สารที่มีฤทธิ์ต้านอนุมูลอิสระจากเอื้องเค้ากิ่ว

นางสาวอาภาพร มิตรภาพ

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FREE RADICAL SCAVENGERS FROM *DENDROBIUM SIGNATUM*

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A Thesis Submitted in Partial Fulfillment of the Requirements

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การศึกษาฤทธิ์ทางเคมีของสารสกัดหยาบด้วยเมทานอลจากต้นเอื้องเค้ากิ่ว (วงศ์กล้วยไม้) สามารถแยกสารบริสุทธิ์ได้ทั้งหมด 5 ชนิด ได้แก่ dendrosignatol ซึ่งเป็นสารชนิดใหม่ ร่วมกับสารที่เคยพบแล้ว 4 ชนิดคือ 3,4-dihydroxy-5,4´ dimethoxybibenzyl, dendrocandin B, dendrocandin I และ dendrofalconerol A พิสูจน์โครงสร้างทางเคมีของสารเหล่านี้ โดยการวิเคราะห์ข้อมูลสเปกโตรสโคปี (UV, IR, MS NMR) ร่วมกับการเปรียบเทียบข้อมูลที่มีรายงานมาแล้ว จากการศึกษาฤทธิ์ในการต้านอนุมูลอิสระด้วย DPPH radical scavenging activity พบว่าสารบริสุทธิ์ทั้งหมดมีฤทธิ์ต้านอนุมูลอิสระที่ดี โดยมีค่าความเข้มข้นที่สามารถต้านอนุมูลอิสระได้ 50% (IC_{50}) คือ 13.05, 8.29, 12.91, 62.49 และ 9.43 ไมโครโมลาร์ ตามลำดับ ซึ่งมีชุดควบคุมผลบวกคือ Quercetin และ Trolox® มีค่า IC_{50} คือ 6.57 และ 10.95 ไมโครโมลาร์ ตามลำดับ นอกจากนี้ เมื่อศึกษาฤทธิ์ของสารเหล่านี้ในการต้านอนุมูล superoxide พบว่าสารบริสุทธิ์ทั้งหมดมีฤทธิ์ต้านอนุมูลอิสระ โดยมีค่าความเข้มข้นที่สามารถต้านอนุมูลอิสระ 50% (IC_{50}) คือ 51.17, 13.85, 58.23, 9.30 และ 15.32 ไมโครโมลาร์ ตามลำดับ โดย Trolox® ซึ่งใช้ควบคุมผลบวก มีค่า IC_{50} คือ 319.61 ไมโครโมลาร์

ภาควิชา เภสัชเวทและเภสัชพฤกษศาสตร์ ลายมือชื่อนิสิต .....

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A methanol extract prepared from *Dendrobium signatum* (Orchidaceae) showed significant free radical scavenging activity in the DPPH assay. Subsequent chemical study led to the isolation of 5 pure compounds, including a new compound, named dendrosignatol, together with 4 known compounds 3,4-dihydroxy-5,4´-dimethoxybibenzyl, dendrocandin B, dendrocandin I and dendrofalconerol A. Their structures were determined through by analysis of spectroscopic data (UV, IR, MS NMR). The DPPH radical scavenging activities of the isolated compounds were evaluated, and their IC_{50} values were determined to be 13.05, 8.29, 12.91, 62.49 and 9.43 μM, respectively. Quercetin (IC_{50} 6.57 μM) and Trolox® (IC_{50} 10.95 μM) were used as positive controls. In addition, these compounds were further investigated for their activity against superoxide radicals. Their IC_{50} values were found to be 51.17, 13.85, 58.23, 9.30 and 15.32 μM, respectively (Trolox® IC_{50} 319.61 μM).

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

Acetone-d_6	=	Deuterated acetone
α	=	Alpha
β	=	Beta
br	=	Broad singlet (for NMR spectra)
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
ε	=	Molar absorptivity
ESIMS	=	Electrospray Ionization Mass Spectrometry
EtOAc	=	Ethyl acetate
FCC	=	Flash Column Chromatography
g	=	Gram
GF	=	Gel Filtration
HMBC	=	^{1}H-detected Heteronuclear Multiple Bond Correlation

HRESIMS	=	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	=	Infared
J	=	Coupling constant
Kg	=	Kilogram
L	=	Liter
λ_{max}	=	Wavelength at maximal absorption
$[M]^{+}$	=	Molecular ion
$[M+Na]^{+}$	=	Sodium-adduct molecular ion
m	=	Multiplet (for NMR spectra)
MeOH	=	Methanol
mg	=	Milligram
µg	=	Microgram
min	=	Minute
ml	=	Milliliter
µL	=	Microliter
µM	=	Micromolar
mm	=	Millimeter
MS	=	Mass spectrum
MW	=	Molecular weight

m/z	=	Mass to charge ratio
nm	=	Nanometer
NMR	=	Nuclear Magnetic Resonance
NOESY	=	Nuclear Overhauser Effect Spectroscopy
ν_{max}	=	Wave number at maximal absorption
ppm	=	Part per million
ROS	=	Reactive oxygen species
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

Reactive free radical species are associated with several forms of tissue damage and disease, such as hypertension, hypercholesterolemia, diabetes, cardiovascular events, and also with the process of aging.

Free radicals are atoms or groups of atoms containing unpaired electrons and can be formed when oxygen interacts with certain molecules. Reactive radicals can start a chain reaction, causing the damage of important cellular components such as DNA or the cell membrane. Reactive oxygen species (ROS) represent the most important class of radical species generated in living systems that are derived from reduction of molecular oxygen. Multiple enzyme systems use different substrates as sources of electrons to produce a variety of ROS, including superoxide, hydroxyl radical, and hydrogen peroxide (Valko et al., 2006).

Antioxidants are molecules which can safely interact with free radicals and terminate the chain reaction before vital molecules are damaged. Many defense mechanisms within the organism have evolved to limit the levels of reactive oxidants and the damage. Among the defenses are enzymes such as superoxide dismutase, catalase, and glutathione peroxidase.

In addition to the protective effects of endogenous enzymatic antioxidant defenses, several non-enzyme systems within the body that can scavenge free radicals appears to be of great importance. For example, micronutrient (vitamin) antioxidants are vitamin E, beta-carotene, and vitamin C. Selenium, a trace metal that is required for proper function of one of the body's antioxidant enzyme systems, is sometimes

included in this category. The body cannot manufacture these micronutrients so they must be supplied in food, fruits, and vegetables (Do *et al.* 2015).

Orchidaceae is the second largest family of angiosperms, with approximately 25,000 species. They are mostly found in the tropical and subtopical region, widely distributed throughout Asian countries. Several members of this family have been described in Traditional Chinese Medicine (TCM) and have been used as sources of therapeutic agents (Lam *et al.* 2015).

The genus *Dendrobium* is one of the three largest genera in the family Orchidaceae with approximately 1,100 species, mainly distributed in Asia and Australia. In recents years, studies on *Dendrobium* have attracted more attention due to the potential inhibition and prevention of cancer development, as well as, immunostimulatory and antioxidant activity (Lam *et al.* 2015).

Dendrobium plants are primarily epiphytic with sympodial growth. Their stems have various shapes, spherical or cylindrical, with several segments. There are plenty of long leaves. Some species are deciduous in nature. Their leaves last for 1-2 years. Following that period, the leaves fall off prior to the appearance of the blooms. Some of Dendrobium plants have been used in traditional medicine for thirst, fever, faucitis, atropic gastritis and hyperglycemia (Gutiérrez 2010).

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 (Northern)
D. ochreatum Lindl.	**เอื้องตะขาบ** Ueang ta khap (Chiang Mai)
D. oligophyllum Gagnep.	**ข้าวตอกปราจีน** Khao tok prachin (General)
D. pachyglossum C.S.P.Parish & Rchb.f	**เอื้องขนหมู** Ueang khon mu (Mae Hong 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)

Dendrobium signatum Rchb.f. is known in Thai as Ueang Khao Kio (เอื้องเค้ากิ่ว). It is an epiphytic orchid with thin or fleshy stems. It produces racemes of white to cream coloured flowers with twisted petals and sepals in the size 6-7 cm. This species is distributed in Laos, Myanmar and Thailand. The flowering period is in February to April (Vaddhanaphuti 2005).

Although *D. signatum* Rchb.f. has been identified in Thailand and several other countries, the plant has not been chemically studied. In our preliminary screening, DPPH free radical scavenging activity was observed for the crude methanolic extract of *D. signatum.* This extract at 100 μg/mL exhibited 90% free radical scavenging activity. This study attempts to investigate the chemical constituents and free radical

scavenging activity of *D. signatum*. The phytochemical data to be obtained in this study would broaden our knowledge on the chemotaxonomy of this plant family and would also give us additional information on antioxidant constituents of botanical origin.

The major objectives of this study are as follows.

1. To isolate and purify the chemical constituents from *Dendrobium signatum*
2. To characterize the chemical structures of the isolated compounds.
3. To evaluate the free radical scavenging activity of the isolated compounds.

Figure 1 *Dendrobium signatum* Rchb.f.

CHAPTER II

HISTORICAL

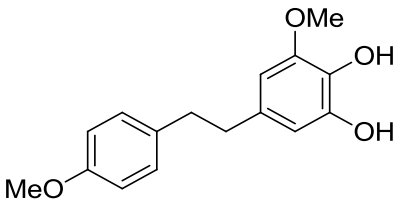
1. Chemical constituents of *Dendrobium*

The secondary metabolites reported from the genus *Dendrobium* can be catagonized into several classes (Figures 2A - 2D). Bibenzyls and related compounds are the largest group (Figure 2A; Table 1A). They can be found as monomeric and oligomeric bibenzyls, or as phenanthrenes. The other major aromatic compounds are flavonoids (Figure 2B; Table 1B). Bibenzyls and derivatives are member of stilbenes. Stilbenes are derived from a 4-hydroxycinamoyl-CoA unit via shikimate pathway, with chain extension linking to three molecules of malonyl-CoA. According to the nature of the enzyme, the subsequent reaction can proceed in two different ways, via the enzyme stilbene synthase to give a stilbene or the enzyme chalcone synthase to give a chalcone. Chalcones then act as precursors for many flavonoid derivatives (Dewick, 2002).

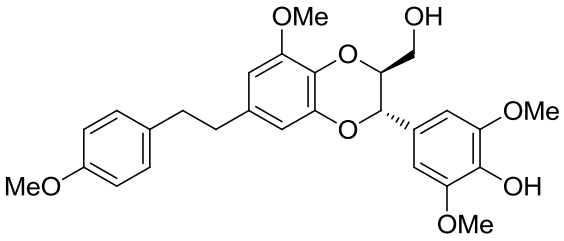
Dendrobium plants also produce terpenoids (Figure 2C), which mostly are sesquiterpenes. They are summarized in Table 1C. Terpenoids can occur via two pathways; the mevalonate pathway and mevalonate-independent pathway through deoxyxylulose phosphate. They are derived from C_5 isoprene units. Typical structures have carbon skeletons represented by $(C_5)_n$, which are called hemiterpenes (C_5), monoterpenes (C_{10}), sesquiterpenes (C_{15}), diterpenes (C_{20}), sesterterpenes (C_{25}), triterpene (C_{30}) and tetraterpenes (C_{40}) (Dewick, 2002).

In addition, several small groups of compounds not frequently found in *Dendrobium* are placed together in Table 1D and Figure 2D as Miscellaneous

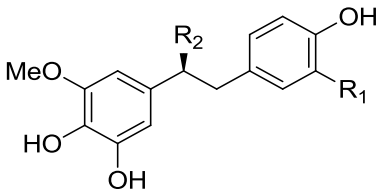
compounds. They include phenylpropanoids, coumarins, fluorenones, lignans, neolignans, benzoic acid derivatives and aliphatic compounds.



