistance (Tushuizen *et al.*, 2007).

Pancreatic lipase is the key enzyme responsible for lipid digestion of triglycerides into monoacylglycerides and free fatty acids (Sergent *et al.*, 2012). Interestingly, pancreatic lipase inhibitors can also reduce the lipid absorption and prevent the pancrease β-cells able to produce normal level of insulin (You *et al.*, 2012). However, the pancreatic lipase inhibitors of *Dendrobium* species have not been reported previously. The active form of the enzyme is a non-covalent homodimer which contains multiple functional domains required for normal hydrolytic activity

including a catalytic domain, as well as sites involved in co-factor heparin and lipid binding (Santamarina-Fojo and Brewer, 1994).

Dendrobium is one of the largest and most important genera in the family Orchidaceae with approximately 1,100 species (Lam *et al.*, 2015). There are 80 species in China have been used as a traditional Chinese medicine (Chen *et al.*, 2015). There are several bioactive components of *Dendrobium* plants such as alkaloids, bibenzyls, phenanthrenes, dihydrophenanthrenes, phenanthrenequinones, fluorenones, sesquiterpenoids and polysaccharides (Chen *et al.*, 2014b; Zhao *et al.*, 2016) which showed various biological activities including neuroprotective activity, anticancer activity, anti-angiogenesis activity, immunomodulatory activity, antioxidant, anti-senescence activity, antiplatelet aggregation activity and nitric oxide production inhibitory activity (Lam *et al.*, 2015).

In Thailand, more than 90 species of *Dendrobium* have been identified as follows (Smitinand, 2001):

Dendrobium acerosum Lindl.	**กล้วยไม้มือนาง** Kluai mai mue nang (Chumphon)
D. acinaciforme Roxb.	**เอื้องยอดสร้อย** Ueang yot soi (Northern)
D. albosanguineum Lindl.	**เอื้องตางัว** Ueang ta ngua (Mae Hong Son)
D. aloifolium (Blume) Rchb.f.	**เอื้องมณี** Ueang mani (Bangkok)
D. anosmum Lindl.	**เอื้องสาย** Ueang sai (Chiang Mai, Peninsular)
D. aphyllum (Roxb.) C.E.C.Fisch.	**เอื้องงวงช้าง** Ueang nguang chang (Mae Hong Son)
D. bellatulum Rolfe	**เอื้องแซะภู** Ueng sae phu
D. bicameratum Lindl.	**เอื้องเข็ม** Ueang khem (Northern)
D. bilobulatum Seidenf.	**กล้วยไม้ก้างปลา** Kluai mai kang pla (General)
D. binoculare Rchb.f.	**เอื้องคำสาย** Ueang kham sai (Northern)
D. brymerianum Rchb.f.	**เอื้องคำฝอย** Ueang kham foi (Northern)
D. capillipes Rchb.f.	**เอื้องคำกิ่ว** Ueang kham kio (Lampang, Phrae)

D. cariniferum Rchb.f.	**เอื้องกาจก** Ueang kachok (Chiang Mai)
D. christyanum Rchb.f.	**เอื้องแซะภูกระดึง** Ueang sae phu kradueng (Loei)
D. chrysanthum Lindl.	**เอื้องสายมรกต** Ueang sai morakot (Bangkok)
D. chrysotoxum Lindl.	**เอื้องคำ** Ueang kham (Northern)
D. compactum Rolfe ex Hackett	**เอื้องข้าวตอก** Ueang khao tok (Northern)
D. concinnum Miq.	**หางเปีย** Hang pia (Narathiwat)
D. crepidatum Lindl. & Paxton	**เอื้องสายน้ำเขียว** Ueang sai nam khiao (General)
D. crocatum Hook.f.	**เอื้องนางนวล** Ueang nang nuan (Peninsular)
D. cruentum Rchb.f.	**เอื้องนกแก้ว** Ueang nok kaeo (Bangkok)
D. crumenatum Sw.	**หวายตะมอย** Wai tamoi (Central, Peninsular)
D. crystallinum Rchb.f.	**เอื้องนางฟ่อน** Ueang nang fon (Chiang Mai)
D. cumulatum Lindl.	**เอื้องสายสี่ดอก** Ueang sai si dok (Northern, Southeastern)
D. dantaniense Guillaumin	**เอื้องเข็ม** Ueang khem (Chiang Mai)
D. densiflorum Lindl.	**เอื้องมอนไข่** Ueang mon khai (Northern)
D. devonianum Paxton	**เอื้องเมี่ยง** Ueang miang (Chiang Mai)
D. dickasonii L.O. Williams	**เอื้องเคี้ยะ** Ueang khia (Chiang Mai)
D. discolor Lindl.	**หวายกลัก** Wai klak (Bangkok)
D. dixanthum Rchb.f.	**เอื้องเทียน** Ueang thian (Northern)
D. draconis Rchb.f.	**เอื้องเงิน** Ueang ngoen (Northern)
D. ellipsophyllum Tang & Wang	**เอื้องทอง** Ueang thong (Genaeral)
D. exile Schltr.	**เอื้องเสี้ยน** Ueang sian (General)
D. falconeri Hook.	**เอื้องสายวิสูตร** Ueang sai wisut (Bangkok)
D. farmeri Paxton	**เอื้องมัจฉาณุ** Ueang mat chanu (Bangkok)

D. fimbriatum Hook.	**เอื้องคำน้อย** Ueang kham noi (Chiang Mai)
*D. findlayanu*m Parish & Rchb.f.	**พวงหยก** Phuang yok (Bangkok)
D. formosum Roxb. ex Lindl.	**เอื้องเงินหลวง** Ueang ngoen luang (Chiang Mai)
D. friedericksianum Rchb.f.	**เอื้องเหลืองจันทบูร** Ueang lueang chantabun (Bangkok)
D. fuerstenbergianum Schltr.	**เอื้องแซะภูกระดึง** Ueang sae phukradueng (Loei)
D. gibsonii Lindl.	**เอื้องคำสาย** Ueang kham sai (Northern)
D. grande Hook.f	**เอื้องแผงใบใหญ่** Ueang pheang bai yai (Peninsular)
D. gratiosissimum Rchb.f.	**เอื้องกิ่งดำ** Ueang king dam (Bangkok)
D. gregulus Seidenf.	**เอื้องมะต่อม** Ueang matom (Chiang Mai)
D. griffithianum Lindl.	**เอื้องมัจฉาณุ** Ueang matchanu (Bangkok)
D. harveyanum Rchb.f.	**เอื้องคำฝอย** Ueang kham foi (Chiang Mai)
D. hendersonii Hawkes & Heller	**หวายตะมอยน้อย** Wai tamoi noi (Peninsular)
D. hercoglossum Rchb.f.	**เอื้องดอกมะเขือ** Ueang dok ma kuea (Bangkok)
D. heterocarpum Lindl.	**เอื้องสีตาล** Ueang si tan (Chiang Mai)
D. indivisum (Blume) Miq. var. *indivisum*	**ตานเสี้ยนไม้** Tan sian mai (Chumphon)
D. indivisum (Blume) Miq. var. *pallidum* Seidenf.	**ก้างปลา** Kang pla (General)
D. infundibulum Lindl.	**เอื้องตาเหิน** Ueang ta hoen (General)
D. intricatum Gagnep.	**เอื้องชมพู** Ueang chom phu (Chanthaburi)
D. jenkinsii Wall. ex Lindl.	**เอื้องผึ้งน้อย** Ueang phueng noi(Chiang Mai)
D. kanburiense Seidenf.	**หวายเมืองกาญจน์** Wai muang kan (Kanchanaburi)

D. leonis (Lindl.) Rchb.f.	**เอื้องตะขาบใหญ่** Ueang ta khap yai (General)
D. lindleyi Steud.	**เอื้องผึ้ง** Ueang phueng (Northern)
D. lituiflorum Lindl.	**เอื้องสายม่วง** Ueang sai muang (Bangkok, Northern)
D. moschatum (Buch.-Ham.) Sw.	**เอื้องจำปา** Ueang champa (Northern)
D. nathanielis Rchb.f.	**เกล็ดนิ่ม** Klet nim (Chantaburi)
D. nobile Lindl.	**เอื้องเค้ากิ่ว** Ueang khao kio (Nortern)
D. ochreatum Lindl.	**เอื้องตะขาบ** Ueang ta khap (Chiang Mai)
D. oligophyllum Gagnep.	**ข้าวตอกปราจีน** Khao tok prachin (General)
D. pachyglossum	**เอื้องขนหมู** Ueang khon mu (Mae Hong C.S.P.Parish & Rchb.f Son)
D. pachyphyllum (Kuntze) Bakh.f.	**เอื้องน้อย** Ueang noi (General)
D. palpebrae Lindl.	**เอื้องมัจฉา** Ueang mat cha, **เอื้องมัจฉาณุ** Ueang mat chanu (Bangkok)
D. parcum Rchb.f.	**เอื้องก้านกิ่ว** Ueang kan kio (Bangkok)
D. parishii Rchb.f.	**เอื้องครั่ง** Ueang khrang (Northern)
D. pendulum Roxb.	**เอื้องไม้เท้าฤาษี** Ueang mai thao ruesi (Bangkok, Chiang Mai)
D. pensile Ridl.	**หวาย** Wai (Narathiwat)
D. porphyrophyllum Guillaumin	**เอื้องลิ้น** Ueang lin (Lampang)
D. primulinum Lindl.	**เอื้องสายประสาท** Ueang sai prasat (Bangkok)
D. pulchellum Roxb. ex Lindl.	**เอื้องคำตาควาย** Ueang kham ta khwai (Mae Hong Son)
D. pychnostachyum Lindl.	**เศวตสอดสี** Sawet sot si (Chiang Mai)

D. salaccense (Blume) Lindl.	**เอื้องใบไผ่** Ueang bai phai (Chiang Mai)
D. scabrilingue Lindl.	**เอื้องแซะ** Ueang sae (Mae Hong Son)
D. secundum (Blume) Lindl.	**เอื้องแปรงสีฟัน** Ueang preang si fan (Bangkok)
D. seidenfadenii Rchb.f.	**เอื้องเกี๊ยะ** Ueang kia (Chiang Mai)
D. senile Parish & Rchb.f.	**เอื้องชะนี** Ueang chani (Bangkok)
D. signatum Rchb.f.	**เอื้องเค้ากิ่ว** Ueang khao kio (Chiang Mai)
D. stuposum Lindl.	**เอื้องสาย** Ueang sai (Chiang Mai)
D. sulcatum Lindl.	**เอื้องจำปาน่าน** Ueang champa nan (Bangkok)
D. superbiens Rchb.f.	**หวายคิง** Wai khing (Bangkok)
D. sutepense Rolfe ex Downie	**เอื้องมะลิ** Ueang mali (Chiang Mai)
D. terminale Parish & Rchb.f	**เอื้องแผงโสภา** Ueang phaeng sopha (Peninsular)
D. thyrsiflorum Rchb.f	**เอื้องมอนไข่ใบมน** Ueang mon khai bai mon (Northern)
D. tortile Lindl.	**เอื้องไม้ตึง** Ueang mai tueng (Mae Hong Son)
D. trigonopus Rchb.f.	**เอื้องคำเหลี่ยม** Ueang kham liam (Chiang Mai)
D. trinervium Ridl.	**เทียนลิง** Thian ling (Chumphon)
D. unicum Seidenf.	**เอื้องครั่งแสด** Ueang krang saet (General)
D. uniflorum Griff.	**เอื้องทอง** Ueang thong (Pattani)
D. venustum Teijsm. & Binn	**ข้าวเหนียวลิง** Khao niao ling (Central)
D. villosulum Lindl.	**กล้วยหญ้านา** Kluai ya na (Bangkok)
D. virgineum Rchb.f.	**เอื้องเงินวิลาศ** Ueang ngoen wilat (Northern)
D. wardianum Warner	**เอื้องมณีไตรรงค์** Ueang mani trai rong (Northern)
D. wattii (Hook.f.) Rchb.f.	**เอื้องแซะ** Ueang sae (Northern)
D. ypsilon Seidenf.	**เอื้องแบนปากตัด** Ueang baen pak tat (General)

D. formosum Roxb. ex Lindl. is known in Thai as “Ueang ngoen luang” (เอื้องเงินหลวง). It is a rare orchid with thin or fleshy stems. It produces large flowers of white sepals and petals, white lip with yellow blotch and sepals in the size 10 cm. This

species is distributed throughout Thailand. The flowering period is in October to December (Smitinand, 2001; Vaddhanaphuti, 2005).

Even though *D. formosum* Roxb. ex Lindl. has been reported of antitumor activity from ethanol extract (IC_{50} = 350 µg/mL) (Prasad and Koch, 2014) but this plant has not been phytochemically studied. In a preliminary study, evaluations for α-glucosidase and lipase inhibitory activities were conducted on a methanol crude extract *of D. formosum.* This extract at 100 µg/mL exhibited 95.64% α-glucosidase and 98.97% lipase inhibitory activities. This study attempts to investigate the chemical compositions and α-glucosidase and lipase inhibitory activities of *D. formosum*, which might be useful for the developement anti-diabetic and anti-obesity drugs.

The major objectives of this study are as follows.

1. To isolate and purify the chemical constituents from *Dendrobium formosum*.
2. To characterize the chemical structures of the isolated compounds.
3. To investigate the α-glucosidase and lipase enzyme inhibitory activities of the isolated compounds.

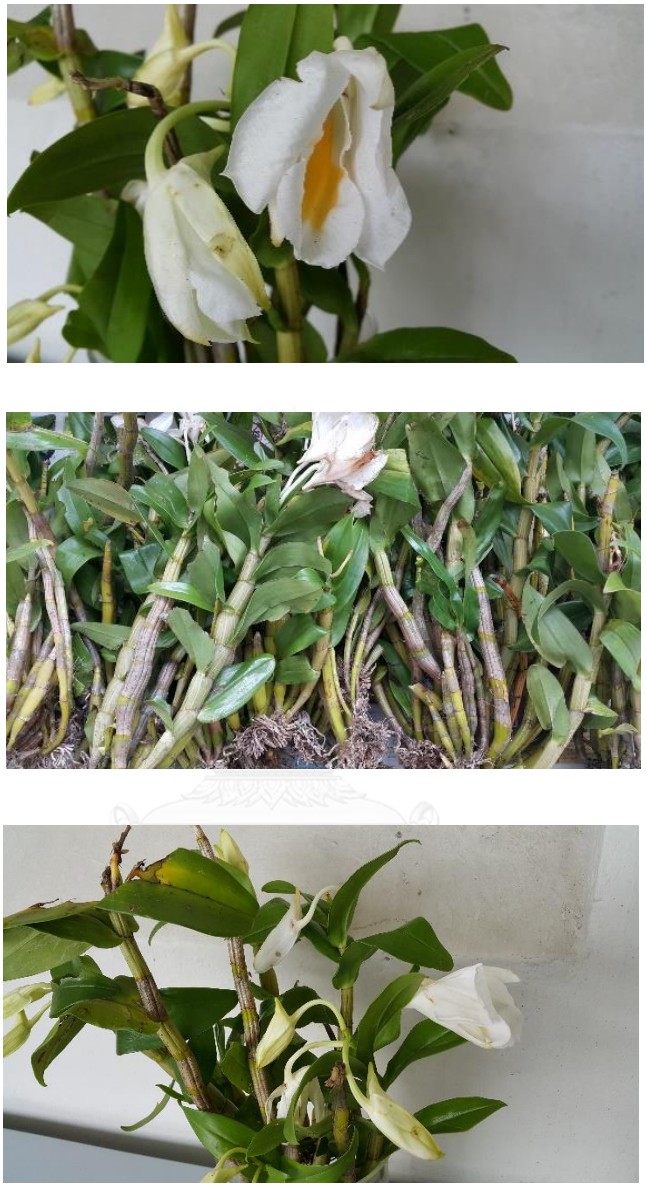


Figure 1 *Dendrobium formosum Roxb. ex Lindl.*

CHAPTER II
HISTORICAL

1. Chemical constituents of *Dendrobium*

Plants of the genus *Dendrobium* have been reported on chemical constituents of various classes, for example, bibenzyls and derivatives, flavonoids, terpenoids and miscellaneous compounds (**Figures 2-5**).

Bibenzyls and derivatives, as shown in **Table 1**, are member of stilbenes. Stilbenoids derive from cinnamic acid (via the shikimic pathway) and three acetate units from malonyl coenzyme A (Gorham, 1989). The first part of the pathway is common to stilbenoids and flavonoids. They diverge at the point of a styryl-3,5,7-triketoheptanoic acid : an aldol condensation gives a stilbene 2-carboxylic acid generally unstable and intermediate to several structures such as stilbenoids (bibenzyls, bis-bibenzyls, stilbenes, phenanthrenes, 9,10-dihydrophenanthrenes); an acylation produces a chalcone, which is subsequently modified to give flavonoids (Orsini and Verotta, 1999) as shown in **Table 2**.

Terpenoids, as shown in **Table 3**, can occur via two pathways, the mevalonate pathway and mevalonate-independent pathway, through deoxyxylulose phosphate. They are derived from C5 isoprene units. Characteristic structures have carbon skeletons represented by (C5)n, which are called hemiterpenes (C5), monoterpenes (C10), sesquiterpenes (C15), diterpenes (C20), sesterterpenes (C25), triterpenes (C30) and tetraterpenes (C40) (Dewick, 2002).

Miscellaneous compounds including aliphatic compounds, benzoic acid derivatives, phenylpropanoids, fluorenones, coumarins, lignans and neolignans, which are several minor compounds are grouped together in **Table 4**.

Table 1 Distribution of bibenzyls and derivatives in the genus *Dendrobium*

Compounds	**Plant**	**Plant part**	**Reference**
Dendrocandin A [**1**]	*D. candidum*	Stem	Li *et al.*, 2008
Dendrocandin B [**2**]	*D. candidum*	Stem	Li *et al.*, 2008
	D. signatum	Whole plant	Mittraphab *et al.*, 2016
Dendrocandin C [**3**]	*D. candidum*	Stem	Li *et al.*, 2009a
Dendrocandin D [**4**]	*D. candidum*	Stem	Li *et al.*, 2009a
Dendrocandin E [**5**]	*D. candidum*	Stem	Li *et al.*, 2009a
Dendrocandin F [**6**]	*D. candidum*	Stem	Li *et al.*, 2009b
Dendrocandin G [**7**]	*D. candidum*	Stem	Li *et al.*, 2009b
Dendrocandin H [**8**]	*D. candidum*	Stem	Li *et al.*, 2009b
Dendrosinen A [**9**]	*D. sinense*	Whole plant	Chen *et al.*, 2014
Dendrosinen B [**10**]	*D. sinense*	Whole plant	Chen *et al.*, 2014
Dendrosinen C [**11**]	*D. sinense*	Whole plant	Chen *et al.*, 2014
Dendrosinen D [**12**]	*D. sinense*	Whole plant	Chen *et al.*, 2014
Aloifol I [**13**]	*D. longicornu*	Stem	Hu *et al.*, 2008a
Amoenylin [**14**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
Batatasin [**15**]	*D. longicornu*	Stem	Hu *et al.*, 2008a
	D. plicatile	Stem	Yamaki and Honda, 1996

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Batatasin III [**16**]	*D. aphyllum*	Whole plant Stem	Chen *et al.*, 2008 Yang *et al.*, 2015
	D. cariniferum	Stem	Chen *et al.*, 2008
	D. chrysotoxum	Whole plant	Li *et al.*, 2009c
	D. draconis	Stem	Sritularak *et al.*, 2011a
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. loddigesii	Stem	Ito *et al.*, 2010
	D. venustum	Whole plant	Sukphan *et al.*, 2014
Brittonin A [**17**]	*D. secundum*	Stem	Sritularak *et al.*, 2011b
Chrysotobibenzyl [**18**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.*, 2006a
	D. capillipes	Stem	Phechrmeekha *et al.*, 2012
	D. chrysanthum	Stem	Yang *et al.*, 2006b
	D. chryseum	Stem	Ma *et al.*, 1998
	D. chrysotoxum	Stem	Hu *et al.*, 2012
	D. nobile	Stem	Zhang *et al.*, 2007a
	D. pulchellum	Stem	Chanvorachote *et al.*, 2013

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
Chrysotoxine [**19**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al*., 2006a
	D. chrysanthum	Stem	Yang *et al*., 2006b
	D. chryseum	Stem	Ma *et al.*, 1998
	D. nobile	Stem	Zhang *et al*., 2007a
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
Crepidatin [**20**]	*D. aurantiacum var. denneanum*	Whole plant	Liu *et al.*, 2009a
	D. capillipes	Stem	Phechrmeekha *et al*., 2012
	D. chrysanthum	Stem	Yang *et al*., 2006b
	D. crepidatum	Whole plant	Majumder and Chatterjee, 1989
	D. nobile	Stem	Zhang *et al*., 2007a
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
Cumulatin [**21**]	*D. cumulatum*	Whole plant	Majumder and Pal, 1993
Dendrobin A [**22**]	*D. nobile*	Stem	Wang *et al.*, 1985; Ye and Zhao, 2002a

Table 1 (continued)

Compounds	Plant	Plant part	Reference
3,3′-Dihydroxy-4,5-dimethoxybibenzyl [**23**]	*D. williamsonii*	Whole plant	Rungwichaniwat *et al*., 2014
3,4′-Dihydroxy-5-methoxybibenzyl [**24**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
3,4′-Dihydroxy-5,5′-dimethoxydihydro stilbene [**25**]	*D. nobile*	Stem	Hwang *et al.*, 2010
4,5-Dihydroxy-3,3′-dimethoxybibenzyl [**26**]	*D. nobile*	Stem	Ye and Zhao, 2002a
Erianin [**27**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Gigantol [**28**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008
	D. aurantiacum var. denneanum	Whole plant	Liu *et al.*, 2009a
	D. brymerianum	Whole plant	Klongkumnuankarn *et al*., 2015
	D. densiflorum	Stem	Fan *et al*., 2001
	D. devonianum	Whole plant	Sun *et al*., 2014
	D. draconis	Stem	Sritularak *et al*., 2011a
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Gigantol [**28**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
	D. longicornu	Stem	Hu *et al*., 2008a
	D. nobile	Stem	Zhang *et al*., 2007a
	D. polyanthum	Stem	Hu *et al*., 2009
	D. trigonopus	Stem	Hu *et al*., 2008b
	D. venustum	Whole plant	Sukphan *et al*., 2014
4-Hydroxy-3,5,3′-trimethoxybibenzyl [**29**]	*D. nobile*	Stem	Ye and Zhao, 2002a
5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl [**30**]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Isoamoenylin [**31**]	*D. amoenum*	Whole plant	Majumder *et al*., 1999
Moscatilin [**32**]	*D. amoenum*	Whole plant	Majumder *et al*., 1999
	D. aurantiacum var. *denneanum*	Stem	Yang *et al*., 2006a
	D. brymerianum	Whole plant	Klongkumnuankarn *et al*., 2015
	D. chrysanthum	Stem	Yang *et al*., 2006b

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Moscatilin [**32**]	*D. densiflorum*	Stem	Fan *et al*., 2001
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al*., 2014
	D. gratiosissimum	Stem	Zhang *et al*., 2008a
	D. loddigesii	Whole plant	Chen *et al*., 1994; Ito *et al*., 2010
	D. longicornu	Stem	Hu *et al*., 2008a
	D. moscatum	Whole plant	Majumder and Sen, 1987
	D. nobile	Stem	Miyazawa *et al*., 1999; Yang *et al*., 2007
	D. polyanthum	Stem	Hu *et al*., 2009
	D. pulchellum	Stem	Chanvorachote *et al*., 2013
	D. secundum	Stem	Sritularak *et al*., 2011b
3,3′,4-Trihydroxy bibenzyl [**33**]	*D. longicornu*	Stem	Hu *et al*., 2008a
3,3′,5-Trihydroxy bibenzyl [**34**]	*D. caniniferum*	Whole plant	Liu *et al*., 2009b

Table 1 (continued)

Compounds	Plant	Plant part	Reference
3,5,4′-Trihydroxy bibenzyl [**35**]	*D. gratiosissimum*	Stem	Zhang *et al*., 2008a
4,5,4′-Trihydroxy-3,3′-dimethoxy bibenzyl [**36**]	*D. secundum*	Stem	Sritularak *et al*., 2011b
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al*., 2014
Tristin [**37**]	*D. aphyllum*	Stem	Yang *et al*., 2015
	D. chrysotoxum	Stem	Hu *et al*., 2012
	D. densiflorum	Stem	Fan *et al*., 2001
	D. gratiosissimum	Stem	Zhang *et al*., 2008a
	D. longicornu	Stem	Hu *et al*., 2008a
	D. trigonopus	Stem	Hu *et al*., 2008b
Dendromoniliside E [**38**]	*D. nobile*	Stem	Miyazawa *et al*., 1999
Dendrophenol [**39**]	*D. candidum*	Stem	Li *et al*., 2008
3,4-Dihydroxy-5,4′-dimethoxybibenzyl [**40**]	*D. candidum*	Stem	Li *et al*., 2008
	D. signatum	Whole plant	Mittraphab *et al*., 2016
	D. tortile	Whole plant	Limpanit *et al*., 2016

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
4,4′-Dihydroxy-3,5-dimethoxybibenzyl [**41**]	*D. candidum*	Stem	Li *et al*., 2008;
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al*., 2014
Loddigesiinol C [**42**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
3-O-Methylgigantol [**43**]	*D. candidum*	Stem	Li *et al*., 2008
	D. plicatile	Stem	Yamaki and Honda, 1996
Dendrocandin I [**44**]	*D. candidum*	Stem	Li *et al*., 2009b
	D. signatum	Whole plant	Mittraphab *et al*., 2016
Densiflorol A [**45**]	*D. densiflorum*	Stem	Fan *et al*., 2001
Longicornuol A [**46**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Trigonopol A [**47**]	*D. trigonopus*	Stem	Hu *et al*., 2008b
Trigonopol B [**48**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
	D. trigonopus	Stem	Hu *et al*., 2008b
Crepidatuol A [**49**]	*D. crepidatum*	Stem	Li *et al*., 2013
Crepidatuol B [**50**]	*D. crepidatum*	Stem	Li *et al*., 2013
Loddigesiinol D [**51**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
Dencryol A [**52**]	*D. crystallinum*	Stem	Wang *et al*., 2009
Dencryol B [**53**]	*D. crystallinum*	Stem	Wang *et al*., 2009
Dengraol A [**54**]	*D. gratiosissimum*	Stem	Zhang *et al*., 2008a
Dengraol B [**55**]	*D. gratiosissimum*	Stem	Zhang *et al*., 2008a

Table 1 (continued)

Compounds	Plant	Plant part	Reference
4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxy phenol [**56**]	*D. longicornu*	Stem	Hu *et al.*, 2008a
Nobilin A [**57**]	*D. nobile*	Stem	Zhang *et al.*, 2006b
Nobilin B [**58**]	*D. nobile*	Stem	Zhang *et al.*, 2006b
Nobilin C [**59**]	*D. nobile*	Stem	Zhang *et al.*, 2006b
Nobilin D [**60**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Nobilin E [**61**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Dendrofalconerol A [**62**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
	D. signatum	Whole plant	Mittraphab *et al.*, 2016
	D. tortile	Whole plant	Limpanit *et al.*, 2016
Dendrofalconerol B [**63**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
Dendrosignatol [**64**]	*D. signatum*	Whole plant	Mittraphab *et al.*, 2016
2,2′-Dihydroxy-3,3′,4,4′,7,7-hexamethoxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene [**65**]	*D. nobile*	Stem	Yang *et al.*, 2007

Table 1 (continued)

Compounds	Plant	Plant part	Reference
2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9′,10,10′-tetrahydro-1,1′-biphenanthrene [**66**]	*D. plicatile*	Stem	Yamaki and Honda, 1996
Flavanthrin [**67**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008
Phoyunnanin C [**68**]	*D. venustum*	Whole plant	Sukphan *et al.*, 2014
Phoyunnanin E [**69**]	*D. venustum*	Whole plant	Sukphan *et al.*, 2014
(*S*)-3,4,α-trihydroxy-5,4′ dimethoxybibenzyl [**70**]	*D. candidum*	Stem	Li *et al.*, 2015
Amoenumin [**71**]	*D. amoenum*	Whole plant	Veerraju *et al.*, 1989
Crystalltone [**72**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
	D. crystallinum	Stem	Wang *et al.*, 2009
Chrysotoxol A [**73**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Chrysotoxol B [**74**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Confusarin [**75**]	*D. chryseum*	Stem	Ma *et al.*, 1998
	D. chrysotoxum	Stem	Hu *et al.*, 2012
	D. nobile	Stem	Zhang *et al.*, 2008b

Table 1 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
2,6-Dihydroxy-1,5,7-trimethoxyphenanthrene [**76**]	*D. densiflorum*	Stem	Fan *et al*., 2001
Dendrochrysanene [**77**]	*D. chrysanthum*	Stem	Yang *et al*., 2006b
Bulbophyllanthrin [**78**]	*D. nobile*	Stem	Yang *et al*., 2007
Denthyrsinin [**79**]	*D. thyrsiforum*	Stem	Zhang *et al.*, 2005
5-Hydroxy-2,4-dimethoxy phenanthrene [**80**]	*D. loddigesii*	Whole plant	Ito *et al*., 2010
3-Hydroxy-2,4,7-trimethoxyphenanthrene [**81**]	*D. nobile*	Stem	Yang *et al.*, 2007
Cypripedin [**82**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
Densiflorol B [**83**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
	D. venustum	Whole plant	Sukphan *et al.*, 2014
Denbinobin [**84**]	*D. moniliforme*	Stem	Lin *et al.*, 2001
	D. nobile	Stem	Yang *et al.*, 2007
Fimbriatone [**85**]	*D. nobile*	Stem	Zhang *et al.*, 2008b
	D. pulchellum	Stem	Chanvorachote *et al.*, 2013
Loddigesiinol B [**86**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010

Table 1 (continued)

Compounds	Plant	Plant part	Reference
Dendronone [**87**]	*D. chrysanthum*	Stem	Yang *et al.*, 2006b
	D. longicornu	Stem	Hu *et al.*, 2008a
Ephemeranthoquinone [**88**]	*D. plicatile*	Stem	Yamaki and Honda, 1996
5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**]	*D. draconis*	Stem	Sritularak *et al.*, 2011a
Moniliformin [**90**]	*D. moniliforme*	Stem	Lin *et al.*, 2001
Moscatin [**91**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008
	D. chrysanthum	Stem	Yang *et al.*, 2006b
	D. chrysotoxum	Whole plant	Li *et al.*, 2009c
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. polyanthum	Stem	Hu *et al.*, 2009
Coelonin [**92**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008
	D. nobile	Stem	Yang *et al.*, 2007
9,10-Dihydromoscatin [**93**]	*D. polyanthum*	Stem	Hu *et al.*, 2009
9,10-Dihydrophenanthrene-2,4,7-triol [**94**]	*D. polyanthum*	Stem	Hu *et al.*, 2009

Table 1 (continued)

Compounds	Plant	Plant part	Reference
4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [**95**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al.*, 2014
	D. sinense	Whole plant	Chen *et al.*, 2013
4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene [**96**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene [**97**]	*D. nobile*	Stem	Ye and Zhao, 2002a
4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene [**98**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Lusianthridin [**99**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al.*, 2015
	D. plicatile	Stem	Yamaki and Honda, 1996
	D. venustum	Whole plant	Sukphan *et al.*, 2014

Table 1 (continued)

Compounds	Plant	Plant part	Reference
2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene [**100**]	*D. densiflorum*	Stem	Yang *et al.*, 2007
2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**101**]	*D. nobile*	Stem	Fan *et al.*, 2001
4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene [**102**]	*D. rotundatum*	Whole plant	Majumder and Pal, 1992
Ephemeranthol A [**103**]	*D. nobile*	Stem	Yang *et al.*, 2007; Hwang *et al.*, 2010
Ephemeranthol C [**104**]	*D. nobile*	Stem	Yang *et al.*, 2007; Hwang et al., 2010
Erianthridin [**105**]	*D. nobile*	Stem	Hwang *et al.*, 2010
	D. plicatile	Stem	Yamaki and Honda, 1996
Flavanthridin [**106**]	*D. nobile*	Stem	Hwang *et al.*, 2010
Hircinol [**107**]	*D. aphyllum*	Stem	Yang *et al.*, 2015
	D. draconis	Stem	Sritularak *et al.*, 2011a
3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene [**108**]	*D. nobile*	Stem	Yang *et al.*, 2007

Table 1 (continued)

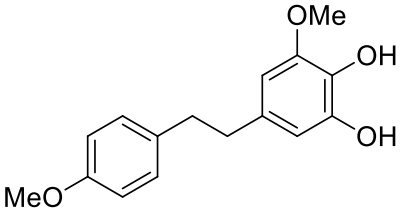
Compounds	**Plant**	**Plant part**	**Reference**
2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene [**109**]	*D. nobile*	Stem	Yang *et al*., 2007
7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol [**110**]	*D. draconis*	Stem	Sritularak *et al*., 2011a
2,5,7-Trimethoxy-4-methoxy-9,10-dihydrophenanthrene [**111**]	*D. longicornu*	Stem	Hu *et al.*, 2008
Plicatol C [**112**]	*D. plicatile*	Stem	Honda and Yamaki, 2000
Rotundatin [**113**]	*D. rotundatum*	Whole plant	Majumder and Pal, 1992
2,5-Dihydroxy-3,4 dimethoxyphenanthrene [**114**]	*D. nobile*	Stem	Yang *et al.*, 2007
2,5-Dihydroxy-4,9-dimethoxyphenanthrene [**115**]	*D. nobile*	Stem	Zhang *et al.*, 2008b
2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene [**116**]	*D. nobile*	Stem	Yang *et al.*, 2007
Epheranthol B [**117**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
	D. plicatile	Stem	Yamaki and Honda, 1996

Table 1 (continued)

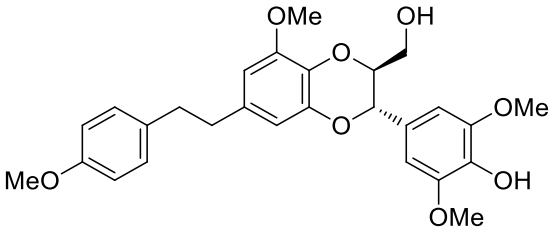
Compounds	**Plant**	**Plant part**	**Reference**
Fimbriol B [**118**]	*D. nobile*	Stem	Yang *et al*., 2007; Hwang *et al.*, 2010
Flavanthrinin [**119**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al*., 2015
	D. nobile	Stem	Zhang *et al.*, 2008b
	D. venustum	Whole plant	Sukphan *et al.*, 2014
Loddigesiinol A [**120**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Nudol [**121**]	*D. nobile*	Stem	Yang *et al.*, 2007
	D. rotundatum	Whole plant	Majumder and Pal, 1992
Plicatol A [**122**]	*D. nobile*	Stem	Yang *et al*., 2007
	D. plicatile	Stem	Honda and Yamaki, 2000
Plicatol B [**123**]	*D. plicatile*	Stem	Honda and Yamaki, 2000
2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene [**124**]	*D. nobile*	Stem	Yang *et al.*, 2007
3,4,8-Trimethoxy phenanthrene-2,5-diol [**125**]	*D. nobile*	Stem	Hwang *et al.*, 2010
Aphyllone [**126**]	*D. nobile*	Stem	Hwang *et al.*, 2010

Table 1 (continued)

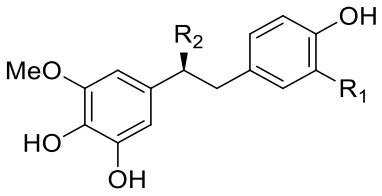
Compounds	Plant	Plant part	Reference
(*S*)-2,4,5,9-tetrahydroxy-9,10-dihydrophenanthrene [**127**]	*D. fimbriatum*	Stem	Xu *et al.*, 2014
1,5,7-trimethoxyphenanthren-2-ol [**128**]	*D. nobile*	Stem	Kim *et al.*, 2015
9,10-dihydrophenanthrene,1,5-dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**129**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2016
2,4,5,9*S*-tetrahydroxy-9,10-dihydrophenanthrene 4-O-β-D-glucopyranoside [**130**]	*D. primulinum*	Whole plant	Ye *et al.*, 2016
Loddigesiinol G [**131**]	*D. loddigesii*	Stem	Lu *et al*., 2014
Loddigesiinol H [**132**]	*D. loddigesii*	Stem	Lu *et al*., 2014
Loddigesiinol I [**133**]	*D. loddigesii*	Stem	Lu *et al*., 2014
Loddigesiinol J [**134**]	*D. loddigesii*	Stem	Lu *et al*., 2014



[**1**] Dendrocandin A



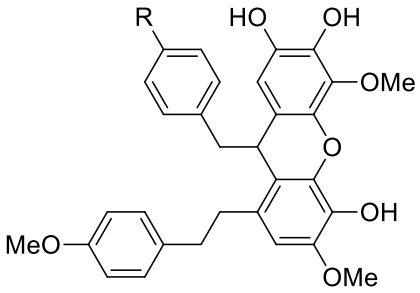
[**2**] Dendrocandin B



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

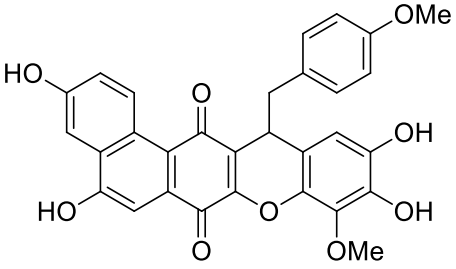
[**4**] Dendrocandin D: R_1 = H, R_2 = OCH_2CH_3

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



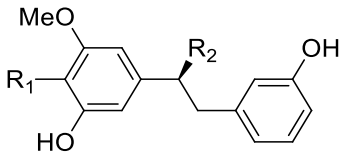
[**6**] Dendrocandin F: R = OMe

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

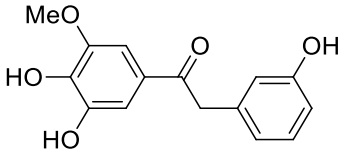


[**8**] Dendrocandin H

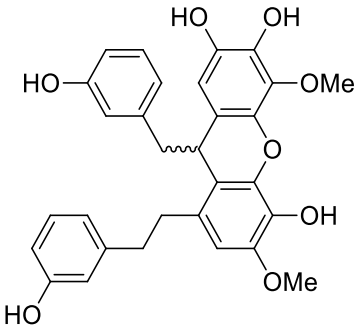
Figure 2 Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species



	R_1	R_2
[**9**] Dendrosinen A	OCH_3	OH
[**10**] Dendrosinen B	OH	H

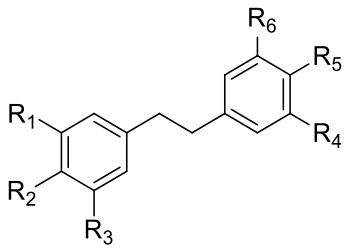


[**11**] Dendrosinen C



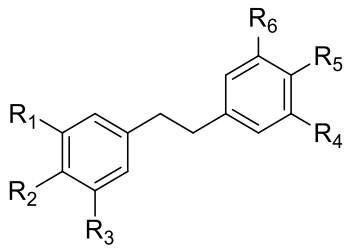
[**12**] Dendrosinen D

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



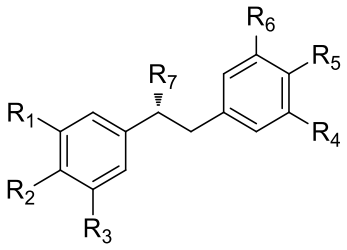
	R_1	R_2	R_3	R_4	R_5	R_6
[**13**] Aloifol I	OMe	OH	OMe	OH	H	H
[**14**] Amoenylin	OMe	OH	OMe	H	OMe	H
[**15**] Batatasin	OMe	H	H	OH	H	OH
[**16**] Batatasin III	OH	H	OMe	H	H	OH
[**17**] Brittonin A	OMe	OMe	OMe	OMe	OMe	OMe
[**18**] Chrysotobibenzyl	OMe	OMe	OMe	OMe	OMe	H
[**19**] Chrysotoxine	OMe	OH	OMe	OMe	OMe	H
[**20**] Crepidatin	OMe	OMe	OMe	OMe	OH	H
[**21**] Cumulatin	OMe	OMe	OH	OH	OMe	OMe
[**22**] Dendrobin A	OH	OH	OMe	H	H	OMe
[**23**] 3,3′-Dihydroxy-4,5-dimethoxybibenzyl	OMe	OMe	OH	H	H	OH
[**24**] 3,4′-Dihydroxy-5-methoxybibenzyl	OH	H	OMe	H	OH	H
[**25**] 3,4′-Dihydroxy-5,5′-dimethoxydihydrostilbene	OH	H	OMe	OMe	OH	H

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

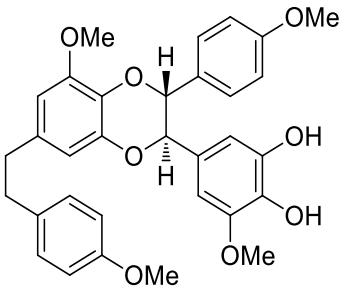


	R_1	R_2	R_3	R_4	R_5	R_6
[**26**] 4,5-Dihydroxy-3,3′-dimethoxybibenzyl (Dendrobin A)	OMe	OH	OH	H	H	OMe
[**27**] Erianin	OMe	OMe	OMe	H	OMe	OH
[**28**] Gigantol	OMe	H	H	H	OH	OMe
[**29**] 4-Hydroxy-3,5,3′ trimethoxybibenzyl	OMe	OH	OMe	H	H	OMe
[**30**] 5-Hydroxy-3,4,3′,4′,5′ pentamethoxybibenzyl	OMe	OMe	OH	OMe	OMe	OMe
[**31**] Isoamoenylin	OMe	OMe	OMe	H	H	OH
[**32**] Moscatilin	OMe	OH	OMe	H	OH	OMe
[**33**] 3,3′,4-Trihydroxybibenzyl	OH	OH	H	H	H	OH
[**34**] 3,3′,5-Trihydroxybibenzyl	OH	H	OH	H	H	OH
[**35**] 3,5,4′-Trihydroxybibenzyl	OH	H	OH	H	OH	H
[**36**] 4,5,4′-Trihydroxy-3-3′-dimethoxybibenzyl	OMe	OH	OH	H	OH	OMe
[**37**] Tristin	OH	H	OH	H	OH	OMe
[**38**] Dendromoniliside E	OGlc	OGlc	OMe	H	OMe	H

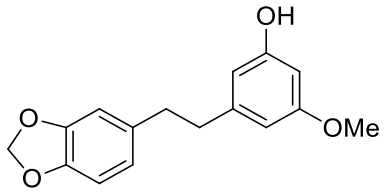
Figure 2 Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**39**] Dendrophenol	OMe	OH	OMe	OH	OH	H	H
[**40**] 3,4-Dihydroxy-5,4′-dimethoxybibenzyl	OH	OH	OMe	H	OMe	H	H
[**41**] 4,4′-Dihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	H	OH	H	H
[**42**] Loddigesiinol C	OMe	OH	OMe	H	OH	OMe	OMe
[**43**] 3-*O*-Methylgigantol	OMe	H	OH	OMe	OMe	H	H

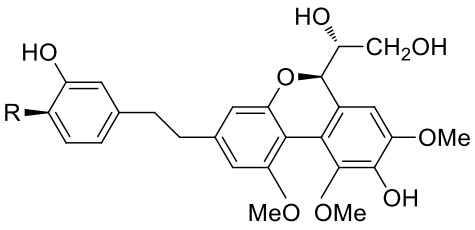


[**44**] Dendrocandin I



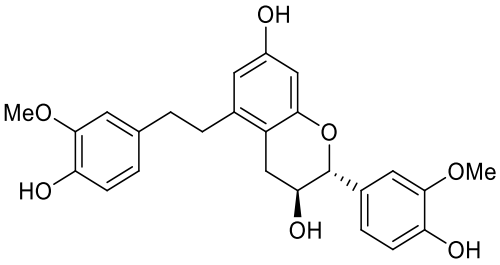
[**45**] Densiflorol A

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

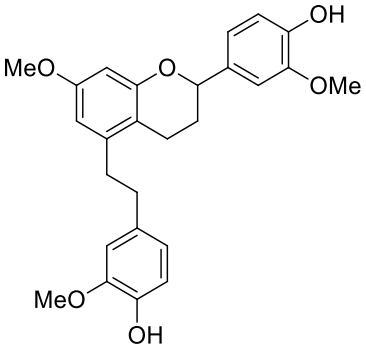


[**46**] Longicornuol A: R = H

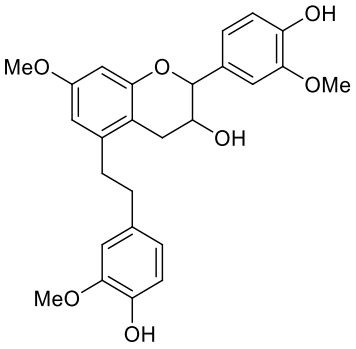
[**47**] Trigonopol A: R = OMe



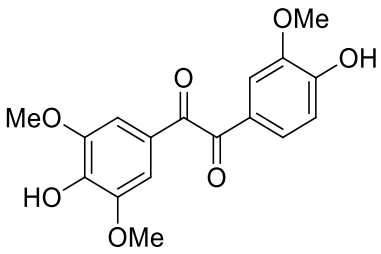
[**48**] Trigonopol B



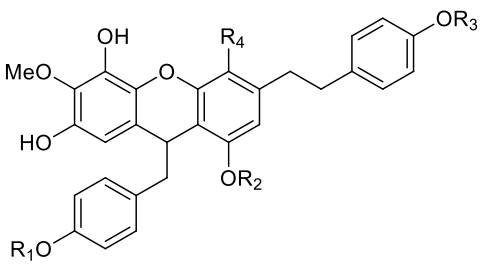
[**49**] Crepidatuol A



[**50**] Crepidatuol B



[**51**] Loddigesiinol D

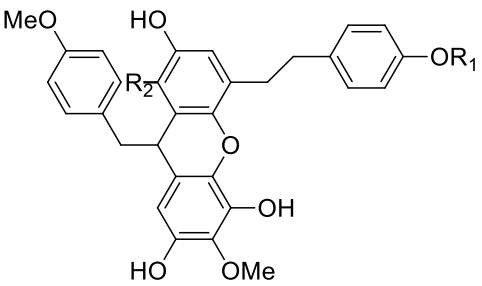


[**52**] Dencryol A:

R_1 = Me, R_2 = R_3 = R_4 = H

[**53**] Dencryol B:

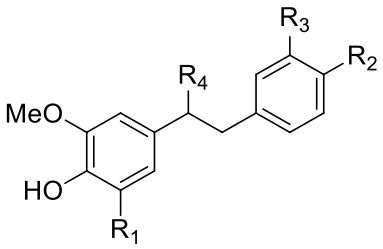
R_1 = H, R_2 = R_3 = Me, R_4 = OH



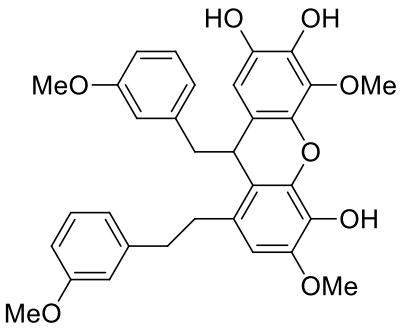
[**54**] Dengraol A: R_1 = R_2 = H

[**55**] Dengraol B: R_1 = Me, R_2 = OMe

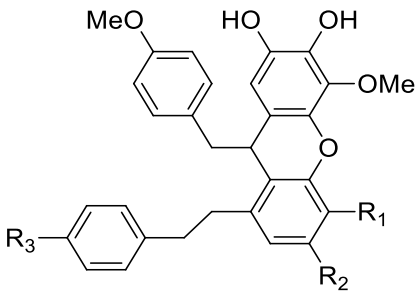
Figure 2 Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species



	R_1	R_2	R_3	R_4
[**56**] 4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol	OMe	H	OH	OMe
[**57**] Nobilin A	OH	H	OMe	OMe
[**58**] Nobilin B	OMe	OH	OMe	OMe
[**59**] Nobilin C	OMe	OMe	OMe	OMe
[**60**] Nobilin D	OMe	OH	OMe	OH



[**61**] Nobilin E

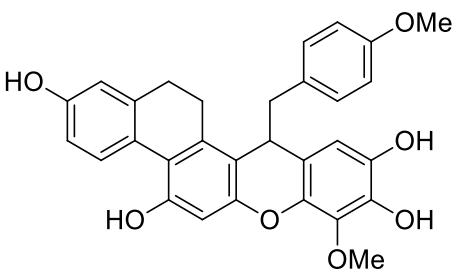


[**62**] Dendrofalconerol A:

R_1 = OH, R_2 = R_3 = OMe

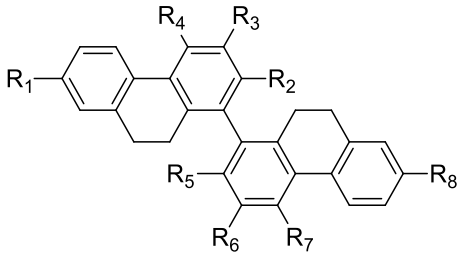
[**63**] Dendrofalconerol B:

R_1 = H, R_2 = R_3 = OH

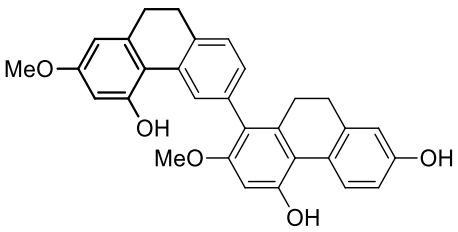


[**64**] Dendrosignatol

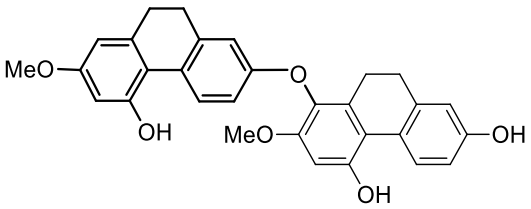
Figure 2 Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
[**65**] 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
[**66**] 2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OH	OMe	H	OH	OMe	H	OH	OH
[**67**] Flavanthrin	OH	OH	H	OMe	OH	H	OMe	OH

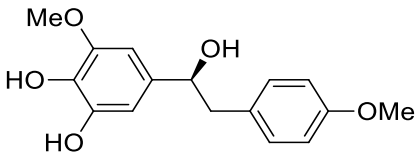


[**68**] Phoyunnanin C

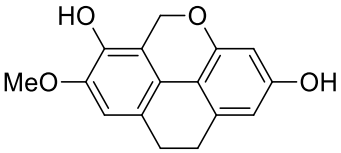


[**69**] Phoyunnanin E

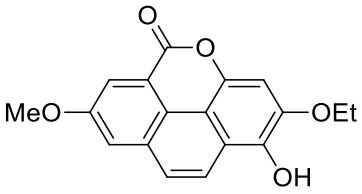
Figure 2 Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



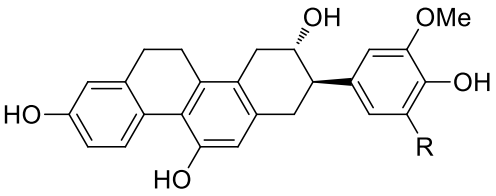
[**70**] (*S*)-3,4,α-trihydroxy-5,4′-dimethoxybibenzyl



[**71**] Amoenumin

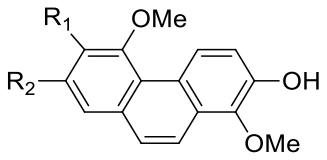


[**72**] Crystalltone



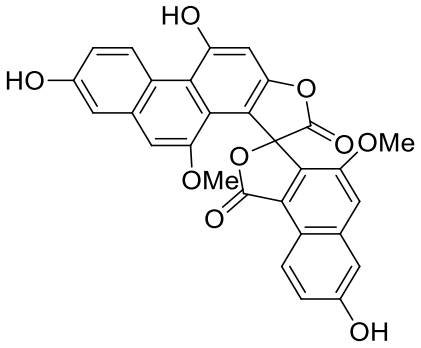
[**73**] Chrysotoxol A: R = H

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



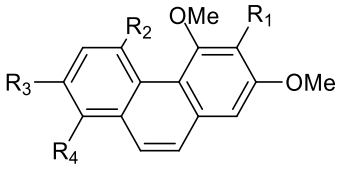
[**75**] Confusarin: R_1 = OMe, R_2 = OH

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

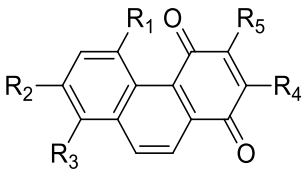


[**77**] Dendrochrysanene

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

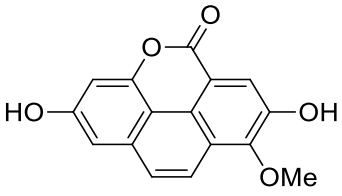


	R_1	R_2	R_3	R_4
[**78**] Bulbophyllanthrin	OH	OH	H	H
[**79**] Denthyrsinin	OH	H	OH	OMe
[**80**] 5-Hydroxy-2,4-dimethoxy phenanthrene	H	OH	H	H
[**81**] 3-Hydroxy-2,4,7-trimethoxy phenanthrene	OH	H	OMe	H

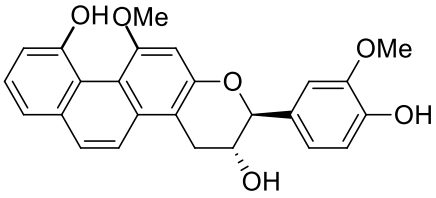


	R_1	R_2	R_3	R_4	R_5
[**82**] Cypripedin	H	OH	OMe	OMe	H
[**83**] Densiflorol B	H	OH	H	OMe	H
[**84**] Denbinobin	OH	OMe	H	H	OMe

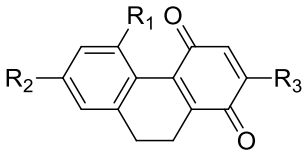
Figure 2 Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



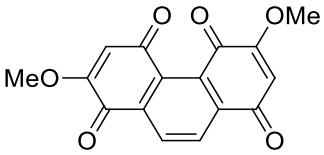
[**85**] Fimbriatone



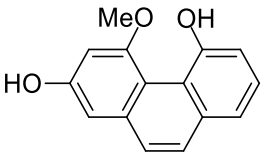
[**86**] Loddigesiinol B



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

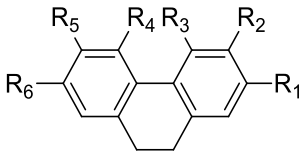


[**90**] Moniliformin



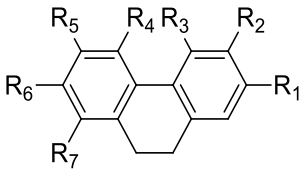
[**91**] Moscatin

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



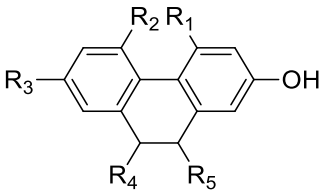
	R_1	R_2	R_3	R_4	R_5	R_6
[**92**] Coelonin	OH	H	OMe	H	H	OH
[**93**] 9,10-Dihydromoscatin	H	H	OH	OMe	H	OH
[**94**] 9,10-Dihydrophenanthrene-2,4,7-triol	OH	H	OH	H	H	OH
[**95**] 4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	OH	H	H
[**96**] 4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene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

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



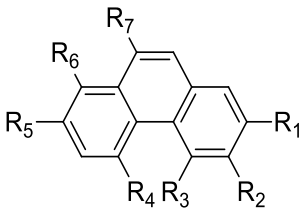
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**100**] 2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydro phenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**101**] 2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydro phenanthrene	OH	OMe	OMe	H	H	OMe	OH
[**102**] 4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydro phenanthrene	OMe	OMe	OH	H	OMe	OH	H
[**103**]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

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



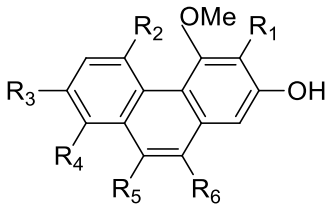
		R_1	R_2	R_3	R_4	R_5	
[**109**]	2-Hydroxy-4,7-dimethoxy-9,10-dihydro phenanthrene	OMe	H	OMe	H	H	
[**110**]	7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol	OH	OH	OMe	H	H	
[**111**]	2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene	OMe	OH	OH	H	H	
[112]	Plicatol C	H	OMe	OH	H	OMe	OMe
[**113**]	Rotundatin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

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



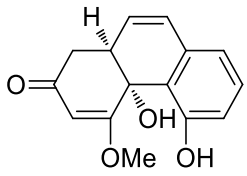
		R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**114**]	2,5-Dihydroxy-3,4-dimethoxyphenanthrene	OH	OMe	OMe	OH	H	H	H
[**115**]	2,5-Dihydroxy-4,9-dimethoxyphenanthrene	OH	H	OMe	OH	H	H	OMe
[**116**]	2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**117**]	Epheranthol B	H	H	OMe	OH	OMe	H	H
[**118**]	Fimbriol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

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

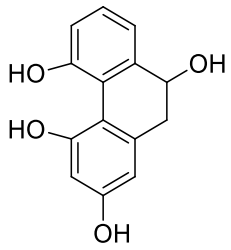


	R_1	R_2	R_3	R_4	R_5	R_6
[**120**] Loddigesiinol A	H	OMe	H	H	OH	H
[**121**] Nudol	OMe	H	OH	H	H	H
[**122**] Plicatol A	H	OH	H	H	OMe	OMe
[**123**] Plicatol B	H	OH	H	H	H	H
[**124**] 2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene	OH	OH	H	H	OMe	H
[**125**] 3,4,8-Trimethoxy phenanthrene-2,5-diol	OMe	OH	H	OMe	H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

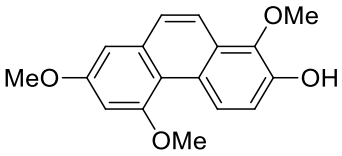
Figure 2A Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



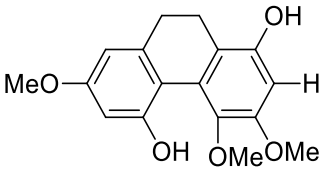
[**126**] Aphyllone



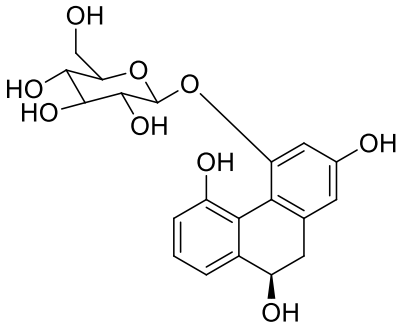
[**127**] (*S*)-2,4,5,9-Tetrahydroxy-9,10-dihydrophenanthrene



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

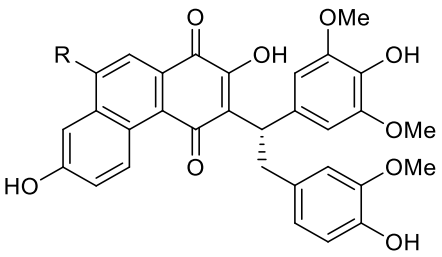


[**129**] 9,10-Dihydrophenanthrene,1,5-dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene



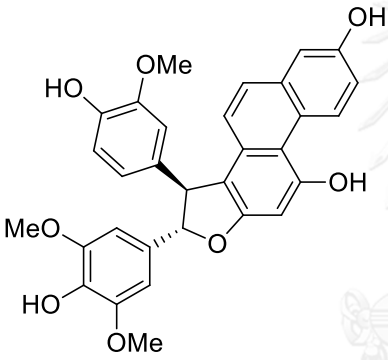
[**130**] 2,4,5,9S-Tetrahydroxy-9,10-dihydrophenanthrene 4-*O*-β-*D*-glucopyranoside

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

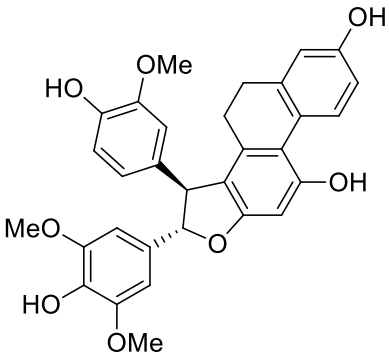


[**131**] Loddigesiinol G: R = H

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



[**133**] Loddigesiinol I



[**134**] Loddigesiinol J

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

Table 2 Distribution of flavonoids in the genus *Dendrobium*

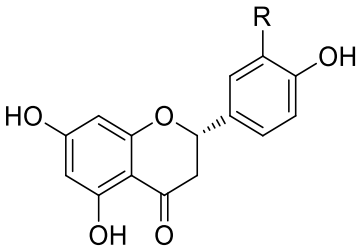
Compounds	**Plant**	**Plant part**	**Reference**
(2*S*)-Homoeriodictyol [**135**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al.*, 2014
Naringenin [**136**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.*, 2006a
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. longicornu	Stem	Hu *et al.*, 2008a
(2*S*)-Eriodictyol [**137**]	*D. trigonopus*	Stem	Hu *et al.*, 2008b
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al.*, 2014
	D. tortile	Whole plant	Limpanit *et al.*, 2016
Vicenin-2 [**138**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
Apigenin [**139**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
	D. williamsonii	Whole plant	Rungwichaniwat *et al.*, 2014
5,6-Dihydroxy-4′-methoxy-flavone [**140**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Chrysoeriol [**141**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al.*, 2014

Table 2 (continued)

Compounds	**Plant**	**Plant part**	**Reference**
Luteolin [**142**]	*D. aurantiacum* var. *denneanum*	Whole plant	Liu *et al.*, 2009a
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al.*, 2014
6-C-(α-Arabinopyranosyl)-8-C-[(2-O-α-rhamnopyranosyl) -β-galactopyranosyl] apigenin [**143**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2010
6-C-(α-Arabinopyranosyl)-8-C-[(2-O-α-rhamnopyranosyl) -β-glucopyranosyl] apigenin [**144**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2010
6‴-Glucosyl-vitexin [**145**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Isoschaftoside [**146**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2010
Isoviolanthin [**147**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
6-C-[(2-O-α-Rhamno pyranosyl)-β-gluco pyranosyl]-8-C-(α-arabinopyranosyl) apigenin [**148**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2010

Table 2 (continued)

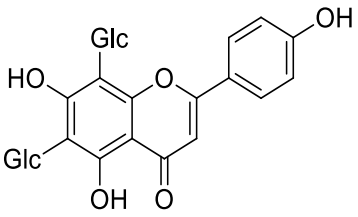
Compounds	**Plant**	**Plant part**	**Reference**
6-C-(β-Xylopyranosyl)-8-C-[(2-O-α-rhamnopyranosyl)-β-glucopyranosyl] apigenin [**149**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2010
Kaempferol [**150**]	*D. aurantiacum var. denneanum*	Stem	Yang *et al.*, 2006a
Kaempferol-3-O-α-L-rhamnopyranoside [**151**]	*D. secundum*	Stem	Phechrmeekha *et al.*, 2012
Kaempferol-3,7-O-di-α-L-rhamnopyranoside [**152**]	*D. secundum*	Stem	Phechrmeekha *et al.*, 2012
Kaempferol-3-O-α-L-rhamnopyranosyl-(1⟶2)-β-D-gluco pyranoside [**153**]	*D. capillipes*	Stem	Phechrmeekha *et al.*, 2012
Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylo pyranoside [**154**]	*D. capillipes*	Stem	Phechrmeekha *et al.*, 2012
Quercetin-3-*O*-L-rhamnopyranoside [**155**]	*D. secundum*	Stem	Phechrmeekha *et al.*, 2012
Quercetin-3-*O*-α-L-rhamnopyranosyl-(1′2)-β-D-xylopyranoside [**156**]	*D. capillipes*	Stem	Phechrmeekha *et al.*, 2012
5-Hydroxy-3-methoxy-flavone-7-O-[β-D-apiosyl-(1⟶6)]-β-D-glucoside [**157**]	*D. devonianum*	Stem	Sun *et al.*, 2014



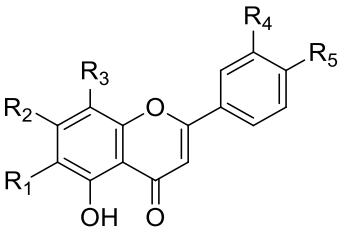
[**135**] (2*S*)-Homoeriodictyol: R = OMe

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

[**137**] (2*S*)-Eriodictyol; R = OH

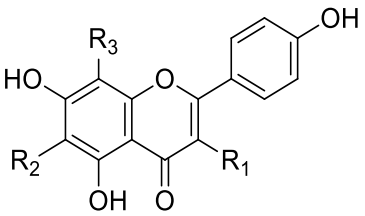


[**138**] Vicenin-2



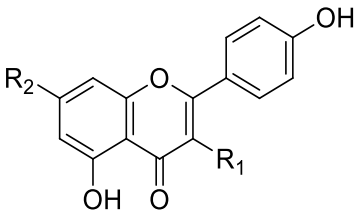
	R_1	R_2	R_3	R_4	R_5
[**139**] Apigenin	H	OH	H	H	OH
[**140**] 5,6-Dihydroxy-4′-methoxy-flavone	OH	H	H	H	OMe
[**141**] Luteolin	H	OH	H	OH	OH
[**142**] Chrysoeriol	H	OH	H	OMe	OH
[**143**] 6-C-(α-Arabinopyranosyl)-8-C-[(2-O-α-rhamnopyranosyl) -β-galactopyranosyl] apigenin	-Ara	OH	-Gal-Rha	H	OH
[**144**] 6-C-(α-Arabinopyranosyl)-8-C-[(2-O-α-rhamnopyranosyl) -β-glucopyranosyl] apigenin	-Ara	OH	-Glc-Rha	H	OH

Figure 3 Structures of flavonoids previously isolated from *Dendrobium* species

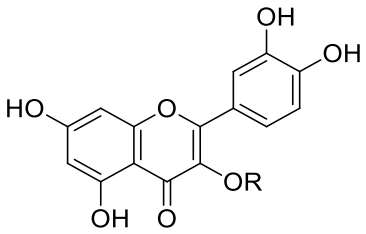


	R_1	R_2	R_3
[**145**] *6‴*-Glucosyl-vitexin	H	H	-Glc
[**146**] Isoschaftoside	H	-Ara	-Glc
[**147**] Isoviolanthin	H	-Rha	-Glc
[**148**] 6-*C*-[(2-*O*-α-Rhamnopyranosyl)-β-glucopyranosyl]-8-*C*-(α-arabinopyranosyl) apigenin	H	-Glc-Rha	-Ara
[**149**] 6-*C*-(β-Xylopyranosyl)-8-*C*-[(2-*O*-α-rhamnosepyranosyl)-β-glucopyranosyl] apigenin	H	-Xyl	-Glc-Rha
[**150**] Kaempferol	OH	H	H

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

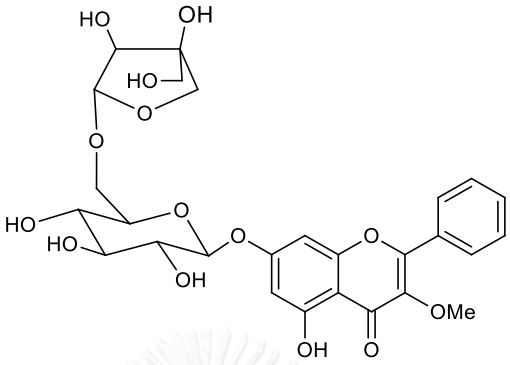


	R_1	R_2
[**151**] Kaempferol-3-*O*-α-L-rhamnopyranoside	O-Rha	OH
[**152**] Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside	O-Rha	O-Rha
[**153**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-glucopyranoside	O-Glc-Rha	OH
[**154**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside	O-Xyl-Rha	OH



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

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



[**157**] 5-Hydroxy-3-methoxy-flavone-7-O-[β-D-apiosyl-(1⟶6)]-β-D-glucoside

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

Table 3 Distribution of terpenoids in the genus *Dendrobium*

Compounds	Plant	Plant part	Reference
Aduncin [**158**]	*D. longicornu*	Stem	Hu *et al.*, 2008a
Amoenin [**159**]	*D. aduncum*	Whole plant	Gawell and Leander, 1976
Amotin [**160**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
α-Dihydropicrotoxinin [**161**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
Dendrobane A [**162**]	*D. moniliforme*	Stem	Bi *et al.*, 2004
Dendronobilin A [**163**]	*D. nobile*	Stem	Zhang *et al.*, 2007a
Dendronobilin B [**164**]	*D. wardianum*	Stem	Zhang *et al.*, 2007b
	D. nobile	Stem	Wang *et al.*, 2009
Dendronobilin C [**165**]	*D. crystallium*	Stem	Wang *et al.*, 2009
Dendronobilin D [**166**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Dendronobilin E [**167**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Dendronobilin F [**168**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Dendronobilin G [**169**]	*D. nobile*	Stem	Zhang *et al.*, 2007b

Table 3 (continued)

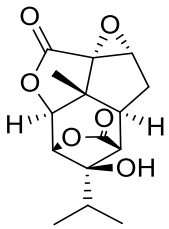
Compounds	**Plant**	**Plant part**	**Reference**
Dendronobilin H [**170**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Dendronobilin I [**171**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Dendronobilin J [**172**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Dendronobilin K [**173**]	*D. wardianum*	Stem	Fan *et al.*, 2013
Dendronobilin L [**174**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Dendronobilin M [**175**]	*D. nobile*	Stem	Zhang *et al.*, 2008c
Dendronobilin N [**176**]	*D. nobile*	Stem	Zhang *et al.*, 2008c
Dendrowardol A [**177**]	*D. nobile*	Stem	Zhang *et al.*, 2008c
Dendrowardol B [**178**]	*D. nobile*	Stem	Zhang *et al.*, 2008c
Dendrowardol C [**179**]	*D. wardianum*	Stem	Fan *et al.*, 2013
Corchoionoside C [**180**]	*D. wardianum*	Stem	Fan *et al.*, 2013
Crystallinin [**181**]	*D. wardianum*	Stem	Fan *et al.*, 2013
Findlayanin [1**82**]	*D. polyanthum*	Stem	Hu *et al.*, 2009
3-Hydroxy-2-oxodendrobine [**183**]	*D. findlayanum*	Whole plant	Qin *et al.*, 2011

Table 3 (continued)

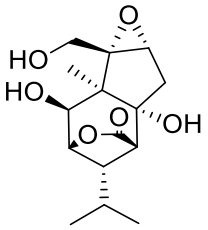
Compounds	Plant	Plant part	Reference
Dendrobine [**184**]	*D. nobile*	Stem	Wang *et al.*, 1985
Dendromoniliside A [**185**]	*D. nobile*	Stem	Zhang *et al.*, 2007b
Dendromoniliside B [**186**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
Dendromoniliside C [**187**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
Dendromoniliside D [**188**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
Dendronobiloside A [**189**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
	D. nobile	Stem	Zhao *et al.*, 2001; Ye and Zhao, 2002a
Dendronobiloside B [**190**]	*D. nobile*	Stem	Zhao *et al.*, 2001; Ye and Zhao, 2002a
Dendronobiloside C [**191**]	*D. nobile*	Stem	Zhao *et al.*, 2001; Ye and Zhao, 2002a
Dendronobiloside D [**192**]	*D. nobile*	Stem	Zhao *et al.*, 2001; Ye and Zhao, 2002a
Dendronobiloside E [**193**]	*D. nobile*	Stem	Zhao *et al.*, 2001; Ye and Zhao, 2002a
Dendroside A [**194**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
	D. nobile	Stem	Zhao *et al.*, 2001; Ye and Zhao, 2002a
Dendroside B [**195**]	*D. nobile*	Stem	Ye and Zhao, 2002a; Zhao *et al.*, 2003

Table 3 (continued)

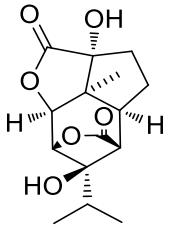
Compounds	Plant	Plant part	Reference
Dendroside C [**196**]	*D. moniliforme*	Stem	Zhao et al., 2003
	D. nobile	Stem	Ye and Zhao, 2002a
Dendroside D [**197**]	*D. nobile*	Stem	Ye and Zhao, 2002a
Dendroside E [**198**]	*D. nobile*	Stem	Ye *et al.*, 2002b
Dendroside F [**199**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
Dendroside G [**200**]	*D. nobile*	Stem	Ye *et al.*, 2002b



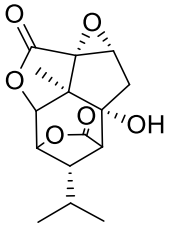
[**158**] Aduncin



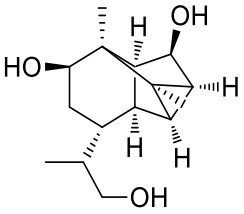
[**159**] Amoenin



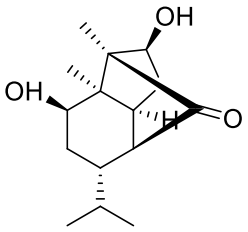
[**160**] Amotin



[**161**] α-Dihydropicrotoxinin

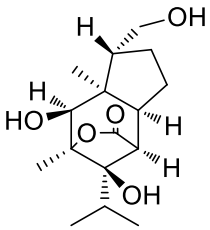


[**162**] Dendrobane A

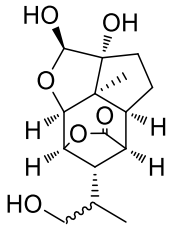


[**163**] Dendronobilin A

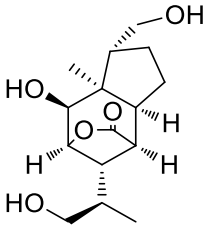
Figure 4 Structures of terpenoids previously isolated from *Dendrobium* species



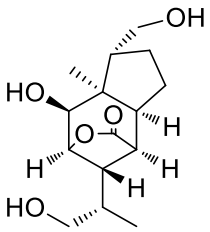
[**164**] Dendronobilin B



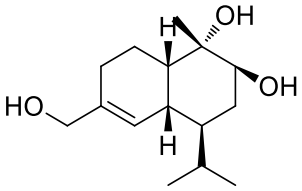
[**165**] Dendronobilin C



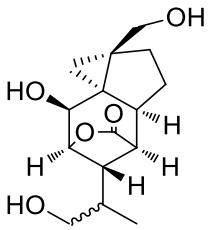
[**166**] Dendronobilin D



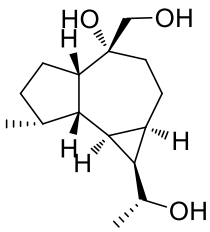
[**167**] Dendronobilin E



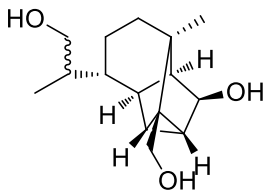
[**168**] Dendronobilin F



[**169**] Dendronobilin G

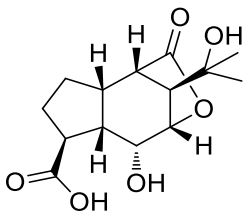


[**170**] Dendronobilin H

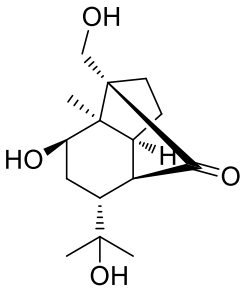


[**171**] Dendronobilin I

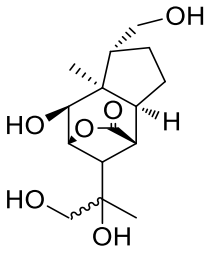
Figure 4 Structures of terpenoids previously isolated from *Dendrobium* species (continued)



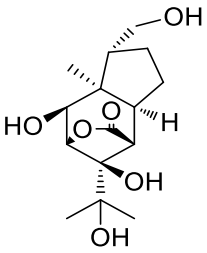
[**172**] Dendronobilin J



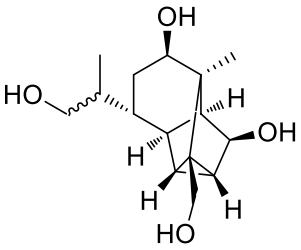
[**173**] Dendronobilin K



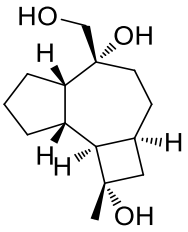
[**174**] Dendronobilin L



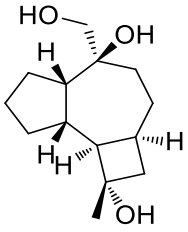
[**175**] Dendronobilin M



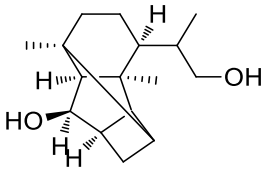
[**176**] Dendronobilin N



[**177**] Dendrowardol A

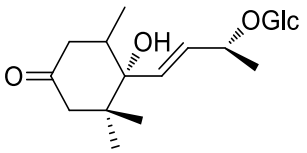


[**178**] Dendrowardol B

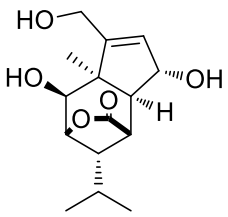


[**179**] Dendrowardol C

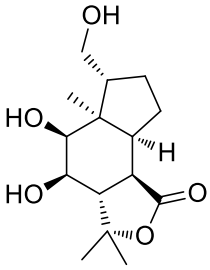
Figure 4 Structures of terpenoids previously isolated from *Dendrobium* species (continued)



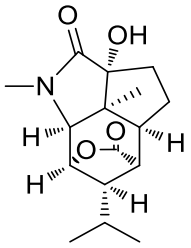
[**180**] Corchoionoside C



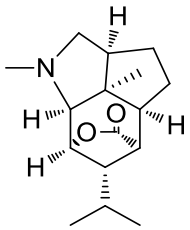
[**181**] Crystallinin



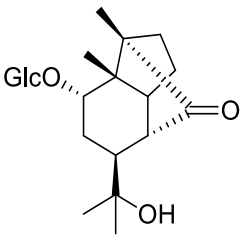
[**182**] Findlayanin



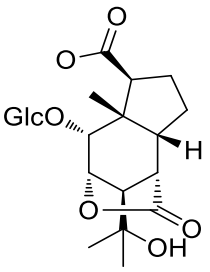
[**183**] 3-Hydroxy-2-oxodendrobine



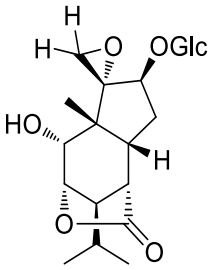
[**184**] Dendrobine



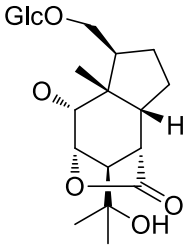
[**185**] Dendromoniliside A



[**186**] Dendromoniliside B

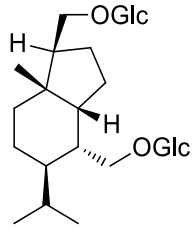


[**187**] Dendromoniliside C

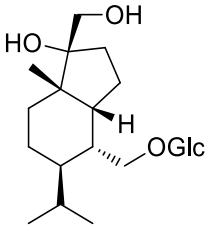


[**188**] Dendromoniliside D

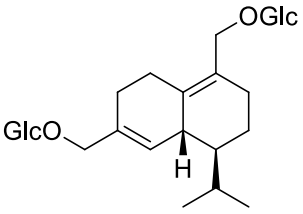
Figure 4 Structures of terpenoids previously isolated from *Dendrobium* species (continued)



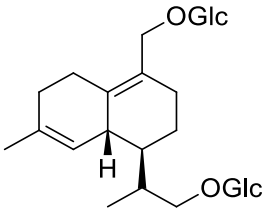
[**189**] Dendronobiloside A



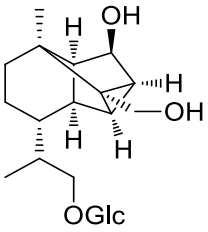
[**190**] Dendronobiloside B



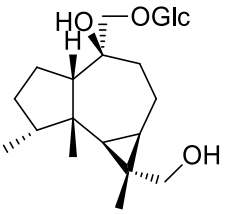
[**191**] Dendronobiloside C



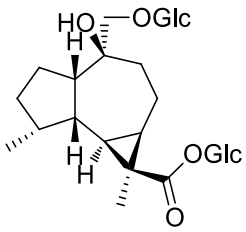
[**192**] Dendronobiloside D



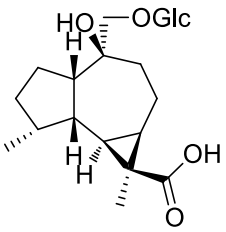
[**193**] Dendronobiloside E



[**194**] Dendroside A

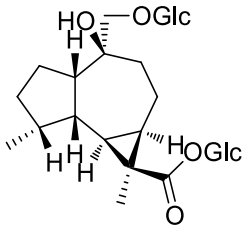


[**195**] Dendroside B

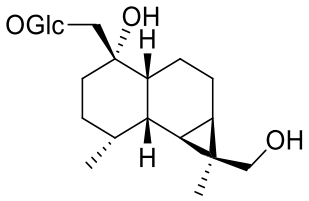


[**196**] Dendroside C

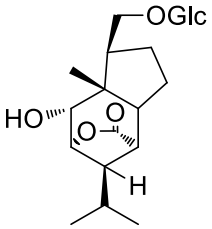
Figure 4 Structures of terpenoids previously isolated from *Dendrobium* species (continued)



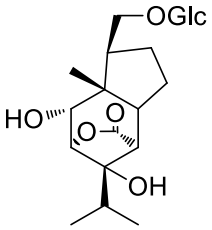
[**197**] Dendroside D



[**198**] Dendroside E



[**199**] Dendroside F



[**200**] Dendroside G

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

Table 4 Distribution of miscellaneous compounds in the genus *Dendrobium*

Category and Compound	**Plant**	**Plant part**	**References**
Aliphatic acid derivatives			
Aliphalic acids [**201**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.*, 2001
Aliphatic alcohols [**202**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.*, 2001
Malic acid [**203**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2001
Dimethyl malate [**204**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2010
(-)-Shikimic acid [**205**]	*D. fuscescens*	Whole plant	Tarapatra *et al.*, 1989
	D. huoshanense	Aerial part	Chang *et al.*, 2010
	D. longicornu	Stem	Hu *et al.*, 2008
	D. pulchellum	Stem	Chanvorachote *et al.*, 2013
Isopentyl butyrate [**206**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2010
Benzoic acid derivatives and phenolic compounds			
3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid [**207**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Salicylic acid [**208**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2010
Vanilloside [**209**]	*D. denneanum*	Stem	Pan *et al.*, 2012
Gallic acid [**210**]	*D. longicornu*	Whole plant	Li *et al.*, 2009d
Syringic acid [**211**]	*D. crystallinum*	Stem	Wang *et al.*, 2009

Table 4 (continued)

Category and Compound	**Plant**	**Plant part**	**Reference**
Vanillic acid [**212**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
	D. williamsonii	Whole plant	Rungwichaniwat *et al.*, 2014
Antiarol [**213**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Ethylhaematommate [**214**]	*D. longicornu*	Whole plant	Li *et al.*, 2009d
p-Hydroxybenzaldehyde [**215**]	*D. devonianum*	Whole plant	Sun *et al.*, 2014
	D. falconeri	Stem	Sritularak and Likhitwitayawuid, 2009
	D. tortile	Whole plant	Limpanit *et al.*, 2016
Methyl β-orsellinate [**216**]	*D. longicornu*	Stem	Hu *et al.*, 2008a
Protocatechuic acid [**217**]	*D. nobile*	Stem	Ye and Zhao, 2002a
Tachioside [**218**]	*D. denneanum*	Stem	Pan *et al.*, 2012
Alkyl 4′-hydroxy-*trans*-cinnamates [**219**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.*, 2001
Alkyl *trans*-ferulates [**220**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.*, 2001

Table 4 (continued)

Category and Compound	**Plant**	**Plant part**	**Reference**
Defuscin [**221**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.*, 2006a
	D. aurantiacum var. *denneanum*	Stem	Yang *et al.*, 2006a
	D. moniliforme	Stem	Bi *et al.*, 2004
n-Octacosyl ferulate [**222**]	*D. aurantiacum var. denneanum*	Stem	Yang *et al.*, 2006a
	D. moniliforme	Stem	Bi *et al.*, 2004
n-Triacontyl *p*-hydroxy-cis-cinnamate [**223**]	*D. moniliforme*	Stem	Bi *et al.*, 2004
Tetratriacontanyl-*trans*-*p*-coumarate [**224**]	*D. williamsonii*	Whole plant	Rungwichaniwat *et al.*, 2014
n-Docosyl *trans*-ferulate [**225**]	*D. longicornu*	Whole plant	Li *et al.*, 2009d
	D. williamsonii	Whole plant	Rungwichaniwat *et al.*, 2014
trans-Tetracosyl ferulate [**226**]	*D. tortile*	Whole plant	Limpanit *et al.*, 2016
cis-Hexacosanoyl ferulate [**227**]	*D. tortile*	Whole plant	Limpanit *et al.*, 2016
Ferulaldehyde [**228**]	*D. longicornu*	Whole plant	Li *et al.*, 2009d

Table 4 (continued)

Category and Compound	**Plant**	**Plant part**	**Reference**
Ferulic acid [**229**]	*D. secundum*	Stem	Sritularak *et al.*, 2011b
2-(*p*-Hydroxyphenyl) ethyl *p*-coumarate [**230**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
Dihydroconiferyl dihydro-*p*-coumarate [**231**]	*D. nobile*	Stem	Zhang *et al.*, 2006b
1-[4-(β-D-Lucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone [**232**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
Coniferyl alcohol [**233**]	*D. trigonopus*	Stem	Hu *et al.*, 2008b
p-Hydroxyphenyl propionic methyl ester [**234**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008
Phloretic acid [**235**]	*D. candidum*	Whole plant	Li *et al.*, 2010
	D. ellipsophyllum	Whole plant	Tanagornmeatar *et al.*, 2014)
Dihydroconiferyl alcohol [**236**]	*D. longicornu*	Stem	Hu *et al.*, 2008a
Salidrosol [**237**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012

Table 4 (continued)

Category and Compound	**Plant**	**Plant part**	**Reference**
Shashenoside I [**238**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
Syringin [**239**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
Tetracosyl(Z)-*p*-coumarate [**240**]	*D. falconeri*	Whole plant	Sritularak and Likhitwitayawuid, 2009
Coumarins			
Ayapin [**241**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
Coumarin [**242**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.*, 2006a
	D. clavatum var. *aurantiacum*	Stem	Chang *et al.*, 2001
Denthyrsin [**243**]	*D. thyrsiflorum*	Stem	Zhang *et al.*, 2005
Scoparone [**244**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
	D. thyrsiflorum	Stem	Zhang *et al.*, 2005
Scopoletin [**245**]	*D. densiflorum*	Stem	Fan *et al.*, 2001
Lignans and neolignans			
Dehydrodiconiferyl alcohol-4-**O**-β-D-glucoside [**246**]	*D. chrysanthum*	Stem	Ye *et al.*, 2004

Table 4 (continued)

Category and Compound	**Plant**	**Plant part**	**Reference**
Episyringaresinol [**247**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
	D. longicornu	Stem	Hu *et al.*, 2008a
	D. nobile	Stem	Zhang *et al.*, 2008b
Episyringaresinol 4′′-O-β-D-glucopyranoside [**248**]	*D. moniliforme*	Stem	Zhao *et al.*, 2003
(-)-(7*S*,8*R*,7′*E*)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4′-oxyneolign-7′-ene-7,9′-triol-7,9′-bis-*O*-β-D-glucopyranoside [**249**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
Lyoniresinol [**250**]	*D. chrysanthum*	Stem	Ye *et al.*, 2004
(-)-Syringaresinol-4,4′-bis-*O*-β–D-glucopyranoside [**251**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
Syringaresinol-4-*O*-D-monoglucopyranoside [**252**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al.*, 2013
(-)-Medioresinol [**253**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
(-)-Pinoresinol [**254**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Syringaresinol [**255**]	*D. secundum*	Stem	Sritularak *et al.*, 2011b

Table 4 (continued)

Category and Compound	**Plant**	**Plant part**	**Reference**
Erythro-1-(4-*O*-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol [**256**]	*D. longicornu*	Stem	Hu *et al.*, 2008a
Acanthoside B [**257**]	*D. chrysanthum*	Stem	Ye *et al.*, 2004
Liriodendrin [**258**]	*D. brymerianum*	Whole plant	Chen *et al.*, 2014b
	D. pulchellum	Stem	Chanvorachote *et al.*, 2013
(-)-(8*R*,7′*E*)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-O-β-D-glucopyranoside [**259**]	*D. auranticum*	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 [**260**]	*D. auranticum*	Stem	Li *et al.*, 2014

Table 4 (continued)

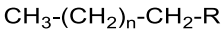
Category and Compound	**Plant**	**Plant part**	**Reference**
(-)-(8*R*,7′*E*)-4-hydroxy-3,3′,5,5′,9′-pentamethoxy-8,4′-oxyneolign-7′-ene-9-ol 4,9-bis-O-β-D-glucopyranoside [**261**]	*D. auranticum*	Stem	Li *et al.*, 2014
Fluorenones			
Denchrysan A [**262**]	*D. chrysotoxum*	Whole plant	Li *et al.*, 2009c
Denchrysan B [**263**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al.*, 2015
	D. chrysotoxum	Whole plant	Chen *et al.*, 2008a
Dendroflorin [**264**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.*, 2006a
	D. brymerianum	Whole plant	Klongkumnuankarn *et al.*, 2015
Dengibsin [**265**]	*D. aurantiacum var. denneanum*	Stem	Yang *et al.*, 2006a
	D. chrysanthum	Stem	Yang *et al.*, 2006b
	D. chrysotoxum	Whole plant	Li *et al.*, 2009c

Table 4 (continued)

Category and Compound	**Plant**	**Plant part**	**Reference**
Nobilone [**266**]	*D. brymerianum*	Whole plant	Klongkumnuankarn *et al*., 2015)
	D. nobile	Stem	Zhang *et al*., 2007a
1,4,5-Trihydroxy-7-methoxy-9*H*-fluoren-9-one [**267**]	*D. chrysotoxum*	Whole plant	Chen *et al.*, 2008a
2,4,7-Trihydroxy-5-methoxy-9-fluorenone [**268**]	*D. chrysotoxum*	Stem	Yang *et al.*, 2004
2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone [**269**]	*D. chrysotoxum*	Stem	Yang *et al.*, 2004
Others			
3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one [**270**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
Palmarumycin JC2 [**271**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Dehydrovomifoliol [**272**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
2,6-Dimethoxy Benzoquinone [**273**]	*D. chryseum*	Stem	Ma *et al.*, 1998