[**1**] Dendrocandin A



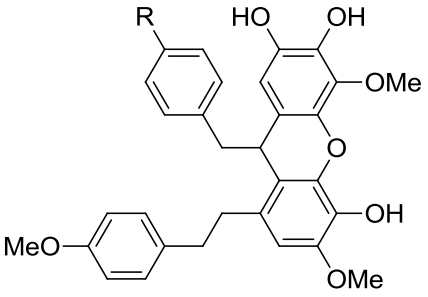
[**2**] Dendrocandin B



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

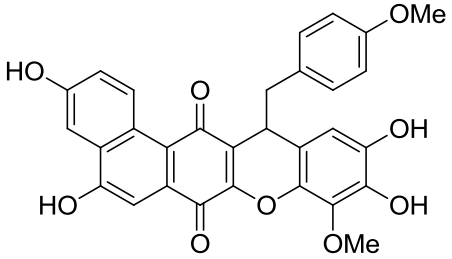
[**4**] Dendrocandin D: R_1 = H, R_2 = OCH_2CH_3

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



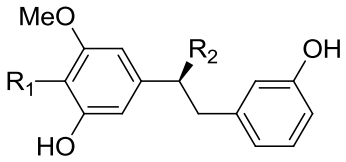
[**6**] Dendrocandin F: R = OMe

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

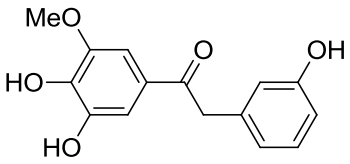


[**8**] Dendrocandin H

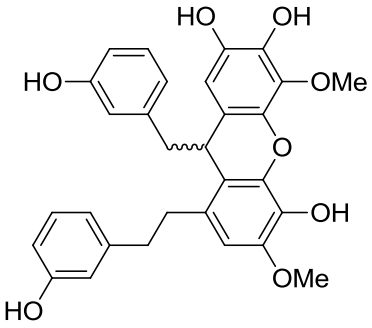
Figure 2A Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species



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

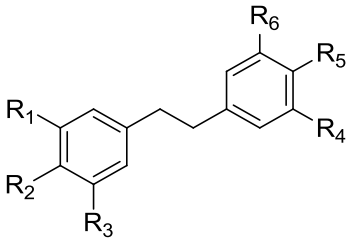


[**11**] Dendrosinen C



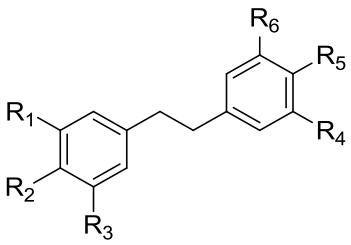
[**12**] Dendrosinen D

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



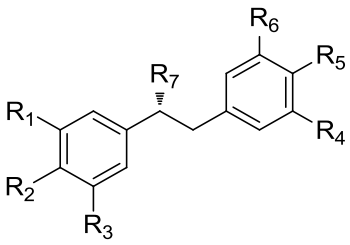
	R_1	R_2	R_3	R_4	R_5	R_6
[**13**] Aloifol I	OMe	OH	OMe	OH	H	H
[**14**] Amoenylin	OMe	OH	OMe	H	OMe	H
[**15**] Betatasin	OMe	H	H	OH	H	OH
[**16**] Betatasin III	OH	H	OMe	H	H	OH
[**17**] Brittonin A	OMe	OMe	OMe	OMe	OMe	OMe
[**18**] Chrysotobibenzyl	OMe	OMe	OMe	OMe	OMe	H
[**19**] Chrysotoxine	OMe	OH	OMe	OMe	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**] 3,4′-Dihydroxy-5-methoxybibenzyl	OH	H	OMe	H	OH	H
[**24**] 3,4′-Dihydroxy-5,5′-Dimethoxydihydrostilbene	OH	H	OMe	OMe	OH	H

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

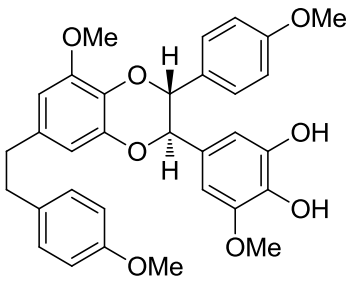


	R_1	R_2	R_3	R_4	R_5	R_6
[**25**] 4,5-Dihydroxy-3,3′-dimethoxybibenzyl (Dendrobin A)	OMe	OH	OH	H	H	OMe
[**26**] Gigantol	OMe	H	H	H	OH	OMe
[**27**] 4-Hydroxy-3,5,3′ Trimethoxybibenzyl	OMe	OH	OMe	H	H	OMe
[**28**] 5-Hydroxy-3,4,3′,4′,5′ Pentamethoxybibenzyl	OMe	OMe	OH	OMe	OMe	OMe
[**29**] Isoamoenylin	OMe	OMe	OMe	H	H	OH
[**30**] Moscatilin	OMe	OH	OMe	H	OH	OMe
[**31**] 3,3′,4-Trihydroxybibenzyl	OH	OH	H	H	H	OH
[**32**] 3,3′,5-Trihydroxybibenzyl	OH	H	OH	H	H	OH
[**33**] 3,5,4′-Trihydroxybibenzyl	OH	H	OH	H	OH	H
[**34**] 4,5,4′-Trihydroxy-3-3′-dimethoxybibenzyl	OMe	OH	OH	H	OH	OMe
[**35**] Tristin	OH	H	OH	H	OH	OMe
[**36**] Dendromoniliside E	OGlc	OGlc	OMe	H	OMe	H

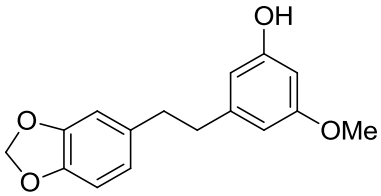
Figure 2A Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



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

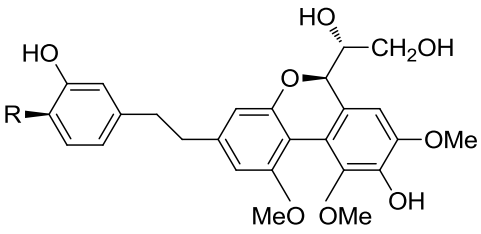


[**43**] Dendrocandin I



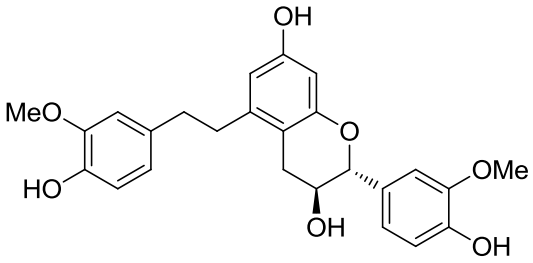
[**44**] Densiflorol A

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

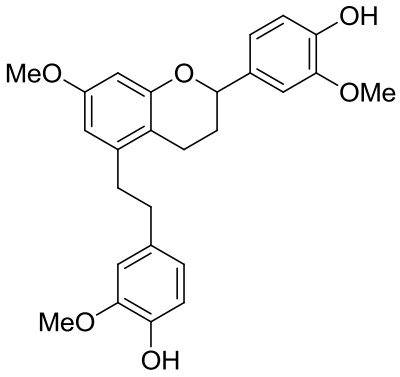


[**45**] Longicornuol A: R = H

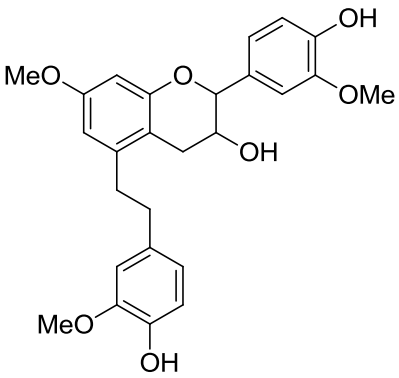
[**46**] Trigonopol A: R = OMe



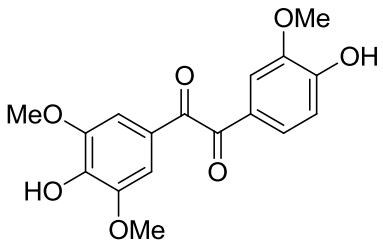
[**47**] Trigonopol B



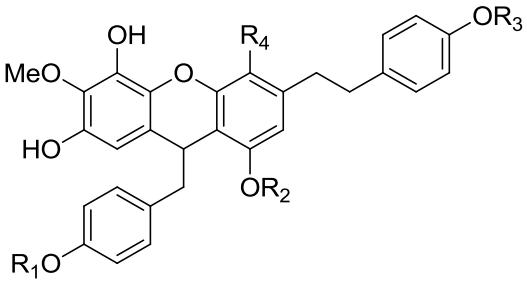
[**48**] Crepidatuols A



[**49**] Crepidatuols B



[**50**] Loddigesiinol D

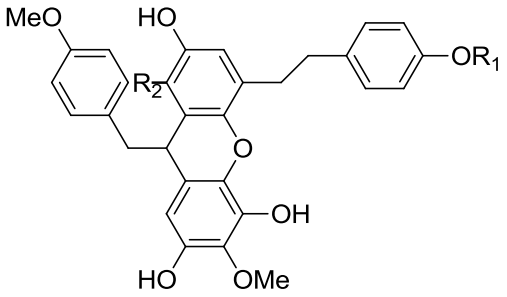


[**51**] Dencryol A:

R_1 = Me, R_2 = R_3 = R_4 = H

[**52**] Dencryol B:

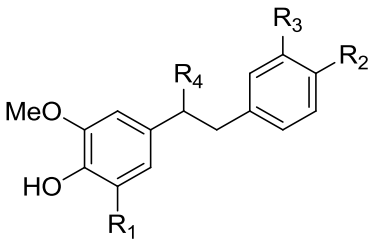
R_1 = H, R_2 = R_3 = Me, R_4 = OH



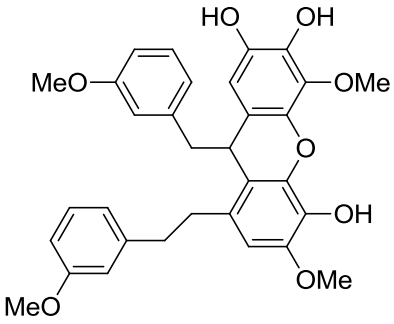
[**53**] Dengraol A: R_1 = R_2 = H

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

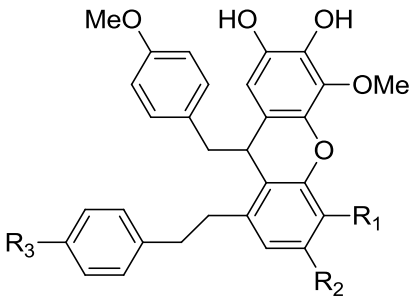
Figure 2A Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



	R_1	R_2	R_3	R_4
[**55**] 4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol	OMe	H	OH	OMe
[**56**] Nobilin A	OH	H	OMe	OMe
[**57**] Nobilin B	OMe	OH	OMe	OMe
[**58**] Nobilin C	OMe	OMe	OMe	OMe
[**59**] Nobilin D	OMe	OH	OMe	OH



[**60**] Nobilin E



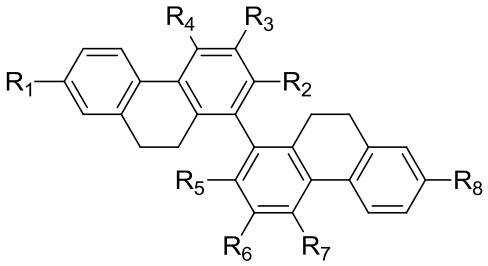
[**61**] Dendrofalconerol A:

R_1 = OH, R_2 = R_3 = OMe

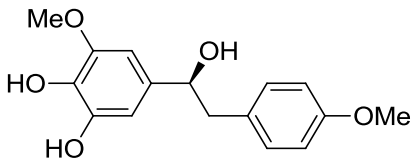
[**62**] Dendrofalconerol B:

R_1 = H, R_2 = R_3 = OH

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

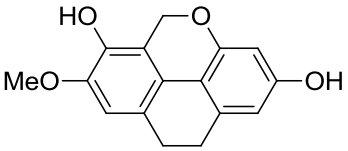


	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
[**63**] 2,2′-Dihydroxy-3,3′,4,4′,7,7′-hexamethoxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OMe	OH	OMe	OMe	OH	OMe	OMe	OMe
[**64**] 2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OH	OMe	H	OH	OMe	H	OH	OH
[**65**] Flavanthrin	OH	OH	H	OMe	OH	H	OMe	OH

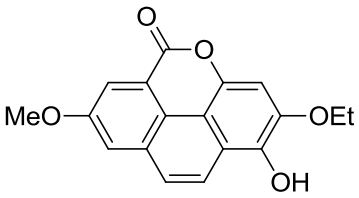


[**66**] (*S*)-3,4,α-trihydroxy-5,4′-dimethoxybibenzyl

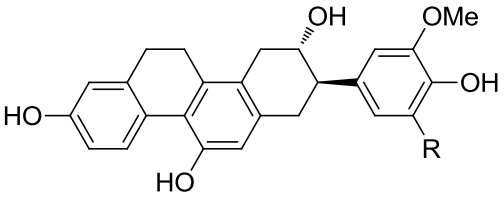
Figure 2A Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