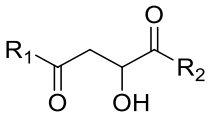
Table 4 (continued)

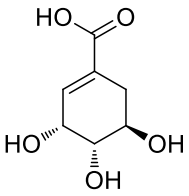
Category and Compound	**Plant**	**Plant part**	**Reference**
4-(2-Hydroxypropyl)-2(5*H*)-furanone [**274**]	*D. tortile*	Whole plant	Limpanit *et al.*, 2016
5,7-Dihydroxy-chromen-4-one [**275**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar *et al.*, 2014



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

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

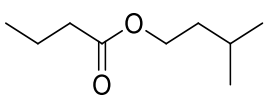


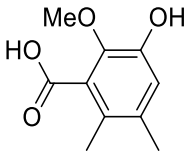


[**203**] Malic acid: R_1 = R_2 = OH

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

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

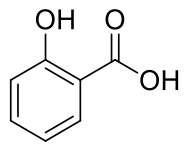




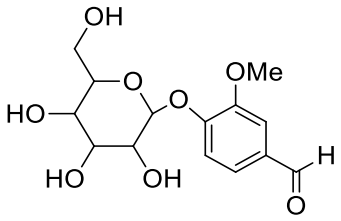
[**206**] Isopentyl butyrate

[**207**] 3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid

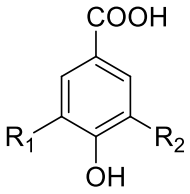
Figure 5 Structures of miscellaneous compounds previously isolated from *Dendrobium* species



[**208**] Salicylic acid



[**209**] Vanilloside

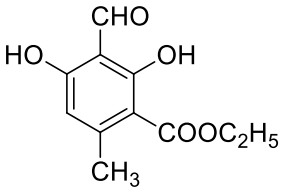


[**210**] Gallic acid: R_1 = OH, R_2 = OH

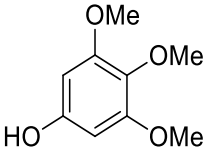
[**211**] Syringic acid: R_1 = OMe, R_2 = OMe

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

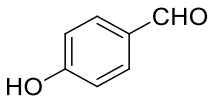
[**213**] Protocatechuic acid: R_1 = H, R_2 = OH



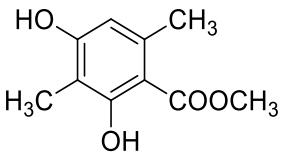
[**214**] Antiarol



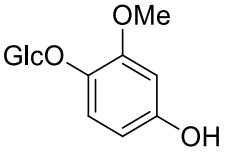
[**215**] Ethylhaematommate



[**216**] *p*-Hydroxybenzaldehyde

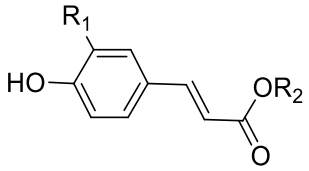


[**217**] Methyl β-orsellinate



[**218**] Tachioside

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



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

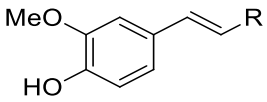
[**220**] Alkyl *trans*-ferulates: R_1 = OMe, R_2 = C_nH_{2n+1}, n = 18-28, 30

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

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

[**223**] *n*-Triacontyl *p*-hydroxy-*cis*-cinnamate: R_1 = H, R_2 = C_nH_{2n+1}, n =30

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



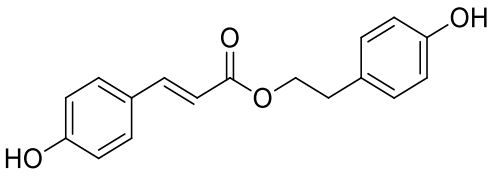
[**225**] *n*-Docosyl *trans*-ferulate: R = $COOCH_2(CH_2)_{20}CH_3$

[**226**] *trans*-Tetracosylferulate: R = $COOCH_2(CH_2)_{22}CH_3$

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

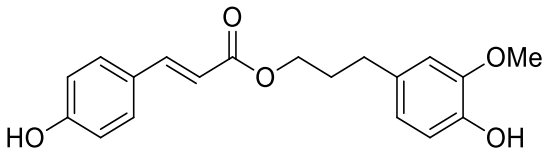
[**228**] Ferulaldehyde: R = CHO

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

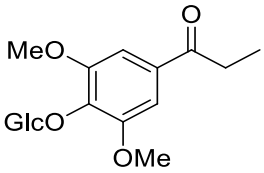


[**230**] 2-(*p*-Hydroxyphenyl) ethyl *p*-coumarate

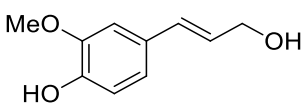
Figure 5 Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)



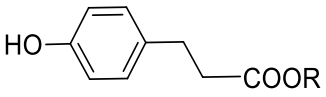
[**231**] Dihydroconiferyl dihydro-*p*-coumarate



[**232**] 1-[4-(β-D-glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone



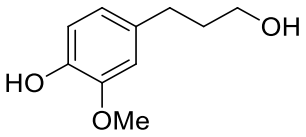
[**233**] Coniferyl alcohol



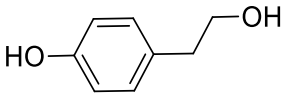
[**234**] *p*-Hydroxyphenyl propionic

Methyl ester: R = CH_3

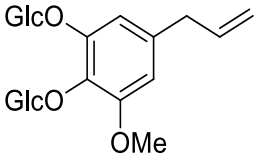
[**235**] Phloretic acid: R = OH



[**236**] Dihydroconiferyl alcohol

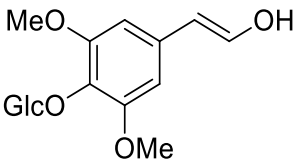


[**237**] Salidrosol

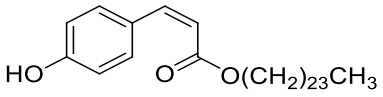


[**238**] Shashenoside I

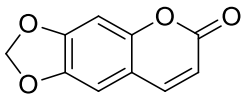
Figure 5 Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)



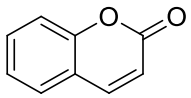
[**239**] Syringin



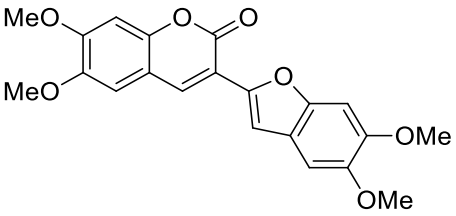
[**240**] Tetracosyl (*Z*)-*p*-coumarate



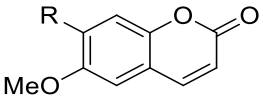
[**241**] Ayapin



[**242**] Coumarin



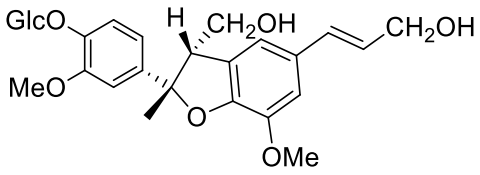
[**243**] Denthyrsin



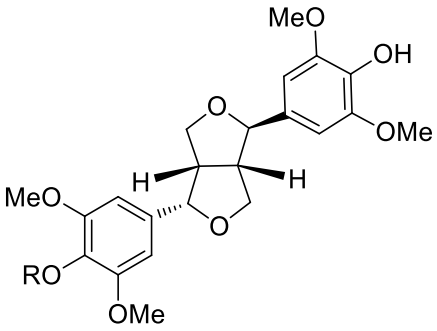
[**244**] Scoparone: R = OMe

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

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

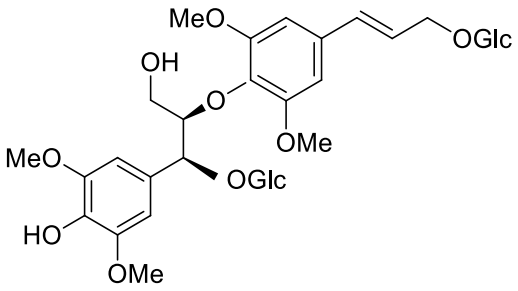


[**246**] Dehydrodiconiferyl alcohol-4-**O**-β-D-glucoside

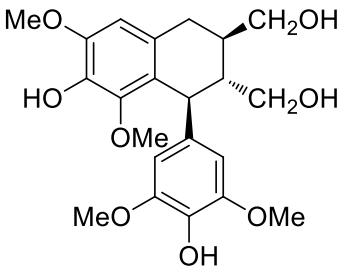


[**247**] Episyringaresinol: R = H

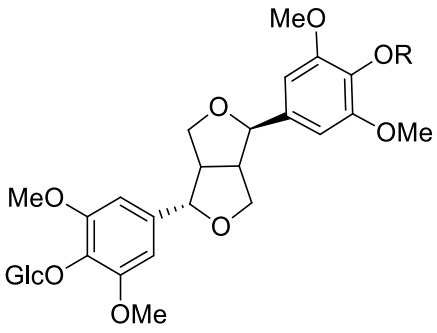
[**248**] Episyringaresinol 4′′-*O*-β-D-glucopyranoside: R = Glc



[**249**] (-)-(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



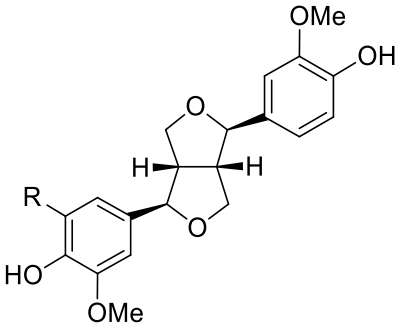
[**250**] Lyoniresinol



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

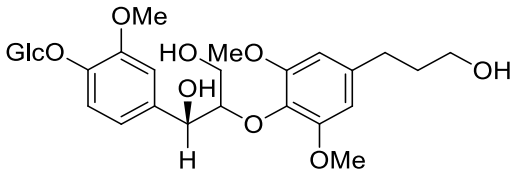
[**252**] Syringaresinol-4-*O*-D-monoglucopyranoside: R = H

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



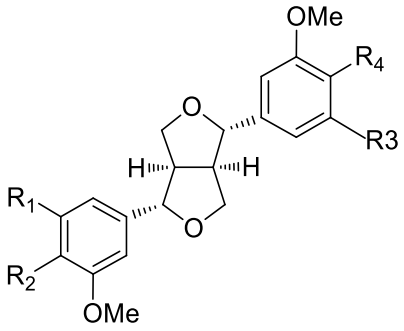
[**253**] (-)-Medioresinol: R = OMe

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

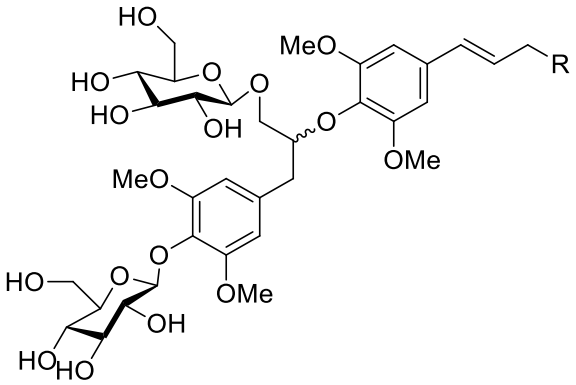


[**255**] Erythro-1-(4-*O*-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol

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



	R_1	R_2	R_3	R_4
[**256**] Syringaresinol	OMe	OH	OMe	OH
[**257**] Acanthoside B	OMe	OGlc	OMe	OH
[**258**] Liriodendrin	OMe	OGlc	OMe	OGlc

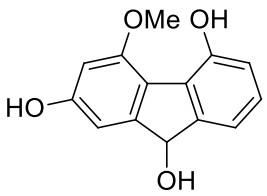


[**259**] (-)-(8*R*,7′*E*)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-*O*-β-D-glucopyranoside: R = OH; 8*R*

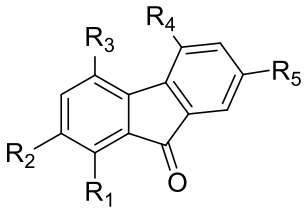
[**260**] (-)-(8*S*,7′*E*)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-*O*-β-D-glucopyranoside: R = OH; 8*S*

[**261**] (-)-(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*

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

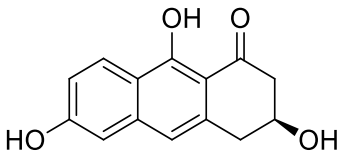


[**263**] Denchrysan B

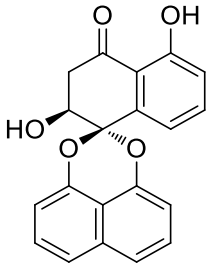


	R_1	R_2	R_3	R_4	R_5
[**262**] Denchrysan A	H	OH	OH	OMe	OH
[**264**] Dendroflorin	OH	H	OH	OMe	OH
[**265**] Dengibsin	H	OH	OMe	OH	H
[**266**] Nobilone	H	OH	H	OMe	OH
[**267**] 1,4,5-Trihydroxy-7-methoxy-9*H*-fluoren-9-one	OH	H	OH	OH	OMe
[**268**] 2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone	OMe	OH	OH	OMe	OH

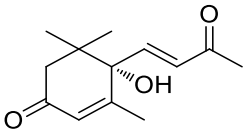
Figure 5 Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)



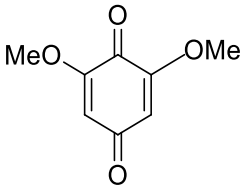
[**269**] 3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one



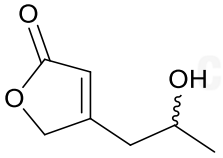
[**270**] Palmarumycin JC2



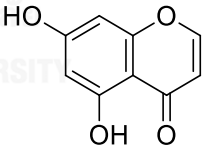
[**271**] Dehydrovomifoliol



[**272**] 2,6-Dimethoxybenzoquinone



[**273**] 4-(2-Hydroxypropyl)-2(5*H*)-furanone



[**274**] 5,7-Dihydroxy-chromen-4-one

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

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

Medicinal plants of the *Dendrobium* species have been used to treat for several indications as traditional Chinese medicine (TCM). For instance, promote the production of body fluid, swelling, red tounge, dry mouth, reduce fever, hyperglycemia, diabetes. They are also used to medicate stomach disease, kidney, lung disorders and relived symptoms such as dryness of the throat and thirst with blurred vision (Ng *et al.*, 2012); (Rungwichaniwat *et al.*, 2014)

Many bioactive constituents from *Dendrobium* plants exhibited various pharmacological properties, for example, anticancer activity, antiangiogenic activity, immunomodulating activity, antidiabetic activity, inhibition of cataractogenesis, neuroprotective activity, hepatoprotective activity, anti-inflammatory activity, antioxidant activity, antibacterial activity, antimalarial activity, antiviral activity, hemagglutininating activity, antiplatelet aggregation, effect on water channels, effect on colonic health, effect on hyperthyroidism and beneficial action on bones. (Teixeira da Silva and Ng, 2017).

In antidiabetic activity, the extract of *D. candidum* have been shown to decrease blood glucose concentration in epinephrine-induced hyperglycemia in mice and streptozotocin-induced diabetes in rats by inhibiting glucagon secretion, stimulating insulin secretion from β-cells, glycogen synthesis and glycogenolysis (Jiang *et al.*, 2014). The compounds (loddigesiinols G-J [**131**, **132**, **133**, **134**] and crepidatuol B [**50**]) from stem of *D. loddigesii* were tested for α-glucosidase inhibitory activity, and the compounds showed stronger activity (IC_{50} values = 16.7, 10.9, 2.7, 3.2, and 18.9 μM, respectively) than *trans*-resveratrol (positive control, IC_{50} values = 27.9 μM) (Lu *et al.*, 2014). Another study, isolated compounds from *D. tortile*, dendrofalconerol A [**62**] and (2*S*)-eriodictyol [**137**] also expressed inhibitory activity on α-glucosidase enzyme with IC_{50} values = 18.0 and 276.2 μM, respectively. In addition, there is research pertaining to diabetic complication, cataract formation, such as the stem of *D. aurantiacum* var. *denneanum* can protect galactose-induced cataract formation in rats by decreasing aldose reductase and inducible NO synthase (NOS) activities (Fang *et al*., 2015) .

There are several compounds from *Dendrobium* plants exhibited anticancer activity. For example, denbinobin [**84**] from *D. nobile*, can decrease the expression level of decoy receptor-3 and synergized with Fas ligand to bring about apoptotic cell death in pancreatic adenocarcinoma cells (Yang *et al*., 2010) and also inhibit Rac1 activity which forestalled lamellipodial formation that cause the migration of prostate cancer (Lu *et al*., 2014a). The bibenzyls and related compounds from *D. brymerianum* such as gigantol [**28**], moscatilin [**32**], lusianthridin [**99**] showed cytotoxic effect against human lung cancer cell lines with IC_{50} values of 23.4, 196.7 and 65.0 μg/mL, respectively (Klongkumnuankarn *et al.*, 2015). Furthermore, dendrofalconerol A [**62**], dendrocandin B [**2**], dendrocandin I [**44**], 3,4-dihydroxy-5,4′-dimethoxybibenzyl [**40**] and dendrosignatol [**94**] from the whole plant of *D. signatum*, manifested cytotoxic activity against colorectal cancer HT-29 cells and hepatoma HepG and breast cancer MDA-23 1 (Mittraphab *et al.*, 2016). Besides, 4,4′-dihydroxy-3,5-dimethoxybibenzyl [**41**], 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**36**], chrysoeriol [**142**] and luteolin [**141**] from *D. ellipsophyllum* demonstrated anoikis-sensitizing, apoptosis-inducing, antimetastatic and cytotoxic activities on H292 human lung cancer cells (Tanagornmeatar *et al.*, 2014).

In platelet aggregation-inhibitory activity, moscatin [**91**] and moscatilin [**32**] from *D. loddigesii* stems inhibited arachidonic acid and collagen-induced platelet aggregation (Chen *et al.*, 1994). Moscatilin [**32**] from *D. densiflorum* also displayed antiplatelet aggregation activity on rat platelets *in vitro* (Fan *et al.*, 2001). Additionally, trigonopol A [**47**], a bibenzyl from *D. trigonopus* exhibited antiplatelet aggregation activity *in vitro* (Hu *et al.*, 2008b).

In relation to antimalarial activity, densifloral B [**83**] and phoyunnanin E [**69**] from *D. venustum* exhibited stronger activity than gigantol [**28**], batatasin III [**16**] and phoyunnanin C [**68**] from the same plant (Sukphan *et al.*, 2014).

CHAPTER III

EXPERIMENTAL

1. Source of plant materials

The whole plant of *Dendrobium formosum* Roxb. ex Lindl. was purchased from Chatuchak market, Bangkok, in September 2015. Authentication was performed by Associate Professor. Thatree Phadungcharoen (Faculty of Pharmacy, Rangsit University) and comparison with database of the Botanical Garden Organization. A voucher specimen (BS-DF-092558) has been deposited at the Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University.

2. General 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 : 6.5 cm

Temperature : Laboratory temperature (30-35 ºC)

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

2. Spraying with anisaldehyde reagent (0.5 ml *p*-anisaldehyde in 50 ml glacial acetic acid and 1 ml 97% sulfuric acid) and heating at 105 ºC for 10 min.

2.2 Column chromatography

2.2.1 Vacuum liquid chromatography (VLC)

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

Packing method : Dry packing

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

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

2.2.2 Flash column chromatography (FCC)

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

Packing method : Dry packing

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

Detection : Fractions were examined as described in section 2.2.1

2.2.3 Gel filtration chromatography

Adsorbent : Sephadex LH-20 (GE Healthcare)

Packing method : The appropriate organic solvent was used as the eluent. Gel filter was suspended in the eluent, left standing about 24 hours prior to use and then poured into the column and left to set tightly.

Sample loading : The sample was dissolved in a small amount of the eluent and then gradually distributed on top of the column.

Detection : Fractions were examined in the same way as described in section 2.2.1

2.3 Spectroscopy

2.3.1 Mass spectra

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

2.3.2 Proton and carbon-13 nuclear magnetic resonance (^{1}H and ^{13}C-NMR) spectra

^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectra were recorded on a Bruker Avance DPX-300 FT-NMR spectrometer (Faculty of Pharmaceutical Sciences, Chulalongkorn University)

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

2.4 Solvents

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

3. Extraction and isolation

3.1 Extraction

The dried whole plants of *D. formosum* (2.0 kg) were ground and then macerated with methanol (3×10 L) for 72 hours three times. The organic solvent was evaporated under reduced pressure to give 115 g of methanol crude extract. This material was suspended in water and partitioned with EtOAc and then *n*-butanol to give an EtOAc extract (57 g), a *n*-butanol extract (25 g), and an aqueous extract (30 g).

All three extracts were tested for α-glucosidase and lipase inhibitory activities. The EtOAc extract showed the highest activity with 96.31% and 83.94% inhibition at 100 µg/mL, respectively. Therefore the EtOAc extract was selected for further studies (**Scheme 1**).

3.2 Isolation

The EtOAc extract (57 g) was initially fractionated by vacuum liquid chromatography (VLC) as described in section 2.2.1. (**Scheme 2**) Silica gel (No.7734, 600 g) was used as the stationary phase and a step gradient of hexane-EtOAc (1:0 to 0:1) as the mobile phase. The eluates were collected about 500 mL per fraction and examined by TLC (silica gel, hexane-EtOAc 7:3) to give eight fractions (A-H). Fractions A (2.4 g), B (3.2 g), C (4.2 g), D (1.1 g), E (3.2 g), F (6.8 g), G (10 g) and H (2.0 g).

3.2.1 Isolation of compound DFM-1 (confusarin)

Fraction F (6.8 g) was further separated by FCC using silica gel (No. 9385) as the stationary phase with a gradient mixture of hexane-EtOAc (1:0 to 0:1) to give nine fractions (FI-FIX).

Fraction FII (271 mg) was separated by FCC using silica gel (No. 9385) as the stationary phase with a gradient of hexane-CH_2Cl_2 to give 4 fractions (FII1-

FII4). Fraction FII2 was purified on a Sephadex LH-20 column, eluted with methanol, to give compound DFM-1 as yellow amorphous solid. (3 mg, R_f 0.46, silica gel, hexane-CH_2Cl_2 = 1:9). It was identified as confusarin.

3.2.2 Isolation of compound DFM-2 (hircinol)

Fraction FII4 (21.5 mg) was separated on a Sephadex LH-20 (methanol) to give compound DFM-2. (15 mg, R_f 0.29, silica gel, 100% CH_2Cl_2). It was identified as hircinol.

3.2.3 Isolation of compound DFM-3 (erianthridin)

Fraction FIII (85.2 mg) was subjected to a Sephadex LH-20 (methanol) to give three fractions (FIII1-FIII3). Fraction FIII2 afforded erianthridin (45 mg, R_f 0.42, silica gel, hexane-EtOAc = 7:3).

3.2.4 Isolation of compound DFM-4 (gigantol)

Fraction FV (648.9 mg) was chromatographed by FCC using silica gel (No. 9385) as the stationary phase with a step gradient mixture of hexane-CH_2Cl_2 (1:0 to 0:1). Six fractions (FV1-FV6) were obtained and combined according to the similarity of their TLC patterns. Compound DFM-4 was obtained from fraction FV3 as a brown amorphous solid (94 mg, R_f 0.38, silica gel, hexane-CH_2Cl_2 = 1:9) and was later identified as gigantol.

3.2.5 Isolation of compound DFM-5 (nudol)

Fraction FV2 (16.9 mg) was purified on Sephadex LH-20 (methanol) to give compound DFM-5 as a yellow amorphous solid (10 mg, R_f 0.45, silica gel, hexane-EtOAc = 7:3) and it was identified as nudol.

3.2.6 Isolation of compound DFM-6 (lusianthridin)

Fraction FV5 (193 mg) was subjected to FCC over silica gel (No. 9385) as the stationary phase, eluted with a gradient mixture of hexane-EtOAc (1:0 to 0:1) to give compound DFM-6 as a brown amorphous solid (8 mg, R_f 0.18, silica gel, 100% CH_2Cl_2) and was identified as lusianthridin.

3.2.7 Isolation of compound DFM-7 (coelonin)

Fraction FVI (361.7 mg) was separated by FCC using silica gel (No. 9385) as the stationary phase, using gradient mixture of hexane-CH_2Cl_2 (1:0 to 0:1) to afford five subfractions (FVI1-FVI5). DFM-7 was obtained from fraction FVI2 as a brown amorphous solid (75 mg, R_f 0.27, silica gel, CH_2Cl_2-EtOAc = 9.5:0.5) and was later identified as coelonin.

3.2.8 Isolation of compound DFM-8 (dihydroconiferyl dihydro-*p*-coumarate)

Fraction FVI4 (58 mg) was separated on a Sephadex LH-20 column, eluted with methanol, to give compound DFM-8 as a yellow amorphous solid (25 mg, R_f 0.22, silica gel, 100% CH_2Cl_2). This compound was identified as dihydroconiferyl dihydro-*p*-coumarate.

3.2.9 Isolation of compound DFM-9 (batatasin III)

Fraction FVI5 (29 mg) was subjected to a Sephadex LH-20 column (MeOH), to give compound DFM-9 as a brown amorphous solid (18 mg, R_f 0.26, silica gel, CH_2Cl_2-EtOAc = 9.5:0.5). It was identified as batatasin III.

3.2.10 Isolation of compound DFM-10 (2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene)

Fraction FVIII (272 mg) was separated by FCC using silica gel (No. 9385) as the stationary phase with CH_2Cl_2-EtOAc gradient to afford three fractions (FVIII1-FVIII3).

Fraction FVIII2 was separated on a Sephadex LH-20 column, eluted with methanol, to give compound DFM-10 as a brown amorphous solid (22 mg, R_f 0.42, silica gel, CH_2Cl_2-EtOAc = 9:1). This compound was identified as 2,5,7-trihydroxy-4- methoxy-9,10-dihydrophenanthrene.

3.2.11 Isolation of compound DFM-11 (moscatilin)

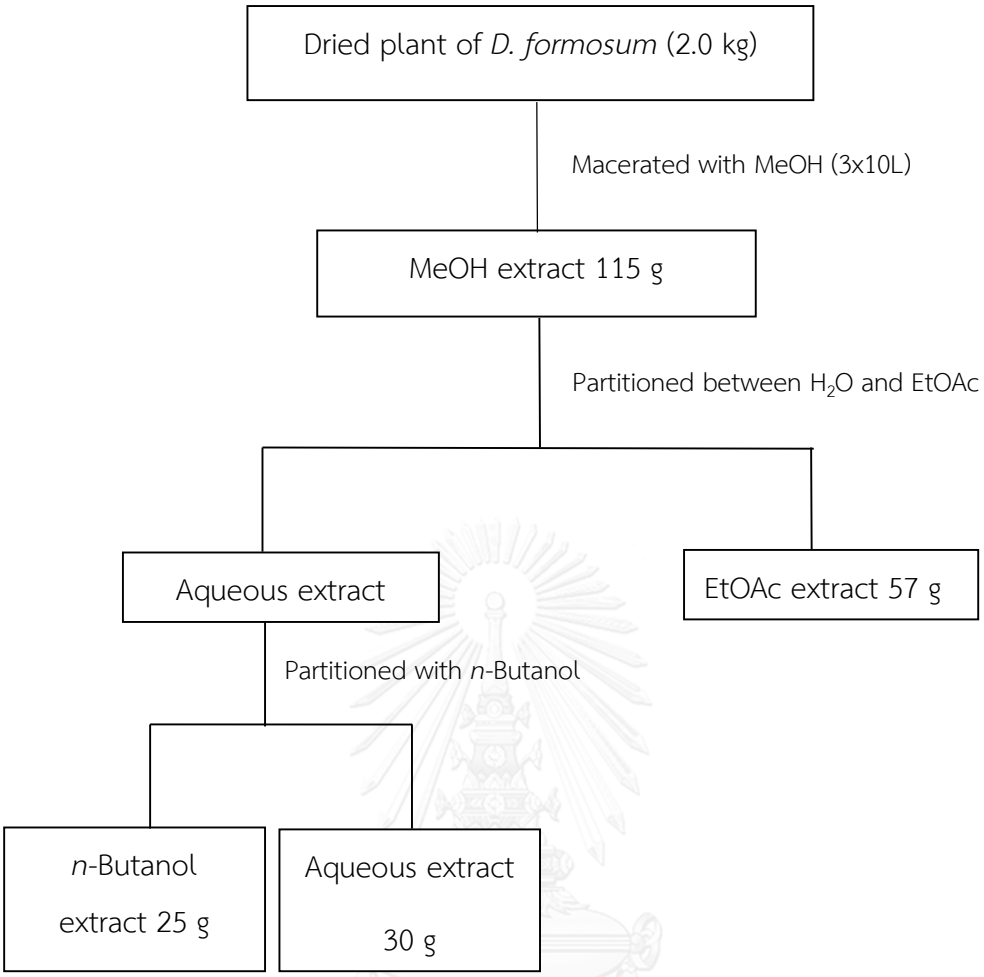
Fraction G (10 g) was separated by FCC using silica gel (No. 9385) as the stationary phase, eluted with a gradient mixture of hexane-EtOAc (1:0 to 0:1) to give seven fractions (GI-GVII).

Fraction GIII (508 mg) was further separated on a Sephadex LH-20 column, eluted with methanol, to give eight fractions (GIII1-GIII8).

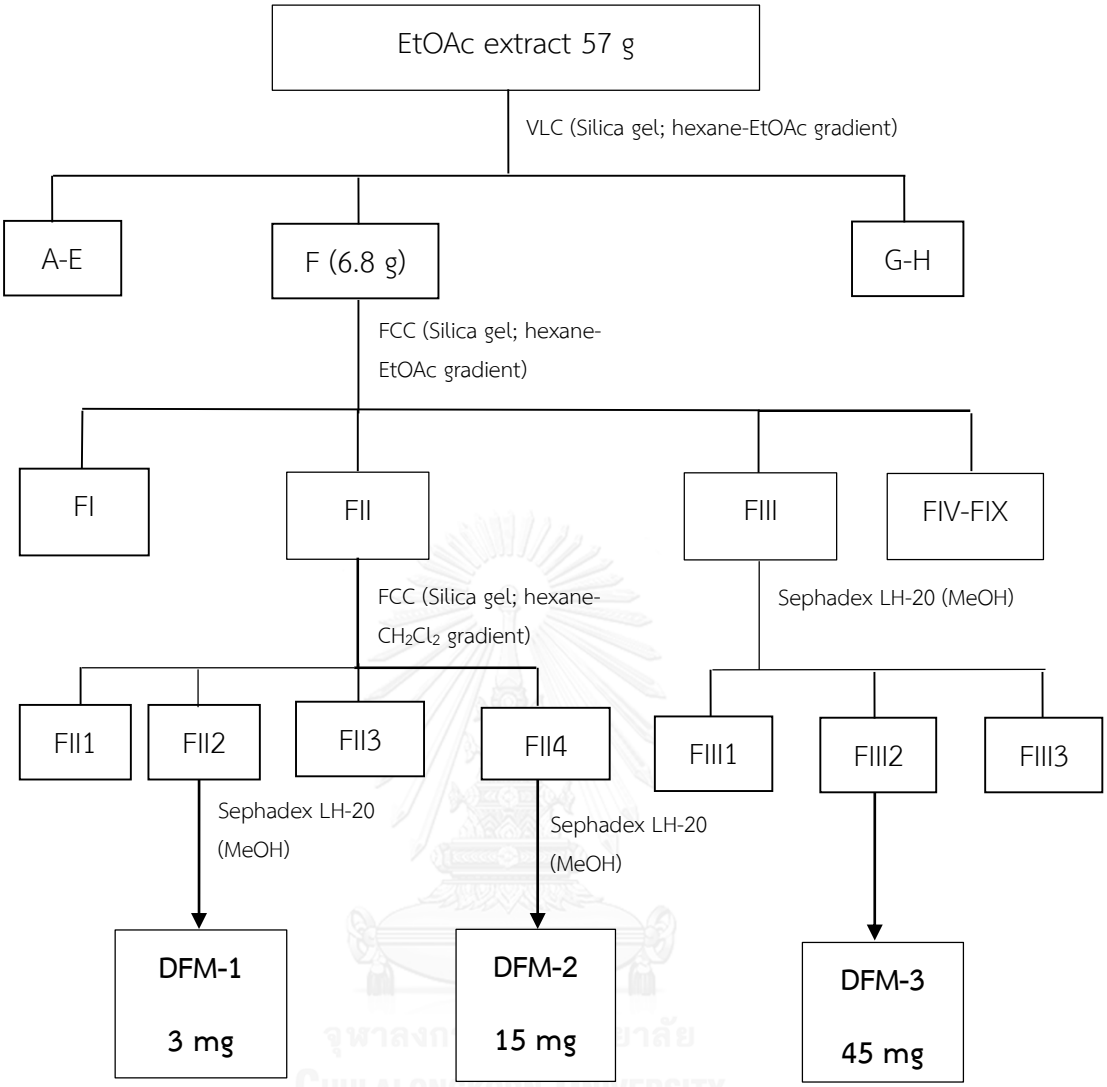
Fraction GIII2 (51 mg) was purified by FCC using silica gel (No. 9385) as the stationary phase with a gradient of CH_2Cl_2-hexane to give compound DFM-11 as brown amorphous solid (3 mg, R_f 0.40, silica gel, CH_2Cl_2-hexane = 9:1). It was identified as moscatilin.

3.2.12 Isolation of compound DFM-12 (5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone)

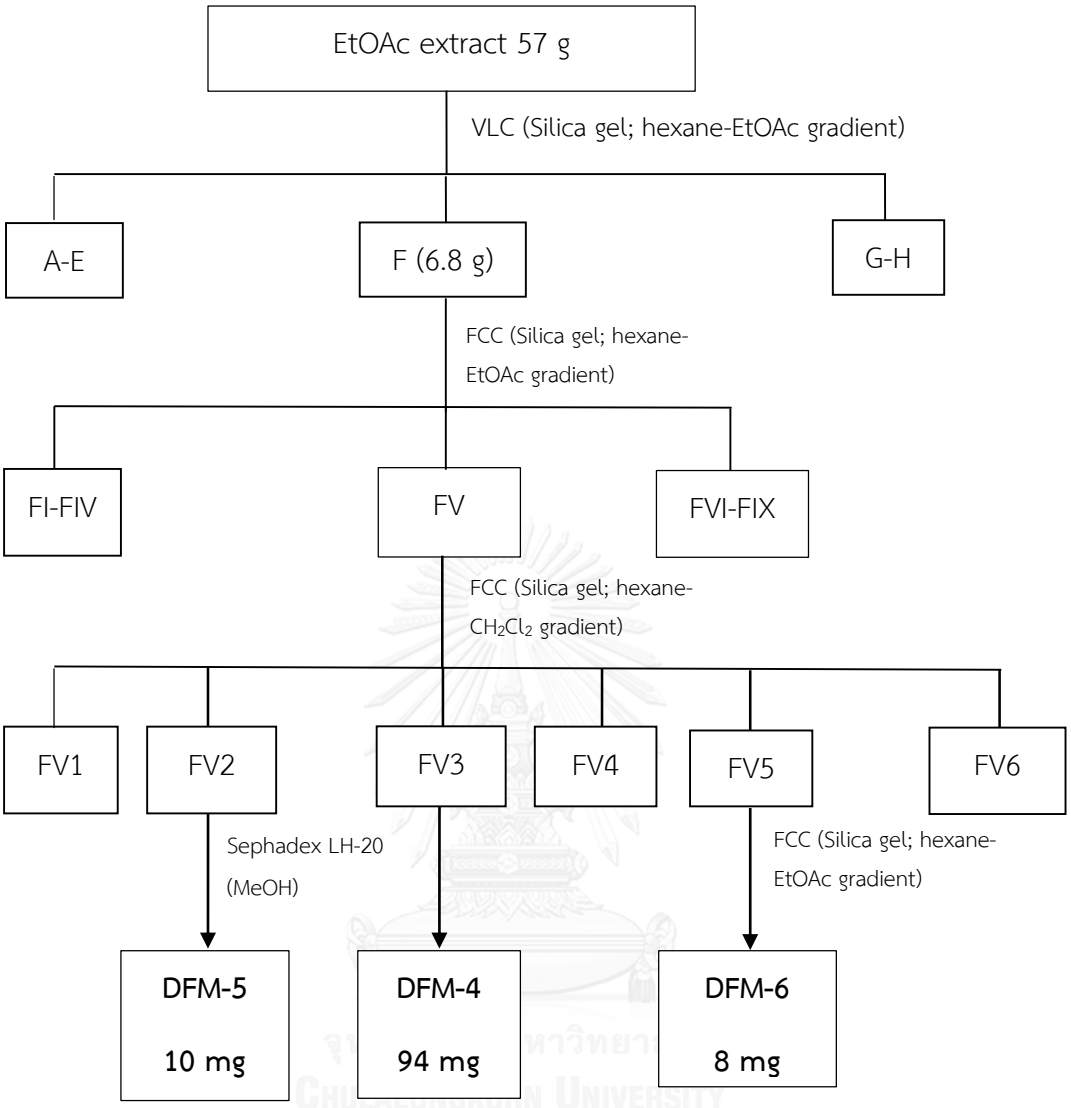
Fraction GIII4 (52 mg) was purified by FCC using silica gel (No. 9385) as the stationary phase with gradient elution of CH_2Cl_2-methanol to give compound DFM-12 as red amorphous solid. (11 mg, R_f 0.44, silica gel, CH_2Cl_2-methanol = 49 : 1) and it was later identified as 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone.



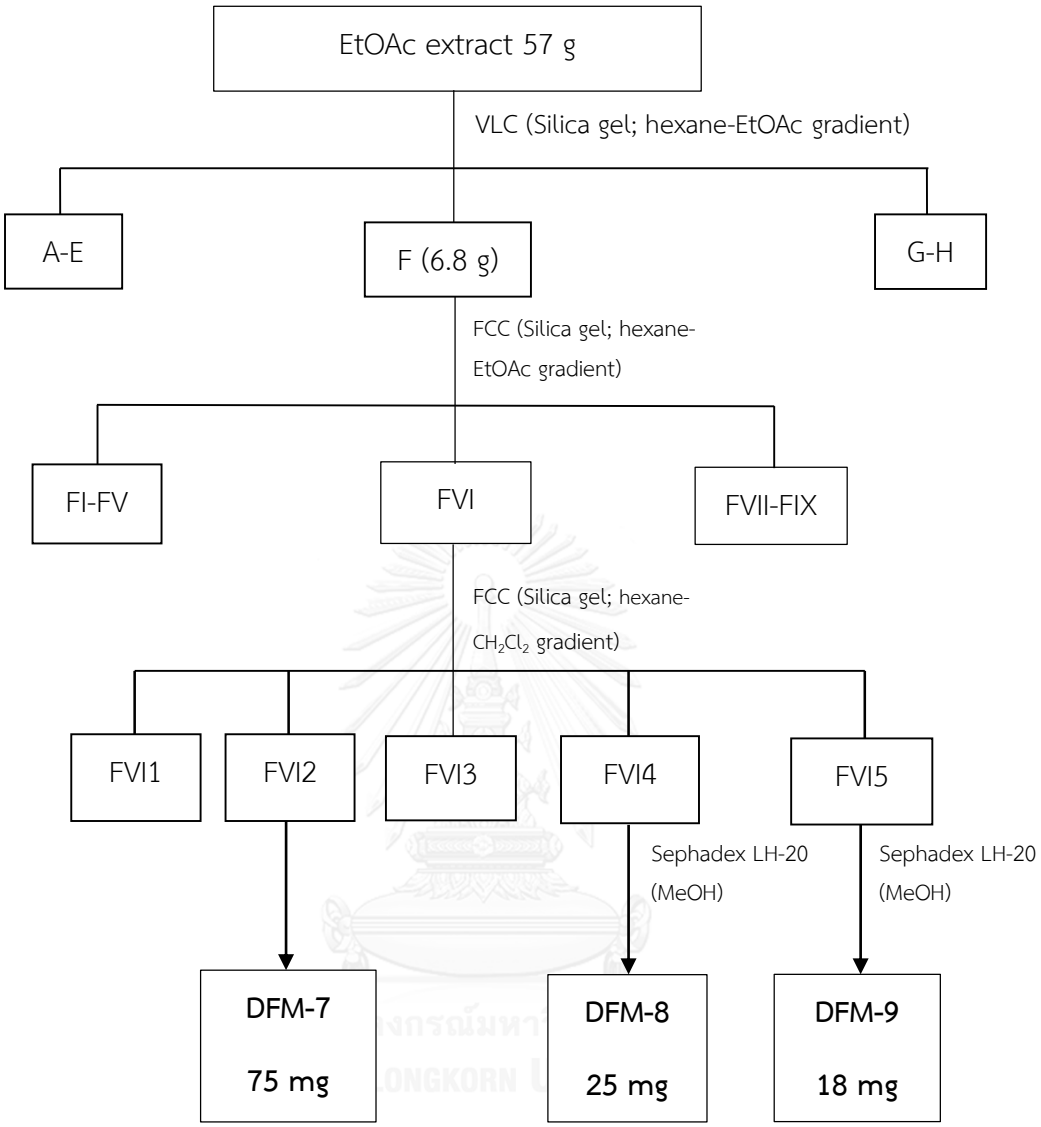
Scheme 1 Separation of the MeOH extract of *Dendrobium formosum*



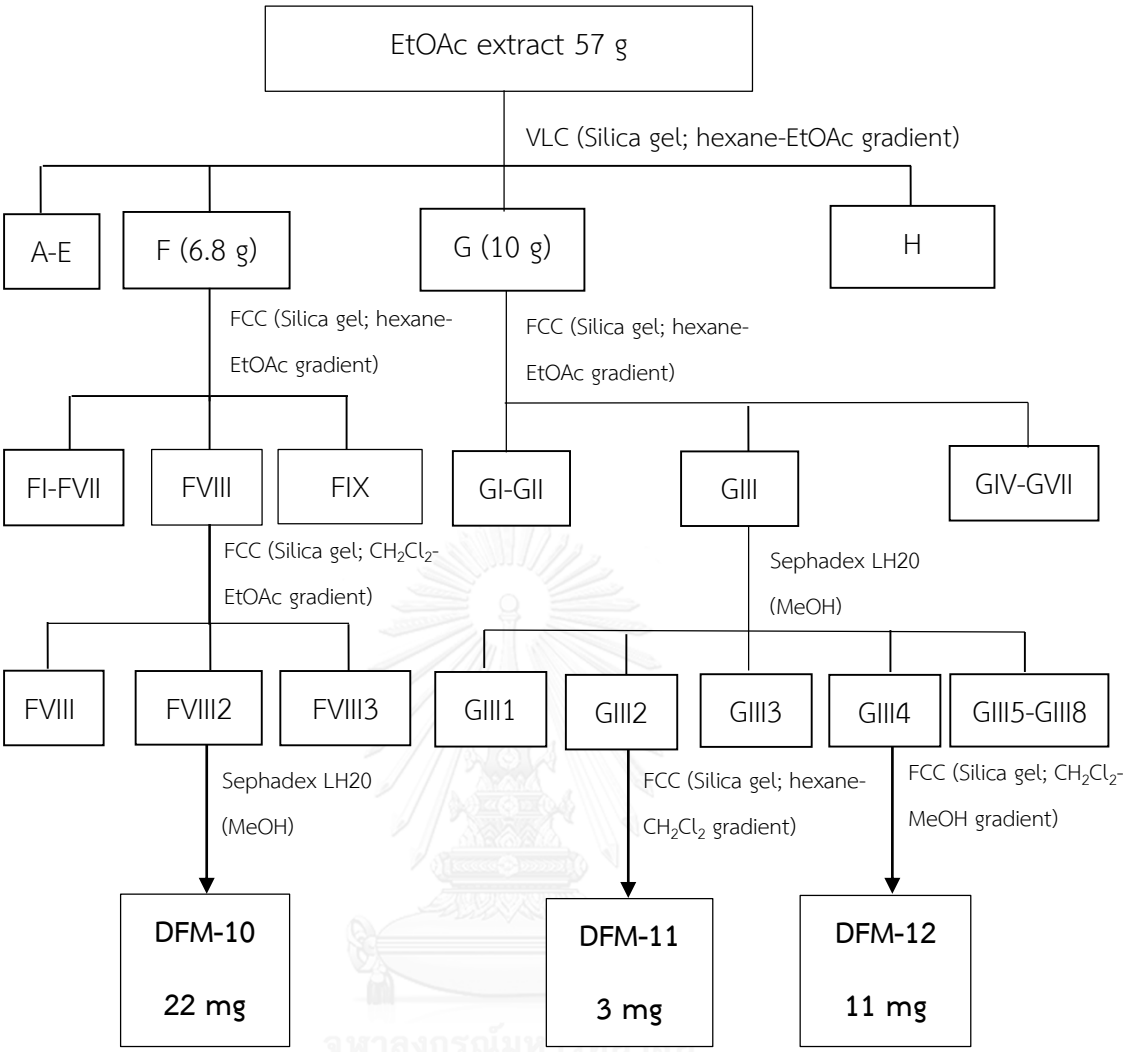
Scheme 2 Separation of the EtOAc extract of *Dendrobium formosum*



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



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



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

4. Physical and spectral data of isolated compounds

4.1 Compound DFM-1 (confusarin)

Compound DFM-1 was obtained as a yellow amorphous solid, soluble in acetone (3.0 mg, 0.00015 % based on dried weight of whole plant).

HR-ESI-MS : $[M-H]^-$ ion at m/z 299.0919 ($C_{17}H_{15}O_5$); **Figure 6**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 5**, **Figure 7**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 5**, **Figure 8**

4.2 Compound DFM-2 (hircinol)

Compound DFM-2 was obtained as a yellow amorphous solid, soluble in acetone (15.0 mg, 0.00075 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 265.0847 ($C_{15}H_{14}O_3Na$); **Figure 12**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 6**, **Figure 13**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 6**, **Figure 14**

4.3 Compound DFM-3 (erianthridin)

Compound DFM-3 was obtained as a yellow amorphous solid, soluble in acetone (45.0 mg, 0.00225 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 295.0949 ($C_{16}H_{16}O_4Na$); **Figure 17**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 7**, **Figure 18**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 7**, **Figure 19**

4.4 Compound DFM-4 (gigantol)

Compound DFM-4 was obtained as a brown amorphous solid, soluble in acetone (94.0 mg, 0.0047 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 297.1111 ($C_{16}H_{18}O_4Na$); **Figure 23**

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

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

4.5 Compound DFM-5 (nudol)

Compound DFM-5 was obtained as a yellow amorphous solid, soluble in acetone (10.0 mg, 0.005 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 293.0793 ($C_{16}H_{14}O_4Na$); **Figure 27**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 8**, **Figure 28**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 8**, **Figure 29**

4.6 Compound DFM-6 (lusianthridin)

Compound DFM-6 was obtained as a brown amorphous solid, soluble in acetone (8.0 mg, 0.004 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 265.0847 ($C_{15}H_{14}O_3Na$); **Figure 32**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 9**, **Figure 33**

13C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 9**, **Figure 34**

4.7 Compound DFM-7 (coelonin)

Compound DFM-7 was obtained as a brown amorphous solid, soluble in acetone (75.0 mg, 0.00375 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 265.0845 ($C_{15}H_{14}O_3Na$); **Figure 37**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 10**, **Figure 38**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 10**, **Figure 39**

4.8 Compound DFM-8 (dihydroconiferyl dihydro-*p*-coumarate)

Compound DFM-8 was obtained as a yellow amorphous solid, soluble in acetone (25.0 mg, 0.00125 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 353.1368 ($C_{19}H_{22}O_5Na$); **Figure 42**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 11**, **Figure 43**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 11**, **Figure 44**

4.9 Compound DFM-9 (batatasin III)

Compound DFM-9 was obtained as a brown amorphous solid, soluble in acetone (18.0 mg, 0.009 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 267.0955 ($C_{15}H_{16}O_3Na$); **Figure 48**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 12**, **Figure 49**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 12**, **Figure 50**

4.10 Compound DFM-10 (2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene)

Compound DFM-10 was obtained as a brown amorphous solid, soluble in acetone (22.0 mg, 0.0011 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 281.0791 ($C_{15}H_{14}O_4Na$); **Figure 52**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 13**, **Figure 53**

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

4.11 Compound DFM-11 (moscatilin)

Compound DFM-11 was obtained as a brown amorphous solid, soluble in chloroform (5.0 mg, 0.00025 % 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 55**

^{1}H NMR : δ ppm, 300 MHz, in $CDCl_3$; see **Table 14**, **Figure 56**

^{13}C NMR : δ ppm, 75 MHz, in in $CDCl_3$; see **Table 14**, **Figure 57**

4.12 Compound DFM-12 (5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone)

Compound DFM-12 was obtained as a red amorphous powder, soluble in acetone (11.0 mg, 0.00055 % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at m/z 279.0633 ($C_{15}H_{12}O_4Na$); **Figure 60**

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see **Table 15**, **Figure 61**

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see **Table 15**, **Figure 62**

5. α-Glucosidase and lipase enzyme inhibitory activity assays

5.1 α-Glucosidase enzyme inhibitory activity assay

α-Glucosidase is the most important enzyme for carbohydrate digestion. α-Glucosidase inhibition reach to protect excess glucose absorption at the small intestine (Xiao *et al*., 2013). Many constituents from medicinal plants have been reported as α-glucosidase inhibitors such as flavonoids, terpenes, phenylpropanoids, phenol, and alkaloids (Yin *et al.*, 2014). Structure-Activity Relationship have been studied in some secondary metabolites groups as well as flavonoids, stilbenes and tannins (Xiao *et al.*, 2013).

5.1.1 Materials and instruments

- *p*-Nitrophenyl-α-D-glucopyranoside (*p*NPG) (Sigma-Aldrich, USA)

- α-Glucosidase enzyme (Sigma-Aldrich, USA)

- Na_2CO_3 (Sigma-Aldrich, USA)

- Microplate reader (Wallac1420 Multilevel counter, Victor3, PerkinElmer)

- Ultrasonic bath (Transsonic 570/H, Elma)

- Vortex mixer (Vortex-Genie2, Scientific industries)

5.1.2 Determination of α-glucosidase enzyme inhibitory activity

The α-glucosidase enzyme inhibitory activity was assayed by monitoring the release of *p*-nitrophenol from *p*-nitrophenyl-α-D-glucopyranoside (*p*NPG). In the assay, 10 µl of test sample and 40 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 to the mixture and incubated at 37 °C for 20 min. Eventually, 100 µL of 0.1 mM Na_2CO_3

solution were added to stop the reaction. The absorbance was then measured at 405 nm using a microplate reader. The percentage of α-glucosidase inhibitory activity was calculated by the following formula:

$$\% \alpha\text{-glucosidase inhibitory activity} = [(A_{control} - A_{sample}) / A_{control}] \times 100$$

Where $A_{control}$ and A_{sample} are the absorbance. The experiment was performed in triplicate. 50%DMSO was used as a negative control. Acarbose was used as a positive control and treated under the same condition as the samples.

The enzyme kinetics was performed by analyzing the double reciprocal Lineweaver-Burk plot. The experiment was operated by varying the concentration of *p*NPG (0.125, 0.25, 0.5, 1.0, 2.0 mM) in the absence and presence of different test sample concentrations (80 and 160 μM) and the reaction were allowed to react at 37 ^{o}C for 5, 10, 15, 20, 25 and 30 min. Data were displayed as mean ± SD. The statistical analysis was done by student's t test (Sun *et al.*, 2014).

5.2 Lipase enzyme inhibitory activity assay

Lipase enzyme is a predominant lipolytic enzyme in humans responsible for the absorption of dietary fats through the hydrolysis of triacylglycerols into monoacylglycerols and free fatty acids in the intestinal lumen (Yang *et al.*, 2014). The lipase enzyme inhibitors from natural products such as polysaccharides, dietary fibers from wheat bran and cholestyramine, soya proteins and synthetic compounds have been investigated for their lipase enzyme inhibition. All of these products have a significant role to decrease dietary fat absorption and help to prevention obesity. (Seyedan *et al.*, 2015).

5.2.1 Materials and instruments

- 4-Methylumbelliferyl oleate (4-MUO) (Sigma-Aldrich, USA)

- Pancreatic lipase enzyme (Sigma-Aldrich, USA)

- Sodium citrate (Merck)

- Microplate reader (Wallac1420 Multilevel counter, Victor3, PerkinElmer)

- Ultrasonic bath (Transsonic 570/H, Elma)

- Vortex mixer (Vortex-Genie2, Scientific Industries)

5.2.2 Determination of lipase enzyme inhibitory activity

The lipase enzyme inhibitory activity was determined by measuring the release of 4-methylumbelliferone (4-MU) from 4-methylumbelliferyl oleate (4-MUO) (Sergent *et al*., 2012). In 96-well plate, 25 µl of test sample, 50 µl of 0.25 mM 4MUO and 25 µl of 0.125 mg/mL pancreatic lipase were mixed and incubated at room temperature for 30 min. After that, 100 µL of 0.1 mM sodium citrate were added to terminate the reaction. Orlistat was used as the positive control. Fluorescence from the release of 4-MU was measured by using a microplate reader with excitation and emission wavelengths of 355 and 460 nm, respectively. The percentage of lipase enzyme inhibitory activity was calculated by the following formula:

$$\% \text{ lipase enzyme inhibitory activity} = [(A_{control} - A_{sample}) / A_{control}] \times 100$$

Where $A_{control}$ and A_{sample} are the absorbance. The experiment was performed in triplicate. 20%DMSO was used as a negative control. Orlistat was used as a positive control and treated under the same condition as the sample.

The enzyme kinetics was performed by analyzing the double reciprocal Lineweaver-Burk plot. The experiment was examined by varying the concentration of 4-MUO (0.0625, 0.125, 0.25, 0.5, 1.0 mM) in the absence and presence of different test sample concentrations (40 and 80 µM) and the reaction were allowed to react at room

temperature for 5, 10, 15, 20, 25 and 30 min. Data were displayed as mean ± SD. The statistical analysis was done by student's t test (Sun *et al.*, 2014).

CHAPTER IV
RESULTS AND DISCUSSION

In this study, the dried and powdered whole plants of *Dendrobium formosum* (2.0 kg) were macerated with methanol. The methanol extract was concentrated under reduced pressure to give 115 g. This methanol extract exhibited approximately 95.60% and 98.97% inhibition of α-glucosidase and lipase inhibitory activities at a concentration of 100 µg/mL. It was further partitioned with EtOAc, Aqueous and *n*-butanol. The EtOAc extract showed the most potent α-glucosidase and lipase inhibitory activities with approximately 96.31% and 83.94% inhibition, respectively. The EtOAc extract was further separated using several chromatographic techniques to give 12 compounds including two phenanthrenes (DFM-1 and DFM-5) together with five dihydrophenanthrene (DFM-2, DFM-3, DFM-6, DFM-7 and DFM-10), a dihydrophenanthrenequinone (DFM-12), three bibenzyls compounds (DFM-4, DFM-9 and DFM-11) and a phenylpropanoid derivative (DFM-8). The structures of these compounds were determined by spectroscopic techniques, including MS and NMR. They were also investigated for their α-glucosidase and lipase inhibitory activities.

1. Structure determination of isolated compounds

1.1 Structure determination of compound DFM-1

Compound DFM-1 was obtained as a yellow amorphous solid. The HR-ESI-MS spectrum (**Figure 6**) showed a pseudomolecular ion $[M-H]^-$ at m/z 299.0919 (calcd. for $C_{17}H_{15}O_5$; 299.0919), suggesting the molecular formula $C_{17}H_{16}O_5$.

The ^{1}H-NMR spectrum (**Figure 7** and **Table 5**) indicated the presence of *ortho*-coupled aromatic protons at δ_H 7.60 (1H, *d*, *J*=9.0 Hz, H-10) and 7.90 (1H, *d*, *J*=9.0 Hz, H-9) and two aromatic carbons at δ_C 119.4 (C-9) and 126.8 (C-10).

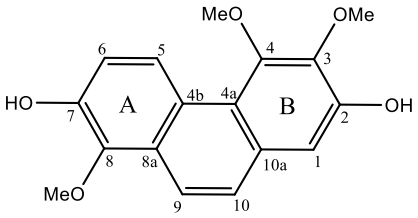
In addition, the ^{1}H-NMR spectrum, in the aromatic region of ring A, showed two doublet proton signals at δ_H 9.14 (1H, *d*, *J*=9.3 Hz, H-5) and δ_H 7.25 (1H, *d*, *J*=9.3 Hz, H-6). For ring B, the ^{1}H-NMR spectrum showed one singlet proton at δ_H 7.18 (*s*, H-1). The ^{1}H-NMR spectrum also exhibited signals for three methoxyls at δ_H 3.94 (*s*, 8-OMe), δ_H 3.98 (*s*, 4-OMe) and δ_H 4.10 (*s*, 3-OMe).

The ^{13}C-NMR spectrum (**Figure 8** and **Table 5**) and HSQC (**Figure 9**) spectral data displayed seventeen carbon signals, including three signals for three methoxyl groups at δ_C 59.2, 60.4 and 60.5. The other fourteen carbon signals of DFM-1 could be differentiated into five methine carbon signals at 108.9 (C-1), 117.3 (C-6), 119.4 (C-9), 123.1 (C-5) and 126.8 (C-10) and nine quaternary carbon signals at 118.4 (C-4a), 124.3 (C-4b), 127.1 (C-8a), 129.3 (C-10a), 141.5 (C-8), 142.1 (C-3), 146.4 (C-7), 149.2 (C-2) and 151.5 (C-4).

The HMBC correlations (**Figure 10**) from 3-OCH_3 to C-3, 4-OCH_3 to C-4, 8-OCH_3 to C-8 supported the position of the methoxyls assigned to C-3, C-4 and C-8, respectively.

In the NOESY spectrum (**Figure 11**), the methoxy protons at δ_H 3.94 (8-OCH_3) and 3.98 (4-OCH_3) revealed a correlation peak with H-9 and H-5, respectively, confirmed the location of the methoxyls at C-8 and C-4. Another methoxyl was attached at C-3, as supported by the HMBC correlations of C-3 to 3-OCH_3 and H-1.

Based on the above data and through comparison of its ^{1}H, ^{13}C-NMR and MS with previously reported data (Majumder and Kar, 1987), DFM-1 was identified as confusarin [**75**]. The first report of confusarin [**75]** in family Orchidaceae has been from *Eria confusa* (Majumder and Kar, 1987). Moreover, this compound also has been found in other *Dendrobium* species such as *D. chryseum* (Ma *et al.*, 1998), *D. chrysotoxum* (Hu *et al.*, 2012) and *D. nobile* (Zhang *et al.*, 2008b).



Confusarin [**75**]

Table 5 NMR spectral data of compound DFM-1 (in acetone-d_6) and confusarin (in $CDCl_3$)

Position	Compound DFM-1		Confusarin[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	7.18 (*s*)	108.9	7.11 (*s*)	107.6
2	-	149.2	-	147.1
3	-	142.1	-	140.4
4	-	151.5	-	150.2
4a	-	118.4	-	118.5
4b	-	124.3	-	124.3
5	9.14 (*d*, 9.3)	123.1	9.12 (*d*, 10.0)	123.4
6	7.25 (*d*, 9.3)	117.3	7.22 (*d*, 10.0)	116.6
7	-	146.4	-	144.9
8	-	141.5	-	140.4
8a	-	127.1	-	125.7
9	7.90 (*d*, 9.0)	119.4	7.79 (*d*, 10.0)	118.8
10	7.60 (*d*, 9.0)	126.8	7.51 (*d*, 10.0)	126.8
10a	-	129.3	-	128.7
3-OMe	4.01 (*s*)	60.4	4.03 (*s*)	60.7
4-OMe	3.98 (*s*)	59.2	3.89 (*s*)	59.2
8-OMe	3.94 (*s*)	60.5	3.89 (*s*)	61.4

[a](Majumder and Kar, 1987)

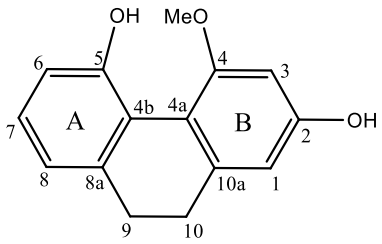
1.2 Structure determination of compound DFM-2

Compound DFM-2 was obtained as a yellow amorphous solid. The HR-ESI-MS spectrum (**Figure 12**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 265.0847 (calcd. for $C_{15}H_{14}O_3Na$; 265.0840), suggesting the molecular formula $C_{15}H_{14}O_3$.

The appearance of methylene protons at δ_H 2.67 (2H, *br s*, H-9) and δ_H 2.67 (2H, *br s*, H-10), which showed HSQC correlations (**Figure 15**) to carbon atoms at δ_C 30.7 (C-9) and 31.2 (C-10), respectively, two methylene indicated a dihydrophenanthrene skeleton (Fisch *et al.*, 1973). Additionally the ^{1}H-NMR data (**Figure 13** and **Table 6**) of ring A showed proton signals at δ_H 6.87 (1H, *br d*, *J*=7.8 Hz, H-8), δ_H 6.92 (1H, *br d*, *J*=7.8 Hz, H-6) and δ_H 7.10 (1H, *t*, *J*=7.8 Hz, H-7). For ring B, the ^{1}H-NMR spectrum showed two protons at δ_H 6.53 (1H, *d*, *J*=2.4 Hz, H-1) and δ_H 6.49 (1H, *d*, *J*=2.4 Hz, H-3). The ^{1}H-NMR spectrum also showed methoxyl group at δ_H 3.80 (1H, *s*, 4-MeO). This methoxyl group was placed at C-4 from its NOESY cross peak with H-3 (**Figure 16**).

The ^{13}C-NMR (**Figure 14** and **Table 6**) and HSQC (**Figure 15**) spectra of DFM-2 revealed the presence of one methoxyl at δ_C 54.6, two methylenes at δ_C 30.7 (C-9) and 31.2 (C-10), five methines at δ_C 101.3 (C-3), 106.3 (C-1), 116.1 (C-6), 119.7 (C-8) and 127.1 (C-7) and seven quaternary carbons at δ_C 113.9 (C-4b), 121.2 (C-4a), 140.8 (C-8a), 142.5 (C-10a), 152.2 (C-4), 154.4 (C-5) and 159.7 (C-2).

Based on the above mentioned spectroscopic properties, compound DFM-2 was identified as hircinol [**107**], which was previously isolated from *D. draconis* (Sritularak *et al.*, 2011a) and *D. aphyllum* (Yang *et al.*, 2015).



Hircinol [**107**]

Table 6 NMR spectral data of compound DFM-2 (in acetone-d_6) and hircinol (in $CDCl_3$)

Position	Compound DFM-2		Hircinol[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	6.53 (*d*, 2.4)	106.3	6.51 (*s*)	109.9
2	-	159.7	-	158.4
3	6.49 (*d*, 2.4)	101.3	6.51 (*s*)	100.0
4	-	152.2	-	154.6
4a	-	121.1	-	128.7
4b	-	113.9	-	114.7
5	-	154.4	-	156.3
6	6.92 (*br d*, 7.8)	116.1	6.77-7.32 (*m*)	118.2
7	7.10 (*t*, 7.8)	127.1		128.1
8	6.87 (*br d*, 7.8)	119.7		120.0
8a	-	140.8	-	141.3
9	2.67 (*br s*)	30.7	2.64 (*br s*)	31.6
10	2.67 (*br s*)	31.2	2.64 (*br s*)	31.8
10a	-	142.5	-	144.1
4-OMe	3.80 (*s*)	54.6	3.89 (*s*)	57.3

[a](Fisch *et al.*, 1973)

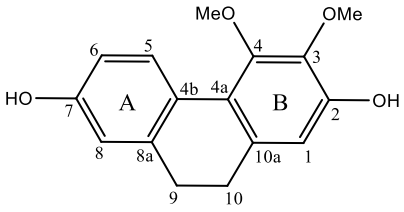
1.3 Structure determination of compound DFM-3

Compound DFM-3 was isolated as a yellow amorphous solid. The HR-ESI-MS spectrum (**Figure 17**) showed a sodium-adduct molecular ion $[M+Na]^+$ *m/z* at 295.0949 (calcd. for $C_{16}H_{16}O_4Na$; 295.0946). Its molecular formula was determined as $C_{16}H_{16}O_4$.

The ^{1}H-NMR spectrum of compound DFM-3 (**Figure 18** and **Table 7**) exhibited two methoxyl groups at δ_H 3.72 (1H, *s*, 4-MeO) and 3.86 (1H, *s*, 3-MeO). In addition, ^{1}H-NMR signals were observed for two methylene protons at δ_H 2.64 (2H, *s*, H_2-9) and 2.64 (2H, *s*, H_2-10). Compound DFM-3 had a dihydrophenanthrene structure similar to DFM-2. On ring A, the ^{1}H-NMR spectrum showed three proton signals at δ_H 6.72 (1H, *br s*, H-8), 6.75 (1H, *br d*, *J*=7.8 Hz, H-6) and 8.08 (1H, *d*, *J*=7.8 Hz, H-5). For ring B, the ^{1}H-NMR spectrum showed one proton at δ_H 6.58, assignable to H-1 (1H, *s*) based on its HMBC correlation with C-10.

The ^{13}C-NMR (**Figure 19** and **Table 7**) and DEPT 135 (**Figure 20**) spectra showed signals of 4 aromatic methines at δ_C 111.0 (C-1), 113.2 (C-6), 114.4 (C-8) and 128.2 (C-5), 8 aromatic quaternary carbons at δ_C 119.7 (C-4a), 124.4 (C-4b), 134.2 (C-10a), 139.3 (C-8a), 139.9 (C-3), 148.8 (C-2), 151.2 (C-4) and 155.7 ppm (C-7), two methoxyls at δ_C 59.3 and 60.1) ppm. The locations of the two methoxyls were determined by HMBC (**Figure 21**) and NOESY experiments (**Figure 22**). The first methoxyl (δ_H 3.72) was located at C-4 according to its NOESY correlation peak with H-5. The second methoxyl (δ_H 3.68) was placed at C-3 based on the HMBC correlations of C-3 with 3-OMe and H-1.

On the basis of the ^{1}H- and ^{13}C-NMR evidence, coumpound DFM-3 was determined to be erianthridin [**105**]. This compound has earlier been isolated from *D. nobile* (Hwang *et al.*, 2010).



Erianthridin [**105**]

Table 7 NMR spectral data of compound DFM-3 (in acetone-d_6) and erianthridin (in CD_3OD)

Position	Compound DFM-3		Erianthridin[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	6.58 (*s*)	111.0	6.56 (*s*)	118.8
2	-	148.8	-	149.6
3	-	139.9	-	140.1
4	-	151.2	-	152.1
4a	-	119.7	-	120.6
4b	-	124.4	-	125.4
5	8.08 (*d*, 7.8)	128.2	8.08 (*d*, 9.2)	129.1
6	6.75 (*br d*, 7.8)	113.2	6.68-6.79 (*m*)	114.1
7	-	155.7	-	156.6
8	6.72 (*br s*)	114.4	6.68-6.79 (*m*)	115.3
8a	-	139.3	-	135.1
9	2.64 (*s*)	29.8	2.63 (*s*)	*
10	2.64 (*s*)	29.9	2.63 (*s*)	*
10a	-	134.2	-	129.1
3-OMe	3.86 (*s*)	60.1	3.85 (*s*)	61.2
4-OMe	3.72 (*s*)	59.3	3.71 (*s*)	61.0

[a](Shimizu *et al.*, 1988) * = Not report

1.4 Structure determination of compound DFM-4

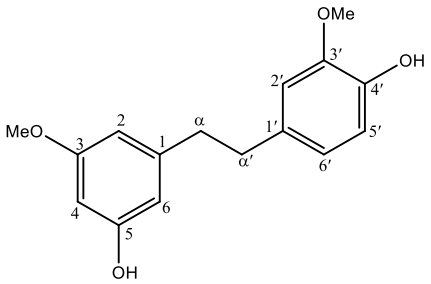
Compound DFM-4 was obtained as a brown amorphous solid. The HR-ESI-MS of this compound (**Figure 23**) showed an $[M+Na]^+$ peak at *m/z* 297.1111 (calcd. for $C_{16}H_{18}O_4Na$; 297.1103), suggesting the molecular formula $C_{16}H_{18}O_4$.

The ^{1}H-NMR spectrum of compound DFM-4 (**Figure 24** and **Table 8**) revealed a pair of methylene proton signals at δ_H 2.80 (4H, *m*, H_2-α, H_2-α') and the ^{13}C-NMR spectrum (**Figure 25**) showed two methylene carbons at 38.2 (C-α) and 37.1 (C-α'), suggesting that compound DFM-4 was a bibenzyl derivative. The ^{1}H-NMR spectrum also showed two methoxy protons at δ_H 3.71 (3H, *s*, 3-MeO) and 3.79 (3H, *s*, 3′-MeO). In addition, the ^{1}H-NMR spectrum exhibited signals for six aromatic protons at δ_H 6.28 (1H, *t*, *J*=2.0 Hz, H-4), 6.32 (1H, *br t*, *J*=2.0 Hz, H-2), 6.35 (1H, *br t*, *J*=2.0 Hz, H-6), 6.67 (1H, *dd*, *J*=8.1, 1.5 Hz, H-6′), 6.75 (1H, *d*, *J*=8.1 Hz, H-5′) and 6.80 (1H, *d*, *J*=1.5 Hz, H-2′).

The NOESY spectrum (**Figure 26**) showed correlations of 3-OMe with H-2 and H-4, and 3′-OMe with H-2′. Thus, the two methoxyl groups were placed at C-3 and C-3′, respectively.

From ^{13}C-NMR data (**Figure 25** and **Table 8**), sixteen carbon signals were observed, including two methoxyls, two methylenes, six aromatic methines and six aromatic quaternary carbons.

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.*, 2008a), compound DFM-4 was identified as gigantol [**28**]. This compound is a bibenzyl frequently found in *Dendrobium spp.*, such as *D. chrysanthum* (Yang *et al.*, 2006b), *D. aurantiacum* var. *denneanum* (Liu *et al.*, 2009a), *D. loddigesii* (Ito *et al.*, 2010), *D. brymerianum* (Klongkumnuankarn *et al.*, 2015) and *D. venustum* (Sukphan *et al.*, 2014).



Gigantol [**28**]

Table 8 NMR spectral data of compound DFM-4 and gigantol (in acetone-d_6)

Position	Compound DFM-4		Gigantol[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	144.4	-	145.4
2	6.32 (*br t*, 2.0)	108.1	6.22 (*t*, 2.0)	108.8
3	-	160.9	-	159.1
4	6.28 (*t*, 2.0)	98.9	6.30 (*dd*, 2.0, 2.0)	99.6
5	-	160.9	-	161.7
6	6.35 (*br t*, 2.0)	105.5	6.30 (*t*, 2.0)	106.2
α	2.80 (*m*)	38.2	2.79 (*m*)	39.0
α′	2.80 (*m*)	37.1	2.78 (*m*)	37.9
1′	-	133.3	-	134.0
2′	6.80 (*d*, 1.5)	114.7	6.80 (*d*, 2.0)	115.4
3′	-	147.2	-	147.9
4′	-	144.6	-	145.1
5′	6.75 (*d*, 8.1)	112.1	6.74 (*d*, 8.0)	112.8
6′	6.67 (*dd*, 8.1, 1.5)	120.8	6.66 (*dd*, 8.0, 2.0)	121.5
3′-OMe	3.79 (*s*)	55.3	3.82 (*s*)	55.2
3-OMe	3.71 (*s*)	54.5	3.73 (*s*)	54.3

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

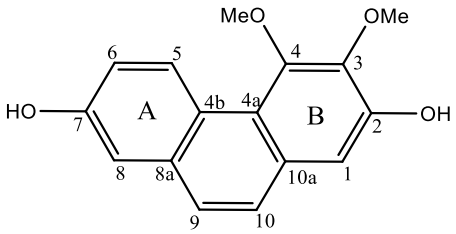
1.5 Structure determination of compound DFM-5

Compound DFM-5 was isolated as a yellow amorphous solid. Its HR-ESI-MS (**Figure 27**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 293.0793 (calcd. for $C_{16}H_{14}O_4Na$; 293.0790), suggesting the molecular formula $C_{16}H_{14}O_4$.

The ^{1}H-NMR data (**Figure 28** and **Table 9**) of DFM-5 showed signals similar to those of DFM-1, except for the absence of the methoxy at position 8. The ^{1}H-NMR spectrum displayed signals for a pair of *cis* olefinic protons at δ_H 7.49 (1H, *d*, *J*=9.0 Hz, H-10) and 7.53 (1H, *d*, *J*=9.0 Hz, H-9). In the aromatic region of ring A, the ^{1}H-NMR spectrum exhibited an ABM spin system at δ_H 7.20 (1H, *dd*, *J*=9.0, 2.4 Hz, H-6), 7.25 (1H, *d*, *J*=2.4 Hz, H-8) and δ_H 9.33 (1H, *d*, *J*=9.0 Hz, H-5). For ring B, the ^{1}H-NMR spectrum showed one singlet signal at δ_H 7.16 (*s*, H-1). Furthermore, the ^{1}H-NMR spectrum also revealed the presence of two methoxyls at 3.98 and 4.01. The locations of the two methoxyls were deduced by HMBC and NOESY experiments (**Figure 30** and **Figure 31**). The first methoxy at δ_H 4.01 was placed at C-3 according to the HMBC correlations of C-3 with H-1 and 3-OMe. The second methoxy at δ_H 3.98 was located at C-4 based on its NOESY cross-peak with H-5.

The ^{13}C-NMR spectrum (**Figure 29** and **Table 9**) displayed sixteen carbon signals, including two signals for two methoxyl groups at δ_C 59.2 and 60.3. The other fourteen carbon signals of DFM-5 could be differentiated into six methine carbon signals at δ_C 108.8 (C-1), 111.6 (C-8), 116.7 (C-6), 126.1 (C-9), 126.7 (C-10) and 128.0 (C-5) and eight quaternary carbon signals at 118.3 (C-4a), 124.3 (C-4b), 129.4 (C-10a), 133.4 (C-8a), 141.9 (C-3), 149.0 (C-2), 151.3 (C-4) and 154.9 (C-7).

On the basis of the ^{1}H- and ^{13}C-NMR data, compound DFM-5 was identified as nudol [**121**], which was previously reported from *D. nobile* (Yang *et al.*, 2007) and *D. rotundatum* (Majumder and Pal, 1992).



Nudol [**121**]

Table 9 NMR spectral data of compound DFM-5 and nudol (in acetone-d_6)

Position	Compound DFM-5		Nudol[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	7.16 (*s*)	108.8	7.15 (*s*)	108.9
2	-	149.0	-	149.0
3	-	141.9	-	142.0
4	-	151.3	-	151.3
4a	-	118.3	-	118.3
4b	-	123.4	-	123.5
5	9.33 (*d*, 9.0)	128.0	9.33 (*d*, 9.2)	128.0
6	7.20 (*dd*, 9.0, 2.4)	116.7	7.19 (*dd*, 9.2, 2.8)	116.7
7	-	154.9	-	155.0
8	7.25 (*d*, 2.4)	111.6	7.24 (*d*, 2.8)	111.6
8a	-	133.7	-	133.7
9	7.53 (*d*, 9.0)	126.1	7.53 (*d*, 8.9)	126.2
10	7.49 (*d*, 9.0)	126.7	7.50 (*d*, 8.9)	126.8
10a	-	129.4	-	129.4
3-OMe	4.01 (*s*)	60.3	-	60.4
4-OMe	3.98 (*s*)	59.2	-	59.2

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

1.6 Structure determination of compound DFM-6

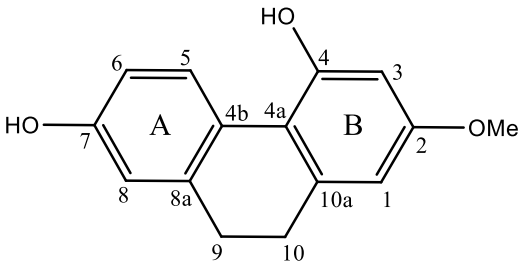
Compound DFM-6 was obtained as a brown amorphous solid. Its HR-ESI-MS (**Figure 32**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 265.0847 (calcd. for $C_{15}H_{14}O_3Na$; 265.0841), suggesting the molecular formula $C_{15}H_{14}O_3$.

The ^{1}H-NMR spectrum (**Figure 33** and **Table 10**), showed signals of aliphatic protons at δ_H 2.67 (*m*, H_2-9, H_2-10), suggesting a dihydrophenanthrene nucleus. The ^{1}H-NMR also exhibited signals of five aromatic protons at δ_H 6.37 (*d*, *J*=2.4 Hz, H-1), 6.44 (*d*, *J*=2.4 Hz, H-3), 6.69 (*br d*, *J*=9.3 Hz, H-6), 6.71 (*br s*, H-8), and 8.23 (*d*, *J*=9.3 Hz, H-5) and one methoxy group at δ_H 3.74 (*s*, 2-OMe).

The ^{13}C-NMR (**Figure 34** and **Table 10**) and HSQC (Figure 35) spectra displayed 15 signals, consisting of one methoxy carbon at δ_C 54.4, two methylene carbons at δ_C 29.8 and 30.6, five methine carbons (δ_C 100.7, 105.0, 112.6, 114.1 and 129.0) and seven quaternary carbons (δ_C 114.9, 125.0, 138.9, 140.5, 155.1, 155.2 and 158.4).

In the NOESY spectrum (**Figure 36**), the methoxy proton at δ_H 3.74 showed correlation peaks with H-1 and H-3 supporting the substitution of this methoxyl at C-2.

From the data mentioned above, compound DFM-6 was identified as lusianthridin [**99**] which was isolated earlier from *D. brymerianum* (Klongkumnuankarn *et al.*, 2015) and *D. venustum* (Sukphan *et al.*, 2014).



Lusianthridin [**99**]

Table 10 NMR spectral data of compound DFM-6 and lusianthridin (in acetone-d_6)

Position	Compound DFM-6		Lusianthridin[a]	
	δ_H (mult., J in Hz)	δ_C	δ_H (mult., J in Hz)	δ_C
1	6.37 (*d*, 2.4)	105.0	6.37 (*d*, 2.6)	106.0
2	-	158.4	-	159.3
3	6.44 (*d*, 2.4)	100.7	6.44 (*d*, 2.6)	101.6
4	-	155.1	-	155.9
4a	-	114.9	-	115.9
4b	-	125.0	-	125.9
5	8.23 (*d*, 9.3)	129.0	8.22 (*d*, 7.5)	129.9
6	6.69 (*br d*, 9.3)	112.6	6.68 (*dd*, 7.5, 2.7)	113.5
7	-	155.2	-	156.1
8	6.71 (*br s*)	114.1	6.69 (*m*)	115.0
8a	-	138.9	-	139.8
9	2.67 (*m*)	29.8	2.67 (*m*)	30.8
10	2.67 (*m*)	30.6	2.67 (*m*)	31.5
10a	-	140.5	-	141.4
2-OMe	3.74 (*s*)	54.4	3.74 (*s*)	55.3

[a](Guo *et al.*, 2007)

1.7 Structure determination of compound DFM-7

Compound DFM-7 was isolated as a brown amorphous solid. Its HR-ESI-MS (**Figure 37**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 265.0845 (calcd. for $C_{15}H_{14}O_3Na$; 265.0841), suggesting the molecular formula $C_{15}H_{14}O_3$.

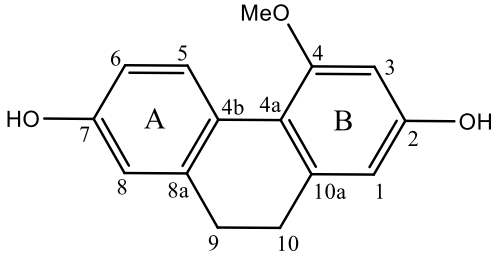
Comparison of the ^{1}H-NMR data of DFM-7 with DFM-6, revealed their structural similarity, excepted for the location of a methoxyl.

The ^{1}H-NMR spectrum (**Figure 38** and **Table 11**) showed signals for four methylene protons at δ_H 2.65 (*s*, H_2-9 and H_2-10), five methine protons at δ_H 6.39 (*d*, *J*=2.4 Hz, H-1), 6.46 (*d*, *J*=2.4 Hz, H-3), 6.67 (*br d*, *J*=2.7 Hz, H-6), 6.70 (*br s*, H-8), and 8.06 (*d*, *J*=9.0 Hz, H-5) and one methoxy group at δ_H 3.84 (*s*, 4-MeO).

The ^{13}C-NMR spectrum (**Figure 39** and **Table 11**) showed 15 carbons, corresponding to one methoxy carbon (δ_C 54.8), two methylene carbons (δ_C 29.9 and 30.5), five methine groups (δ_C 98.3, 107.3, 112.6, 114.1 and 129.0) and seven quaternary carbons (δ_C 115.4, 124.8, 139.1, 140.4, 155.1, 156.4 and 157.8).

In the NOESY spectrum (**Figure 41**), the methoxy protons at δ 3.84 displayed a NOESY interaction with the proton signal at δ_H 6.46 (*s*, H-3) suggested the placement of a methoxyl at C-4. The HMBC spectrum (**Figure 40**) confirmed the proposed structure of DFM-7, demonstrating correlations from the signal of H-3 to C-2, C-4a from H-8 to C-4b, C-6, C-7 and C-9; from H-9 to C-4b, C-8.

On the basis of the ^{1}H- and ^{13}C-NMR data, compound DFM-7 was identified as coelonin [**92**]. Coelonin [**92**] is a dihydrophenanthrene which was previously reported from *D. aphyllum* (Chen *et al.*, 2008a) and *D. nobile* (Yang *et al.*, 2007).



Coelonin [**92**]

Table 11 NMR spectral data of compound DFM-7 (in acetone-d_6) and coelonin (in CD_3OD)

Position	Compound DFM-7		Coelonin[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	6.39 (*d*, 2.4)	107.3	6.26 (*d*, 2.5)	104.8
2	-	156.4	-	155.4
3	6.46 (*d*, 2.4)	98.3	6.30 (*d*, 2.5)	100.1
4	-	157.8	-	158.3
4a	-	115.4	-	114.8
4b	-	124.8	-	125.2
5	8.06 (*d*, 9.0)	129.0	8.13 (*d*, 8.4)	128.6
6	6.67 (*br d*, 2.7)	112.6	6.62 (*dd*, 8.3, 2.7)	112.2
7	-	155.1	-	154.8
8	6.70 (*br s*)	114.1	6.61 (*d*, 2.6)	113.8
8a	-	139.1	-	139.8
9	2.65 (*s*)	29.9	2.59 (*s*)	30.1
10	2.65 (*s*)	30.5	2.59 (*s*)	30.8
10a	-	140.4	-	138.7
4-OMe	3.84 (*s*)	54.8	3.67 (*s*)	54.2

[a](Rueda *et al.*, 2014)

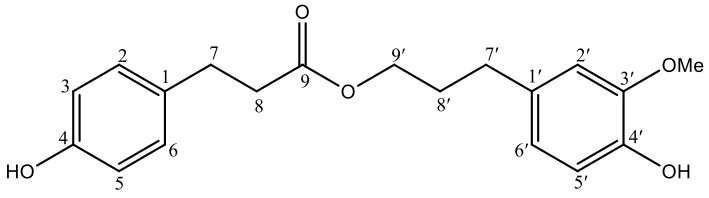
1.8 Structure determination of compound DFM-8

Compound DFM-8 was obtained as a yellow amorphous powder. Its HR-ESI-MS (**Figure 42**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 353.1368 (calcd. for $C_{19}H_{22}O_5Na$; 353.1365), suggesting the molecular formula $C_{19}H_{22}O_5$.

The ^{1}H-NMR spectrum (**Figure 43** and **Table 12**), exhibited five methylene protons at δ_H 1.88 (*m*, H-8′), 2.60 (*t*, *J*=7.5 Hz, H-8), 2.60 (*t*, *J*=7.5 Hz, H-7′), 2.83 (*t*, *J*=7.5 Hz, H-7) and 4.04 (*t*, *J*=7.5 Hz, H-9′) and seven aromatic protons at δ_H 6.63 (*br d*, *J*=8.1 Hz, H-6′), 6.73 (*br d*, *J*=8.1 Hz, H-5′), 6.76 (2H, *d*, *J*=8.1 Hz, H-3, H-5), 6.81 (*br s*, H-2′), 7.07 (2H, *d*, *J*=8.1 Hz, H-2, H-6) and one methoxy group at δ_H 3.83 (*s*, 3′-OMe).

The ^{13}C-NMR (**Figure 44** and **Table 12**) and DEPT 135 (**Figure 45**) spectra showed nineteen signals, corresponding to five aliphatic methylene carbons at δ_C 29.9 (C-7), 30.5 (C-8′), 31.4 (C-7′), 35.9 (C-8) and 63.2 (C-9′); seven aromatic CH carbons at δ_C 111.9 (C-2′), 114.8 (C-8′), 115.2 (C-3), 115.2 (C-4), 120.7 (C-5′), 129.2 (C-2) and 129.2 (C-6); five aromatic quaternary carbons at δ_C 131.5 (C-1), 132.7 (C-1′), 144.8 (C-4′), 147.4 (C-3′), 155.8 (C-4), one methoxy carbon at δ_C 55.3 (3′-OMe) and one carboxylic carbon at δ_C 172.3 (C-9). The NOESY spectrum (**Figure 47**) displayed correlations from the methoxyl group at δ_H 3.83 to H-2′ suggesting the location of a methoxyl at C-3′. Key HMBC correlations (**Figure 46**) were observed from C-9 to H-7 and H-9′; from C-1 to H-3, H-5, H-7, and from C-1′to H-5′and H-8′.

Based on the above spectral evidence, compound DFM-8 was identified as dihydroconiferyl dihydro-*p*-coumarate [**231**]. This compound has been previously isolated from *D. nobile* (Zhang *et al.*, 2006a).



Dihydroconiferyl dihydro-*p*-coumarate [**231**]

Table 12 NMR spectral data of compound DFM-8 (in acetone-d_6) and dihydroconiferyl dihydro-*p*-coumarate (in $CDCl_3$)

Position	Compound DFM-8		Dihydroconiferyl dihydro-*p*-coumarate[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	131.5	-	132.7
2	7.07 (*d*, 8.1)	129.2	7.06 (*d*, 8.4)	129.4
3	6.76 (*d*, 8.1)	115.2	6.74 (*d*, 8.4)	115.3
4	-	155.8	-	154.0
5	6.76 (*d*, 8.1)	115.2	6.74 (*d*, 8.4)	115.3
6	7.07 (d, 8.1)	129.2	7.06 (*d*, 8.4)	129.4
7	2.83 (*t*, 7.5)	29.9	2.88 (*t*, 7.6)	30.2
8	2.60 (*t*, 7.5)	35.9	2.59 (*t*, 7.6)	36.2
9	-	172.3	-	173.1
1′	-	132.7	-	133.1
2′	6.81 (*br s*)	111.9	6.65 (*br s*)	111.0
3′	-	147.4	-	146.4
4′	-	144.8	-	143.8
5′	6.73 (*d*, 8.1)	114.8	6.82 (*d*, 8.6)	114.3
6′	6.63 (*br d*, 8.1)	120.7	6.64 (*dd*, 8.8, 1.8)	121.0
7′	2.60 (*t*, 7.5)	31.4	2.56 (*t*, 7.4)	31.8
8′	1.88 (*m*)	30.5	1.89 (*m*)	30.5
9′	4.04 (*t*, 7.5)	63.2	4.08 (*t*, 6.5)	63.8
3′-OMe	3.83 (*s*)	55.3	3.87 (*s*)	55.9

[a](Zhang *et al.*, 2006a)

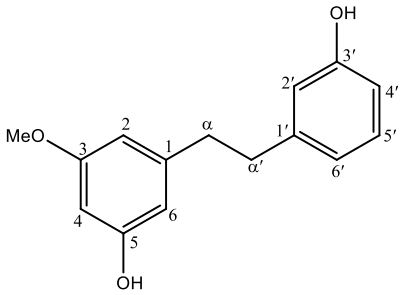
1.9 Structure determination of compound DFM-9

Compound DFM-9 was obtained as a brown amorphous solid. Its HR-ESI-MS (**Figure 48**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 267.0955 (calcd. for $C_{15}H_{16}O_3Na$; 267.0957), suggesting the molecular formula $C_{15}H_{16}O_3$.

The ^{1}H-NMR spectrum (**Figure 49** and **Table 13**) of compound DFM-9 showed two pairs of methylene proton signals at δ_H 2.80 (4H, *s*, H_2-α, H_2-α') and the ^{13}C-NMR spectrum showed two methylene carbons at δ_C 37.4 (C-α') and 37.7 (C-α) which was showed a close resemblance to those of DFM-4, a bibenzyl derivative. In addition, the ^{1}H-NMR spectrum exhibited signals for seven aromatic protons at δ_H 6.25 (1H, *t*, *J*=2.1 Hz, H-4), 6.33 (1H, *br t*, *J*=2.1 Hz, H-2), 6.34 (1H, *br t*, *J*=2.1 Hz, H-6), 6.65 (1H, *dd*, *J*=7.8, 2.1 Hz, H-4′), 6.70 (1H, *br d*, *J*=7.8 Hz, H-6′), 6.73 (1H, *br s*, H-2′) and 7.09 (1H, *t*, *J*=7.8 Hz, H-5′) and a methoxy proton signal at 3.72 (3H, *s*, 3-OMe).

The ^{13}C-NMR data (**Figure 50** and **Table 13**) showed fifteen carbon signals, including one methoxyl carbons at δ_C 54.4, two methylene carbons at δ_C 37.4 and 37.7, seven methine carbons at δ_C 98.9 (C-4), 105.4 (C-2), 107.9 (C-6), 112.7 (C-4′), 115.3 (C-2′), 119.5 (C-6′) and 129.2 (C-5′), and five quaternary carbons at δ_C 143.5 (C-1′), 144.2 (C-1), 157.4 (C-3′), 158.4 (C-5) and 161.0 (C-3). The methoxyl group was located at C-3 due to its NOESY correlations with H-2 and H-4 (**Figure 51**).

Through comparison of ^{1}H, ^{13}C-NMR and MS properties of this compound with previously reported data (Sachdev and Kulshreshtha, 1986), compound DFM-9 was identified as batatasin III [**16**]. Batatasin III [**16**] is a bibenzyl frequently found in *Dendrobium* species, for example, *D. aphyllum* (Yang *et al.*, 2015), *D. chrysotoxum* (Li *et al.*, 2009c), *D. draconis* (Sritularak *et al.*, 2011a) and *D. venustum* (Sukphan *et al.*, 2014).