[**67**] Amoenumin

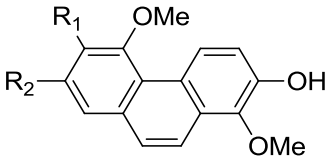


[**68**] Crystalltone



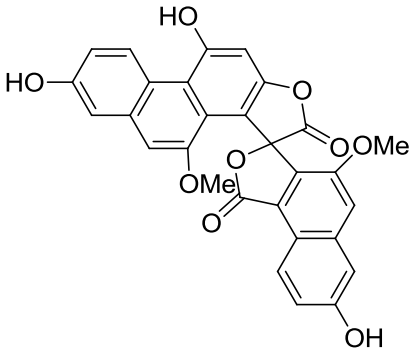
[**69**] Chrysotoxol A: R = H

[**70**] Chrysotoxol A: R = OMe



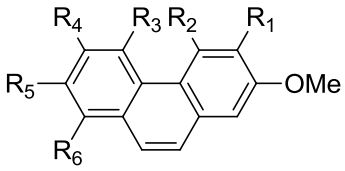
[**71**] Confusarin: R_1 = OMe, R_2 = OH

[**72**] 2,6-Dihydroxy-1,5,7-trimethoxyphenanthrene: R_1 = OH, R_2 = OMe

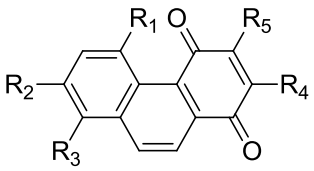


[**73**] Dendrochrysanene

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

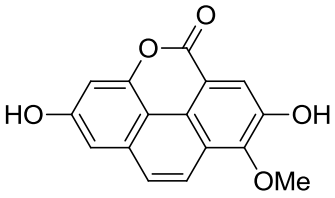


	R_1	R_2	R_3	R_4	R_5	R_6
[**74**] Bulbophyllanthrin	OH	OMe	OH	H	H	H
[**75**] Denthyrsinin	OH	OMe	H	H	OH	OMe
[**76**] 5-Hydroxy-2,4-dimethoxy phenanthrene	H	OMe	OH	H	H	H
[**77**] 3-Hydroxy-2,4,7-trimethoxy phenanthrene	OH	OMe	H	H	OMe	H

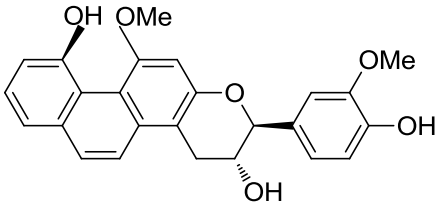


	R_1	R_2	R_3	R_4	R_5
[**78**] Cypripedin	H	OH	OMe	OMe	H
[**79**] Densiflorol B	H	OH	H	OMe	H
[**80**] Denbinobin	OH	OMe	H	H	OMe

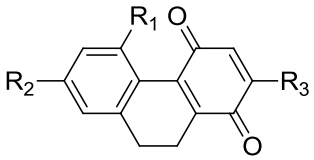
Figure 2A Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



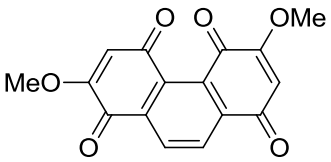
[**81**] Fimbriatone



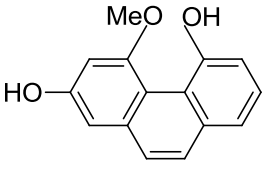
[**82**] Loddigesiinol B



	R_1	R_2	R_3
[**83**] Dendronone	OH	OMe	H
[**84**] Ephemeranthoquinone	H	OH	OMe
[**85**] 5-Methoxy-7-hydroxy-9,10-dihydro-1,4 phenanthrenequinone	OMe	OH	H

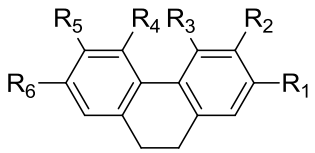


[**86**] Moniliformin



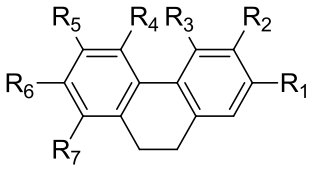
[**87**] Moscatin

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



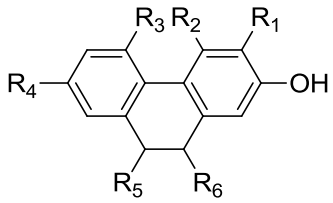
	R_1	R_2	R_3	R_4	R_5	R_6
[**88**] Coelonin	OH	H	OMe	H	H	OH
[**89**] 9,10-Dihydromoscatin	H	H	OH	OMe	H	OH
[**90**] 9,10-Dihydrophenanthrene-2,4,7-triol	OH	H	OH	H	H	OH
[**91**] 4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	OH	H	H
[**92**] 4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	OMe	H
[**93**] 4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene	H	OMe	OH	OH	H	OMe
[**94**] 4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	H	H

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



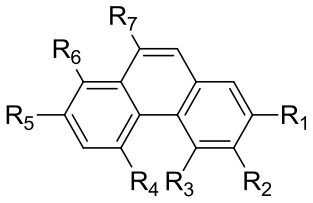
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**95**] 2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydro phenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**96**] 2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydro phenanthrene	OH	OMe	OMe	H	H	OMe	OH
[**97**] 4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydro phenanthrene	OMe	OMe	OH	H	OMe	OH	H
[**98**] Ephemeranthol A	OH	H	H	OH	OMe	OMe	H
[**99**] Ephemeranthol C	OH	OH	OMe	OH	H	H	H
[**100**] Erianthridin	OH	OMe	OMe	H	H	OH	H
[**101**] Flavanthridin	OH	H	H	OMe	OH	OMe	H
[**102**] Hircinol	OH	H	OMe	OH	H	H	H
[**103**] 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)



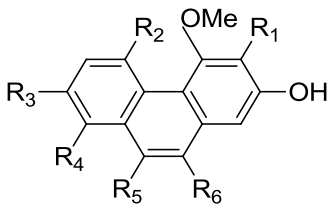
	R_1	R_2	R_3	R_4	R_5	R_6
[**104**] 2-Hydroxy-4,7-dimethoxy-9,10-dihydro phenanthrene	H	OMe	H	OMe	H	H
[**105**] 7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol	H	OH	OH	OMe	H	H
[**106**] Plicatol C	H	OMe	OH	H	OMe	OMe
[**107**] Rotundatin	H	OMe	OH	H	OH	OH

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



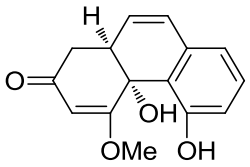
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**108**] 2,5-Dihydroxy-3,4-dimethoxyphenanthrene	OH	OMe	OMe	OH	H	H	H
[**109**] 2,5-Dihydroxy-4,9-dimethoxyphenanthrene	OH	H	OMe	OH	H	H	OMe
[**110**] 2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**111**] Epheranthol B	H	H	OMe	OH	OMe	H	H
[**112**] Fimbriol B	OH	OMe	OH	H	H	H	H
[**113**] Flavanthrinin	H	H	OMe	H	OH	H	H

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

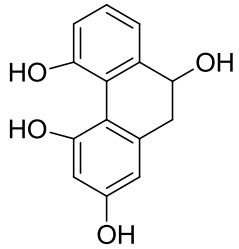


	R_1	R_2	R_3	R_4	R_5	R_6
[**114**] Loddigesiinol A	H	OMe	H	H	OH	H
[**115**] Nudol	OMe	H	OH	H	H	H
[**116**] Plicatol A	H	OH	H	H	OMe	OMe
[**117**] Plicatol B	H	OH	H	H	H	H
[**118**] 2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene	OH	OH	H	H	OMe	H
[**119**] 3,4,8-Trimethoxy phenanthrene-2,5-diol	OMe	OH	H	OMe	H	H

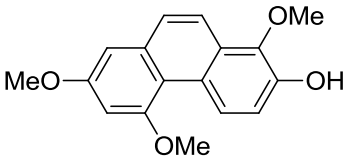
Figure 2A Structures of bibenzyls and derivatives previously isolated from *Dendrobium* species (continued)



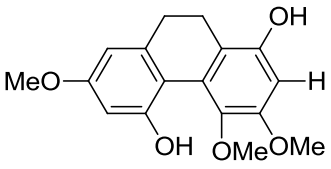
[**120**] Aphyllone



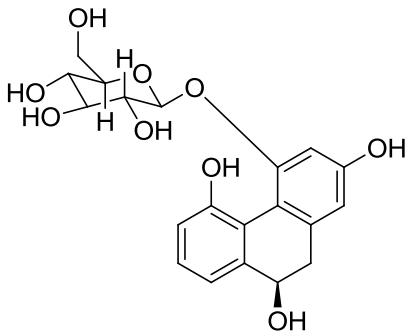
[**121**] (*S*)-2,4,5,9-tetrahydroxy-9,10-dihydrophenanthrene



[**122**] 1,5,7-trimethoxyphenanthren-2-ol



[**123**] 9,10-dihydrophenanthrene,1,5-dihydroxy-3,4,7-trimthoxy-9,10-dihydrophenanthrene



[**124**] 2,4,5,9S-tetrahydroxy-9,10-dihydrophenanthrene 4-*O*-β-*D*-glucopyranoside

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

Table 1A 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
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

Table 1A (continued)

Compounds	Plant	Plant part	Reference
Betatasin [**15**]	*D. longicornu*	Stem	Hu *et al*., 2008a
	D. plicatile	Stem	Yamaki and Honda 1996
Batatasin III [**16**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
	D. chrysotoxum	Whole plant	Li *et al.* 2009c
	D. cariniferum	Stem	Chen *et al.* 2008c
	D. draconis	Stem	Sritularak *et al.* 2011a
	D. gratiosissimum	Stem	Zhang *et al.* 2008a
	D. loddigesii	Whole plant	Ito *et al.* 2010
	D. aphyllum	Stem	Yang *et al.* 2015
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	Hu *et al*., 2012
	D. chrysotoxum	Stem	Hu *et al*., 2012
	D. nobile	Stem	Zhang *et al.* 2007a
	D. pulchellum	Stem	Chanvorachote *et al*., 2013

Table 1A (continued)

Compounds	Plant	Plant part	Reference
Chrysotoxine [**19**]	*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. 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
3,4′-Dihydroxy-5-methoxybibenzyl [**23**]	*D. amoenum*	Whole plant	Majumder *et al*., 1999

Table 1A (continued)

Compounds	Plant	Plant part	Reference
3,4′-Dihydroxy-5,5′-dimethoxydihydro Stilbene [**24**]	*D. nobile*	Stem	Hwang *et al*., 2010
4,5-Dihydroxy-3,3′-dimethoxybibenzyl [**25**]	*D. nobile*	Stem	Ye and Zhao *et al.*, 2002a
Gigantol [**26**]	*D. aphyllum*	Whole plant	Chen *et al*., 2008a
	D. aurantiacum var.denneanum	Whole plant	Liu *et al*., 2009a
	D. candidum	Stem	Li *et al*., 2008
	D. brymerianum	Whole plant	Klongkumnuankarn *et al.* 2014
	D. cariniferum	Stem	Chen *et al*., 2008c
	D. chrysanthum	Stem	Yang *et al*., 2006b
	D. chrysotoxum	Whole plant	Li *et al*., 2009c
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. draconis	Stem	Sritularak *et al*., 2011a
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. loddigesii	Whole plant	Ito *et al.*, 2010
	D. longicornu	Stem	Hu *et al*., 2008a
	D. nobile	Stem	Zhang *et al*., 2007a
	D. polyanthum	Stem	Hu *et al.*, 2009
	D. trigonopus	Stem	Hu *et al.* 2008b
	D. devonianum	Whole plant	Sun *et al.* 2014
4-Hydroxy-3,5,3′-trimethoxybibenzyl [**27**]	*D. nobile*	Stem	Ye and Zhao *et al.*, 2002a

Table 1A (continued)

Compounds	Plant	Plant part	Reference
5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl [**28**]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Isoamoenylin [**29**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
Moscatilin [**30**]	*D. amoenum*	Whole plant	Majumder *et al.*, 1999
	D. aurantiacum var.*denneanum*	Stem	Yang *et al.,* 2006a
	D. brymerianum	Whole plant	Klongkumnuankarn, Busaranon et al. 2014
	D. chrysanthum	Stem	Yang *et al.,* 2006b
	D. densiflorum	Stem	Fan *et al.*, 2001
	D. gratiosissimum	Stem	Zhang *et al.*, 2008a
	D. loddigesii	Whole plant	Chen *et al.*, 1994,
	D. longicornu	Stem	Ito *et al.*, 2010
	D. moscatum	Whole plant	Hu *et al*., 2008a Majumder and Sen 1987
	D. nobile	Stem	
	D. polyanthum	Stem	Yang *et al.* 2007
	D. pulchellum	Stem	Sritularak *et al.*, 2011b
	D. secundum	Stem	Chanvorachote *et al*., 2013 Sritularak *et al.*, 2011b