Batatasin III [**16**]

Table 13 NMR spectral data of compound DFM-9 (in acetone-d_6) and batatasin III (in $CDCl_3$)

Position	Compound DFM-9		Batatasin III[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	144.2	-	144.4
2	6.33 (*br t*, 2.1)	105.4	6.29 (*dd*, 1.4, 1.4)	106.9
3	-	161.0	-	160.7
4	6.25 (*t*, 2.1)	98.9	6.37 (*dd*, 1.4, 1.4)	99.3
5	-	158.4	-	156.4
6	6.34 (*br t*, 2.1)	107.9	6.34 (*dd*, 1.4, 1.4)	108.2
α	2.80 (*s*)	37.7	2.83 (*m*)	36.9
α′	2.80 (*s*)	37.4	2.83 (*m*)	37.3
1′	-	143.5	-	143.4
2′	6.73 (*br s*)	115.3	6.64 (*dd*, 2.4, 2.4)	115.4
3′	-	157.4	-	155.4
4′	6.65 (*dd*, 7.8, 2.1)	112.7	6.67 (*dd*, 8, 2.4)	112.9
5′	7.09 (*t*, 7.8)	129.2	7.12 (*dd*, 8, 8)	129.3
6′	6.70 (*br d*, 7.8)	119.5	6.74 (*d*, 8)	120.8
3-OMe	3.72 (*s*)	54.4	3.73 (*s*)	55.2

[a](Chen *et al.*, 2008a)

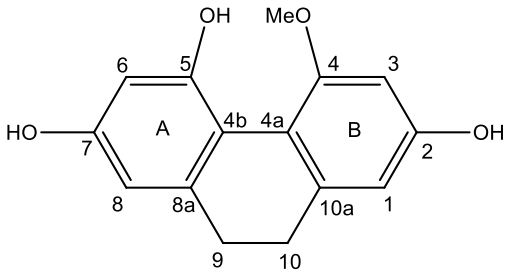
1.10 Structure determination of compound DFM-10

Compound DFM-10 was obtained as a brown amorphous solid. Its HR-ESI-MS (**Figure 52**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 281.0791 (calcd. for $C_{15}H_{14}O_4Na$; 281.0790), suggesting the molecular formula $C_{15}H_{14}O_4$.

The ^{1}H-NMR spectrum (**Figure 53** and **Table 14**) of DFM-10 showed a close resemblance to compound DFM-2, except for the presence of an additional hydroxyl at position 7. The ^{1}H-NMR spectrum of this compound exhibited two pairs of methylene groups at δ_H 2.60 (*m*, H_2-9, H_2-10) and the ^{13}C-NMR showed two methylene carbon signals (δ_C 31.1 and 31.2), confirming the dihydrophenanthrene nucleus. Moreover, signals of four aromatic protons at δ_H 6.34 (*d*, *J*=2.4 Hz, H-6), 6.37 (*d*, *J*=2.4 Hz, H-8), 6.55 (*d*, *J*=2.1 Hz, H-1) and 6.59 (*d*, *J*=2.1 Hz, H-3) and one methoxy groups at δ_H 3.96 (*s*, 4-OMe) were observed.

The ^{13}C-NMR spectrum (**Figure 54** and **Table 14**) displayed 15 carbon signals, corresponding to four methine carbons (δ_C 99.2, 103.8, 107.3 and 109.1), eight quaternary carbons (δ_C 112.7, 114.3, 141.6, 142.5, 154.7, 155.1, 156.8 and 157.0), one methoxy carbon (δ_C 56.5) and two methylene carbons (δ_C 31.1 and 31.2).

On the basis of the ^{1}H and ^{13}C-NMR data, compound DFM-10 was identified as 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene [**111**] which was previously isolated from *D. longicornu* (Hu *et al.*, 2008a)



2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene [**111**]

Table 14 NMR spectral data of compound DFM-10 and 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene (in acetone-d_6)

Position	Compound DFM-10		2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	6.55 (*d*, 2.1)	109.1	6.35 (*d*,2.5)	109.9
2	-	156.8	-	157.6
3	6.59 (*d*, 2.1)	99.2	6.31 (*d*, 2.5)	100.0
4	-	154.7	-	155.5
4a	-	114.3	-	115.1
4b	-	112.7	-	113.6
5		155.1	-	155.9
6	6.34 (*d*, 2.4)	103.8	6.52 (*d*, 2.3)	104.6
7	-	157.0	-	157.9
8	6.37 (*d*, 2.4)	107.3	6.57 (*d*, 2.3)	108.1
8a	-	141.6	-	142.4
9	2.60 (*m*)	31.1	2.56 (*m*)	31.9
10	2.60 (*m*)	31.2	2.56 (*m*)	32.0
10a	-	142.5	-	143.3
4-OMe	3.96 (*s*)	56.5	3.94 (*s*)	57.3

[a](Hu *et al.*, 2008)

1.11 Structure determination of compound DFM-11

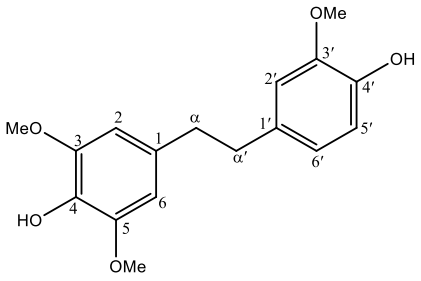
Compound DFM-11 was obtained as a brown amorphous solid. Its HR-ESI-MS (**Figure 55**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 327.1219 (calcd. for $C_{17}H_{20}O_5Na$; 327.1208), suggesting the molecular formula $C_{17}H_{20}O_5$.

The ^{1}H-NMR spectrum of compound DFM-11 (**Figure 56** and **Table 15**) exhibited signals of four methylene protons at δ_H 2.84 (4H, *m*, H_2-α, H_2-α'), and also displayed three methoxy protons at δ_H 3.85 (6H, *s*, 3′-OMe) and 3.86 (3H, *s*, 3-OMe, 5-OMe) and five aromatic protons at δ_H 6.38 (2H, *s*, H-2, H-6), 6.64 (1H, *br s*, H-2′), 6.70 (1H, *br d*, *J*=7.8 Hz, H-6′) and 6.85 (1H, *d*, *J*=7.8 Hz, H-5′).

In the NOESY spectrum (**Figure 58**), the methoxyl signal at δ_H 3.85 (3′-OMe) exhibited a cross peak with H-2′. Two methoxyl groups at δ_H 3.86 (3, 5-OMe) showed a cross peak with H-2 (H-6) suggesting that the methoxyl groups were located at C-3′, C-3 and C-5, respectively.

The ^{13}C-NMR spectrum (**Figure 57** and **Table 15**) showed seventeen carbon signals, including three methoxyls (δ_C 55.9 and 56.3), two methylene carbons (δ_C 37.9 and 38.5), five methines (δ_C 105.2, 111.3, 114.2 and 121.1) and seven quaternary carbons at δ_C 132.9 (C-1, C-4), 133.7 (C-1′), 143.8 (C-4′), 146.3 (C-3′) and 146.9 (C-3, C-5).

By comparing ^{1}H, ^{13}C-NMR and MS data of this compound with previously published data (Majumder and Sen, 1987), DFM-11 was comfirmed as moscatilin [**32**]. This compound has been frequently found in *Dendrobium* plants, such as *D. amoenum* (Majumder *et al.*, 1999), *D. brymerianum* (Klongkumnuankarn *et al.*, 2015), *D. densiflorum* (Fan *et al.*, 2001), *D. moscatum* (Majumder and Sen, 1987) and *D. secundum* (Sritularak *et al.*, 2011b).



Moscatilin [**32**]

Table 15 NMR spectral data of compound DFM-11 and moscatilin (in $CDCl_3$)

Position	Compound DFM-11		Moscatilin[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	132.9	-	132.8
2	6.38 (*s*)	105.2	6.36 (*s*)	105.2
3	-	146.9	-	146.8
4	-	132.9	-	133.5
5	-	146.9	-	146.8
6	6.38 (*s*)	105.2	6.36 (*s*)	105.2
α	2.84 (*m*)	38.5	2.89 (*s*)	38.3
α′	2.84 (*m*)	37.9	2.89 (*s*)	37.7
1′	-	133.7	-	132.8
2′	6.64 (*br s*)	111.3	6.65 (*d*, 2.0)	111.2
3′	-	146.3	-	146.1
4′	-	143.8	-	143.7
5′	6.85 (*d*, 7.8)	114.2	6.94 (*d*, 8.0)	114.1
6′	6.70 (*br d*, 7.8)	121.1	6.75 (*dd*, 8.0, 2.0)	121.0
3′-OMe	3.85 (*s*)	55.9	3.81 (*s*)	55.8
3,5-OMe	3.86 (*s*)	56.3	3.81 (*s*)	56.1

[a](Majumder and Sen, 1987)

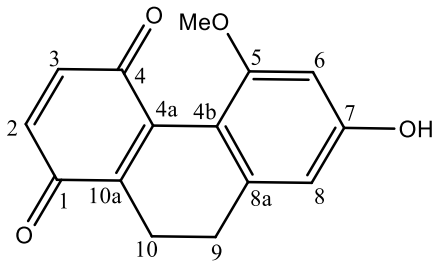
1.12 Structure determination of compound DFM-12

Compound DFM-12 was isolated as a red amorphous powder. Its HR-ESI-MS (**Figure 59**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 279.0642, (calcd. for $C_{15}H_{12}O_4Na$; 279.0633), suggesting the molecular formula $C_{15}H_{12}O_4$.

The presence of two carbonyl carbons at δ_C 184.8 and δ_C 185.1 indicated a dihydrophenanthrenequinone structure for DFM-12. The ^{1}H-NMR spectrum (**Figure 60** and **Table 16**) exhibited proton signals for a methoxy group at δ_H 3.72 (1H, *s*, 5-OMe), a pair of methylene proton signals at δ_H 2.49 (*m*, H_2-10) and 2.63 (*m*, H_2-9) and four methines at δ_H 6.43 (1H, *s*, *J*=2.1 Hz, H-8), 6.45 (1H, *d*, *J*=2.1 Hz, H-6), 6.72 (1H, *d*, *J*=9.9 Hz, H-2), and 6.83 (1H, *d*, *J*=9.9 Hz, H-3).

The ^{13}C-NMR spectrum (**Figure 61** and **Table 16**) displayed 15 signals, consisting of one methoxy carbon at δ_C 55.1, two methylene carbons at δ_C 19.9 and 29.7, four methine carbons at δ_C 98.5, 107.3, 135.1 and 137.1, eight quaternary carbons at δ_C 111.5, 138.9, 140.8, 142.9, 159.3, 160.7, 184.8 and 185.1. The location of the methoxyl group was determined by a NOESY experiment (**Figure 62**). The NOE interaction of the methoxyl signal at δ_H 3.72 with H-6 placed this methoxyl group at C-5.

Through comparison of the ^{1}H- and ^{13}C-NMR data with previously reported data, compound DFM-12 was identified as 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] which was firstly isolated from *D. draconis* (Sritularak *et al.*, 2011a).



5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**]

Table 16 NMR spectral data of compound DFM-12 (in acetone-d_6) and 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone (in $CDCl_3$)

Position	Compound DFM-12		5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	184.8	-	185.4
2	6.72 (*d*, 9.9)	135.1	6.68 (*d*, 10.0)	135.1
3	6.83 (*d*, 9.9)	137.1	6.78 (*d*, 10.0)	137.2
4	-	185.1	-	185.7
4a	-	140.8	-	140.9
4b	-	111.5	-	112.3
5	-	159.3	-	158.9
6	6.45 (*d*, 2.1)	98.5	6.33 (*d*, 2.0)	98.6
7	-	160.7	-	158.8
8	6.43 (*d*, 2.1)	107.3	6.31 (*d*, 2.0)	107.4
8a	-	142.9	-	143.1
9	2.63 (*m*)	29.7	2.60 (*m*)	28.5
10	2.49 (*m*)	19.9	2.55 (*m*)	20.1
10a	-	138.9	-	139.8
5-OMe	3.72 (*s*)	55.1	3.73 (*s*)	55.8

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

2. α-Glucosidase and lipase inhibitory activities

The MeOH extract of *D. formosum* was evaluated for α-glucosidase and lipase inhibitory activities, and showed 95.30% and 98.97% inhibition at 100 μg/mL respectively (**Table 17**). For EtOAC extract was selected for further study on α-glucosidase and lipase inhibitory activities (**Table 18**). For pure compounds, each was first tested at a concentration of 100 μg/mL. An IC_{50} value was determined if the compound showed more than 50% inhibition (**Table 19**).

Table 17 α-Glucosidase and lipase inhibitory activities screening from MeOH extract

Extracts	**%Inhibition**	
	α-Glucosidase (μM)	**Lipase** (μM)
Methanol	95.30	98.97
EtOAc	96.31	83.94
n-Butanol	NA	53.73
H_2O	NA	NA
Positive control	70.55 (Acarbose)	94.24 (Orlistat)

Table 18 Glucosidase and lipase inhibitory activities screening from EtOAc extract

Fractions	**%Inhibition**	
	α-Glucosidase (μM)	**Lipase** (μM)
A	10.47	74.69
B	92.06	82.20
C	98.01	82.96
D	99.63	74.57
E	97.63	67.19
F	80.89	75.72
G	99.85	90.26
H	94.73	69.91
Positive control	70.55 (Acarbose)	94.24 (Orlistat)

Table 19 IC_{50} values of compounds DFM-1 to DFM-12 for α-glucosidase and lipase inhibitory activities

Compounds	**α-Glucosidase** (μM)	**Lipase** (μM)
Confusarin [DFM-1, **75**]	189.78 ± 1.11	154.61 ± 8.58
Hircinol [DFM-2, **107**]	NA	NA
Erianthridin [DFM-3, **105**]	NA	NA
Gigantol [DFM-4, **28**]	NA	NA
Nudol [DFM-5, **121**]	NA	NA
Lusianthridin [DFM-6, **99**]	NA	NA
Coelonin [DFM-7, **92**]	NA	NA
Dihydroconiferyl dihydro-*p*-coumarate [DFM-8, **231**]	NA	NA
Batatasin III [DFM-9, **16**]	NA	NA
2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene [DFM-10, **111**]	NA	NA
Moscatilin [DFM-11, **32**]	NA	NA
5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [DFM-12, **89**]	126.88 ± 0.66	69.45 ± 10.14
Acarbose	745.9 ± 88.4	-
Orlistat	-	0.013 ± 0.004

*NA = no inhibitory activity

As shown in **Table 19**, twelve pure compounds were evaluated for α-glucosidase and lipase enzyme inhibitory activities. Confusarin [**75**] and 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] exhibited α-glucosidase inhibitory activities (IC_{50} values 189.78 and 126.88 μM, respectively) compared with acarbose, the positive control. For lipase enzyme inhibitory activity the two compounds showed IC_{50} values of 154.61 and 69.45 μM, respectively, compared with orlistat, the positive control.

5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] showed stronger inhibitory activities than confusarin [**75**], therefore, 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] was selected for further study on the mechanisms of enzyme inhibitions. In the enzyme kinetic studies, we used *p*-nitrophenyl-α-d-glucopyranoside (*p*NPG) and 4-methylumbelliferyl oleate (4-MUO) as the substrates for α-glucosidase and lipase, respectively.

Kinetics studies of α-glucosidase and lipase inhibition by of 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] were conducted using double reciprocal Lineweaver-Burk analysis. This analysis plotted the velocity against the substrate concentration (0.25, 0.5, 1.0, 2.0 and 4.0 mM) with or without two concentrations of the inhibitor (80 and 160 μM) **(Figure 63)** for α-glucosidase. For lipase, we used the substrate concentration (0.125, 0.25, 0.5, 1.0 and 2.0 mM) with or without two concentration of the inhibitor (40 and 80 μM) **(Figure 64)**. Kinetic constants for the inhibition of α-glucosidase and lipase are listed in **Table 20**.

Table 20 Kinetic parameters of α-glucosidase and lipase enzymes in the presence of 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone

	α-Glucosidase			**Lipase**		
Inhibitor	**Dose (μM)**	**Vmax (ΔA405/min)**	**Km (mM)**	**Dose (μM)**	**Vmax (ΔA355, 460/min)**	**Km (mM)**
None	-	7.10×10^{-3}	0.3	-	1.35×10^{5}	0.4
DFM-12	80	2.70×10^{-3}	0.3	40	9.60×10^{4}	0.4
	160	7.35×10^{-4}	0.3	80	7.60×10^{4}	0.4

α-Glucosidase showed the maximum velocity (V_{max}) value of 7.10×10^{-3} ΔA_{405}/min for *p*NPG hydrolysis, and the Michaelis-Menten constant (K_m) value of 0.3 mM. While lipase showed the V_{max} value of 1.35×10^{5} $\Delta A_{355,460}$/min for an oleate ester hydrolysis from 4-MUO substrate, and the K_m value of 0.4 mM. **Figure 63** shows the Linewaver-Burk plots of 1/V value with different *p*NPG concentrations of 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**]. 5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] was employed at different concentrations (80 and 160 μM). It is interesting to note that when the increase of concentration reduced the V_{max} value (2.70×10^{-3} to 7.35×10^{-4}) but did not influence the K_m value (0.3 mM) of the enzyme. **Figure 64** displays the Linewaver-Burk plots of 1/V value with different 4-MUO concentrations of 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**]. The presence of 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] at different concentration (40 and 80 μM) showed similar affects with the α-glucosidase inhibition, which decreased the V_{max} value (9.60×10^{4} to 7.60×10^{4}), but did not change the K_m value (0.4 mM) of the enzyme.

The results showed that 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] is a non-competitive inhibitor of both α-glucosidase and lipase, which implied that the substrate and inhibitor do not compete for the binding at the active site of enzyme.

CHAPTER V
CONCLUSION

In this study, from the methanol extract of *Dendrobium formosum* Roxb. ex Lindl. (Orchidaceae) twelve known compounds were isolated, consisting of confusarin [**75**], hircinol [**107**], erianthridin [**105**], gigantol [**28**], nudol [**121**], lusianthridin [**99**], coelonin [**92**], dihydroconiferyl dihydro-*p*-coumarate [**231**], batatasin III [**16**], 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene [**111**], moscatilin [**32**] and 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**]. All of isolated compounds were investigated for α-glucosidase and lipase inhibitory activities. 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] exhibited significant activity against both α-glucosidase and lipase enzymes. Therefore, this compound was selected for mechanism study of enzyme inhibition. The results suggested that 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**89**] exhibited non-competitive type of inhibition for both enzymes. Phytochemical information in this study should be useful for the chemotaxonomic study of *Dendrobium* plants. The data on α-glucosidase and lipase inhibitory activities of the isolated compounds should be of interest to the natural product research community.

REFERENCES

American Diabetes Association. (2010). Diagnosis and classification of diabetes mellitus. Diabetes Care 33: 62-64.

American Diabetes Association. (2017). Standards of medical care in diabetes. Diabetes Care 40: 1-135.

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

Chang, C. C., Ku, A. F., Tseng, Y. Y., Yang, W. B., Fang, J. M. and Wong, C. H. (2010). 6,8-DiC-glycosyl flavonoids from *Dendrobium huoshanense*. Journal of Natural Products 73(2): 229-232.

Chang, S. J., Lin, T. H. and Chen, C. C. (2001). Constituents from the stems of *Dendrobium clavatum* var. *aurantiacum*. Journal of Chinese Medicine 12(3): 211-218.

Chanvorachote, P., Kowitdamrong, A., Ruanghrin, T., Sritularak, B., Mungmee, C. and Likhitwittayawuid, K. (2013). Anti-metastatic activities of bibenzyl from *Dendrobium pulchellum*. Natural Product Communications 8(1): 115-118.

Chen, C. C., Wu, L. G., Ko, F. N. and Teng, C. M. (1994). Antiplatelet aggregation principles of *Dendrobium loddigesii*. Journal of Natural Products 57(9): 1271-1274.

Chen, X. G., Mei, W. L., Zuo, W. J. and Zeng, Y. B. (2013). A new antibacterial phenanthrenequinone from *Dendrobium sinense*. Journal of Asian Natural Products Research 15(1): 67-70.

Chen, X. J., Mei, W. L., Cai, C. H., Guo, Z. K., Song, X. Q. and Dai, H. F. (2014). Four new bibenzyl derivatives from *Dendrobium sinense*. Phytochemistry Letters 9: 107-112.

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

Chen, Y. G., Lui, Y., Jiang, J. H., Zhang, Y. and Yin, B. L. (2008). Dendronone, a new phenanthrenequinone from *Dendrobium cariniferum*. Food Chemistry 111(1): 11-12.

Chen, Y. G., Yu, H. and Lian, X. (2015). Isolation of stilbenoids and lignans from *Dendrobium hongdie*. Tropical Journal of Pharmaceutical Research 14(11): 2055-2059.

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

De Ruiter, J. (2003). Overview of the antidiabetic agents. Endocrine Pharmacotherapy Module: 1-33.

Dewick, P. 2002. Medicinal Natural Products: A biosynthetic approach. England: John Wiley and Sons.

Fan, C., Wang, W., Wang, Y., Qin, G. and Zhao, W. (2001). Chemical constituents from *Dendrobium densiflorum*. Phytochemistry 57(8): 1255-1258.

Fan, W. W., Xu, F. Q., Dong, F. W., Li, X. N., Li, Y., Liu, Y. Q., Zhou, J. and Hu, J. M. (2013). Dendrowardol C, a novel sesquiterpenoid from *Dendrobium wardianum* Warner. Natural Products and Bioprospecting 3(3): 89-92.

Fisch, M. H., Flick, F. H. and Arditti, J. (1973). Structure and antifungal activity of hircinol, loroglossol and orchinol. Phytochemistry 12(2): 437-441.

Gawell, L. and Leander, K. (1976). The constitution of aduncin, a sesquiterpene related to picrotoxinin, found in *Dendrobium aduncum*. Phytochemistry 15: 1991-1992.

Gorham, J. 1989. Stilbenes and Phenanthrenes, Methods in Plant Biochemistry. London: Academic press.

Grant, R. W., Donner, T. W., Fradkin, J. E., Hayes, C., Herman, W. H., Hsu, W. C., Kim, E., Laffel, L., Pop-Busui, R., Rasouli, N., Schatz, D., Stankaitis, J. A., Taveira, T. H. and Wexler, D. J. (2015). Diabetes Care 38: 1-94.

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

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

Hu, J. M., Chen, J. J., Yu, H., Zhao, Y. X. and Zhou, J. (2008a). Five new compounds from *Dendrobium longicornu*. Planta Medica 74(5): 535-539.

Hu, J. M., Chen, J. J., Yu, H., Zhao, Y. X. and Zhou, J. (2008b). Two novel bibenzyls from *Dendrobium trigonopus*. Journal of Asian Natural Products Research 10(7): 653-657.

Hu, J. M., Fan, W. W., Dong, F. W., Miao, Z. H. and Zhou, J. (2012). Chemical components of *Dendrobium chrysotoxum*. Chinese Journal of Chemistry 30(6): 1327-1330.

Hu, J. M., Zhao, Y. X., Miao, Z. H. and Zhou, J. (2009). Chemical components of *Dendrobium polyanthum*. Bulletin of the Korean Chemical Society 30(9): 2098-2010.

Hwang, J. S., Lee, S. A., Hong, S. S., Han, X. H., Lee, C., Kang, S., J,,, Lee, D., Kim, Y., Hong, J., T.,, Lee, M. K. and Hwang, B. Y. (2010). Phenanthrenes from *Dendrobium nobile* and their inhibition of the LPS-induced production of nitric oxide in macrophage RAW 2647 cells. Bioorganic & Medicinal Chemistry Letters 20(12): 3785-3787.

Ito, M., Matsuzaki, K., Wang, J., Daikonya, A., Wang, N. L., Yao, X. S. and Kitanaka, S. (2010). New phenanthrenes and stilbenes from *Dendrobium loddigesii*. Chemical and Pharmaceutical Bulletin 58(5): 628-633.

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

Kim, J. H., Oh, S. Y., Han, S. B., Uddin, G. M., Kim, C. Y. and Lee, J. K. (2015). Anti-inflammatory effects of *Dendrobium nobile* derived phenanthrenes in LPS-stimulated murine macrophages. Archives of Pharmacal Research 38(6): 117–1126.

Klongkumnuankarn, P., Busaranon, K., Chanvorachote, P., Sritularak, B., Jongbunprasert, V. and Likhitwitayawuid, K. (2015). Cytotoxic and antimigratory activities of phenolic compounds from *Dendrobium brymerianum*. Evidence-Based Complementary and Alternative Medicine 2015: 1-9.

Lam, Y., Ng, T. B., Yao, R. M., Shi, J., Xu, K., Sze, S. C. W. and Zhang, K. Y. (2015). Evaluation of chemical constituents and important mechanism of

pharmacological biology in *Dendrobium* plants. Evidence-Based Complementary and Alternative Medicine 2015: 1-25.

Li, C. B., Wang, C., Fan, W. W., Dong, F. W., Xu, F. Q., Wan, Q. L., Lou, H. R., Liu, Y. Q., Hu, J. M. and Zhou, J. (2013). Chemical components of *Dendrobium crepidatum* and their neurite outgrowth enhancing activities. Natural Products and Bioprospecting 3(2): 70-73.

Li, J. T., Yin, B. L., Liu, Y., Wang, L. Q. and Chen, Y. G. (2009d). Mono-aromatic constituents of *Dendrobium longicornu*. Chemistry of Natural Compounds 45(2): 234-236.

Li, X. H., Guo, L., Yang, L., Peng, C., He, C. J., Zhou, Q. M., Xiong, L., Liu, J. and Zhang, T. M. (2014). Three new neolignan glucosides from the stems of *Dendrobium aurantiacum* var. *denneanum* Phytochemistry Letters 9: 37-40.

Li, Y., Wang, C. L., Guo, S. X., Yang, J. S. and Xiao, P. G. (2008). Two new compounds from *Dendrobium candidum*. Chemical and Pharmaceutical Bulletin 56(10): 1477-1479.

Li, Y., Wang, C. L., Wang, F. F., Dong, H. L., Guo, S. X., Yang, J. S. and Xiao, P. G. (2010). Phenolic components and flavanones from *Dendrobium candidum*. Chinese Pharmaceutical Journal 45(13): 975-979.

Li, Y., Wang, C. L., Wang, Y. J., Guo, S. X., Yang, J. S., Chen, X. M. and Xiao, P. G. (2009a). Three new bibenzyl derivatives from *Dendrobium candidum*. Chinese Pharmaceutical Journal 57(2): 218-219.

Li, Y., Wang, C. L., Wang, Y. J., Guo, S. X., Yang, J. S., Chen, X. M. and Xiao, P. G. (2009b). Four new bibenzyl derivatives from *Dendrobium candidum*. Chemical and Pharmaceutical Bulletin 57(9): 997-999.

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

Limpanit, R., Chuanasa, T., Likhitwitayawuid, K., Jongbunprasert, V. and Sritularak, B. (2016). α-Glucosidase inhibitors from *Dendrobium tortile*. Records of Natural Products 10(5): 609-616.

Lin, T. H., Chang, S. J., Chen, C. C., Wang, J. P. and Tsao, L. T. (2001). Two phenanthraquinones from *Dendrobium moniliforme*. Journal of Natural Products 64(8): 1084-1086.

Liu, Y., Jiang, J. H., Yin, B. L. and Chen, Y. G. (2009b). Chemical constituents of *Dendrobium cariniferum*. Chemistry of Natural Compounds 45(2): 237-238.

Liu, Y., Jiang, J. H., Zhang, Y. and Chen, Y. G. (2009a). Chemical constituents of *Dendrobium aurantiacum* var. *denneanum*. Chemistry of Natural Compounds 45(4): 525.

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

Ma, G. X., Wang, T. S., Yin, L., Pan, Y., Xu, G. J. and Xu, L. S. (1998). Studies on chemical constituents of *Dendrobium chryseum*. Journal of Chinese Pharmaceutical Sciences 7(1): 52-54.

Majumder, P.L. and Joardar, M. (1985). Erianthridin, a new 9,10-dihydrophenanthrene derivative from the orchids *Eria carinata* & *Eria sticta*. Indian Journal of Chemistry 24(11): 1192-1194.

Majumder, P. L. and Chatterjee, S. (1989). Crepidatin, a bibenzyl derivative from the orchid *Dendrobium crepidatum*. Phytochemistry 28(7): 1986-1988.

Majumder, P. L., Guha, S. and Sen, S. (1999). Bibenzyl derivatives from the orchid *Dendrobium amoenum*. Phytochemistry 52(7): 1365-1369.

Majumder, P. L. and Kar, A. (1987). Confusarin and confusaridin, two phenanthrene derivatives of the orchid *Eria confusa*. Phytochemistry 26(4): 1127-1129.

Majumder, P. L. and Pal, S. (1992). Rotundatin, a new 9,10-dihydrophenanthrene derivative from *Dendrobium rotundatum* Phytochemistry 31(9): 3225-3228.

Majumder, P. L. and Pal, S. (1993). Cumulatin and tristin, two bibenzyl derivatives from the orchids *Dendrobium cumulatum* and *Bulbophyllum triste*. Phytochemistry 52(6): 1561-1565.

Majumder, P. L. and Sen, R. C. (1987). Moscatilin, a bibenzyl derivative from the orchid *Dendrobium moscatum*. Phytochemistry 26: 2121-2124.

Mittraphab, A., Muangnoi, C., Likhitwitayawuid, K., Rojsitthisak, P. and Sritularak, B. (2016). A new bibenzyl-phenanthrene derivative from *Dendrobium signatum* and its cytotoxic activity. Natural Product Communications 11(5): 657-659.

Miyazawa, M., Shimamura, H., Nakamura, S. I., Sugiura, W., Kosaka, H. and Kameoka, H. (1999). Moscatilin from *Dendrobium nobile*, a naturally occurring bibenzyl compound with potential antimutagenic activity. Journal of Agricultural and Food Chemistry 47(5): 2163–2167.

Ng, T. B., Liu, J., Wong, J. H., Ye, X., Sze, S. C. W., Tong, Y. and Zhang, K. Y. (2012). Review of research on *Dendrobium*, a prized folk medicine. Applied Microbiology and Biotechnology 93(5): 1795–1803.

Orsini, F. and Verotta, L. 1999. Stilbenes and bibenzyls with potential anticancer or chemopreventive activity. New York: Plenum Publishers.

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

Phechrmeekha, T., Sritularak, B. and Likhitwitayawuid, K. (2012). New phenolic compounds from *Dendrobium capillipes* and *Dendrobium secundum*. Journal of Asian Natural Products Research 14(8): 748-754.

Prasad, R. and Koch, B. (2014). Antitumor activity of ethanolic extract of *Dendrobium formosum* in T-cell lymphoma: An *in vitro* and *in vivo* study. BioMed Research International 2014: 1-11.

Qin, X. D., Qu, Y., Ning, L., Liu, J. K. and Fan, S. K. (2011). A new picrotoxane-type sesquiterpene from *Dendrobium findlayanum*. Journal of Asian Natural Products Research 13(11): 1047-1050.

Rueda, D. C., Schöffmann, A., Mieri, M. D., Raith, M., Jähne, E. A., Hering, S. and Hamburger, M. (2014). Identification of dihydrostilbenes in *Pholidota chinensis* as a new scaffold for $GABA_A$ receptor modulators. Bioorganic & Medicinal Chemistry 22(4): 1276-1284.

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

Sachdev, K. and Kulshreshtha, D. K. (1986). Phenolic constituents of *Coelogyne ovalis*. Phytochemistry 25(2): 499-502.

Santamarina-Fojo, S. and Brewer, H. B. (1994). Lipoprotein lipase: Structure, function and mechanism of action. International Journal of Clinical and Laboratory Research 24(3): 143-147.

Sergent, T., Vanderstraeten, J., Winand, J., Beguin, P. and Schneider, Y. J. (2012). Phenolic compounds and plant extracts as potential natural anti-obesity substances. Food Chemistry 135(1): 68-73.

Seyedan, A., Alshawsh, M. A., Alshagga, M. A., Koosha, S. and Mohamed, Z. (2015). Medicinal plants and their inhibitory activities against pancreatic lipase: A review. Evidence-Based Complementary and Alternative Medicine 2015: 1-13.

Shimizu, M., Shogawa, H., Hayashi, T., Arisawa, M., Suzuki, S., Yoshizaki, M., Morita, N., Ferro, E., Basualdo, I. and Berganza, L. H. (1988). Anti-inflammatory constituents of topically applied crude drugs. III. Constituents and anti-inflammatory effect of Paraguayan crude drug "Tamandá cuná" (*Catasetum barbatum* Lindle). Chemical and Pharmaceutical Bulletin 36(11): 4447-4452.

Smitinand, T. (2001). Thai plant names (Botanical names-vernacular names). Revised edition. Bangkok: The Forest Herbarium, Royal Forest Department

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

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

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

Sukphan, P., Sritularak, B., Mekboonsonglarp, W., Lipipun, V. and Likhitwitayawuid, K. (2014). Chemical constituents of *Dendrobium venustum* and their antimalarial and anti-herpetic properties. Natural Product Communications 9(6): 825-827.

Sun, J., Zhang, F., Yang, M., Zhang, J., Chen, L., Zhan, R., Li, L. and Chen, Y. (2014). Isolation of α-glucosidase inhibitors including a new flavonol glycoside from *Dendrobium devonianum*. Natural Product Research 28(21): 1900-1905.

Tanagornmeatar, K., Chaotham, C., Sritularak, B., Likhitwitayawuid, K. and Chanvorachote, P. (2014). Cytotoxic and anti-metastatic activities of phenolic compounds from *Dendrobium ellipsophyllum* Anticancer Research 34(11): 6573-6580

Tarapatra, B., Das, A. K. and Tarapatra, S. K. (1989). Defuscin, a new phenolic ester from *Dendrobium fuscescens*: Conformation of shikimic acid. Phytochemistry 28(1): 290-292.

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

Tushuizen, M. E., Bunck, M. C., Pouwels, P. J., Bontemps, S., Waesberghe, J. K. V., Schindhelm, R. K., Mari, A., Heine, R. J. and Diamant, M. (2007). Pancreatic fat content and β-cell function in men with and without type 2 diabetes. Diabetes Care 30: 2916–2921.

Vaddhanaphuti, N. 2005. A field guide to the wild orchids of Thailand fourth and expanded edition: p. 102. Chiang Mai: Silkworm Books.

Veerraju, P., Rao, N. S. P., Rao, L. J., Rao, K. V. J. and Rao, P. R. M. (1989). Amoenumin, a 9,10-dihydro-5*H*-phenanthro-(4,5-b,c,d)-pyran from *Dendrobium amoenum*. Phytochemistry 28(3): 950-951.

Wang, H., Zhao, T. and Che, C. T. (1985). Dendrobine and 3-hydroxy-2-oxodendrobine from *Dendrobium nobile*. Journal of Natural Products 48(5): 796-801.

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

Xiao, J., Kai, G., Yamamoto, K. and Chen, X. (2013). Advance in dietary polyphenols as α-glucosidase inhibitors: A review on structure-activity relationship aspect. Critical Reviews in Food Science and Nutrition 53(8): 818-836.

Xiong, L., Cao, Z. X., Peng, C., Li, X. H., Xie, X. F., Zhang, T. M., Zhou, Q. M., Yang, L. and Guo, L. (2013). Phenolic glucosides from *Dendrobium aurantiacum* var. *denneanum* and their bioactivities. Molecules 18(6): 6153-6160.

Xu, F. Q., Xu, F. C., Hou, B., Fan, W. W., Zi, C. T., Li, Y., Dong, F. W., Liu, Y. Q., Sheng, J., Zuo, Z. L. and Hu, J. M. (2014). Cytotoxic bibenzyl dimers from the stems of *Dendrobium fimbriatum* Hook. Bioorganic & Medicinal Chemistry Letters 24(22): 5268-5273.

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

Yang, D., Liu, L. Y., Cheng, Z. Q., Xu, F. Q., Fan, W. W., Zi, C. T., Dong, F. W., Zhou, J., Ding, Z. T. and Hu, J. M. (2015). Five new phenolic compounds from *Dendrobium aphyllum*. Fitoterapia 100: 11-18.

Yang, H., Chou, G. X., Wang, Z. T., Guo, Y. W., Hu, Z. B. and Xu, L. S. (2004). Two new compounds from *Dendrobium chrysotoxum*. Helvetica Chimica Acta 87(2): 394-399.

Yang, H., Sung, S. H. and Kim, Y. C. (2007). Antifibrotic phenanthrenes of *Dendrobium nobile* stems. Journal of Natural Products 70(12): 1925-1929.

Yang, L., Qin, L. H., Bligh, S. W., Bashall, A., Zhang, C. F., Zhang, M., Wang, Z. T. and Xu, L. S. (2006b). A new phenanthrene with a spirolactone from *Dendrobium chrysanthum* and its anti-inflammatory activities. Bioorganic & Medicinal Chemistry 14(10): 3496-3501.

Yang, M. H., Chin, Y. W., Yoon, K. D. and Kim, J. (2014). Phenolic compounds with pancreatic lipase inhibitory activity from Korean yam (*Dioscorea opposita*). Journal of Enzyme Inhibition and Medicinal Chemistry 29(1): 1-6.

Yang, Y., Wang, Z. and Xu, L. (2006a). Phenols and a triterpene from *Dendrobium auranticum* var. *denneanum* (Orchidaceae). Biochemical Systematics and Ecology 34: 658-600.

Ye, Q., Mei Y., Yang, P., Cheng, L. and Kong, D. (2016). A new 9,10-dihydrophenanthrene glycoside from *Dendrobium primulinum*. Chemistry of Natural Compounds 52(3): 381-383.

Ye, Q., Qin, G. and Zhao, W. (2002b). Immunomodulatory sesquiterpene glycosides from *Dendrobium nobile*. Phytochemistry 61(8): 885-890.

Ye, Q. and Zhao, W. (2002a). New alloaromadendrane, cadinene and cyclocopacamphane type sesquiterpene derivatives and bibenzyls from *Dendrobium nobile*. Planta Medica 68(8): 723-729.

Ye, Q. H., Zhao, W. M. and Qin, G. W. (2004). Lignans from *Dendrobium chrysanthum*. Journal of Asian Natural Products Research 6(1): 39-43.

Yin, Z., Zhang, W., Feng, F., Zhang, Y. and Kanga, W. (2014). α-Glucosidase inhibitors isolated from medicinal plants. Food Science and Human Wellness 3(3-4): 136-174.

You, Q., Chen, F., Wang, X., Jiang, Y. and Lin, S. (2012). Anti-diabetic activities of phenolic compounds in muscadine against alpha-glucosidase and pancreatic lipase. LWT-Food Science Technology 46(1): 164-168.

Zhang, C. F., Wang, M., Wang, L., Linuma, M., Zhang, M., Xu, L. S. and Wang, Z. T. (2008a). Chemical constituents of *Dendrobium gratiosissimum* and their cytotoxic activities. Indian Journal of Chemistry 47B(6): 952-956.

Zhang, G. N., Zhong, L. Y., Bligh, S. W. A., Guo, Y. L., Zhang, C. F., Zhang, M., Wang, Z. T. and Xu, L. S. (2005). Bi-bicyclic and bi-tricyclic compounds from *Dendrobium thyrsiflorum*. Phytochemistry 66(10): 1113-1120.

Zhang, X., Gao, H., Han, H. Y., Liu, H. W., Wang, N. L., Yao, X. S. and Wang, Z. (2007b). Sesquiterpenes from *Dendrobium nobile*. Chinese Traditional and Herbal Drugs 38(12): 1771-1774.

Zhang, X., Gao, H., Wang, N. and Yao, X. (2006a). Phenolic components from *Dendrobium nobile*. Chinese Traditional and Herbal Drugs 37(5): 652-655.

Zhang, X., Gao, H., Wang, N. L. and Yao, X. S. (2006b). Three new bibenzyl derivatives from *Dendrobium nobile*. Journal of Asian Natural Products Research 8(1-2): 113-118.

Zhang, X., Tu, F. J., Yu, H. Y., Wang, N. L., Wang, Z. and Yao, X. S. (2008c). Copacamphane, picrotoxane and cyclocopacamphane sesquiterpenes from *Dendrobium nobile*. Chemical and Pharmaceutical Bulletin 56(6): 854-857.

Zhang, X., Xu, J. K., Wang, J., Wang, N. L., Kurihara, H., Kitanaka, S. and Yao, X. S. (2007a). Bioactive bibenzyl derivatives and fluorenones from *Dendrobium nobile*. Journal of Natural Products 70(1): 24-28.

Zhang, X., Xu, J. K., Wang, N. L., Kurihara, H. and Yao, X. S. (2008b). Antioxidant phenanthrenes and lignans from *Dendrobium nobile*. Journal of Chinese Pharmaceutical Science 17: 314-318.

Zhao, C., Liu, Q., Halaweish, F., Shao, B., Ye, Y. and Zhao, W. (2003). Copacamphane, picrotoxane, and alloaromadendrane sesquiterphene glycosides and phenolic glycosides from *Dendrobium moniliforme*. Journal of Natural Products 66(8): 1140-1143.

Zhao, N., Yang, G., Zhang, Y., Chen, L. and Chen, Y. (2016). A new 9,10-dihydrophenanthrene from *Dendrobium moniliforme*. Natural Product Research 30(2): 174-179.

Zhao, W., Ye, Q., Tan, X., Jiang, H., Li, X., Chen, K. and Kinghorn, A. D. (2001). Three new sesquiterpene glycosides from *Dendrobium nobile* with immunomodulatory activity. Journal of Natural Products 64(9): 1196-1200.