Table 1A (continued)

Compounds	Plant	Plant part	Reference
3,3′,4-Trihydroxy bibenzyl [**31**]	*D. longicornu*	Stem	Hu *et al*., 2008a
3,3′,5-Trihydroxy bibenzyl [**32**]	*D. cariniferum*	Whole plant	Liu *et al.* 2009b
3,5,4′-Trihydroxy bibenzyl [**33**]	*D. gratiosissimum*	Stem	Zhang *et al.*, 2008a
4,5,4′-Trihydroxy-3,3′-dimethoxy bibenzyl [**34**]	*D. secundum*	Stem	Sritularak *et al.*, 2011b
Tristin [**35**]	*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
	D. aphyllum	Stem	Yang *et al.,* 2015
Dendromoniliside E [**36**]	*D. moniliforme*	Stem	Zhao *et al*., 2003
Dendrocandin A [**37**]	*D. candidum*	Stem	Li *et al.* 2008
Dendrophenol [**38**]	*D. candidum*	Stem	Li *et al.,* 2008
3,4-Dihydroxy-5,4′-dimethoxybibenzyl [**39**]	*D. candidum*	Stem	Li *et al.,* 2008
4,4′-Dihydroxy-3,5-dimethoxybibenzyl [**40**]	*D. candidum*	Stem	Ito *et al.*, 2010
Loddigesiinol C [**41**]	*D. loddigesii*	Whole plant	Li *et al.,* 2008
3-*O*-Methylgigantol [**42**]	*D. candidum*	Stem	Yamaki and Honda, 1996
	D. plicatile	Stem	

Table 1A (continued)

Compounds	Plant	Plant part	Reference
Dendrocandin I [**43**]	*D. candidum*	Stem	Li *et al.,* 2009b
Densiflorol A [**44**]	*D. densiflorum*	Stem	Fan *et al.* 2001
Longicornuol A [**45**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Trigonopol A [**46**]	*D. trigonopus*	Stem	Hu *et al.*, 2008b
Trigonopol B [**47**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
	D. trigonopus	Stem	Hu *et al.*, 2008b
Crepidatuols A [**48**]	*D. crepidatum*	Stem	Li et al., 2013
Crepidatuols B [**49**]	*D. crepidatum*	Stem	Li et al., 2013
Loddigesiinol D [**50**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Dencryol A [**51**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Dencryol B [**52**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Dengraol A [**53**]	*D. gratiosissimum*	Stem	Zhang *et al.*, 2008a
Dengraol B [**54**]	*D. gratiosissimum*	Stem	Zhang *et al.*, 2008a
4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxy phenol [**55**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Nobilin A [**56**]	*D. nobile*	Stem	Zhang *et al.* 2006
Nobilin B [**57**]	*D. nobile*	Stem	Zhang *et al.* 2006
Nobilin C [**58**]	*D. nobile*	Stem	Zhang *et al*., 2006
Nobilin D [**59**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Nobilin E [**60**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendrofalconerol A [**61**]	*D. falconeri*	Stem	Sritularak et al., 2009
Dendrofalconerol B [**62**]	*D. falconeri*	Stem	Sritularak et al., 2009

Table 1A (continued)

Compounds	Plant	Plant part	Reference
2,2′-Dihydroxy-3,3′,4,4′,7,7-hexamethoxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene [**63**]	*D. nobile*	Stem	Yang *et al*., 2007
2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9′,10,10′-tetrahydro-1,1′-biphenanthrene [**64**]	*D. plicatile*	Stem	Yamaki and Honda, 1996
Flavanthrin [**65**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
(*S*)-3,4,α-trihydroxy-5,4′ dimethoxybibenzyl [**66**]	*D. candidum*	Stem	Li *et al*., 2015
Amoenumin [**67**]	*D. amoenum*	Whole plant	Veerraju *et al*., 1989
Crystalltone [**68**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
	D. crystallinum	Stem	Wang *et al.*, 2009
Chrysotoxol A [**69**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Chrysotoxol B [**70**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Confusarin [**71**]	*D. chryseum*	Stem	Ma *et al*., 1998
	D. chrysotoxum	Stem	Hu *et al*., 2012
	D. nobile	Stem	Zhang *et al.*, 2008b
2,6-Dihydroxy-1,5,7-trimethoxyphenanthrene [**72**]	*D. densiflorum*	Stem	Fan *et al*., 2001
Dendrochrysanene [**73**]	*D. chrysanthum*	Stem	Yang *et al*., 2006b
Bulbophyllanthrin [**74**]	*D. nobile*	Stem	Yang *et al.*, 2007
Denthyrsinin [**75**]	*D. thyrsiforum*	Stem	Zhang *et al.*, 2005

Table 1A (continued)

Compounds	Plant	Plant part	Reference
5-Hydroxy-2,4-dimethoxy phenanthrene [**76**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
3-Hydroxy-2,4,7-trimethoxyphenanthrene [**77**]	*D. nobile*	Stem	Yang *et al.*, 2007
Cypripedin [**78**]	*D. densiflorum*		Fan *et al.,* 2001
Densiflorol B [**79**]	*D. densiflorum*	Stem	Fan *et al.,* 2001
Denbinobin [**80**]	*D. moniliforme*	Stem	Lin *et al.* 2001
	D. nobile	Stem	Yang *et al.*, 2007
Fimbriatone [**81**]	*D. nobile*	Stem	Zhang *et al.*, 2008b
	D. pulchellum	Stem	Chanvorachote *et al.*, 2013
Loddigesiinol B [**82**]	*D. loddigesii*	Stem	Ito *et al.*, 2010
Dendronone [**83**]	*D. chrysanthum*	Whole plant	Yang *et al*., 2006b
	D. longicornu	Stem	Hu *et al.*, 2008a
Ephemeranthoquinone [**84**]	*D. plicatile*	Stem Stem	Yamaki and Honda, 1996
5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**85**]	*D. draconis*	Stem	Sritularak *et al.,* 2011a
Moniliformin [**86**]	*D. moniliforme*	Stem	Lin *et al.*, 2001
Moscatin [**87**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
	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

Table 1A (continued)

Compounds	Plant	Plant part	Reference
Coelonin [**88**]	*D. aphyllum*	Whole plant	Chen *et al.*, 2008a
	D. nobile	Stem	Yang *et al.*, 2007
9,10-Dihydromoscatin [**89**]	*D. polyanthum*	Stem	Hu *et al.*, 2009
9,10-Dihydrophenanthrene-2,4,7-triol [**90**]	*D. polyanthum*	Stem	Hu *et al.*, 2009
4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [**91**]	*D. sinense*	Whole plant	Chen *et al.* 2013
4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene [**92**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene [**93**]	*D. nobile*	Stem	Ye and Zhao *et al.*, 2002a
4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene [**94**]	*D. nobile*	Stem	Zhang *et al*., 2008b
2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene [**95**]	*D. nobile*	Stem	Yang *et al.*, 2007
2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**96**]	*D. densifloru*	Stem	Fan *et al.,* 2001
4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene [**97**]	*D. rotundatum*	Whole plant	Majumder and Pal, 1992

Table 1A (continued)

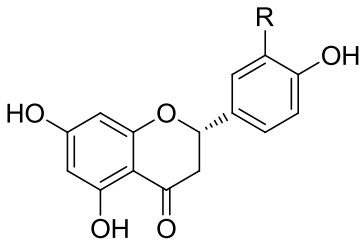
Compounds	Plant	Plant part	Reference
Ephemeranthol A [**98**]	*D. nobile*	Stem	Yang *et al.*, 2007 Hwang *et al.*, 2010
Ephemeranthol C [**99**]	*D. nobile*	Stem	Yang *et al.*, 2007 Hwang *et al.*, 2010
Erianthridin [**100**]	*D. nobile*	Stem	Hwang *et al.*, 2010
Flavanthridin [**101**]	*D. nobile*	Stem	Hwang *et al.*, 2010
Hircinol [**102**]	*D. draconis*	Stem	Sritularak *et al.*, 2011a
	D. aphyllum	Stem	Yang, Liang-YanLiu et al. 2015
3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene [**103**]	*D. nobile*	Stem	Yang *et al.*, 2007
2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene [**104**]	*D. nobile*	Stem	Yang *et al.*, 2007
7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol [**105**]	*D. draconis*	Stem	Sritularak *et al.*, 2011a
Plicatol C [**106**]	*D. plicatile*	Stem	Honda and Yamaki, 2000
Rotundatin [**107**]	*D. rotundatum*	Whole plant	Majumder and Pal, 1992

Table 1A (continued)

Compounds	Plant	Plant part	Reference
2,5-Dihydroxy-3,4-Dimethoxyphenanthrene [**108**]	*D. nobile*	Stem	Yang *et al.*, 2007
2,5-Dihydroxy-4,9-Dimethoxyphenanthrene [**109**]	*D. nobile*	Stem	Zhang *et al.*, 2008b
2,8-Dihydroxy-3,4,7-Trimethoxyphenanthrene [**110**]	*D. nobile*	Stem	Yang *et al.*, 2007
Epheranthol B [**111**]	*D. chrysotoxum*	Stem	Hu *et al.*, 2012
	D. plicatile	Stem	Yamaki and Honda, 1996
Fimbriol B [**112**]	*D. nobile*	Stem	Yang *et al.*, 2007; Hwang *et al.*, 2010
Flavanthrinin [**113**]	*D. nobile*	Stem	Zhang *et al.*, 2008b
Loddigesiinol A [**114**]	*D. loddigesii*	Whole plant	Ito *et al.*, 2010
Nudol [**115**]	*D. nobile*	Stem	Yang *et al.*, 2007
	D. rotundatum	Whole plant	Majumder and Pal, 1992
Plicatol A [**116**]	*D. nobile*	Stem	Yang *et al.*, 2007
	D. plicatile	Stem	Honda and Yamaki, 2000
Plicatol B [**117**]	*D. plicatile*	Stem	Honda and Yamaki, 2000
2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene [**118**]	*D. nobile*	Stem	Yang *et al.*, 2007

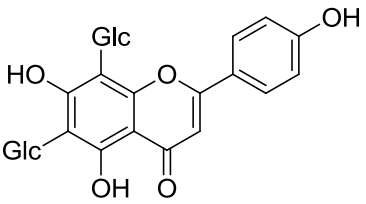
Table 1A (continued)

Compounds	Plant	Plant part	Reference
3,4,8-Trimethoxy phenanthrene-2,5-diol [**119**]	*D. nobile*	Stem	Hwang *et al.*, 2010
Aphyllone [**120**]	*D. nobile*	Stem	Hwang *et al.*, 2010
(S)-2,4,5,9-tetrahydroxy-9,10-dihydro phenanthrene [**121**]	*D. fimbriatum*	Stem	Xu *et al*., 2014
1,5,7-trimethoxyphenanthren-2-ol [**122**]	*D. nobile*	Stem	Kim *et al*., 2015
9,10-dihydrophenanthrene,1,5-dihydroxy-3,4,7-trimthoxy-9,10-dihydro phenanthrene [**123**]	*D. moniliforme*	Whole plant	Zhao *et al.*, 2015
2,4,5,9S-tetrahydroxy-9,10-dihydrophenanthrene 4-*O*-β-*D*-glucopyranoside [**124**]	*D. primulinum*	Whole plant	Ye *et al*., 2016

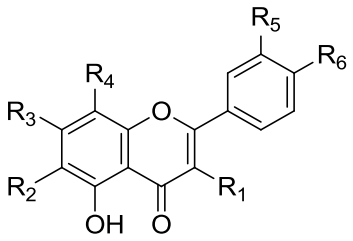


[**125**] (2*S*)-Homoeriodictyol: R = OMe

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

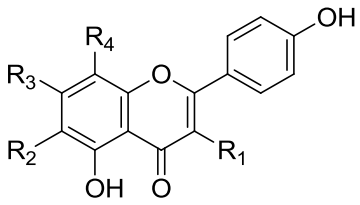


[**127**] Vicenin-2



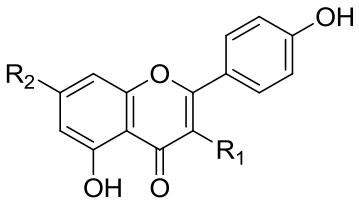
	R_1	R_2	R_3	R_4	R_5	R_6
[**128**] Apigenin	H	H	OH	H	H	OH
[**129**] 5,6-Dihydroxy-4′-methoxy-flavone	H	OH	H	H	H	OMe
[**130**] Luteolin	H	H	OH	H	OH	OH
[**131**] 6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl) -β-galactopyranosyl] apigenin	H	-Ara	OH	-Gal-O-Rha	H	OH
[**132**] 6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl) -β-glucopyranosyl] apigenin	H	-Ara	OH	-Glc-O-Rha	H	OH

Figure 2B Structures of flavonoids previously isolated from *Dendrobium* species

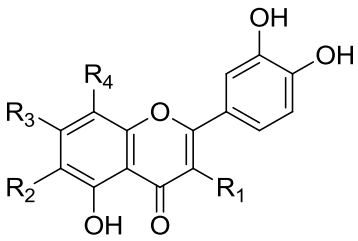


	R_1	R_2	R_3	R_4
[**133**] 6‴-Glucosyl-vitexin	H	H	OH	Glc
[**134**] Isoschaftoside	H	-Ara	OH	-Glc
[**135**] Isoviolanthin	H	-Rha	OH	-Glc
[**136**] 6-*C*-[(2-*O*-α-Rhamnopyranosyl)-β-glucopyranosyl]-8-*C*-(α-arabinopyranosyl) apigenin	H	-Glc-Rha	OH	-Ara
[**137**] 6-*C*-(β-Xylopyranosyl)-8-*C*-[(2-*O*-α-rhamnosepyranosyl)-β-glucosepyranosyl] apigenin	H	-Xyl	OH	-Glc-Rha
[**138**] Kaempferol	OH	H	OH	H

Figure 2B Structures of flavonoids previously isolated from *Dendrobium* species (continued)



	R_1	R_2
[**139**] Kaempferol-3-*O*-α-L-rhamnopyranoside	O-Rha	OH
[**140**] Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside	O-Rha	O-Rha
[**141**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-glucopyranoside	O-Glc-Rha	OH
[**142**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside	O-Xyl-Rha	OH



	R_1	R_2	R_3	R_4
[**143**] Quercetin-3-*O*-α-L-rhamnopyranoside	O-Rha	H	OH	H
[**144**] Quercetin-3-*O*-α-L-rham nopyranosyl-(1⟶2)-β-D-xylopyranoside	O-Xyl-Rha	H	OH	H

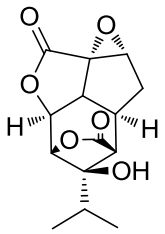
Figure 2B Structures of flavonoids previously isolated from *Dendrobium* species (continued)

Table 1B Distribution of flavonoids in the genus *Dendrobium*

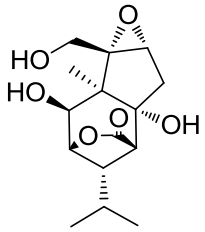
Compounds	Plant	Plant part	Reference
(2*S*)-Homoeriodictyol [**125**]	*D. densiflorum*	Stem	Fan et al., 2001
Naringenin [**126**]	*D. aurantiacum var.denneanum*	Stem	Yang et al., 2006a
	D. densiflorum	Stem	Fan et al., 2001
	D. longicornu	Stem	Hu et al., 2008aHu et al., 2008b
	D. trigonopus	Stem	
Vicenin-2 [**127**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al. 2013
Apigenin [**128**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
5,6-Dihydroxy-4′-methoxy-flavone [**129**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Luteolin [**130**]	*D. aurantiacum* var.*denneanum*	Whole plant	Liu *et al.*, 2009a
6-*C*-(α-Arabino pyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl) -β-galactopyranosyl] apigenin [**131**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
6-*C*-(α-Arabino pyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl) -β-glucopyranosyl] apigenin [**132**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
6‴-Glucosyl-vitexin [**133**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Isoschaftoside [**134**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Isoviolanthin [**135**]	*D. crystallinum*	Stem	Wang *et al.*, 2009

Table 1B (continued)

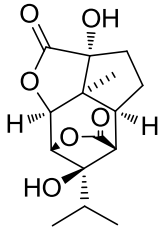
Compounds	Plant	Plant part	Reference
6-C-[(2-O-α-Rhamno pyranosyl)-β-gluco pyranosyl]-8-C-(α-arabinopyranosyl) apigenin [**136**]	*D. huoshanense*	Aerial part	Chang et al., 2010
6-C-(β-Xylopyranosyl)-8-C-[(2-O-α-rhamnopyranosyl)-β-glucopyranosyl] apigenin [**137**]	*D. huoshanense*	Aerial part	Chang et al., 2010
Kaempferol [**138**]	*D. aurantiacum* var. *denneanum*	Stem	Yang *et al.,* 2006a
Kaempferol-3-*O*-α-L-rhamnopyranoside [**139**]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside [**140**]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-gluco pyranoside [**141**]	*D. capillipes*	Stem	Phechrmeekha *et al*., 2012
Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylo pyranoside [**142**]	*D. capillipes*	Stem	Phechrmeekha *et al*., 2012
Quercetin-3-*O*-L-rhamnopyranoside [**143**]	*D. secundum*	Stem	Phechrmeekha *et al*., 2012
Quercetin-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside [**144**]	*D. capillipes*	Stem	Phechrmeekha *et al*., 2012



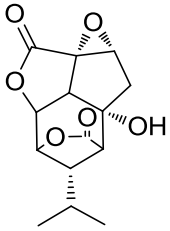
[**145**] Aduncin



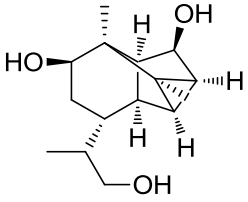
[**146**] Amoenin



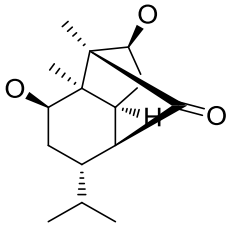
[**147**] Amotin



[**148**] α-Dihydropicrotoxinin

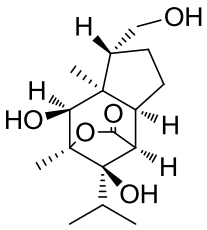


[**149**] Dendrobane A

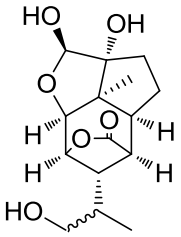


[**150**] Dendronobilin A

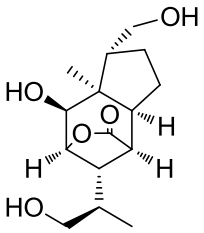
Figure 2C Structures of terpenoids previously isolated from *Dendrobium* species



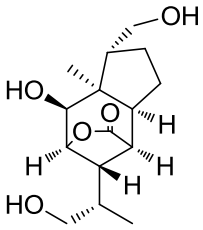
[**151**] Dendronobilin B



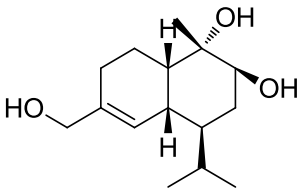
[**152**] Dendronobilin C



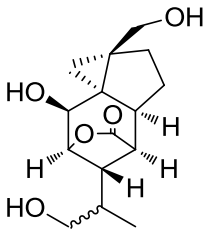
[**153**] Dendronobilin D



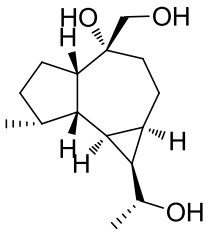
[**154**] Dendronobilin E



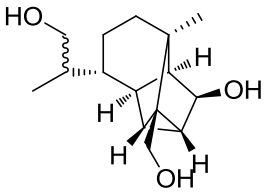
[**155**] Dendronobilin F



[**156**] Dendronobilin G

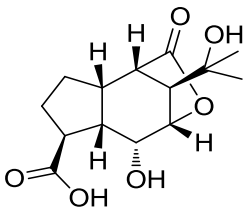


[**157**] Dendronobilin H

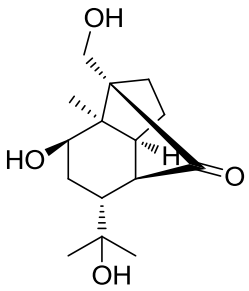


[**158**] Dendronobilin I

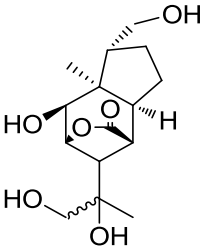
Figure 2C Structures of terpenoids previously isolated from *Dendrobium* species (continued)



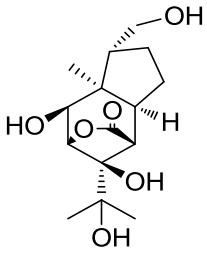
[**159**] Dendronobilin J



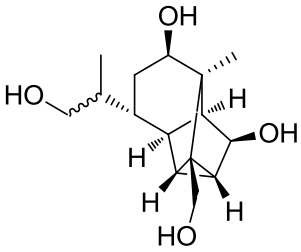
[**160**] Dendronobilin K



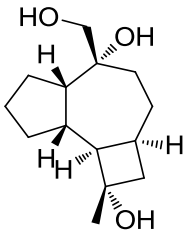
[**161**] Dendronobilin L



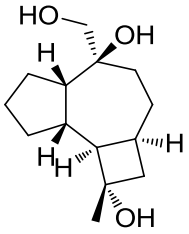
[**162**] Dendronobilin M



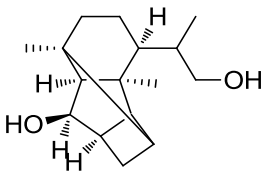
[**163**] Dendronobilin N



[**164**] Dendrowardol A

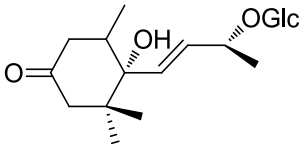


[**165**] Dendrowardol B

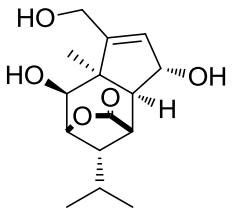


[**166**] Dendrowardol C

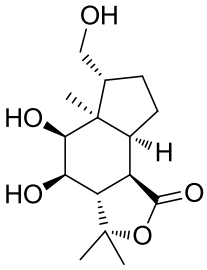
Figure 2C Structures of terpenoids previously isolated from *Dendrobium* species (continued)



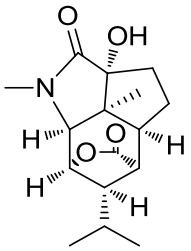
[**167**] Corchoionoside C



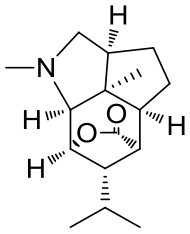
[**168**] Crystallinin



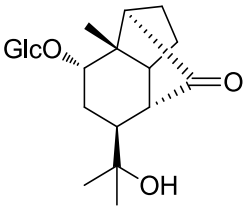
[**169**] Findlayanin



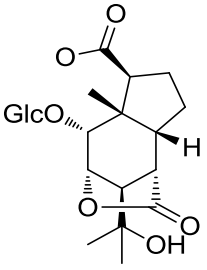
[**170**] 3-Hydroxy-2-oxodendrobine



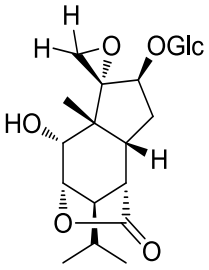
[**171**] Dendrobine



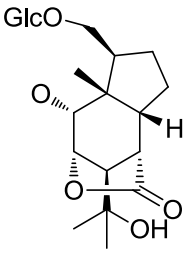
[**172**] Dendromoniliside A



[**173**] Dendromoniliside B

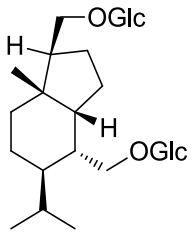


[**174**] Dendromoniliside C

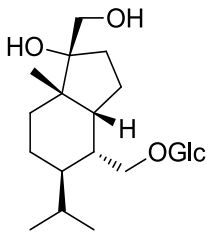


[**175**] Dendromoniliside D

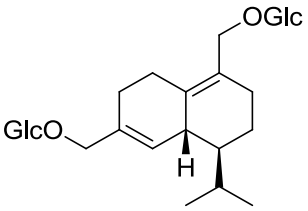
Figure 2C Structures of terpenoids previously isolated from *Dendrobium* species (continued)