APPENDIX

Mass Spectrum List Report

Analysis Info

Analysis Name	OS600602001.d	Acquisition Date	5/3/2017 9:26:43 AM
Method	tune_low_negative_Tawatchai_201602054.m	Operator	Administrator
Sample Name	DF5	Instrument	micrOTOF 72
	DF5		

Acquisition Parameter

Source Type	ESI	Ion Polarity	Negative	Set Corrector Fill	75 V
Scan Range	n/a	Capillary Exit	-110.0 V	Set Pulsar Pull	372 V
Scan Begin	50 m/z	Hexapole RF	90.0 V	Set Pulsar Push	372 V
Scan End	3000 m/z	Skimmer 1	-30.0 V	Set Reflector	1300 V
		Hexapole 1	-25.0 V	Set Flight Tube	9000 V
				Set Detector TOF	2295 V

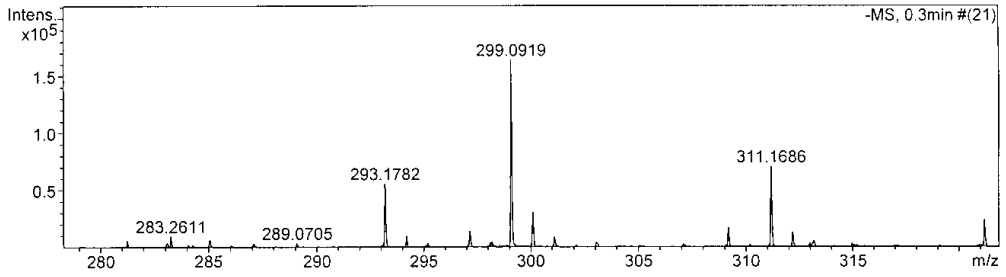


Figure 6 Mass spectrum of compound DFM-1

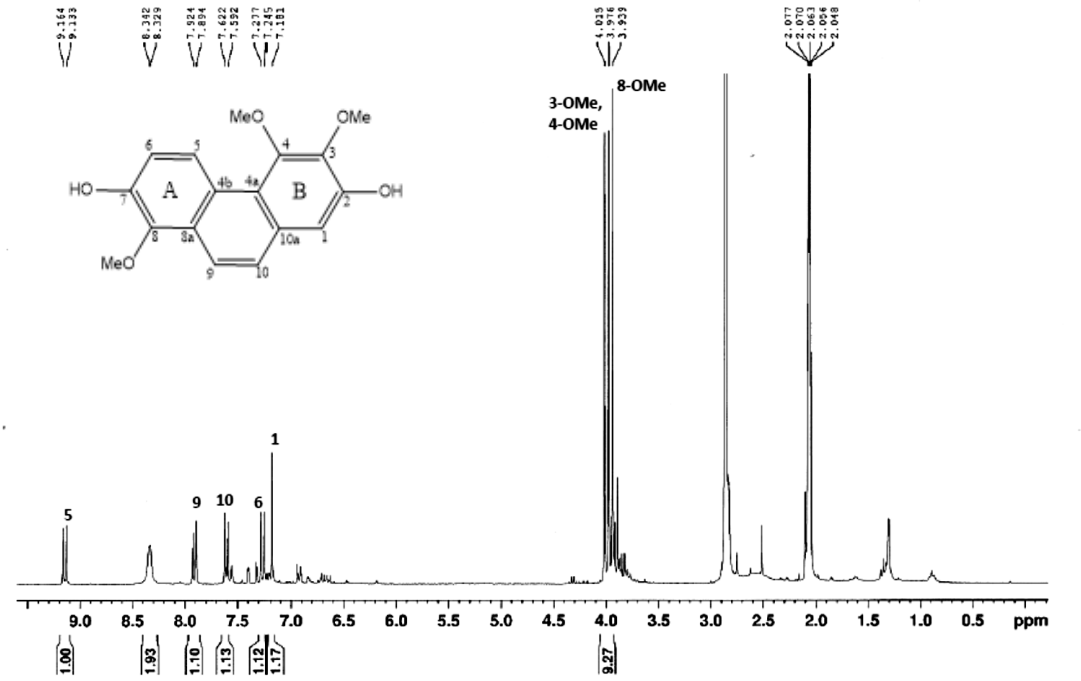


Figure 7 ^{1}H-NMR (300 MHz) spectrum of compound DFM-1 (in acetone-d_6)

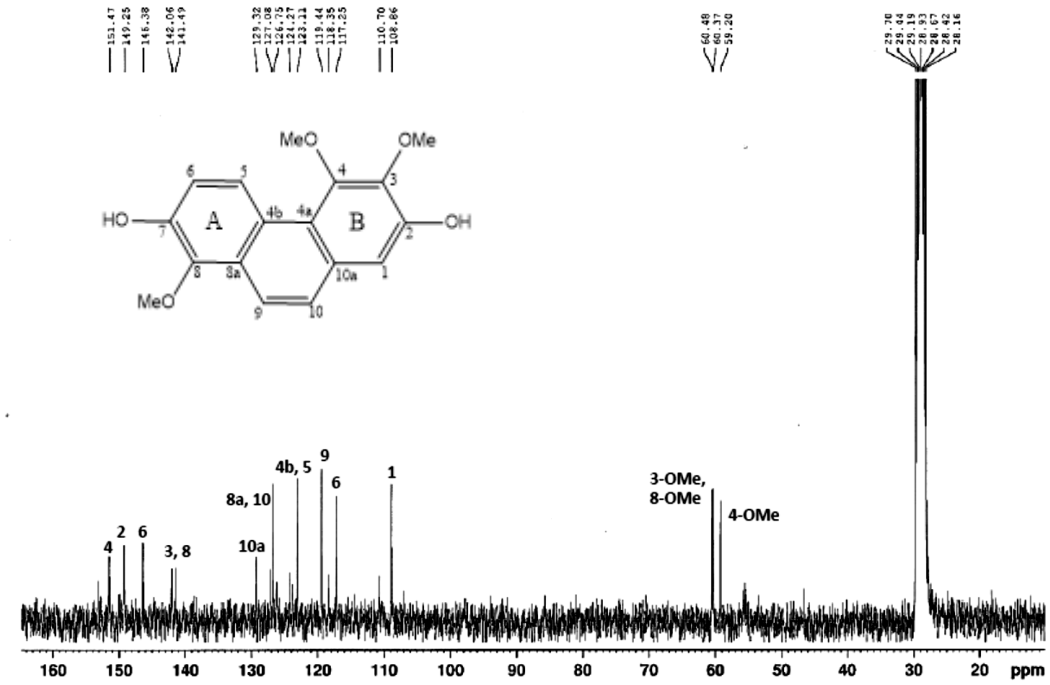


Figure 8 ^{13}C-NMR (75 MHz) spectrum of compound DFM-1 (in acetone-d_6)

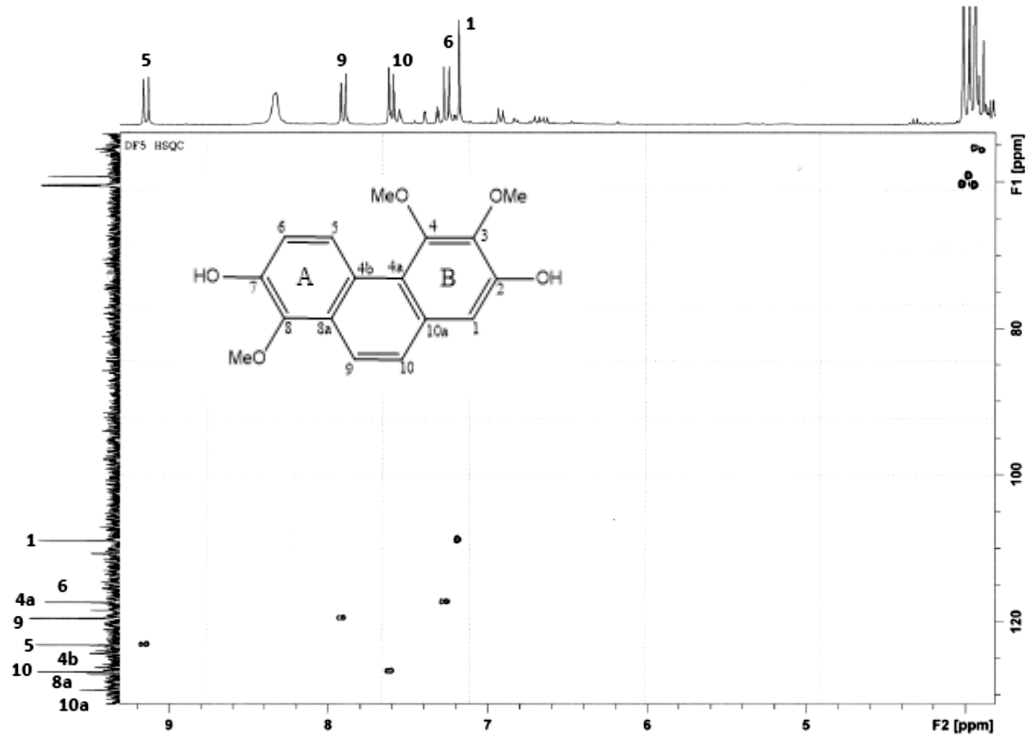


Figure 9 HSQC spectrum of compound DFM-1 (in acetone-d_6)

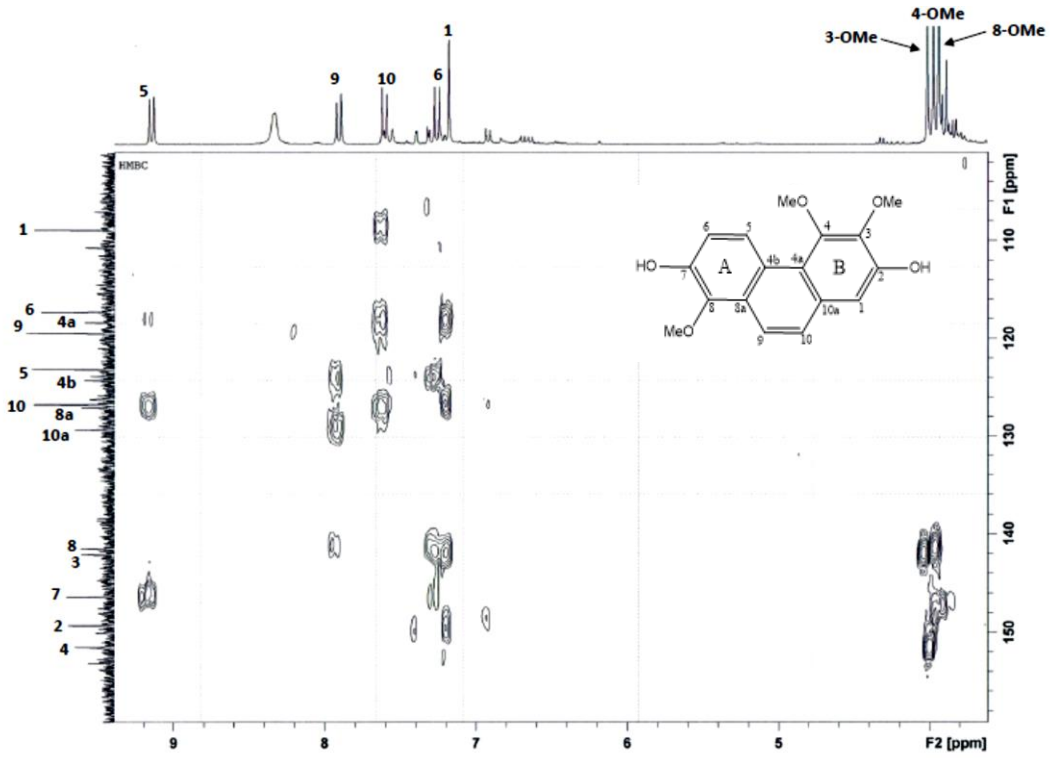


Figure 10 HMBC spectrum of compound DFM-1 (in acetone-d_6)

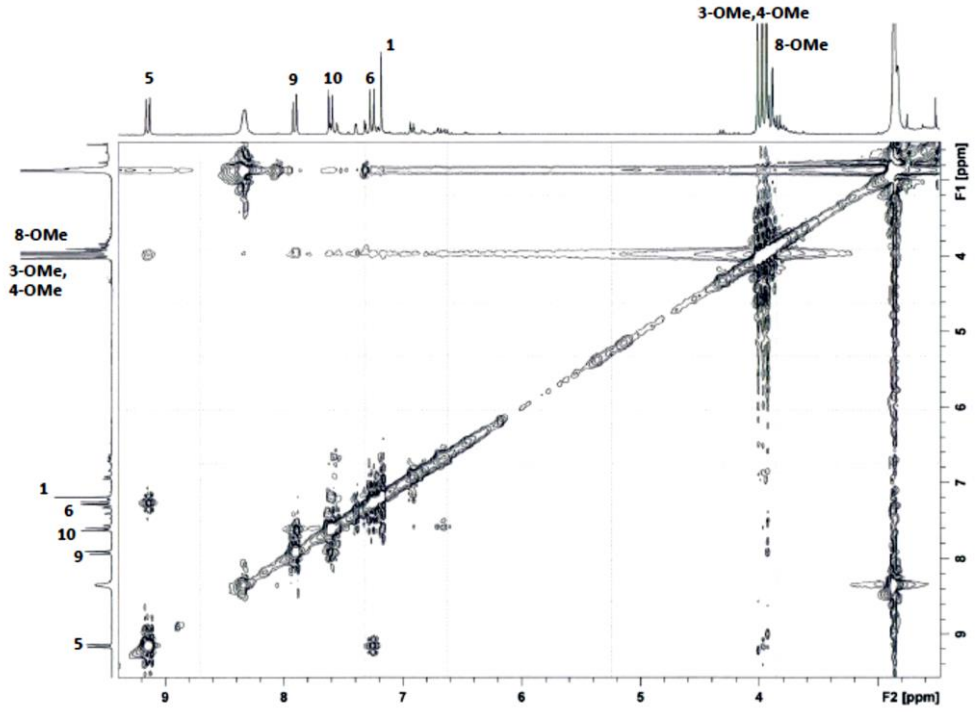


Figure 11 NOSEY spectrum of compound DFM-1 (in acetone-d_6)

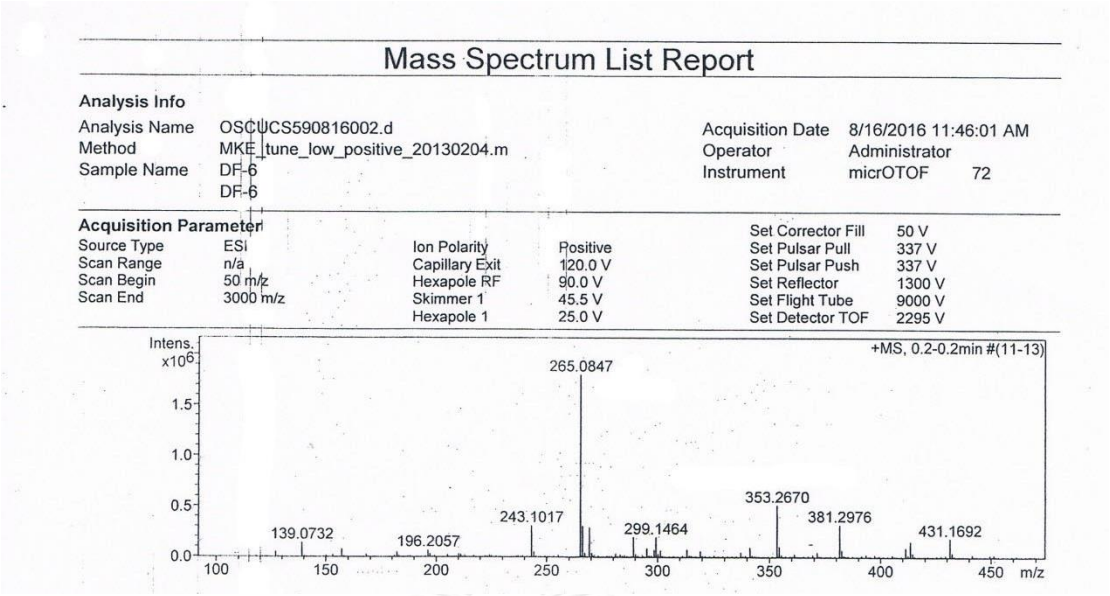


Figure 12 Mass spectrum of compound DFM-2

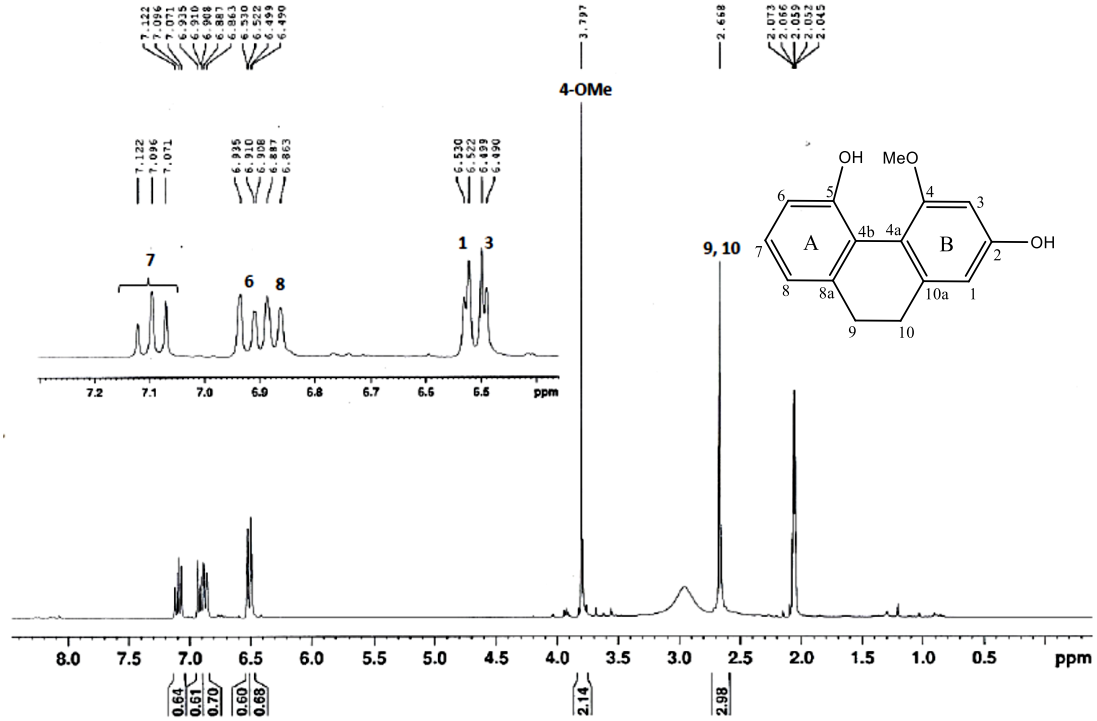


Figure 13 ^{1}H-NMR (300 MHz) spectrum of compound DFM-2 (in acetone-d_6)

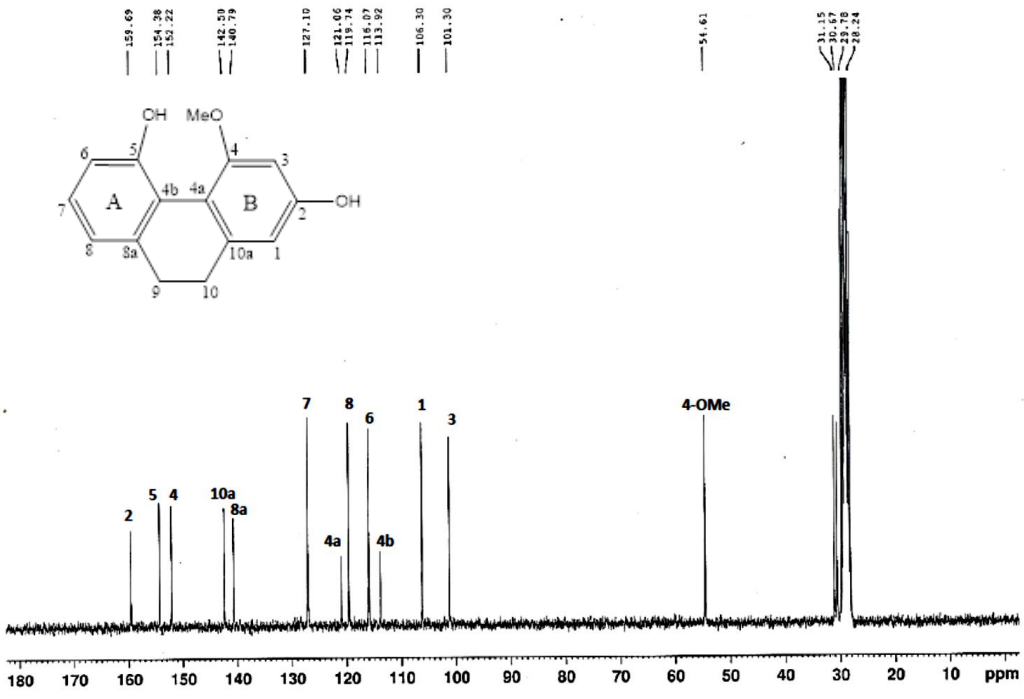


Figure 14 ^{13}C-NMR (75 MHz) spectrum of compound DFM-2 (in acetone-d_6)

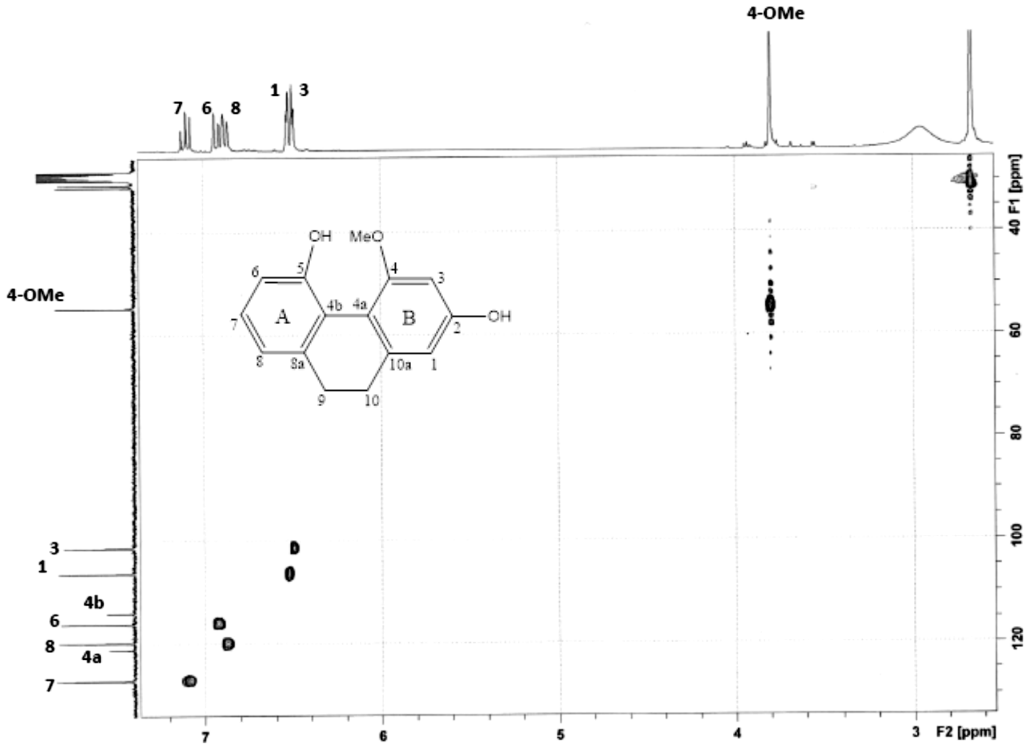


Figure 15 HSQC spectrum of compound DFM-2 (in acetone-d_6)

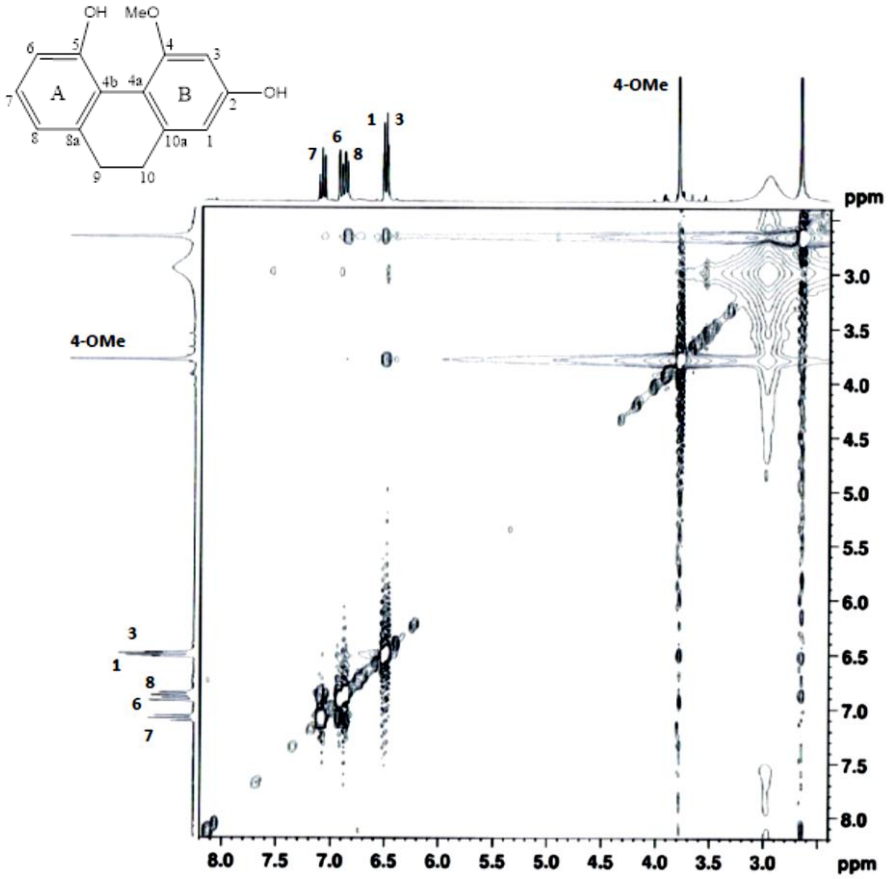


Figure 16 NOESY spectrum of compound DFM-2 (in acetone-d_6)

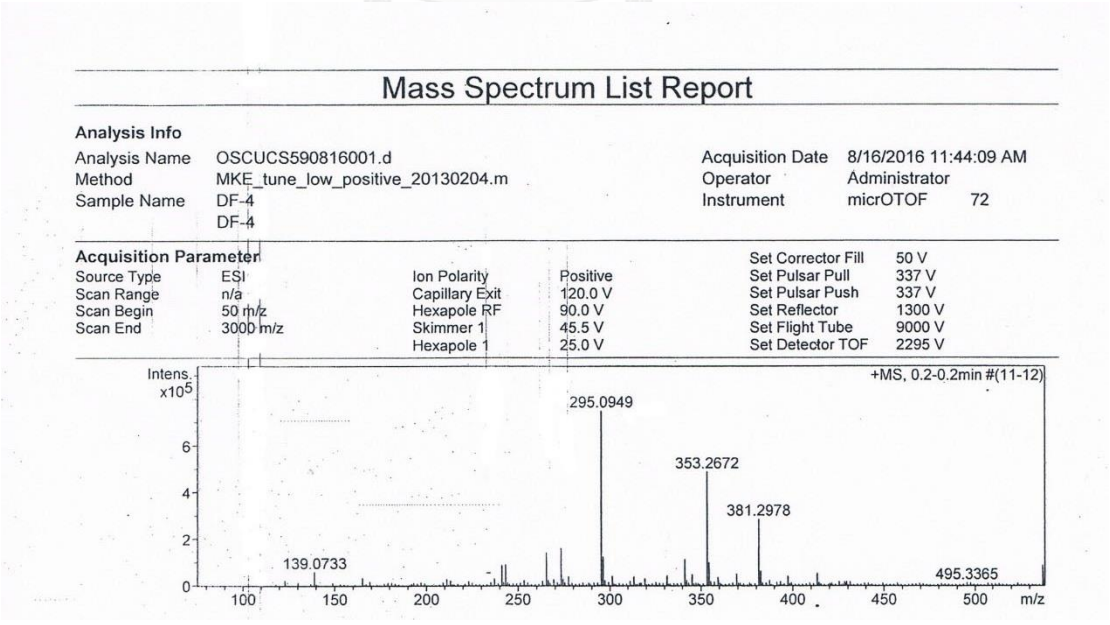


Figure 17 Mass spectrum of compound DFM-3

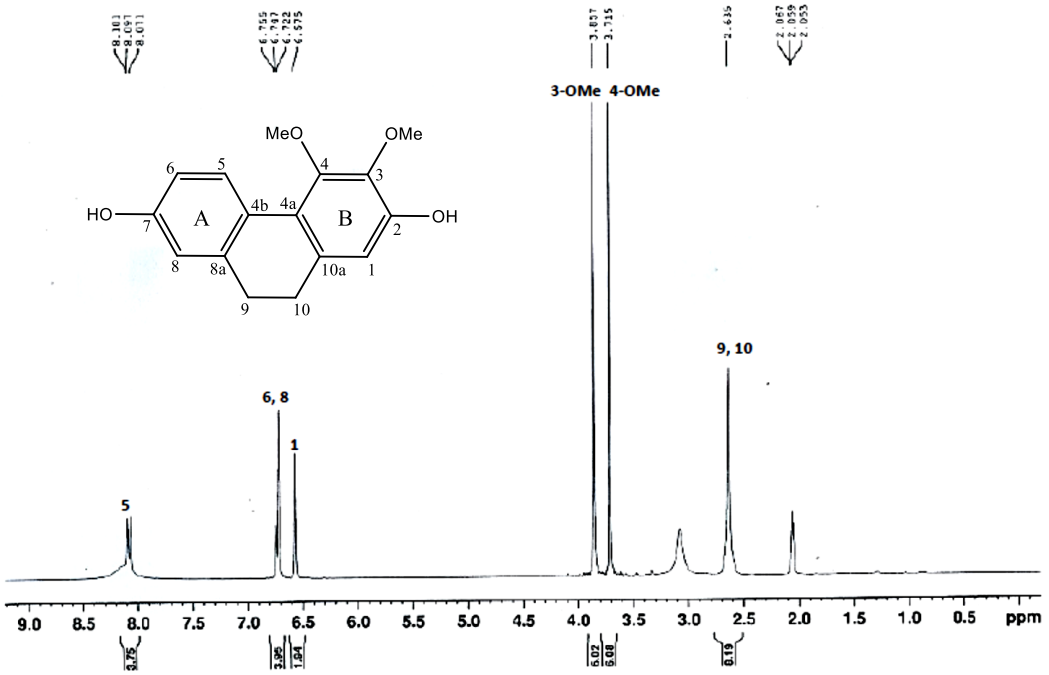


Figure 18 ^{1}H-NMR (300 MHz) spectrum of compound DFM-3 (in acetone-d_6)

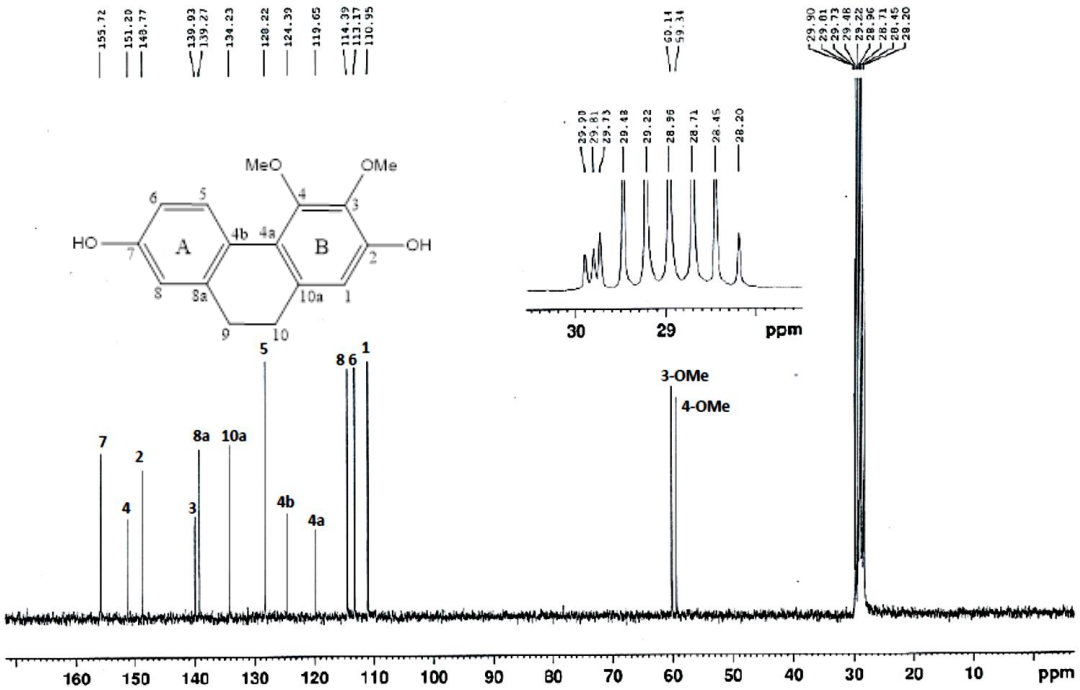


Figure 19 ^{13}C-NMR (75 MHz) spectrum of compound DFM-3 (in acetone-d_6)

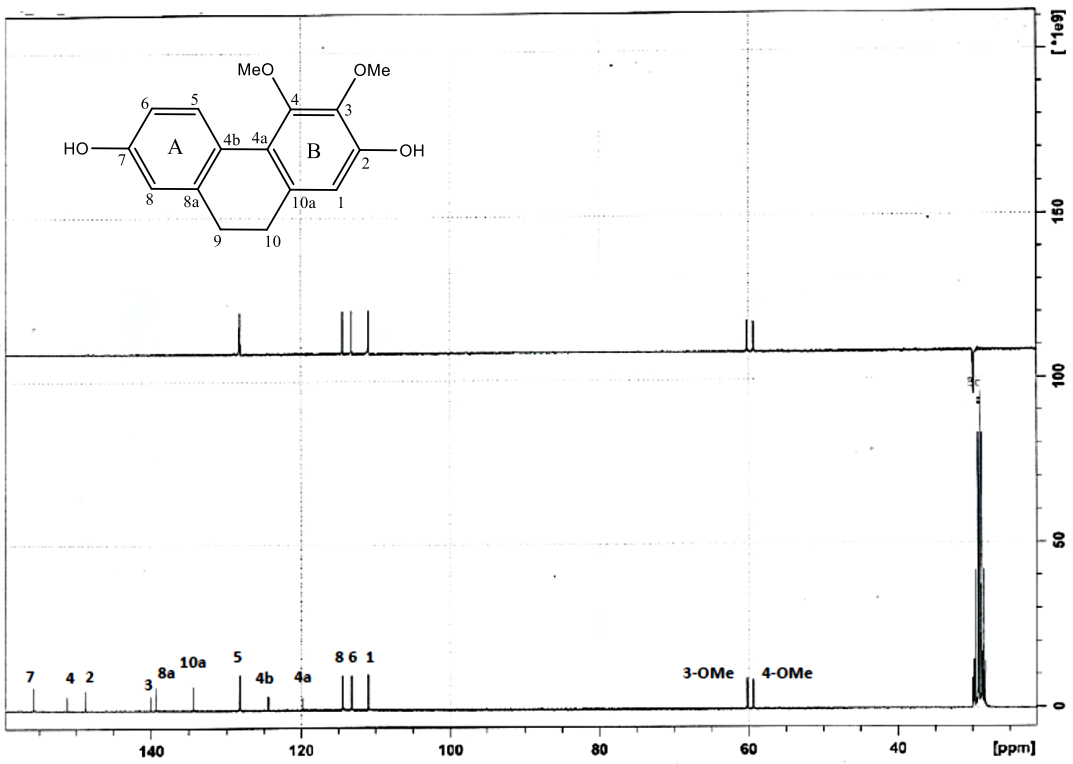


Figure 20 DEPT 135 spectrum of compound DFM-3 (in acetone-d_6)

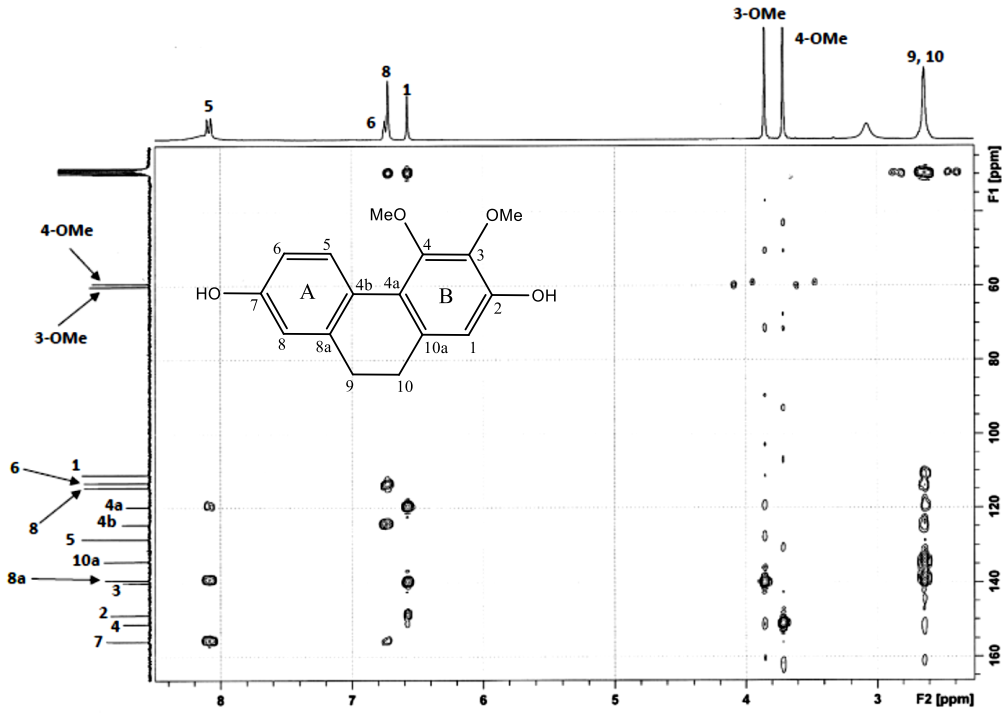


Figure 21 HMBC spectrum of compound DFM-3 (in acetone-d_6)

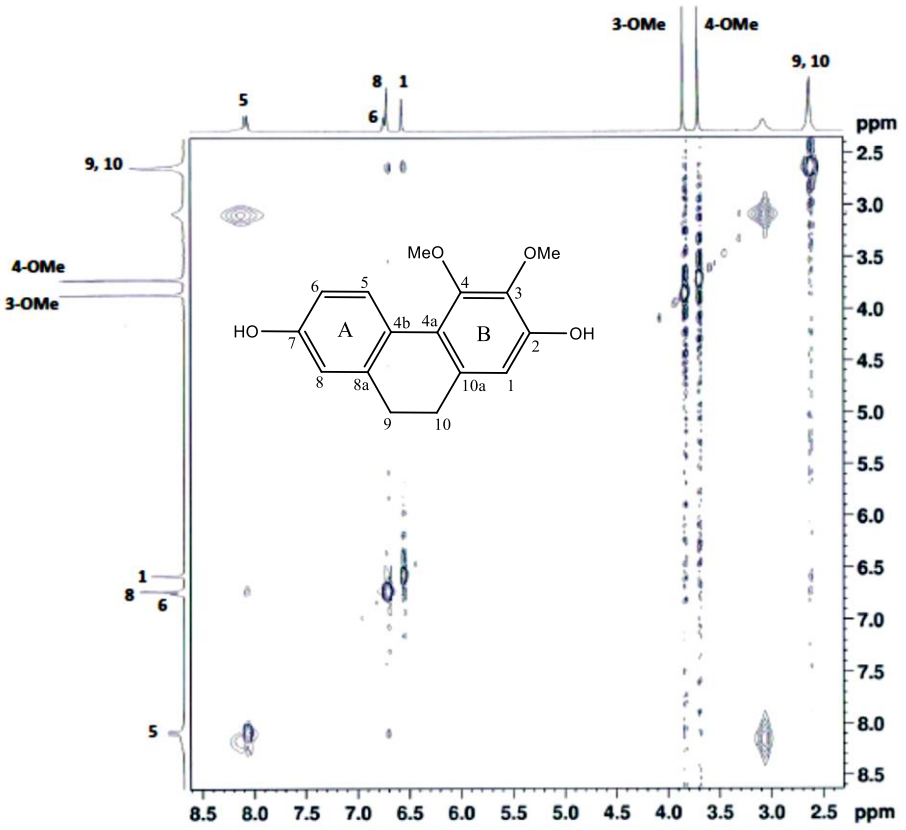


Figure 22 NOESY spectrum of compound DFM-3 (in acetone-d_6)

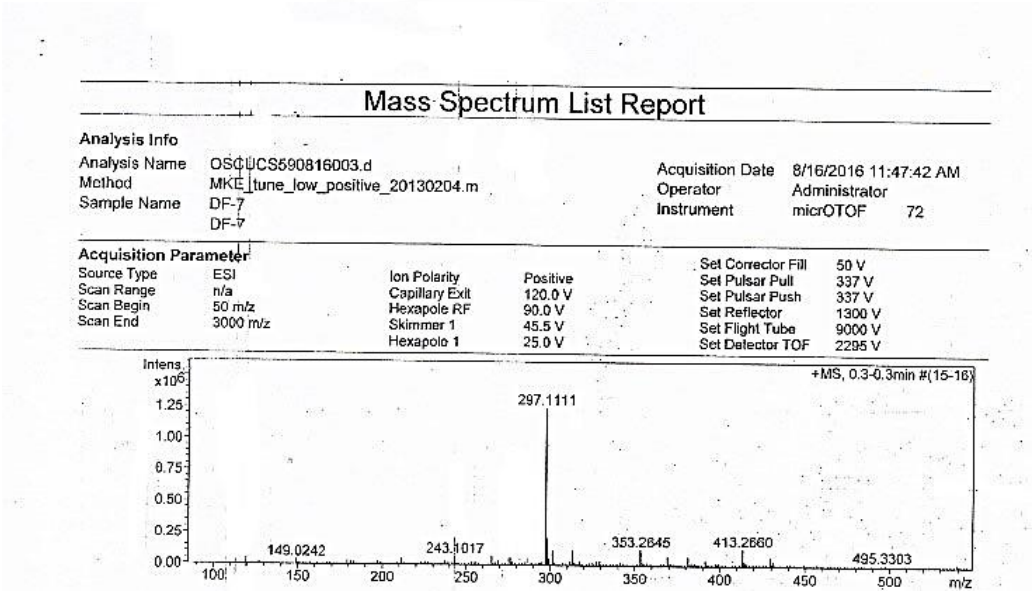


Figure 23 Mass spectrum of compound DFM-4

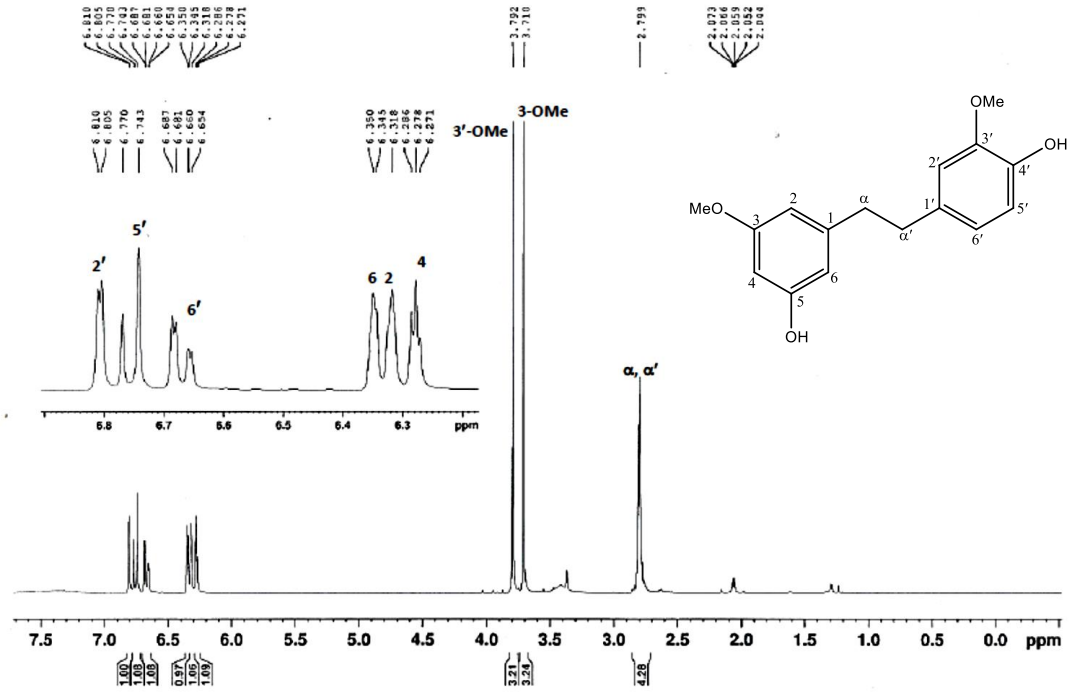


Figure 24 ^{1}H-NMR (300 MHz) spectrum of compound DFM-4 (in acetone-d_6)

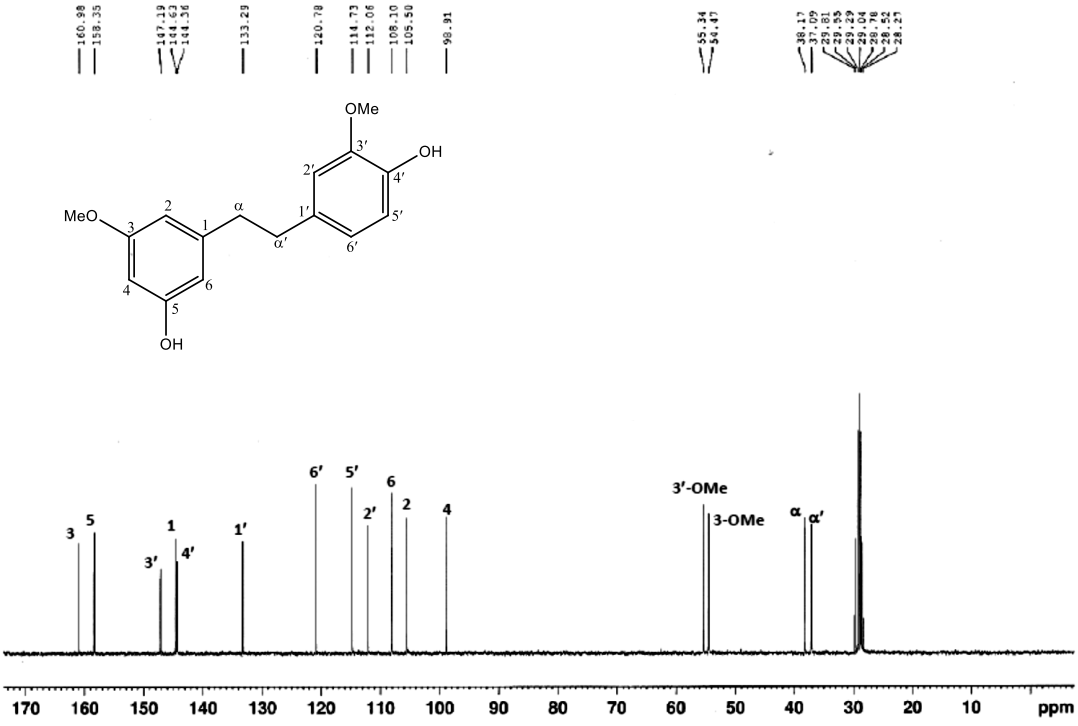


Figure 25 ^{13}C-NMR (75 MHz) spectrum of compound DFM-4 (in acetone-d_6)

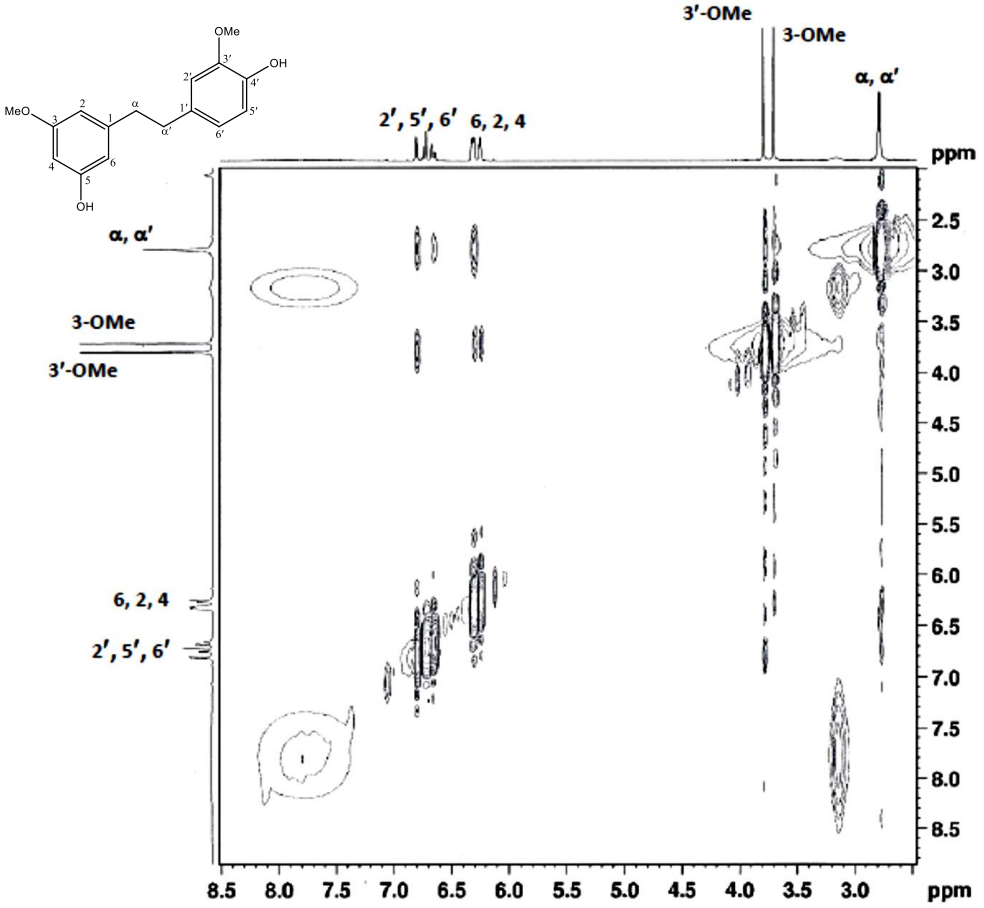


Figure 26 NOSEY spectrum of compound DFM-4 (in acetone-d_6)