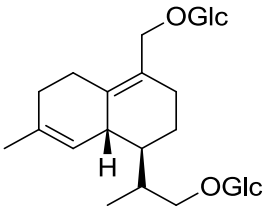
[**176**] Dendronobiloside A



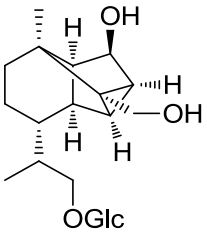
[**177**] Dendronobiloside B



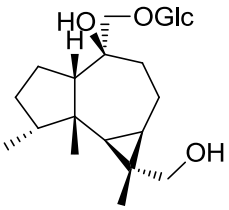
[**178**] Dendronobiloside C



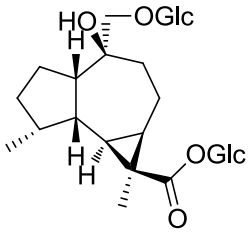
[**179**] Dendronobiloside D



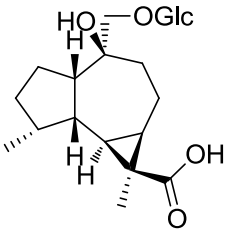
[**180**] Dendronobiloside E



[**181**] Dendroside A

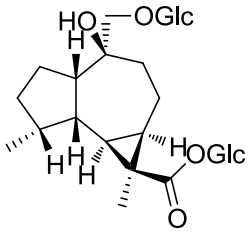


[**182**] Dendroside B

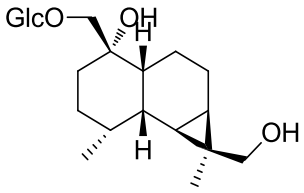


[**183**] Dendroside C

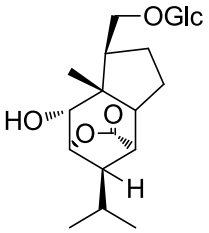
Figure 2C Structures of terpenoids previously isolated from *Dendrobium* species (continued)



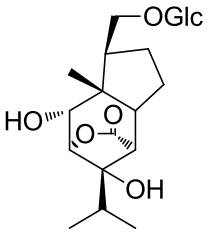
[**184**] Dendroside D



[**185**] Dendroside E



[**186**] Dendroside F



[**187**] Dendroside G

Figure 2C Structures of terpenoids previously isolated from *Dendrobium* species (continued)

Table 1C Distribution of terpenoids in the genus *Dendrobium*

Compounds	Plant	Plant part	Reference
Aduncin [**145**]	*D. longicornu*	Stem	Hu et al., 2008a
Amoenin [**146**]	*D. aduncum*	Whole plant	Gawell and Leander 1976
Amotin [**147**]	*D. amoenum*	Whole plant	Majumder et al., 1999
α-Dihydropicrotoxinin [**148**]	*D. amoenum*	Whole plant	Majumder et al., 1999
Dendrobane A [**149**]	*D. moniliforme*	Stem	Bi *et al.*, 2004
Dendronobilin A [**150**]	*D. nobile*	Stem	Zhang *et al*., 2007a
Dendronobilin B [**151**]	*D. wardianum*	Stem	Fan *et al.* 2013
	D. nobile	Stem	Zhang et al. 2007b
Dendronobilin C [**152**]	*D. crystallium*	Stem	Wang et al., 2009
Dendronobilin D [**153**]	*D. nobile*	Stem	Zhang et al., 2007b
Dendronobilin E [**154**]	*D. nobile*	Stem	Zhang et al., 2007b
Dendronobilin F [**155**]	*D. nobile*	Stem	Zhang et al., 2007b
Dendronobilin G [**156**]	*D. nobile*	Stem	Zhang et al., 2007b
Dendronobilin H [**157**]	*D. nobile*	Stem	Zhang et al., 2007b
Dendronobilin I [**158**]	*D. nobile*	Stem	Zhang et al., 2007b
Dendronobilin J [**159**]	*D. nobile*	Stem	Zhang et al., 2007b
Dendronobilin K [**160**]	*D. wardianum*	Stem	Fan et al., 2013
Dendronobilin L [**161**]	*D. nobile*	Stem	Zhang et al., 2007b
Dendronobilin M [**162**]	*D. nobile*	Stem	Zhang et al. 2008c
Dendronobilin N [**163**]	*D. nobile*	Stem	Zhang et al., 2008c
Dendrowarnol A [**164**]	*D. nobile*	Stem	Zhang et al., 2008c
Dendrowarnol B [**165**]	*D. nobile*	Stem	Zhang et al., 2008c
Dendrowarnol C [**166**]	*D. wardianum*	Stem	Fan et al., 2013

Table 1C (continued)

Compounds	Plant	Plant part	Reference
Corchoionoside C [**167**]	*D. wardianum*	Stem	Fan et al., 2013
Crystallinin [**168**]	*D. wardianum*	Stem	Fan et al., 2013
Findlayanin [**169**]	*D. polyanthum*	Stem	Hu et al., 2009
3-Hydroxy-2-oxodendrobine [**170**]	*D. findlayanum*	Whole plant	Qin et al. 2011
Dendrobine [**171**]	*D. nobile*	Stem	Wang et al.,1985
Dendromoniliside A [**172**]	*D. nobile*	Stem	Zhang et al., 2007b
Dendromoniliside B [**173**]	*D. moniliforme*	Stem	Zhao *et al*, 2003
Dendromoniliside C [**174**]	*D. moniliforme*	Stem	Zhao *et al*, 2003
Dendromoniliside D [**175**]	*D. moniliforme*	Stem	Zhao et al, 2003
Dendronobiloside A [**176**]	*D. moniliforme*	Stem	Zhao et al, 2003
	D. nobile	Stem	Zhao et al., 2001; Ye and Zhao et al., 2002a
Dendronobiloside B [**177**]	*D. nobile*	Stem	Zhao et al., 2001; Ye and Zhao et al., 2002a
Dendronobiloside C [**178**]	*D. nobile*	Stem	Zhao et al., 2001; Ye and Zhao et al., 2002a
Dendronobiloside D [**179**]	*D. nobile*	Stem	Zhao et al., 2001; Ye and Zhao et al., 2002a
Dendronobiloside E [**180**]	*D. nobile*	Stem	Zhao et al., 2001; Ye and Zhao et al., 2002a

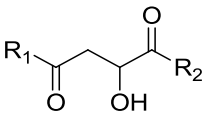
Table 1C (continued)

Compounds	Plant	Plant part	Reference
Dendroside A [**181**]	*D. moniliforme*	Stem	Zhao et al, 2003
	D. nobile	Stem	Zhao et al., 2001; Ye and Zhao et al., 2002a
Dendroside B [**182**]	*D. nobile*	Stem	Ye and Zhao *et al.*, 2002a
Dendroside C [**183**]	*D. moniliforme*	Stem	Zhao et al, 2003
	D. nobile	Stem	Ye and Zhao et al., 2002a
Dendroside D [**184**]	*D. nobile*	Stem	Ye and Zhao *et al.*, 2002a
Dendroside E [**185**]	*D. nobile*	Stem	Ye et al., 2002b
Dendroside F [**186**]	*D. moniliforme*	Stem	Zhao et al, 2003
Dendroside G [**187**]	*D. nobile*	Stem	Ye et al., 2002b
	D. nobile	Stem	Ye et al., 2002b

CH_3-$(CH_2)_n$-CH_2-R

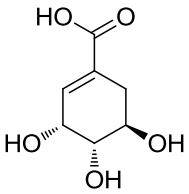
[**188**] Aliphatic acids: R = COOH, n = 19-31

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

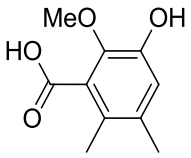


[**190**] Malic acid: R_1 = R_2 = OH

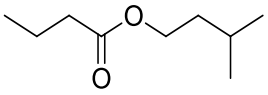
[**191**] Dimethyl malate: R_1 = R_2 =OMe



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

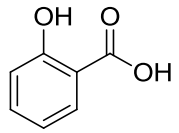


[**194**] 3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid

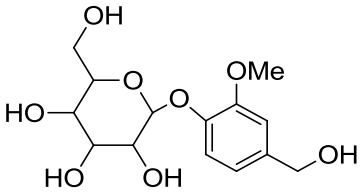


[**193**] Isopentyl butyrate

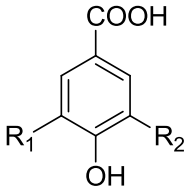
Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species



[**195**] Salicylic acid



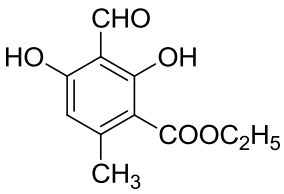
[**196**] Vanilloside



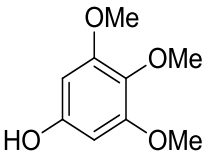
[**197**] Gallic acid: R_1 = OH, R_2 = OH

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

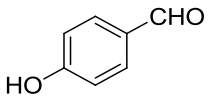
[**199**] Vanillic acid: R_1 = OMe, R_2 = OH



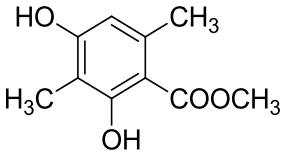
[**200**] Antiarol



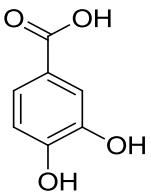
[**201**] Ethylhaematommate



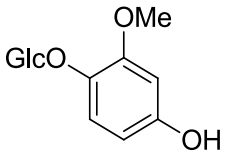
[**202**] *p*-Hydroxybenzaldehyde



[**203**] Methyl β-orsellinate

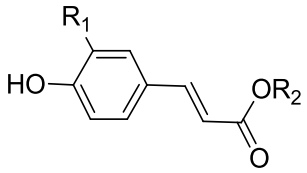


[**204**] Protocatechuic acid



[**205**] Tachioside

Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)



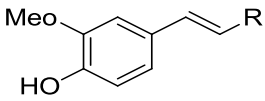
[**206**] Alkyl 4′-hydroxy-*trans*-cinnamates: R_1 = H, R_2 = C_nH_{2n+1}, n =22-32

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

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

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

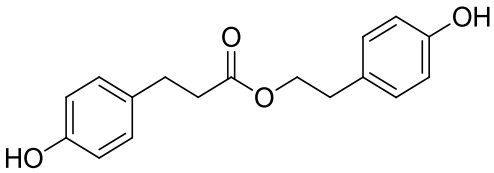
[**210**] *n*-Triacontyl *p*-hydroxy-*cis*-cinnamate: R_1 = H, R_2 = C_nH_{2n+1}, n =30



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

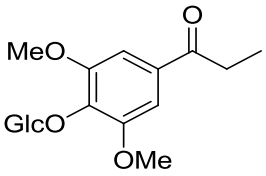
[**212**] Ferulaldehyde: R = CHO

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

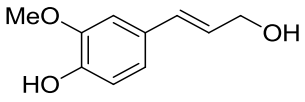


[**214**] 2-(*p*-Hydroxyphenyl) ethyl *p*-coumarate

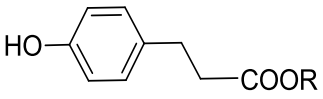
Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)



[**215**] 1-[4-(β-D-glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone

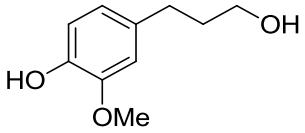


[**216**] 3-(4-Hydroxy-3-methoxyphenyl)-2-propen-1-ol

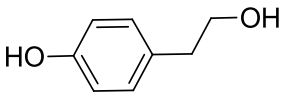


[**217**] *p*-Hydroxyphenyl propionic Methyl ester: R = CH_3

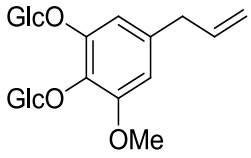
[**218**] Phloretic acid: R = OH



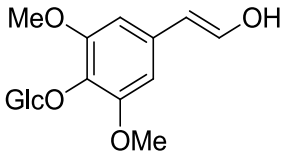
[**219**] 3-(3-Methoxy,4-hydroxyphenyl)-1-propanol



[**220**] Salidrosol

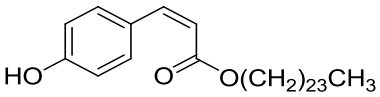


[**221**] Shashenoside I

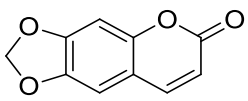


[**222**] Syringin

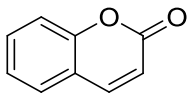
Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)



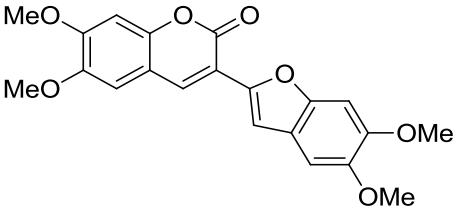
[**223**] Tetracosyl (*Z*)-*p*-coumarate