Mass Spectrum List Report

Analysis Info

Analysis Name	OSCU600425001.d	Acquisition Date	4/25/2017 10:42:38 AM
Method	Tune_low_POS_130_150.m	Operator	Administrator
Sample Name	DF8	Instrument	micrOTOF 72
	DF8		

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Corrector Fill	50 V
Scan Range	n/a	Capillary Exit	130.0 V	Set Pulsar Pull	337 V
Scan Begin	50 m/z	Hexapole RF	150.0 V	Set Pulsar Push	337 V
Scan End	3000 m/z	Skimmer 1	45.0 V	Set Reflector	1300 V
		Hexapole 1	24.3 V	Set Flight Tube	9000 V
				Set Detector TOF	2295 V

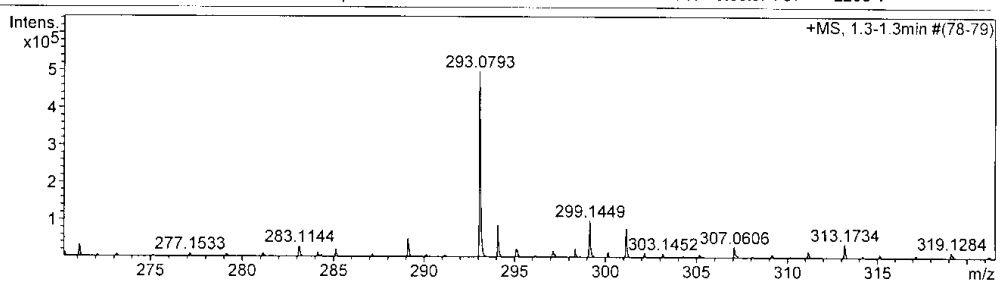


Figure 27 Mass spectrum of compound DFM-5

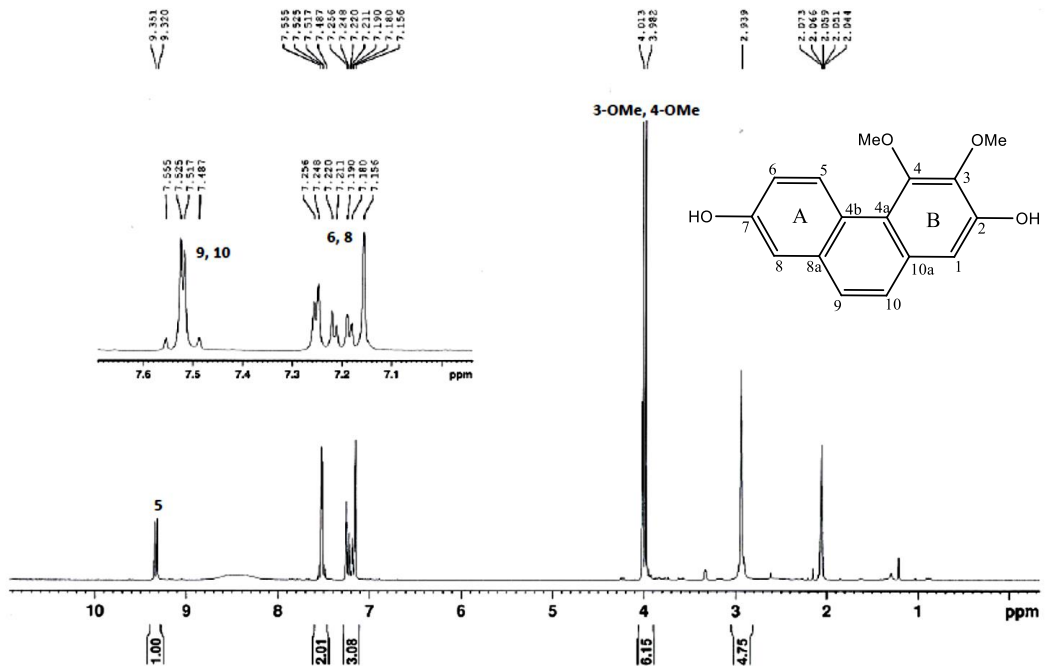


Figure 28 ^{1}H-NMR (300 MHz) spectrum of compound DFM-5 (in acetone-d_6)

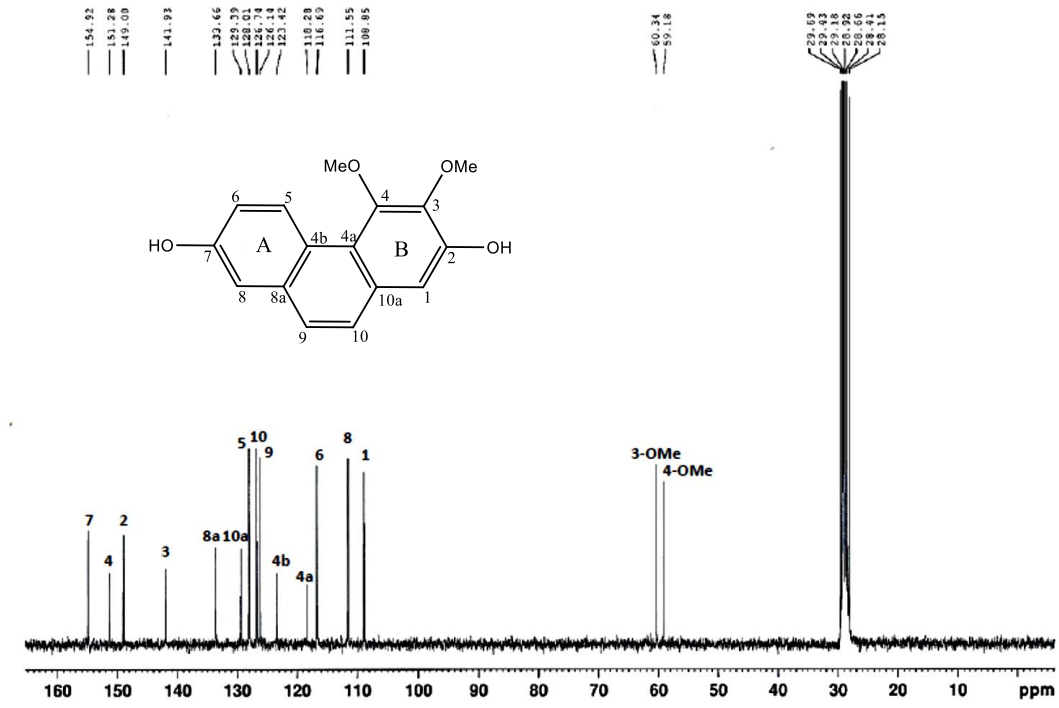


Figure 29 ^{13}C-NMR (75 MHz) spectrum of compound DFM-5 (in acetone-d_6)

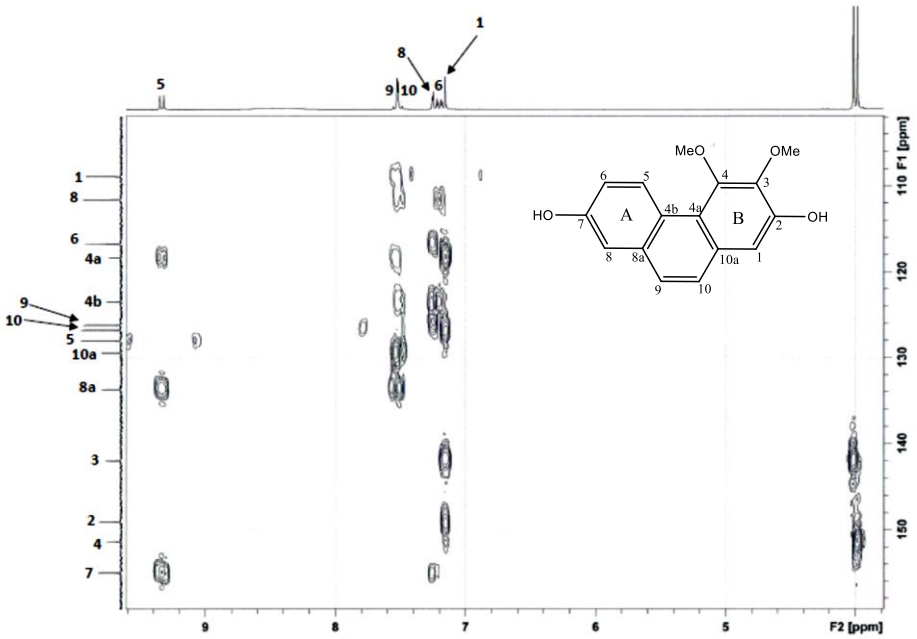


Figure 30 HMBC spectrum of compound DFM-5 (in acetone-d_6)

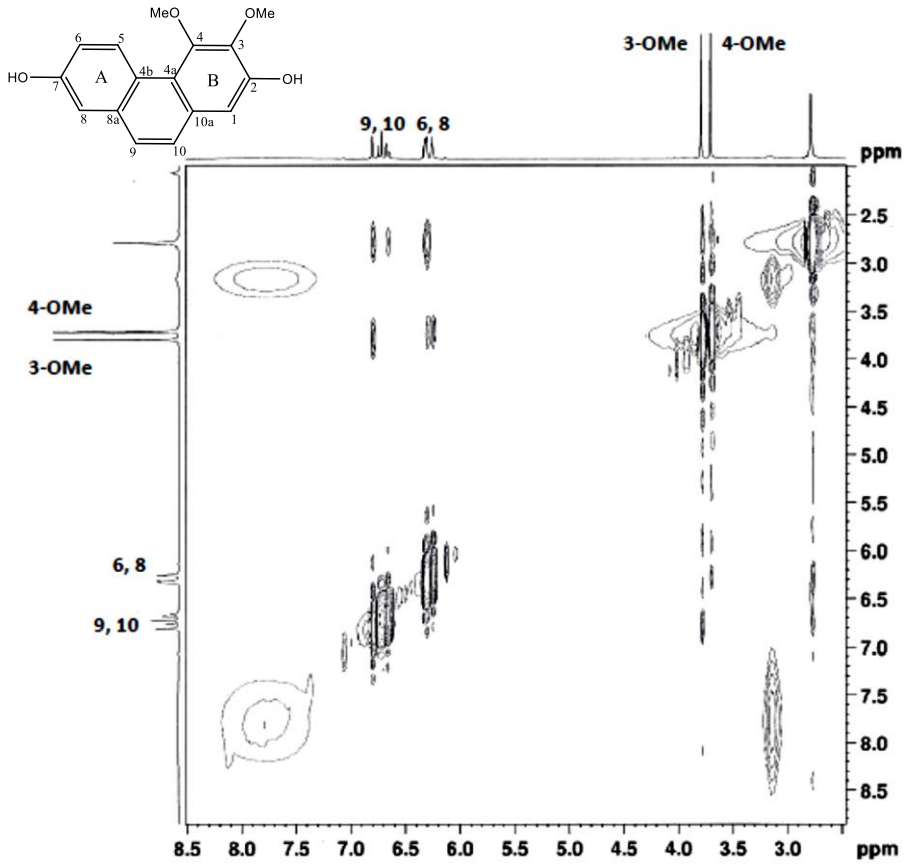


Figure 31 NOESY spectrum of compound DFM-5 (in acetone-d_6)

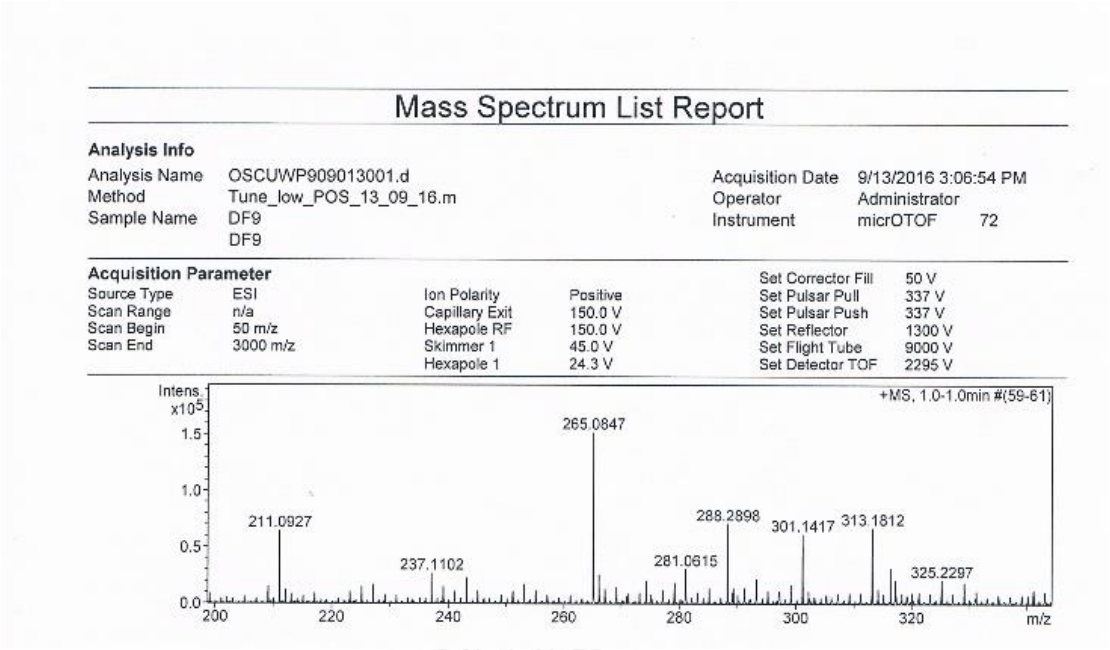


Figure 32 Mass spectrum of compound DFM-6

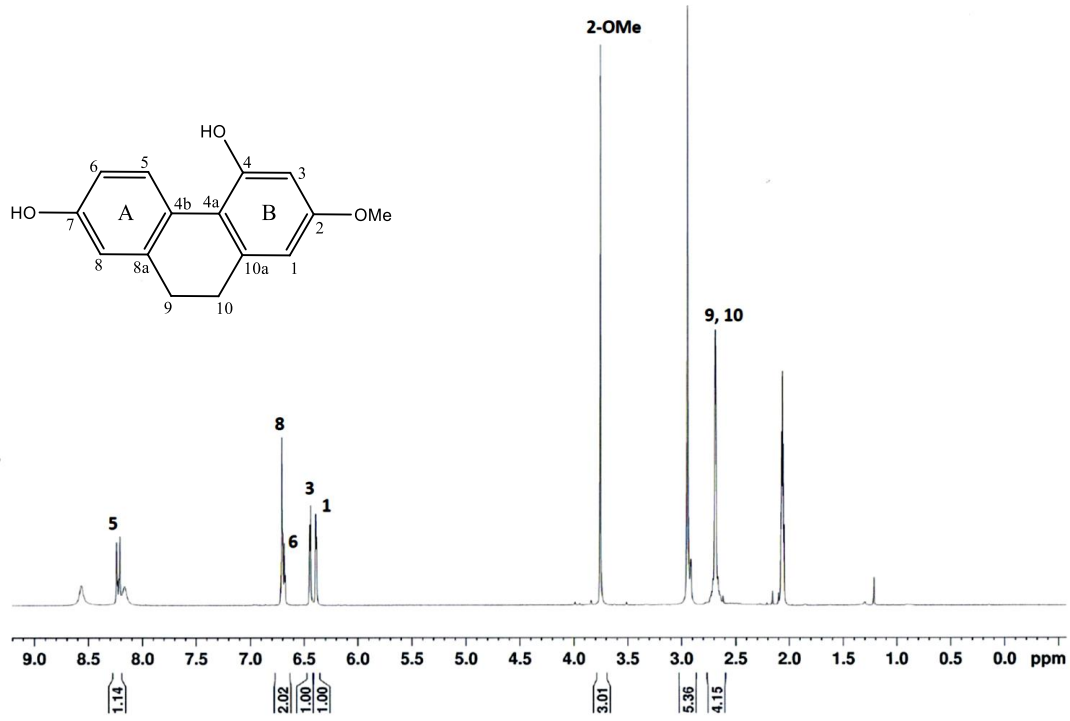


Figure 33 ^{1}H-NMR (300 MHz) spectrum of compound DFM-6 (in acetone-d_6)

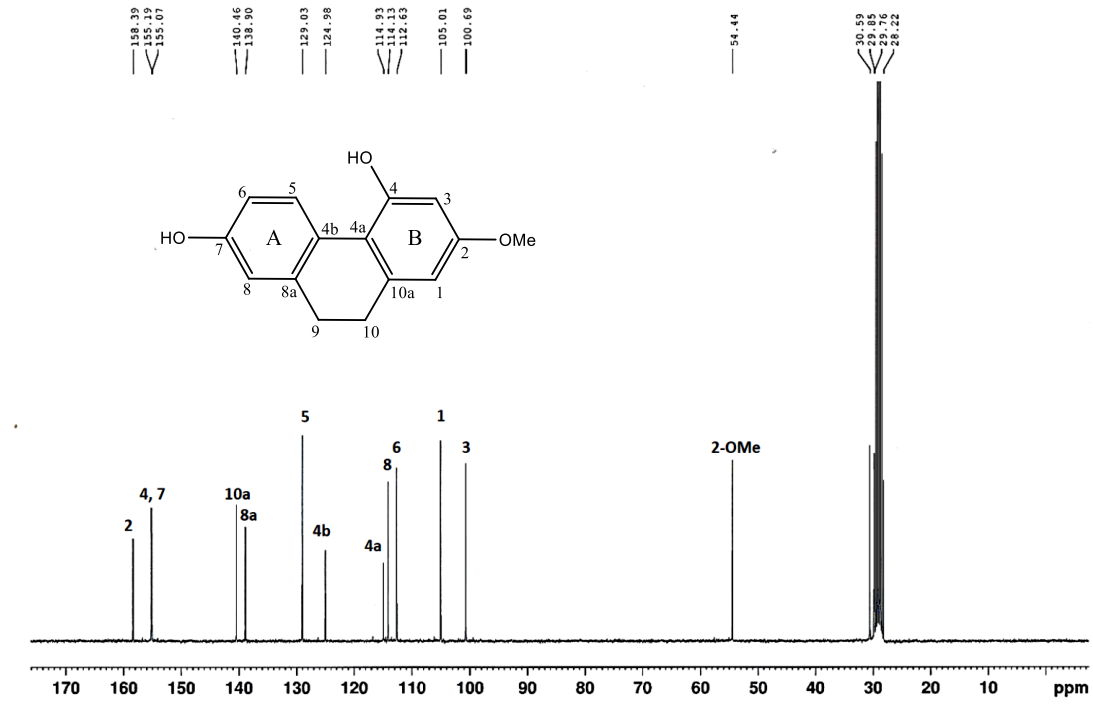


Figure 34 ^{13}C-NMR (75 MHz) spectrum of compound DFM-6 (in acetone-d_6)

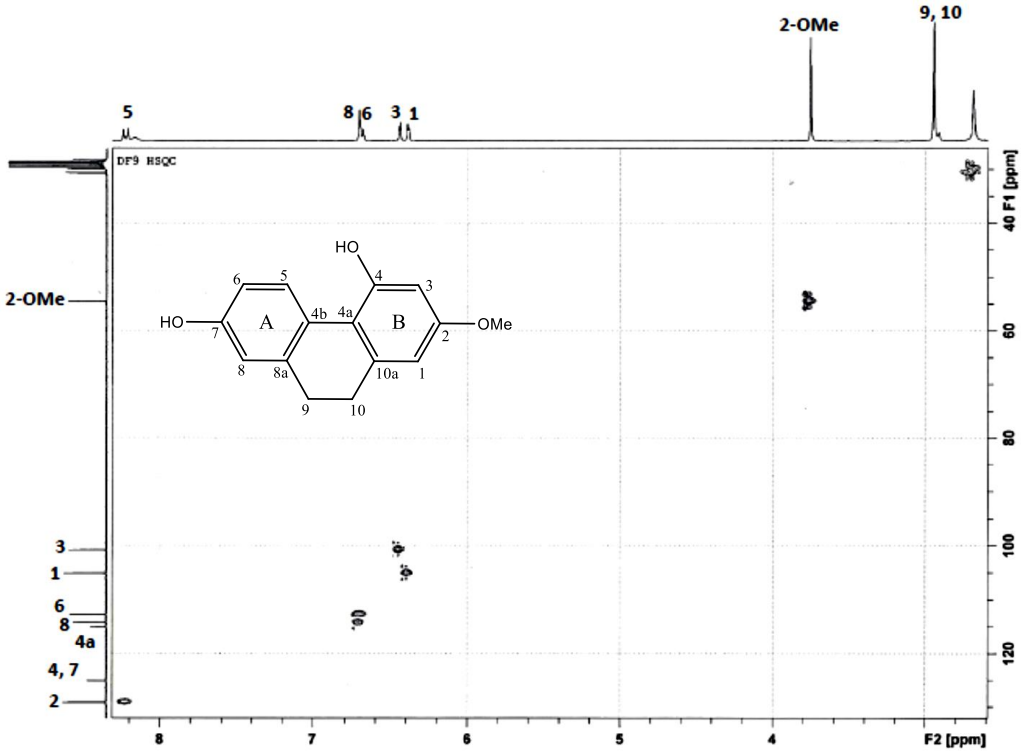


Figure 35 HSQC spectrum of compound DFM-6 (in acetone-d_6)

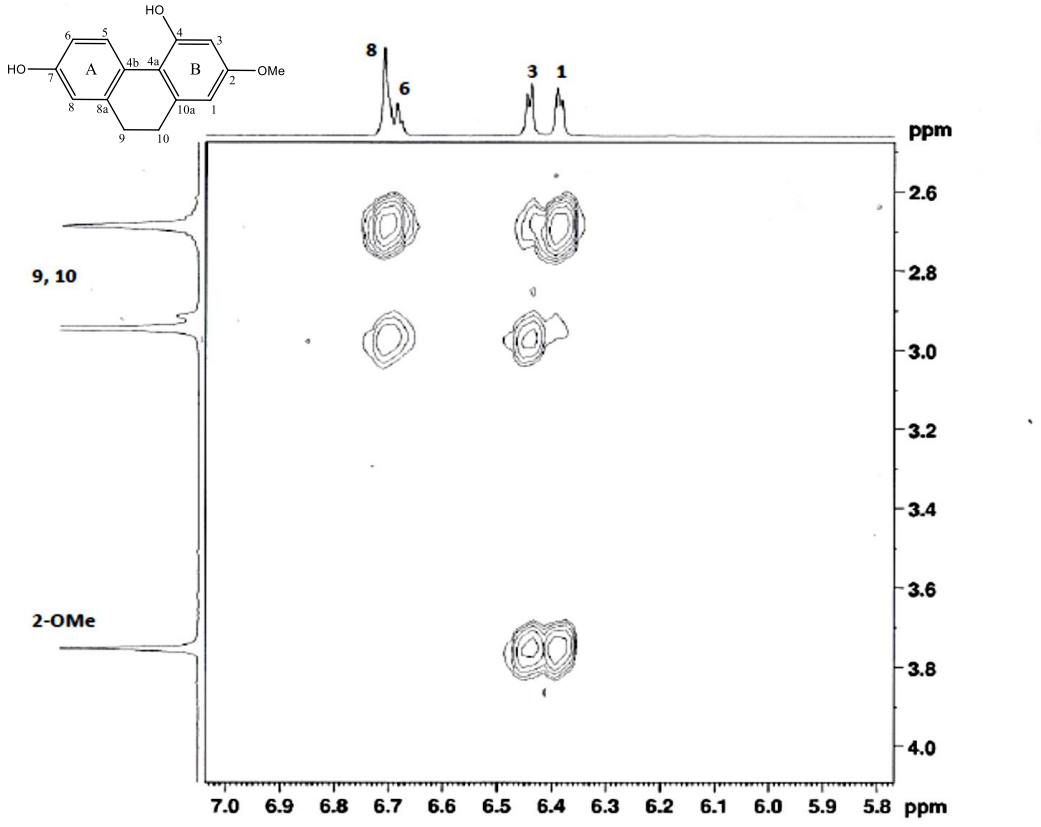


Figure 36 NOESY spectrum of compound DFM-6 (in acetone-d_6)

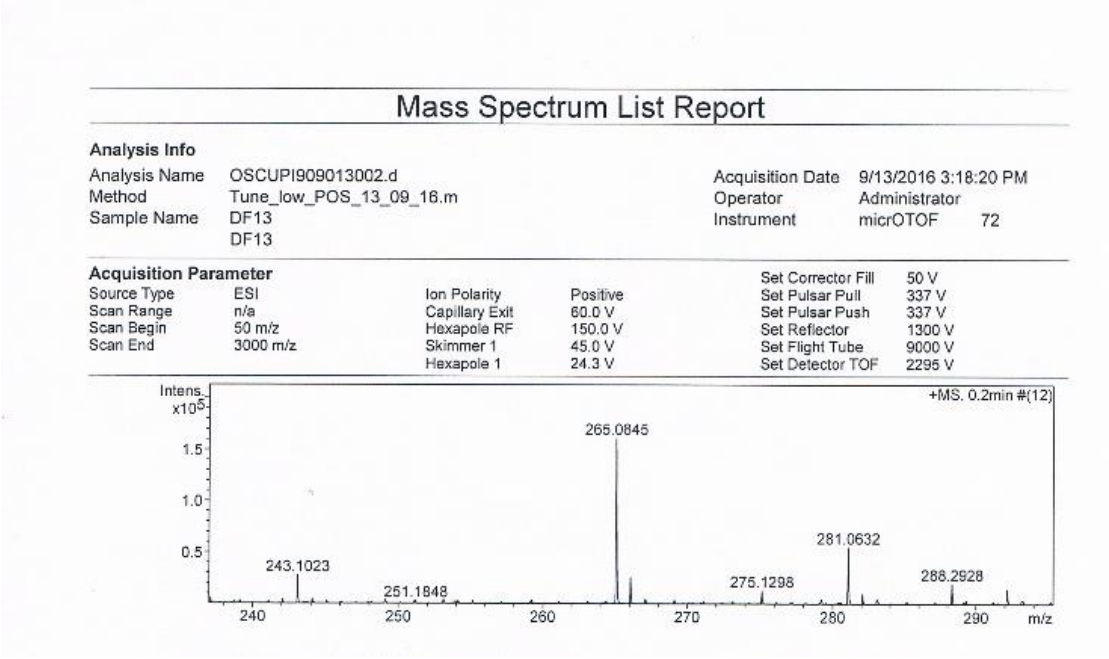


Figure 37 Mass spectrum of compound DFM-7

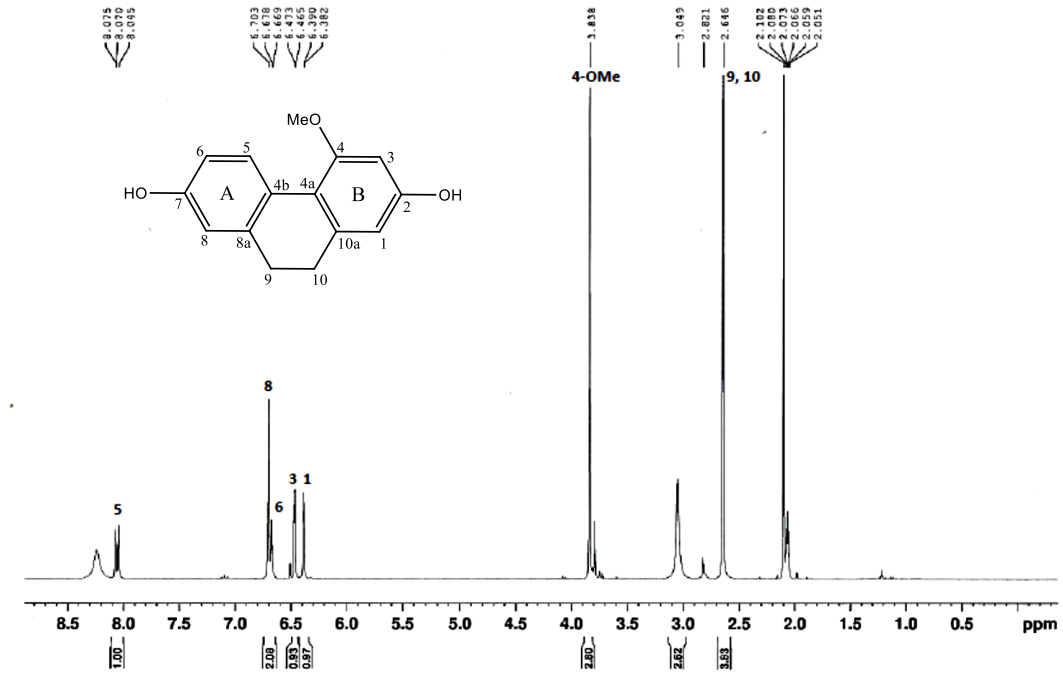


Figure 38 ^{1}H-NMR (300 MHz) spectrum of compound DFM-7 (in acetone-d_6)

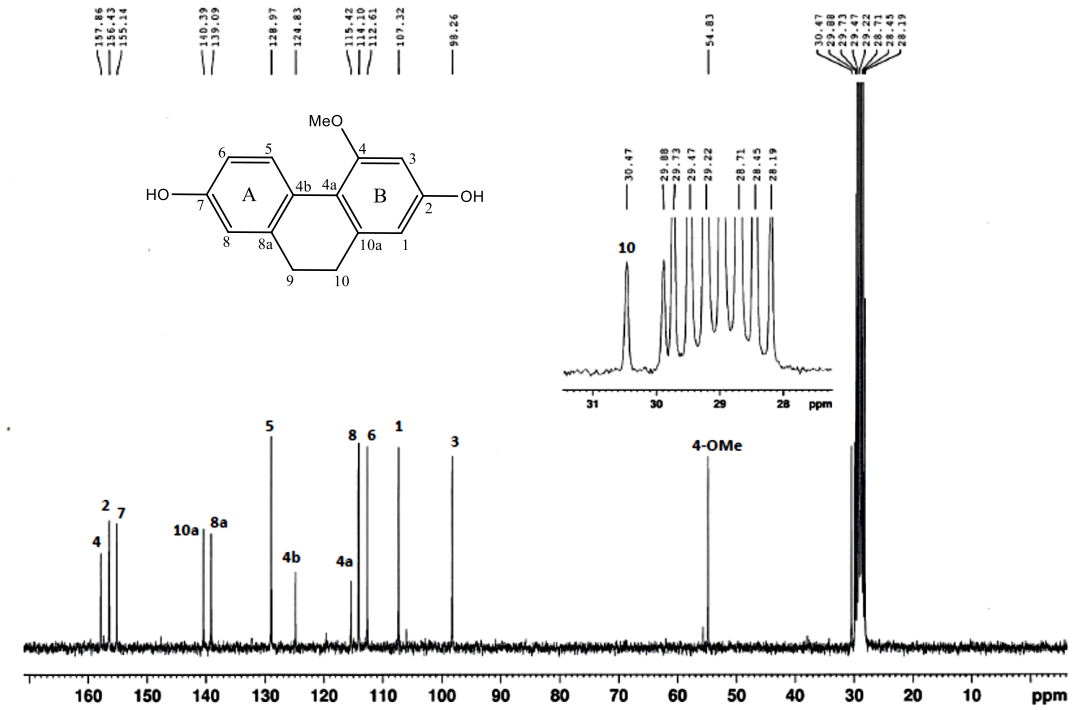


Figure 39 ^{13}C-NMR (75 MHz) spectrum of compound DFM-7 (in acetone-d_6)

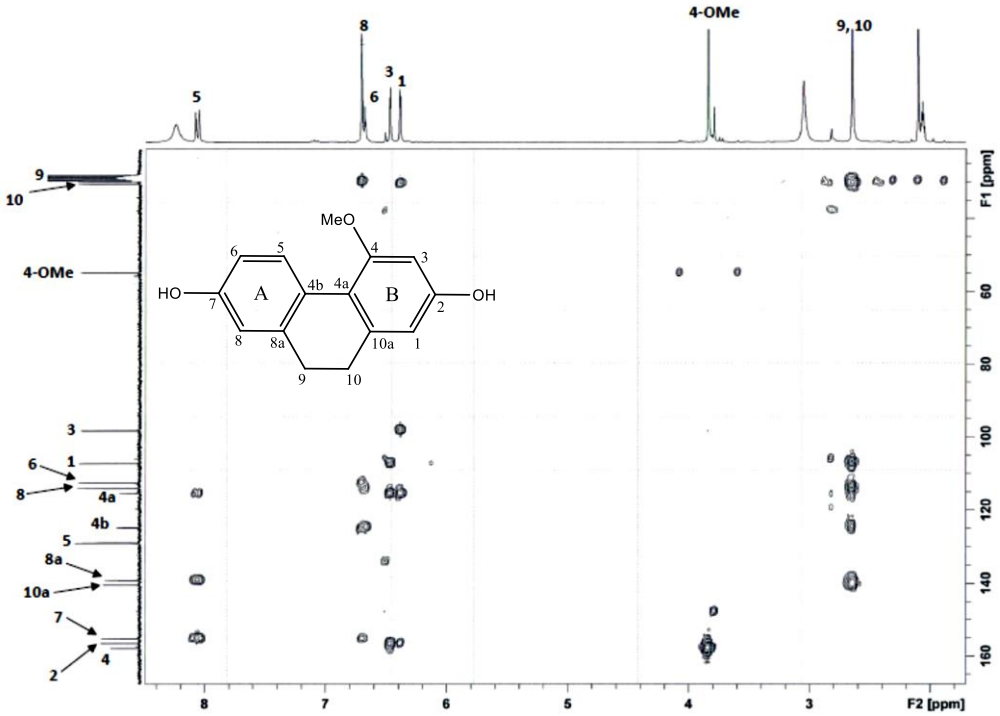


Figure 40 HMBC spectrum of compound DFM-7 (in acetone-d_6)

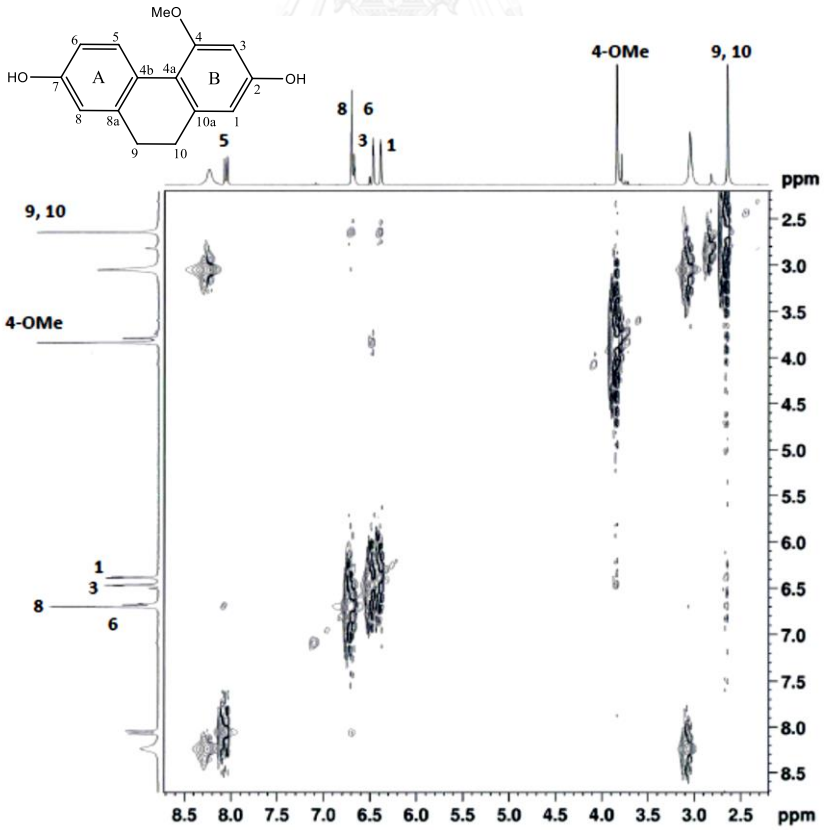


Figure 41 NOESY spectrum of compound DFM-7 (in acetone-d_6)

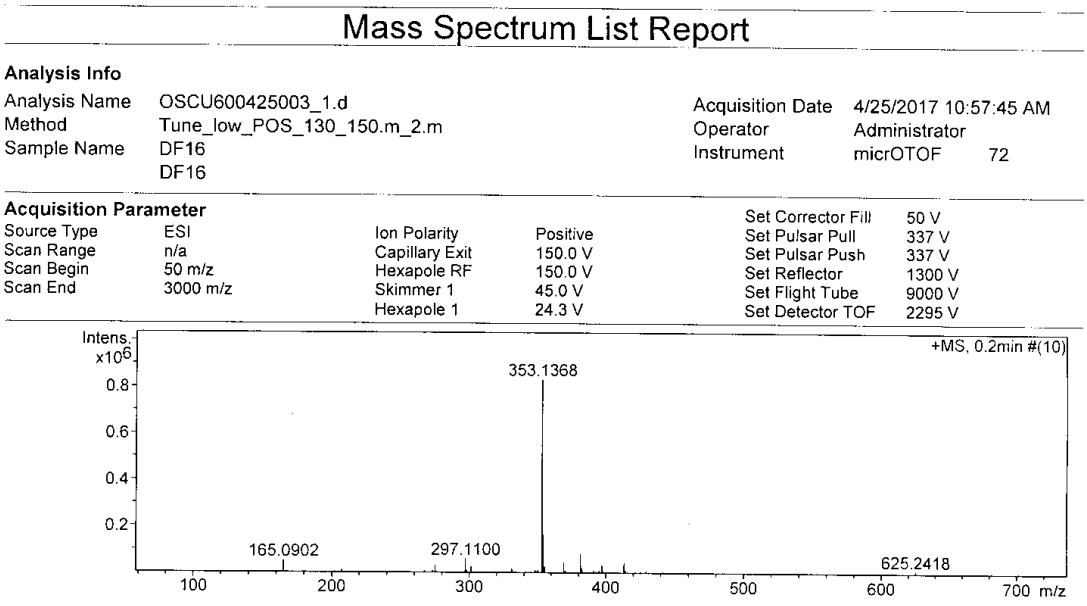


Figure 42 Mass spectrum of compound DFM-8

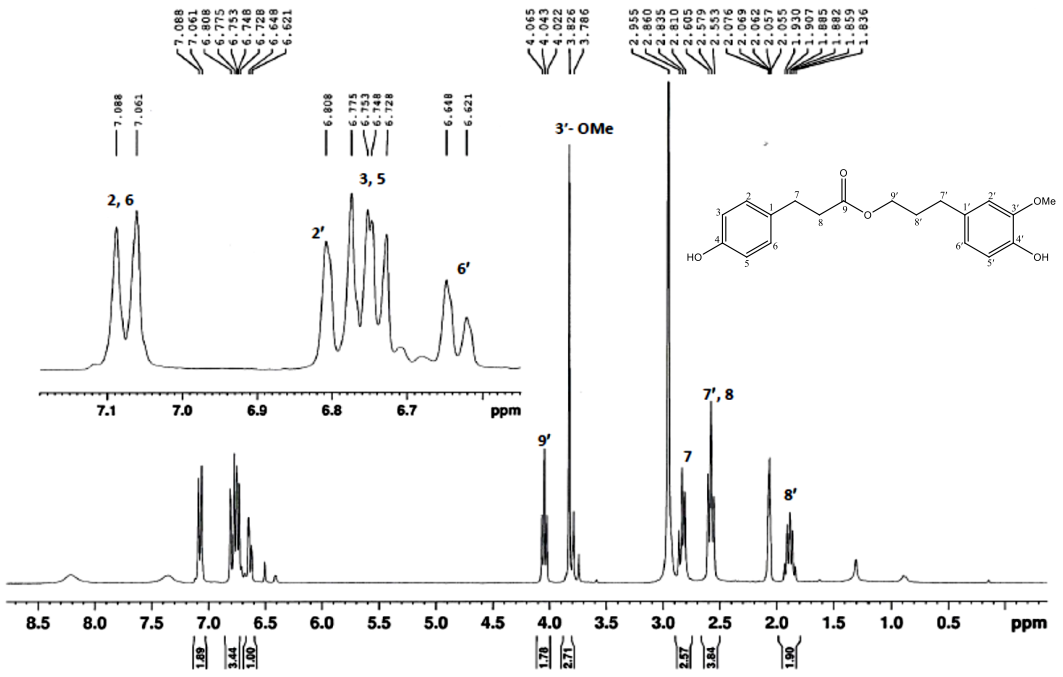


Figure 43 ^{1}H-NMR (300 MHz) spectrum of compound DFM-8 (in acetone-d_6)

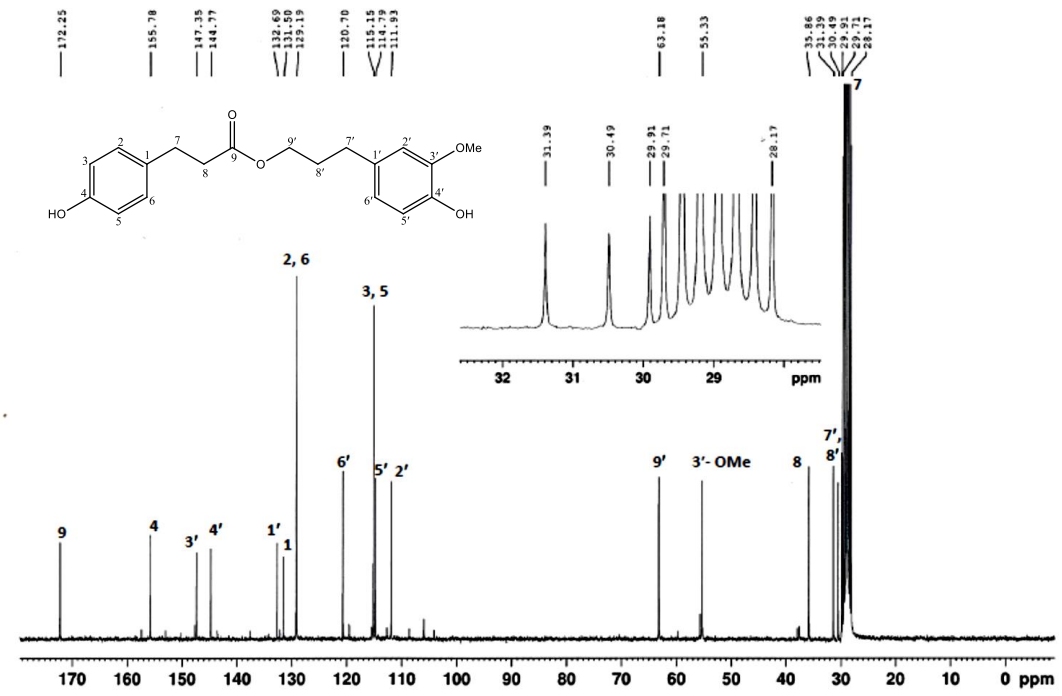


Figure 44 ^{13}C-NMR (75 MHz) spectrum of compound DFM-8 (in acetone-d_6)

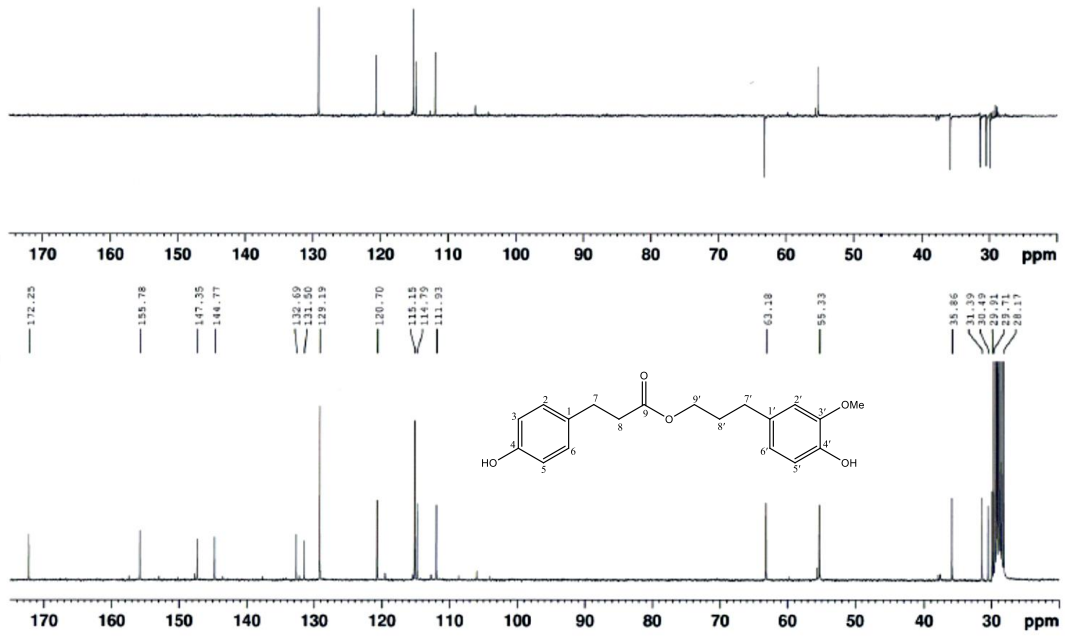


Figure 45 DEPT 135 spectrum of compound DFM-8 (in acetone-d_6)