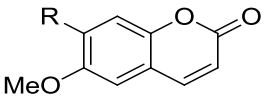
[**224**] Ayapin



[**225**] Coumarin

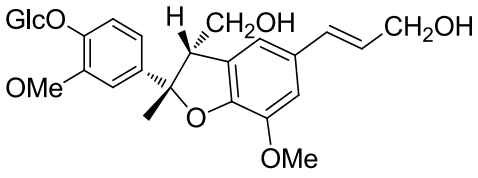


[**226**] Dehydrysin

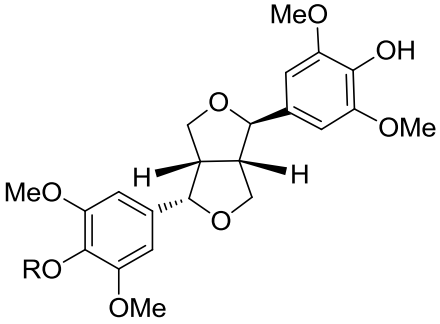


[**227**] Scoparone: R = OMe
[**228**] Scopoletin: R = OH

Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)

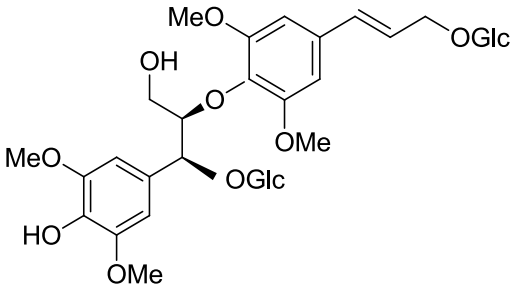


[**229**] Dehydrodiconiferyl alcohol-4-β-D-glucoside

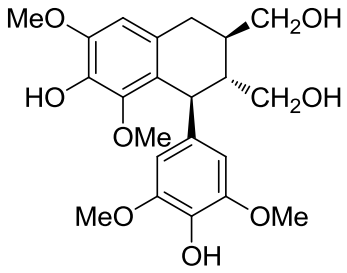


[**230**] Episyringaresinol: R = H

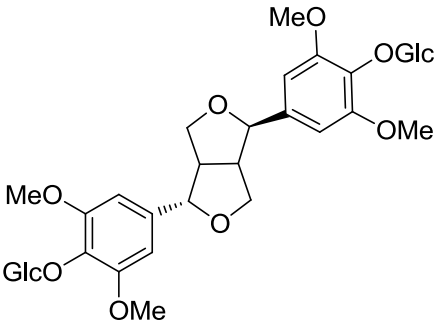
[**231**] Episyringaresinol 4′′-*O*-β-D-glucopyranoside: R = β-D-Glucose



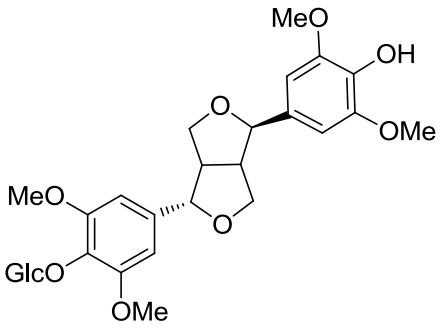
[**232**] (-)-(7S,8R,7′E)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-7,9,9′-triol-7,9′-bis-*O*-β-D-glucopyranoside



[**233**] Lyoniresinol

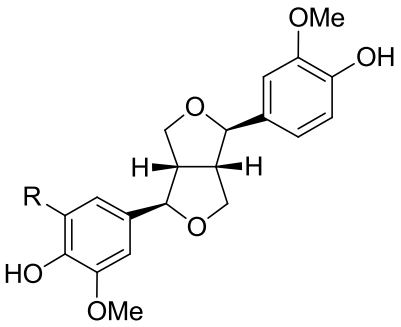


[**234**] (-)-Syringaresinol-4,4′-bis-*O*-β-D-glucopyranoside

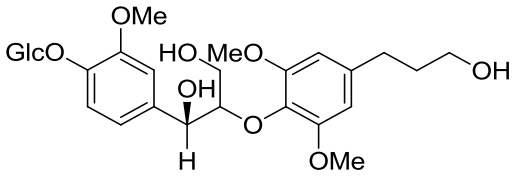


[**235**] Syringaresinol-4-*O*-D-monoglucopyranoside

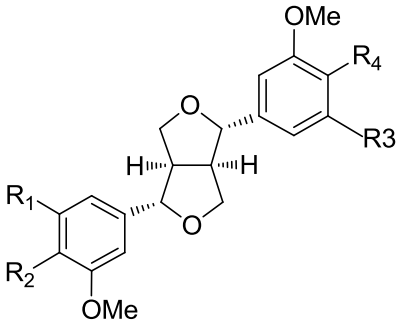
Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)



[**236**] (-)-Medioresinol: R = OMe
[**237**] (-)-Pinoresinol: R = H

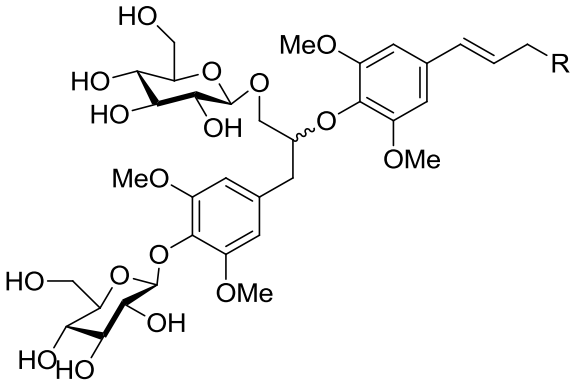


[**240**] Erythro-1-(4-*O*-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol



	R_1	R_2	R_3	R_4
[**238**] Syringaresinol	OMe	OH	OMe	OH
[**239**] Pinoresinol	H	OH	H	OH
[**241**] Acanthoside B	OMe	OGlc	OMe	OH
[**242**] Liriodendrin	OMe	OGlc	OMe	OGlc

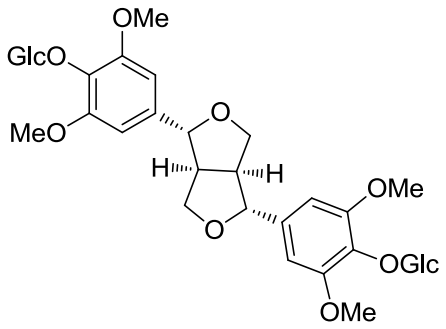
Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)



[**243**] (-)-(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; 8R

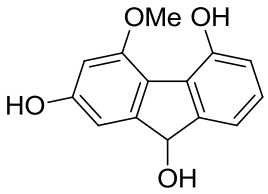
[**244**] (-)-(8*S*,7′E)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-*O*-β-D-glucopyranoside: R = OH; 8S

[**245**] (-)-(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; 8R

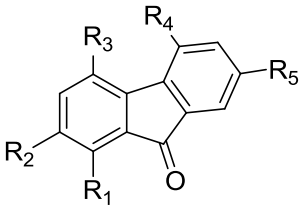


[**246**] Liriodendrin

Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)

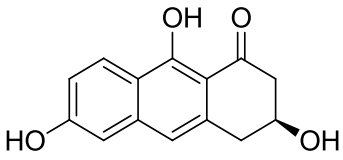


[**248**] Denchrysan B

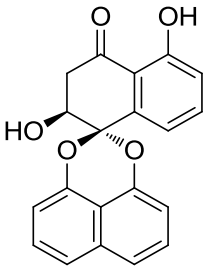


	R_1	R_2	R_3	R_4	R_5
[**247**] Denchrysan A	H	OH	OH	OMe	OH
[**249**] Dendroflorin	OH	H	OH	OMe	OH
[**250**] Dengibsin	H	OH	OMe	OH	H
[**251**] Nobilone	H	OH	H	OMe	OH
[**252**] 1,4,5-Trihydroxy-7-methoxy-9H-fluoren-9-one	OH	H	OH	OH	OMe
[**253**] 2,4,7-Trihydroxy-5-methoxy-9-fluorenone	H	OH	OH	OMe	OH
[**254**] 2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone	OMe	OH	OH	OMe	OH

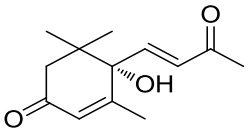
Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)



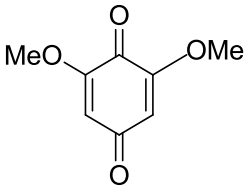
[**255**] 3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one



[**256**] Palmarumycin JC2



[257] Dehydrovomifoliol



[**258**] 2,6-Dimethoxybenzoquinone

Figure 2D Structures of miscellaneous compounds previously isolated from *Dendrobium* species (continued)

Table 1D Distribution of miscellaneous compounds in the genus *Dendrobium*

Catergory and Compound	Plant	Plant part	References
Aliphatic acid derivatives			
Aliphalic acids [**188**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.* 2001
Aliphatic alcohols [**189**]	*D. clavatum* var. *aurantiacum*	Stem	Chang *et al.* 2001
Malic acid [**190**]	*D. huoshanense*	Aerial part	Chang et al., 2001
Dimethyl malate [**191**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
(-)-Shikimic acid [**192**]	*D. huoshanense*	Aerial part	Chang et al., 2010
	D. fuscescens	Whole plant	Talapatra et al., 1989
	D. pulchellum	Stem	Chanvorachote et al., 2013
	D. longicornu	Stem	Hu et al., 2008a
Isopentyl butyrate [**193**]	*D. huoshanense*	Aerial part	Chang *et al.*, 2010

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
Benzoic acid derivatives and **small phenolic compounds**			
3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid [**194**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Salicylic acid [**195**]	*D. huoshanense*	Aerial part	Chang *et al*., 2010
Vanilloside [**196**]	*D. denneanum*	Stem	Pan *et al*.., 2012
Gallic acid [**197**]	*D. longicornu*	Whole plant	Li *et al.,*. 2009d
Syringic acid [**198**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Vanillic acid [**199**]	*D. crystallinum*	Stem	Wang *et al.*, 2009
Antiarol [**200**]	*D. chrysotoxum*	Stem	Hu et al., 2012
Ethylhaematommate [**201**]	*D. longicornu*	Whole plant	Li et al., 2009d

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
p-Hydroxybenzaldehyde [**202**]	*D. falconeri*	Stem	Sritularak et al., 2009
	D. devonianum	Whole plant	Sun, Zhang et al. 2014
Methyl β-orsellinate [**203**]	*D. longicornu*	Stem	Hu et al., 2008a
Protocatechuic acid [**204**]	*D. nobile*	Stem	Ye and Zhao et al., 2002a
Tachioside [**205**]	*D. denneanum*	Stem	Pan et al., 2012
Phenylpropanoids			
Alkyl 4′-hydroxy-transcinnamates [**206**]	*D. clavatum var. aurantiacum*	Stem	Chang et al., 2001
Alkyl trans-ferulates [**207**]	*D. clavatum var. aurantiacum*	Stem	Chang et al., 2001
Defuscin [**208**]	*D. aurantiacum var. denneanum*	Stem	Yang et al., 2006a

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
n-Octacosyl ferulate [**209**]	*D. aurantiacum var. denneanum*	Stem	Yang et al., 2006a
	D. moniliforme	Stem	Bi et al., 2004
n-Triacontyl *p*-hydroxy-*cis*-cinnamate [**210**]	*D. moniliforme*	Stem	Bi *et al*., 2004
n-Docosyl *trans*-ferulate [**211**]	*D. longicornu*	Whole plant	Li *et al*., 2009d
Ferulaldehyde [**212**]	*D. longicornu*	Whole plant	Li et al., 2009d
Ferulic acid [**213**]	*D. secundum*	Stem	Sritularak et al., 2011b
2-(p-Hydroxyphenyl) ethyl p-coumarate [**214**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid, 2009
1-[4-(β-D-lucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone [**215**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong et al., 2013
3-(4-Hydroxy-3-methoxyphenyl)-2-propen-1-ol [**216**]	*D. trigonopus*	Stem	Hu et al., 2008b

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
p-Hydroxyphenyl propionic methyl ester [**217**]	*D. aphyllum*	Whole plant	Chen et al., 2008a
Phloretic acid [**218**]	*D. candidum*	Whole plant	Li *et al.* 2010
3-(3-Methoxy,4-hydroxyphenyl)-1-propanol [**219**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Salidrosol [**220**]	*D. chrysotoxum*	Stem	Hu *et al*., 2012
Shashenoside I [**221**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al., 2013
Syringin [**222**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al., 2013
Tetracosyl(*Z*)-p-coumarate [**223**]	*D. falconeri*	Whole plant	Sritularak et al., 2009

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
Coumarins			
Ayapin [**224**]	*D. densiflorum*	Stem	Fan et al., 2001
Coumarin [**225**]	*D. aurantiacum var.denneanum*	Stem	Yang et al., 2006a Chang et al., 2001
	D. clavatum var. aurantiacum	Stem	
Denthyrsin [**226**]	*D. thyrsiforum*	Stem	Zhang et al., 2005
Scoparone [**227**]	*D. densiflorum*	Stem	Fan et al., 2001 Zhang et al., 2005
	D. thyrsiforum	Stem	
Scopoletin [**228**]	*D. densiflorum*	Stem	Fan et al., 2001
Lignans and neolignans			
Dehydrodiconiferyl alcohol-4-β-D-glucoside [**229**]	*D. chrysanthum*	Stem	Ye *et al*., 2004
Episyringaresinol [**230**]	*D. chrysotoxum*	Stem	Hu et al., 2012 Hu et al., 2008a
	D. longicornu	Stem	Zhang et al., 2008b
	D. nobile	Stem	