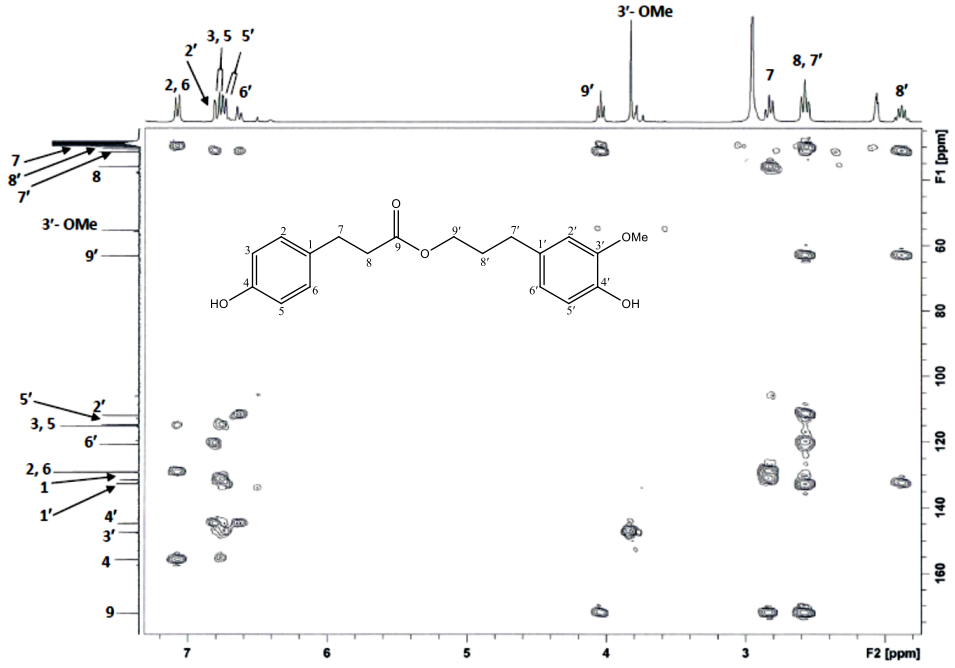


Figure 46 HMBC spectrum of compound DFM-8 (in acetone-d_6)

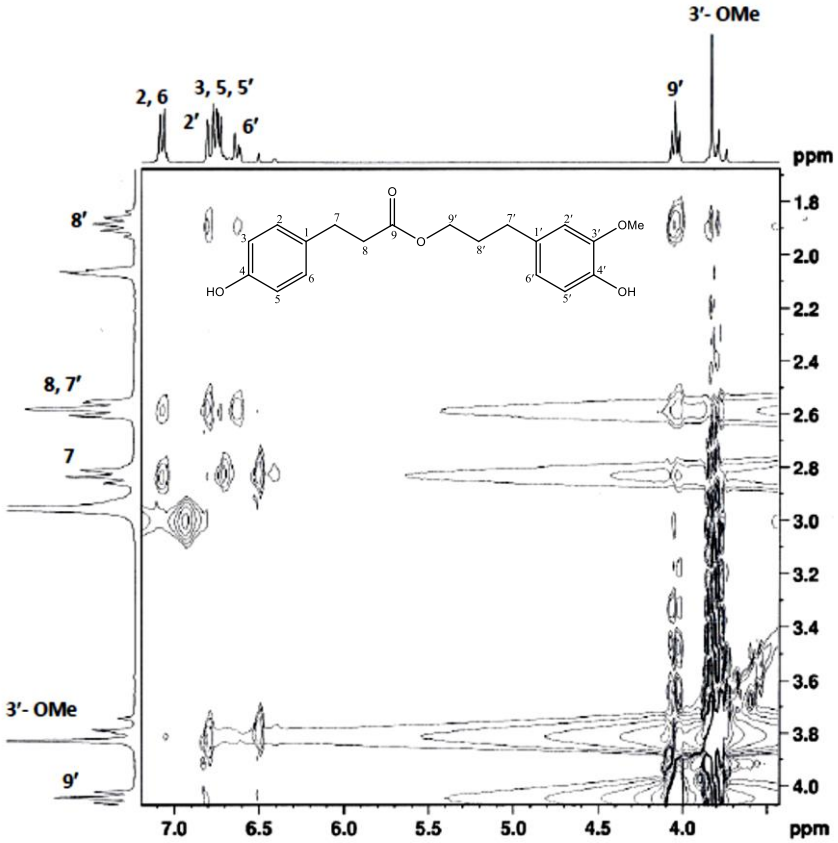


Figure 47 NOESY spectrum of compound DFM-8 (in acetone-d_6)

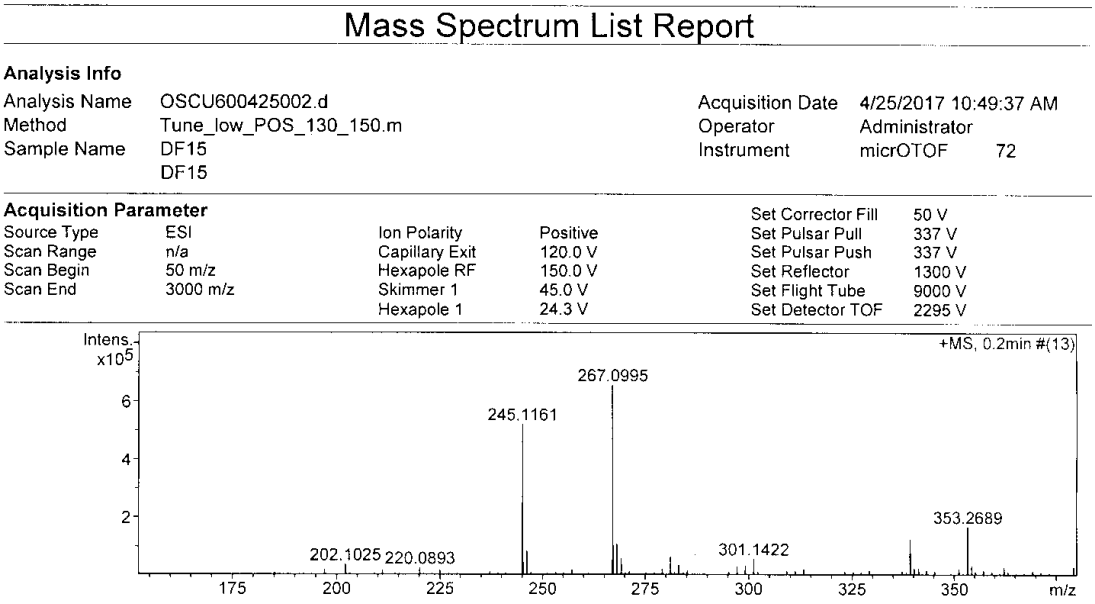


Figure 48 Mass spectrum of compound DFM-9

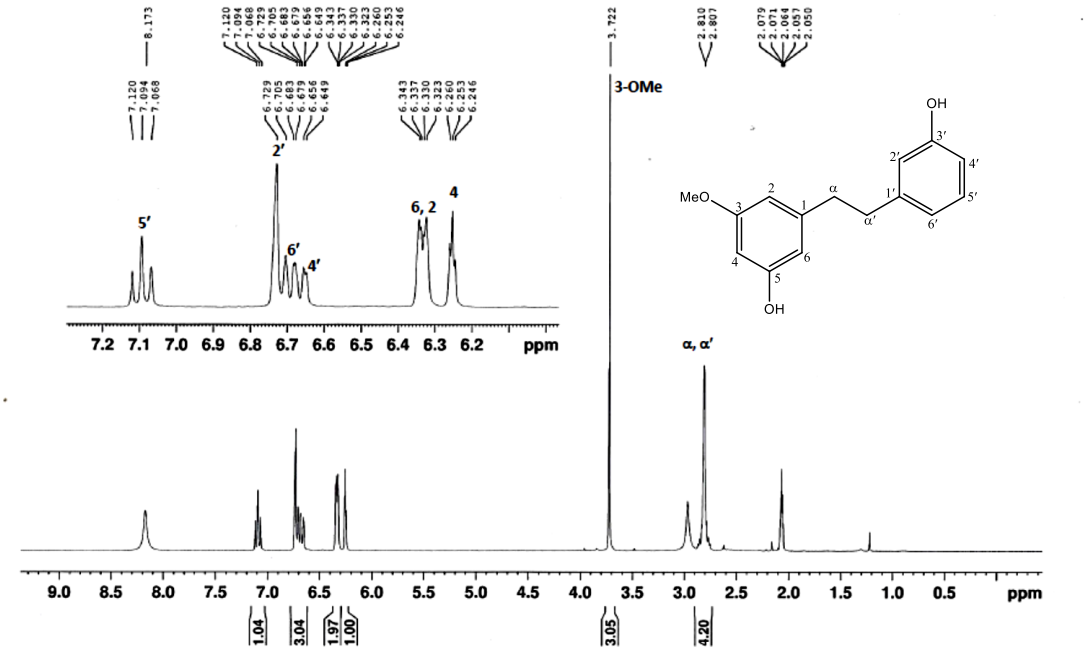


Figure 49 ^{1}H-NMR (300 MHz) spectrum of compound DFM-9 (in acetone-d_6)

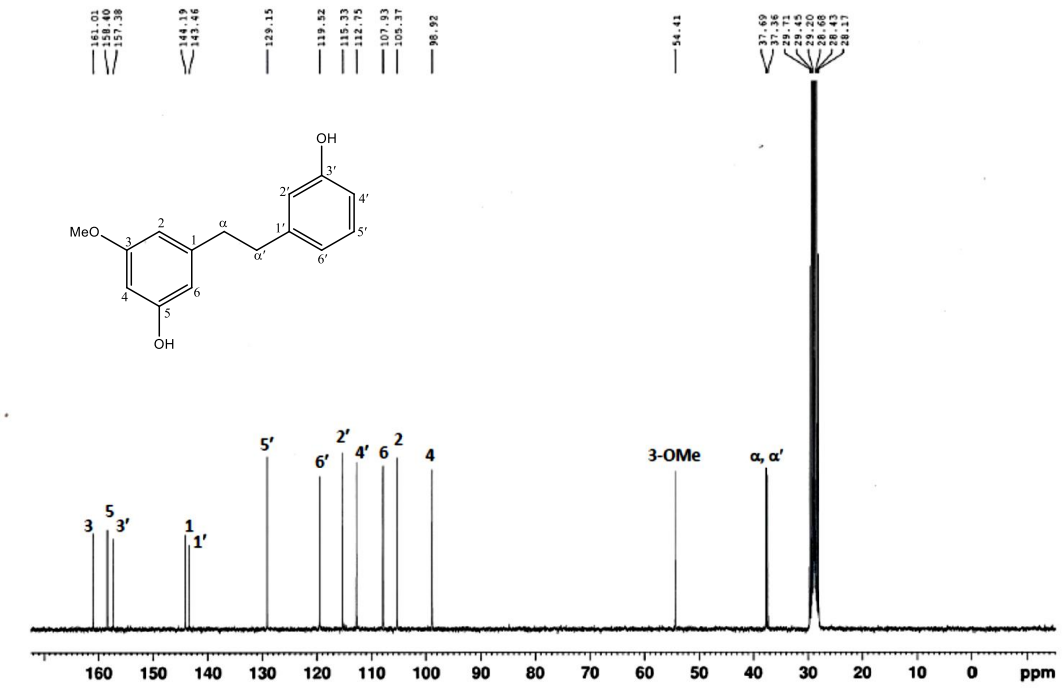


Figure 50 ^{13}C-NMR (75 MHz) spectrum of compound DFM-9 (in acetone-d_6)

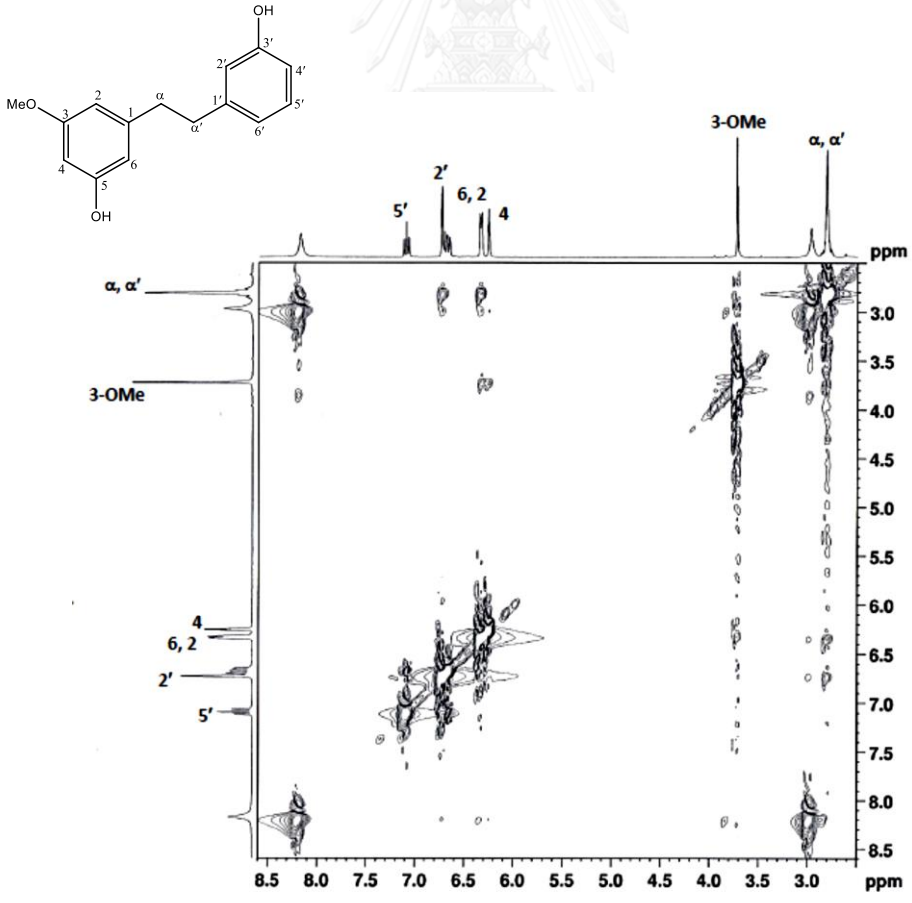


Figure 51 NOESY spectrum of compound DFM-9 (in acetone-d_6)

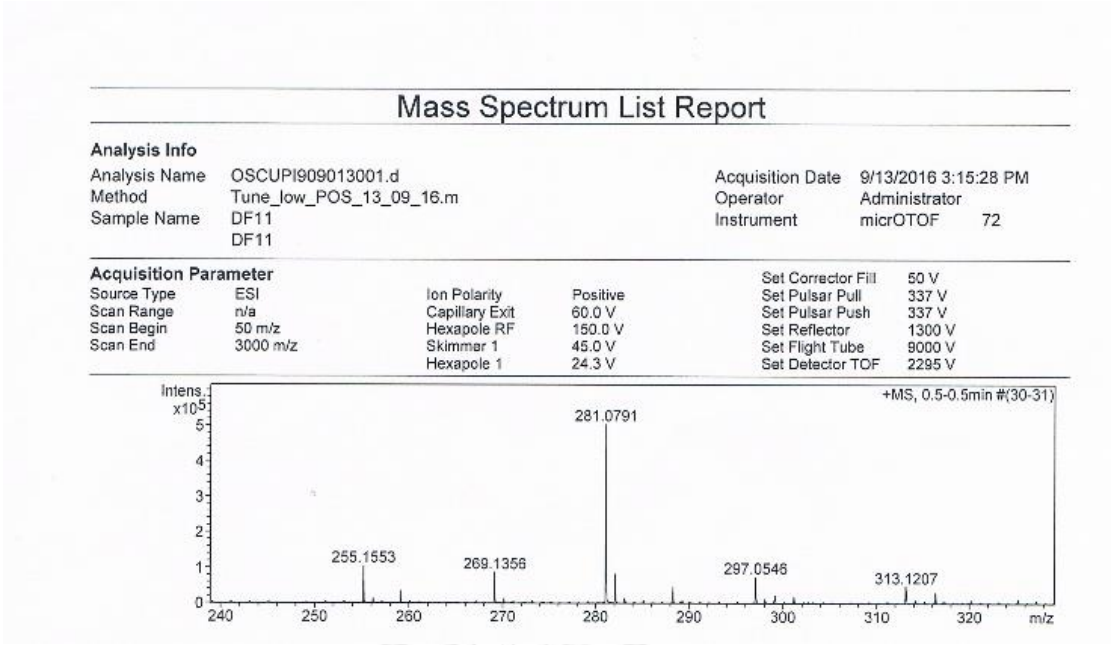


Figure 52 Mass spectrum of compound DFM-10

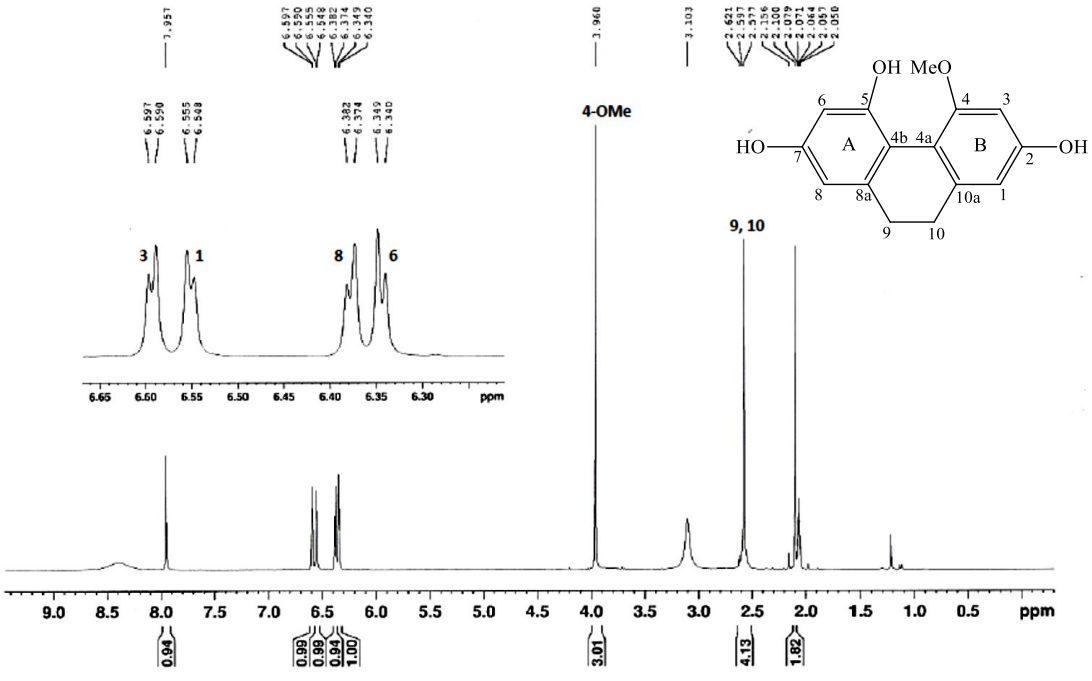


Figure 53 ^{1}H-NMR (300 MHz) spectrum of compound DFM-10 (in acetone-d_6)

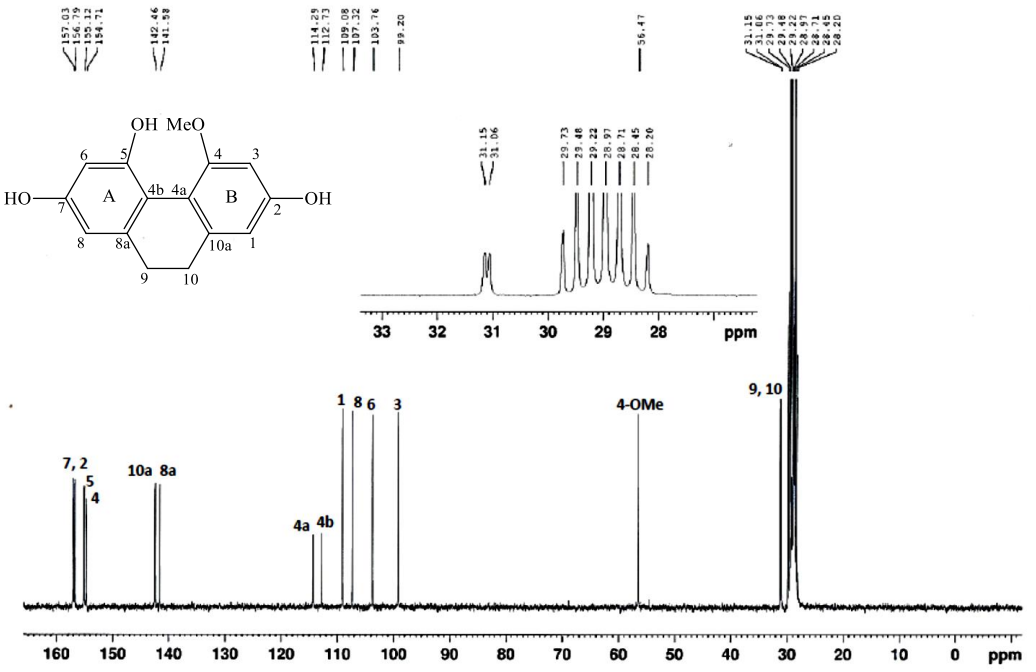


Figure 54 ^{13}C-NMR (75 MHz) spectrum of compound DFM-10 (in acetone-d_6)

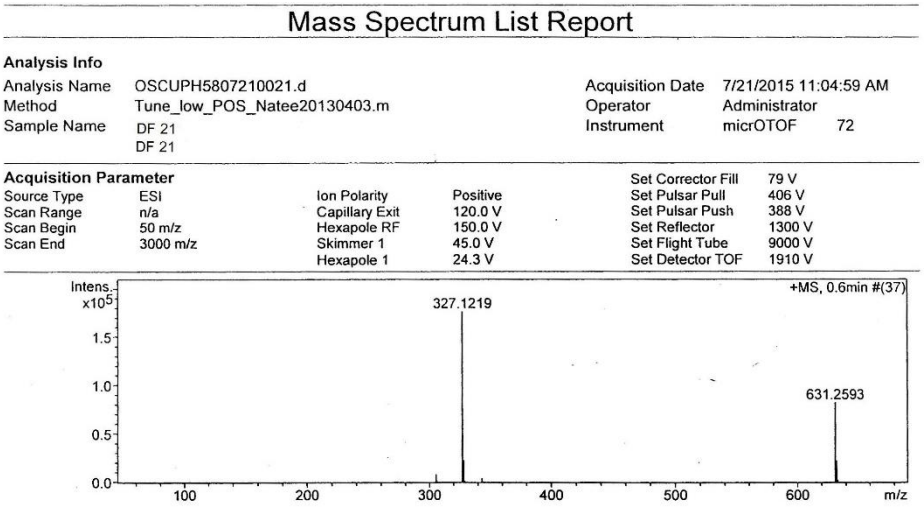


Figure 55 Mass spectrum of compound DFM-11

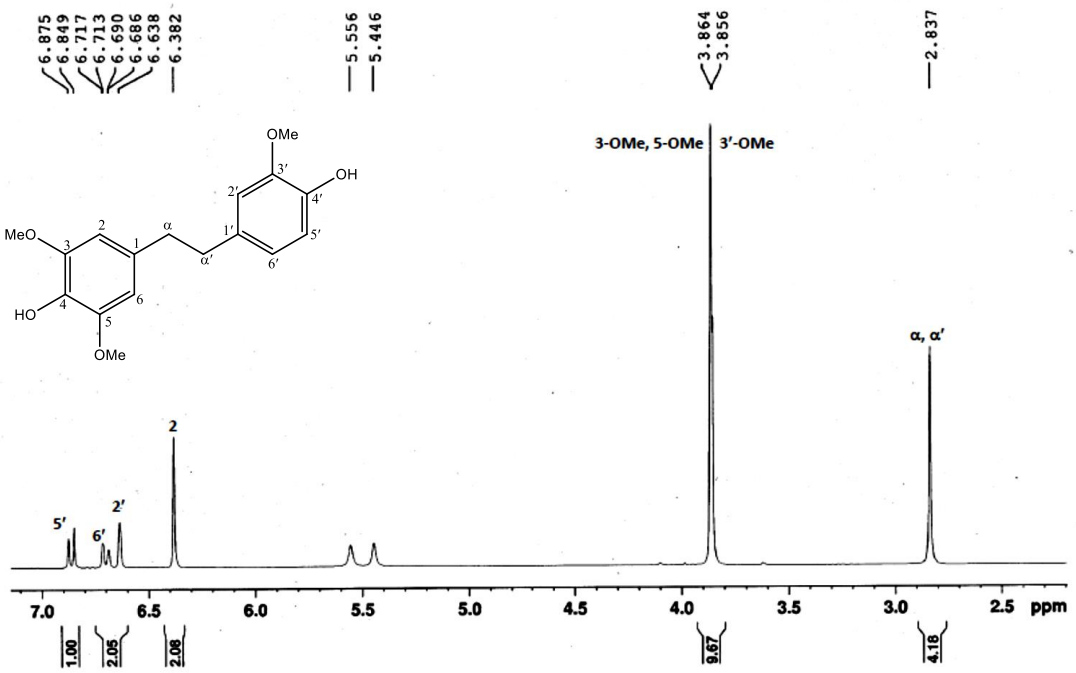


Figure 56 ^{1}H-NMR (300 MHz) spectrum of compound DFM-11 (in $CDCl_3$)

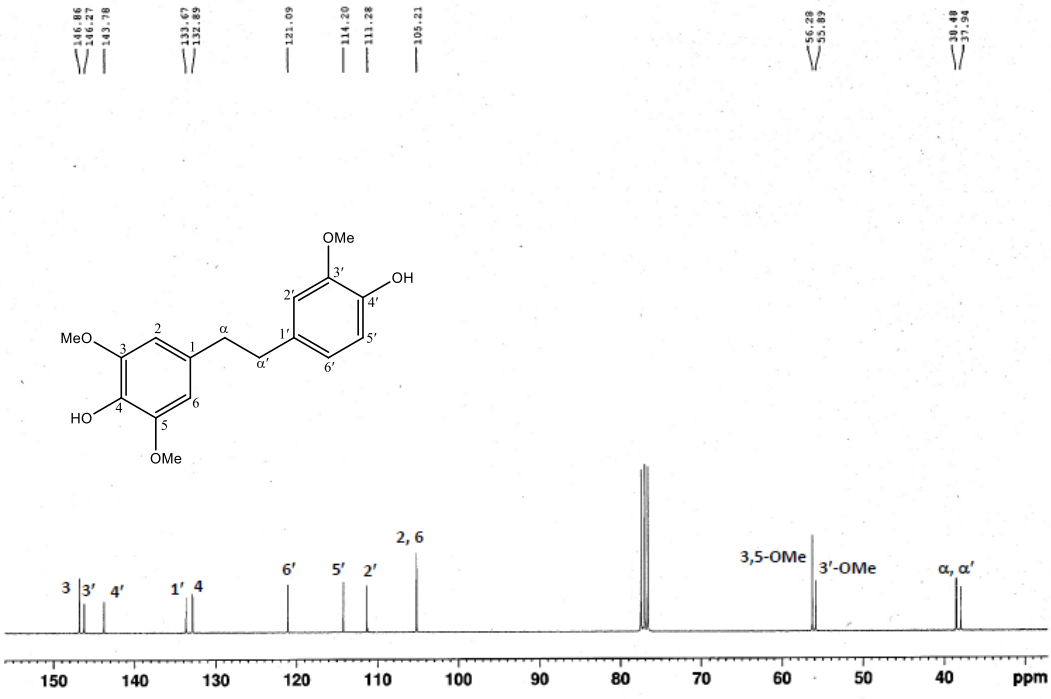


Figure 57 ^{13}C-NMR (75 MHz) spectrum of compound DFM-11 (in $CDCl_3$)

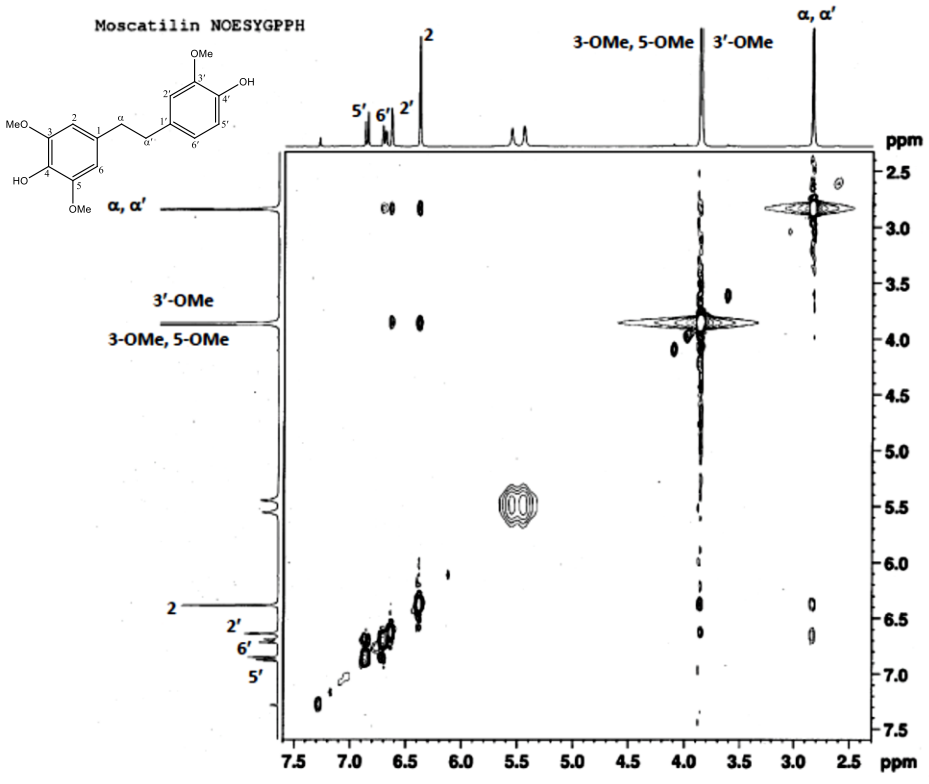


Figure 58 NOESY spectrum of compound DFM-11 (in $CDCl_3$)

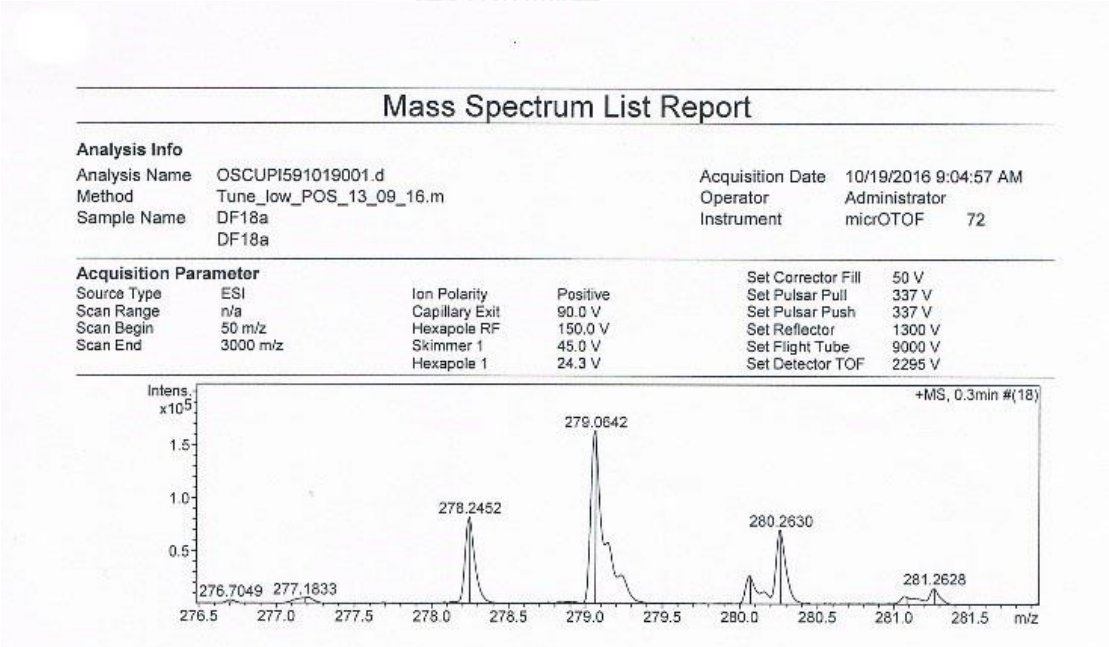


Figure 59 Mass spectrum of compound DFM-12

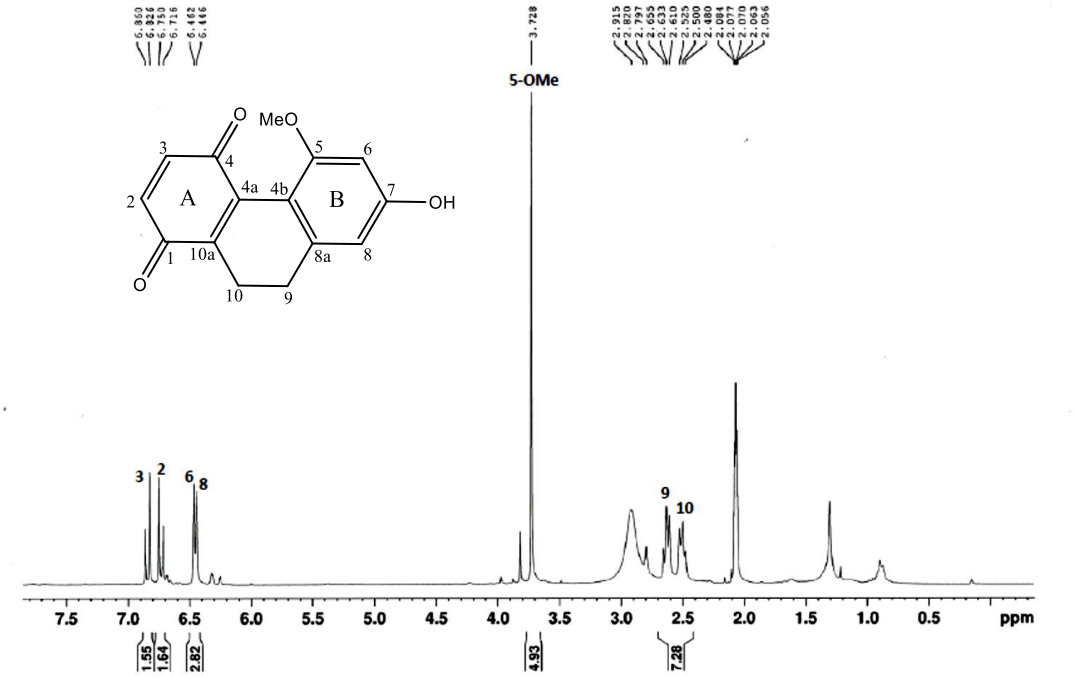


Figure 60 ^{1}H-NMR (300 MHz) spectrum of compound DFM-12 (in acetone-d_6)

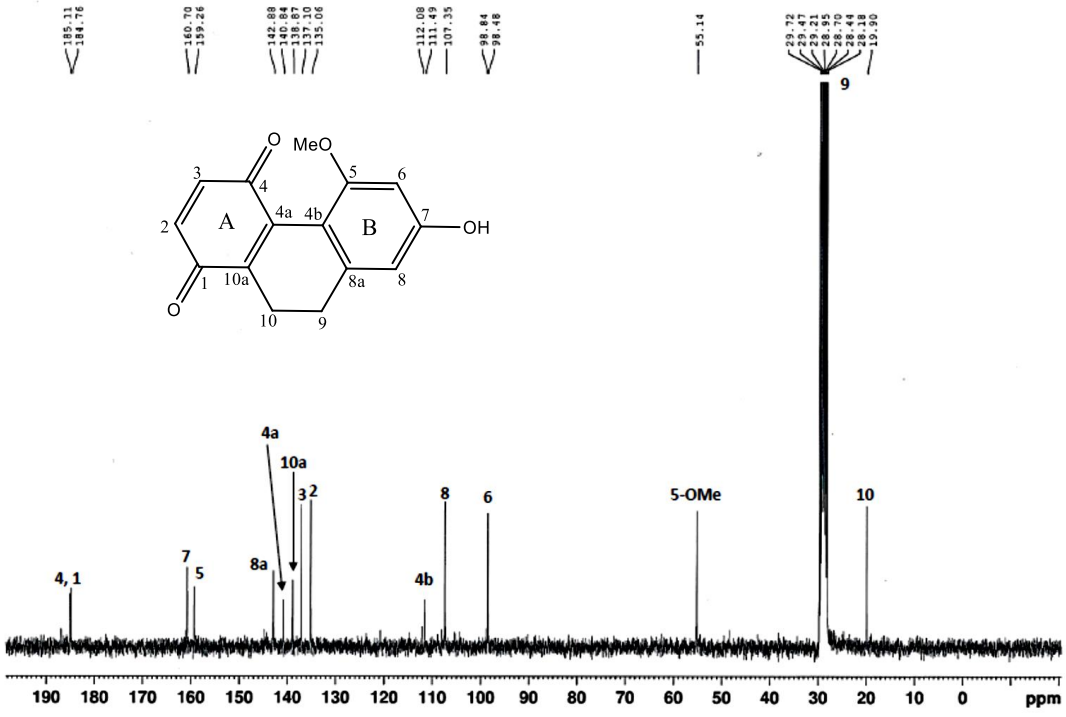


Figure 61 ^{13}C-NMR (75 MHz) spectrum of compound DFM-12 (in acetone-d_6)

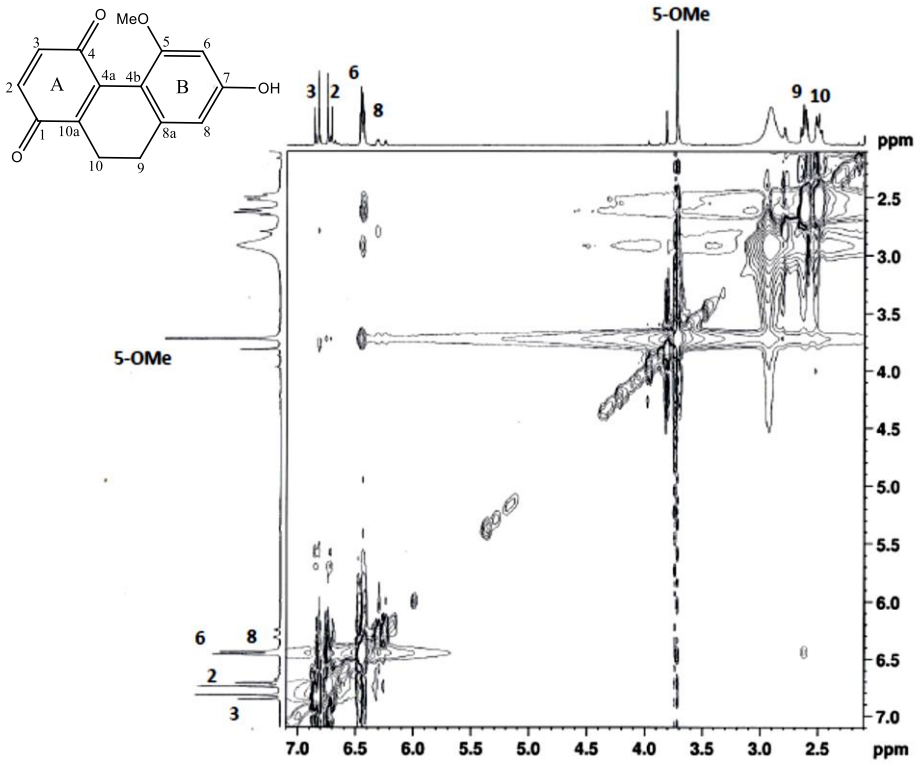


Figure 62 NOESY spectrum of compound DFM-12 (in acetone-d_6)

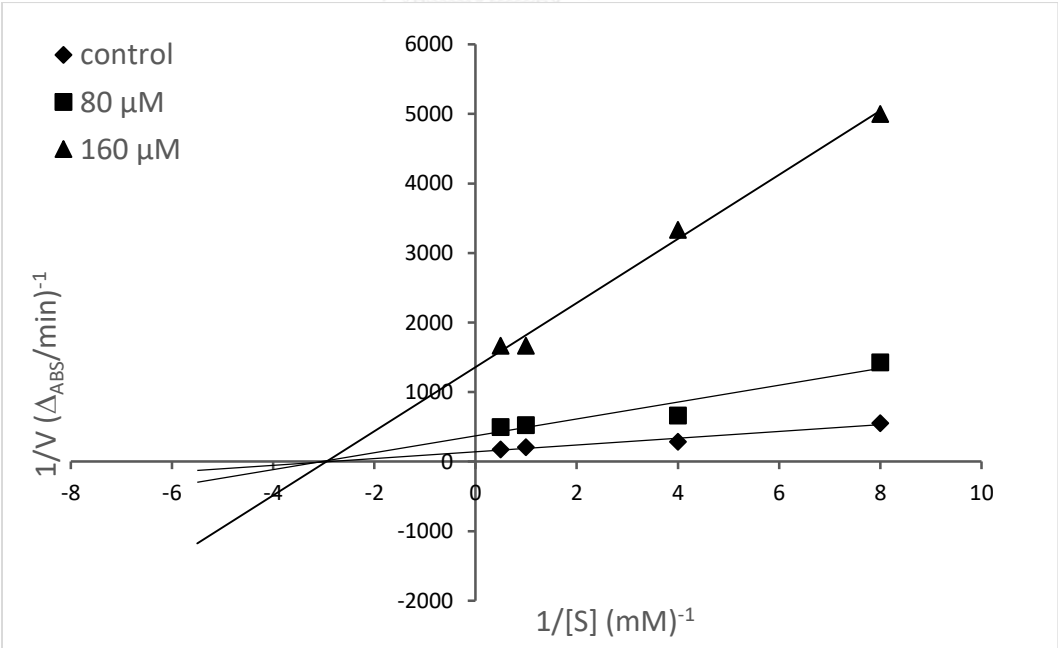


Figure 63 α-Glucosidase inhibition at different concentrations of 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone

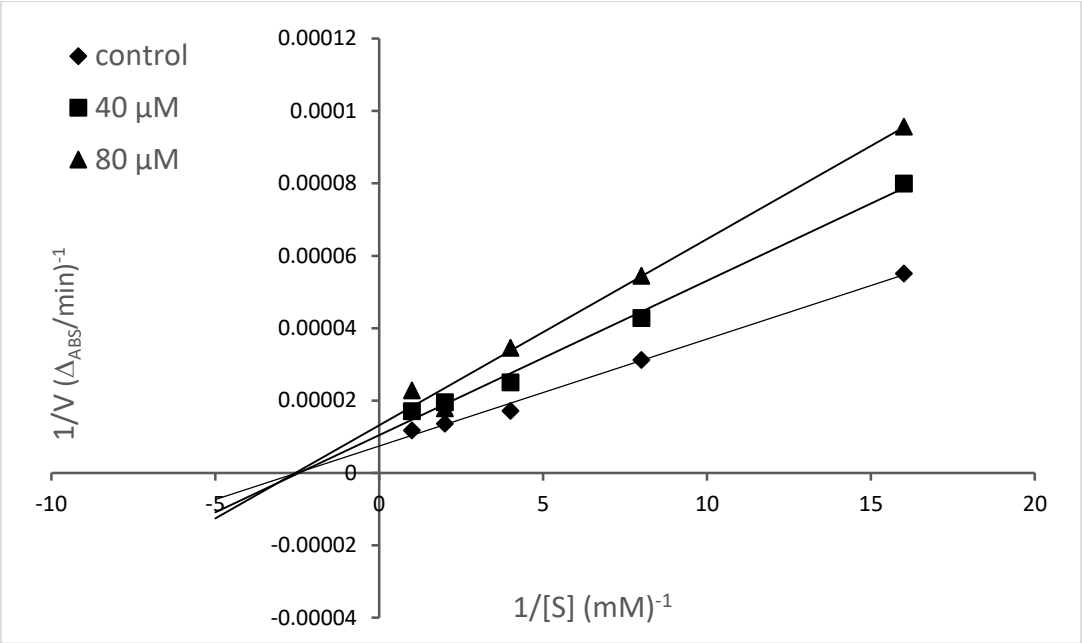


Figure 64 Lipase inhibition at different concentrations of 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone

VITA

Miss Prachyaporn Inthongkaew, was born on November 27, 1985, in Phatthalung, Thailand. She graduated with Bachelor' s degree in Pharmacy in 2009 from the Faculty of Pharmaceutical Sciences, Prince of Songkhla University.

Publications:

Inthongkaew, P., Chatsumpun, N., Supasuteekul, C., Kitisripanya, T., Putalun, W., Likhitwitayawuid, K., Sritularak, B. (2017) " Alpha-glucosidase and pancreatic lipase inhibitory activities and glucose uptake stimulatory effect of phenolic compounds from Dendrobium formosum." Revista Brasileira de Farmacognosia, accepted.