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
Episyringaresinol 4′′-O-β-D-glucopyranoside [**231**]	*D. moniliforme*	Stem	Zhao *et al*, 2003
(-)-(7S,8R,7′E)-4-Hydroxy-3,3',5,5'-tetramethoxy-8,4′-Oxyneolign-7′-ene-7,9′-triol-7,9′-bis-O-β-D-glucopyranoside [**232**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Lyoniresinol [**233**]	*D. chrysanthum*	Stem	Ye *et al*., 2004
(-)-Syringaresinol-4,4′-bis-*O*-β–D-glucopyranoside [**234**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
Syringaresinol-4-*O*-D-monoglucopyranoside [**235**]	*D. aurantiacum* var. *denneanum*	Stem	Xiong *et al*., 2013
(-)-Medioresinol [**236**]	*D. loddigesii*	Whole plant	Ito et al., 2010
(-)-Pinoresinol [**237**]	*D. loddigesii*	Whole plant	Ito et al., 2010
Syringaresinol [**238**]	*D. secundum*	Stem	Sritularak et al., 2011b

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
Pinoresinol [**239**]	*D. nobile*	Stem	Zhang et al., 2008b
	D. nobile	Stem	Zhang et al., 2008b
Erythro-1-(4-*O*-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol [**240**]	*D. longicornu*	Stem	Hu *et al*., 2008a
Acanthoside B [**241**]	*D. chrysanthum*	Stem	Ye *et al*., 2004
Liriodendrin [**242**]	*D. pulchellum*	Stem	Chanvorachote *et al*., 2013
(-)-(8R,7′E)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-O-β-D-glucopyranoside [**243**]	*D. auranticum*	Stem	Li et al., 2014

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
(-)-(8R,7′E)-4-hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-O-β-D-glucopyranoside [**244**]	D. auranticum	Stem	Li et al., 2014
(-)-(8R,7′E)-4-hydroxy-3,3′,5,5′,9′-pentamethoxy-8,4′-oxyneolign-7′-ene-9-ol 4,9-bis-O-β-D-glucopyranoside [**245**]	D. auranticum	Stem	Li et al., 2014
Liriodendrin [**246**]	D. brymerianum	Whole plant	Chen et al., 2014
Fluorenones			
Dencrysan A [**247**]	*D. chrysotoxum*	Whole plant	Li et al., 2009c
Dencrysan B [**248**]	*D. chrysotoxum*	Whole plant	Chen et al,. 2008b

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
Dendroflorin [**249**]	*D. aurantiacum var. denneanum*	Stem	Yang et al., 2006a Chen et al., 2008b
	D. chrysotoxum	Whole plant	Zhang et al., 2007a
	D. nobile	Stem	
Dengibsin [**250**]	*D. aurantiacum var. denneanum*	Stem	Yang et al., 2006a
	D. chrysanthum	Stem	Yang et al., 2006b
	D. chrysotoxum	Whole plant	Li et al., 2009c
	D. densiflorum	Stem	Fan et al., 2001
Nobilone [**251**]	*D. nobile*	Stem	Zhang et al., 2007a
1,4,5-Trihydroxy-7-methoxy-9H-fluoren-9-one [**252**]	*D. chrysotoxum*	Whole plant	Chen et al., 2008b
2,4,7-Trihydroxy-5-methoxy-9-fluorenone [**253**]	*D. chrysotoxum*	Stem	Yang et al. 2004

Table 1D (continued)

Catergory and Compound	Plant	Plant part	Reference
2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone [**254**]	*D. chrysotoxum*	Stem	Yang et al., 2004
Others			
3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2H)-one [**255**]	*D. chrysotoxum*	Stem	Hu et al. 2012
Palmarumycin JC2 [**256**]	*D. crystallinum*	Stem	Wang et al., 2009
Dehydrovomifoliol [**257**]	*D. loddigesii*	Whole plant	Ito et al., 2010
2,6-Dimethoxy Benzoquinone [**258**]	*D. chryseum*	Stem	Ma et al. 1998

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

Many *Dendrobium* species have been used in traditional medicine. Their chemical components and pharmacology of *Dendrobium* species have been studied. Several studies have been undertaken to provide scientific evidence to justify medicinal uses for the treatment of various diseases including anti-inflammatory, antioxidant, antiplatelet aggregation, lymphocyte stimulation and α-glucosidase inhibitory activities (Gutiérrez 2010).

A number of studies on the antioxidative property of the bibenzyl derivatives and phenanthrenes from *Dendrobium* plants indicated that they were potent antioxidants. For instance, crepidatin [**20**], moscatilin [**30**], tristin [**35**] and moscatin [**87**] exhibited stronger antioxidative activity than BHA as determined by the method of ferric thiocyanate (Ono *et al*., 1995). Chrysotoxine [**19**], crepidatin [**20**], nobilin D [**59**] and nobilin E [**60**] bibenzyl derivatives, which were obtained from *D. nobile*, illustrated free radical scavenging activity stronger than or equivalent to vitamin C in the DPPH assay. In the ORAC assay, chrysotoxine [**19**], crepidatin [**20**], gigantol [**26**], moscatilin [**30**], nobilin D [**59**], dendroflorin [**249**] and nobilone [**251**] exhibited antioxidant activity stronger than vitamin C (Zhang *et al*., 2007a). The DPPH free radical scavenging assay was used to evaluate the antioxidant activities of dendrocandin C [**3**], D [**4**], and E [**5**] from *D. candidum*. The results indicated that dendrocandin E [**5**] had the most potent scavenging activity (Li *et al*., 2009a). 7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol [**105**], a phenanthrene derivative obtained from *D. draconis*, showed antioxidant potency similar to that of Trolox when tested with the DPPH radical scavenging assay (Sritularak *et al.* 2011).

The bibenzyl derivatives from *D. densiflorum* such as gigantol [**26**] and moscatilin [**30**], and the coumarin scoparone [**227**] were preliminarily investigated for their antiplatelet aggregation activity on SD rat platelet *in vitro* (Fan *et al*., 2001). Moscatilin [**30**] and moscatin [**87**] exhibited strong inhibitory effect on arachidonic acid and collagen induced platelet aggregation (Chen 1994).

In the anti-inflammation research, several compounds from *D. nobile* were tested for inhibitory effects on lipopolysaccharides-induced nitric oxide generation in macrophage cells (RAW 264.7). The results showed that 9,10-dihydrophenanthrene structures, including coelonin [**88**], ephemeranthol A [**98**] and erianthridin [**100**] illustrated more potent inhibitory activity than phenanthrenes and bibenzyls, such as, moscatilin [**30**], and fimbriol B [**112**] (Hwang *et al*., 2010). Regarding the inhibitory effects on nitric oxide production, strong activities were observed for nobilins D [**59**], E [**60**], and dendroflorin [**249**] (Zhang *et al.* 2007).

In a preliminary *in vitro* biological evaluation, dendrosides D-G [**184-187**], the sesquiterpene glycosides isolated from *D. nobile*, were able to stimulate the proliferation of murine T and/or B lymphocytes (Ye and Zhao., 2002). Another subject described the stimulatory activity of dendronobiloside A [**176**] from *D. nobile* on the proliferation of B lymphocytes (Zhao *et al.* 2001).

Regarding α-glucosidase inhibitory activity, some compounds obtained from *Dendrobium* plants were found to possess this activity. The bibenzyl derivative gigantol [**26**], which was isolated from *D. devonianum*, and the dimeric stilbenes Loddigesiinols, which were isolated from *D. loddigesii*, exhibited significant α-glucosidase inhibitory activity (Lu *et al.* 2014).

CHAPTER III

EXPERIMENTAL

1. Source of plant materials

The whole plants of *Dendrobium signatum* Rchb.f. were purchased from Chatuchak market, Bangkok, in October 2012. Authentication was performed by comparison with herbarium specimens at the Department of National Park, Wildlife and Plant Conservation, Ministry of National Resources and Environment. A voucher specimen (BS-DS-102555) has been deposited at the Department of Pharmacognosy, Faculty of Pharmaceutical Sciences, Chulalongkorn University.

2.General techniques

2.1 Analytical thin-layer chromatography (TLC)

Technique : One dimension ascending

Absorbent : Silica gel 60 F_{254} (E. Merck) precoated plate

Layer thickness : 0.2 mm

Distance : 6.5 cm

Temperature : Laboratory temperature (30-35 °C)

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 °C 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 : Wet 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 (Pharmacia)

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

2.2.4 Ion exchange chromatography

Adsorbent : Diaion HP 20 (Supelco)

Packing method : The appropriate organic solvent was used as the eluent. Diaion HP 20 was suspended in the eluent, left standing about 24 hours prior to use and then poured into the column 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 Science, Mahidol University).

2.3.2 Ultraviolet (UV) absorption spectra

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

2.3.3 Infrared (IR) spectra

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

2.3.4 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) or a Varian Unity INOVA-500 NMR spectrometer.

Deuterated for NMR spectra were used by deuteratedacetone (acetone-d_6). Chemical shifts were reported in ppm scale using the chemical shift of the solvent as the reference signal.

2.4 Optical activity

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

2.5 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. signatum* (3.5 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 200 g of Methanol crude extract. This material was suspended in water and partitioned with EtOAc and then *n*-butanol to give an EtOAc extract (41 g), an *n*-butanol extract (130 g), and an aqueous extract (28 g). All three extracts were tested for antioxidant activity using the DPPH free radical scavenging assay. The EtOAc extract showed the highest activity with 90% inhibition at 100 µg/mL. The n-butanol extract showed 70% inhibition at 100 µg/mL. Based on these bioaasay results, the EtOAc extract was first selected for further studies, followed by the *n*-Butanol extract.

3.2 Separation of EtOAc extract

The EtOAc extract (41 g) was initially fractionated by vacuum liquid chromatography (VLC) as described in section 2.2.1. Silica gel (No.7734, 600 g) was used

as the stationary phase and a step gradient of hexane-acetone (1:0 to 0:1) and acetone-MeOH (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-acetone 6:4) to give sixty fractions. Fractions with similar chromatographic pattern were combined into eight fractions, A (2.4 g), B (3.2 g), C (4.2 g), D (1.1 g), E (3.2 g), F (1.5 g), G (4.1 g) and H (2.0 g).

3.2.1 Isolation of compound DS01 (3,4-dihydroxy-5,4′-dimethoxybibenzyl)

Fraction E (3.2 g) was separated by FCC using silica gel (No. 9385) as the stationary phase with a step gradient mixture of hexane-acetone (1:0 to 0:1). Twenty-nine fractions (1E-29E) were obtained and combined according to the similarity of their TLC patterns (silica gel, Hexane-Acetone 7:3). Fraction 17E (0.54 g) was further separated on a Sephadex LH-20 column, eluted with acetone, to give sixteen fractions: 17E1-17E16. Compound DS01 was obtained from fraction 17E9 as a red amorphous solid (184.8 mg, R_f 0.25, silica gel, hexane-acetone = 7:3) and was later identified as 3,4-dihydroxy-5,4′-dimethoxybibenzyl.

3.2.2 Isolation of compound DS02 (dendrocandin B)

Fraction G (4.1 g) was further separated by FCC using silica gel (No. 9385) as the stationary phase with a step gradient mixture of hexane-acetone (1:0 to 0:1). Thirty-seven fractions were obtained: 1G-37G. Fractions 18G-20G (980.3 mg) were combined and further separated by FCC using silica gel (No. 9385) as the stationary phase with a step gradient mixture of hexane-acetone (1:0 to 0:1). Forty-eight fractions: 18G(1)-18G(48) were obtained and combined according to the similarity of their TLC patterns (silica gel, hexane-acetone 6:4). Fractions 18G(9) to 18G(20) were combined and separated on Sephadex LH-20 (acetone) to give twenty-one fractions. Fractions 18G(9)(5)- 18G(9)(7) (38.2 mg) were combined and separated on Sephadex LH-20

(acetone) to give 18 fractions: 18G(9)(5)(1)-18G(9)(5)(18). Fractions 18G(9)(5)(3)-18G(9)(5)(8) (21.2 mg), after purification by CC (silica gel; EtOAc: *n*-hexane gradient, 1:0 to 0:1) gave thirty-two fractions. Fractions 21-25 afforded dendrocandin B (4.8 mg, R_f 0.39, silica gel, Hexane-acetone = 6:4).

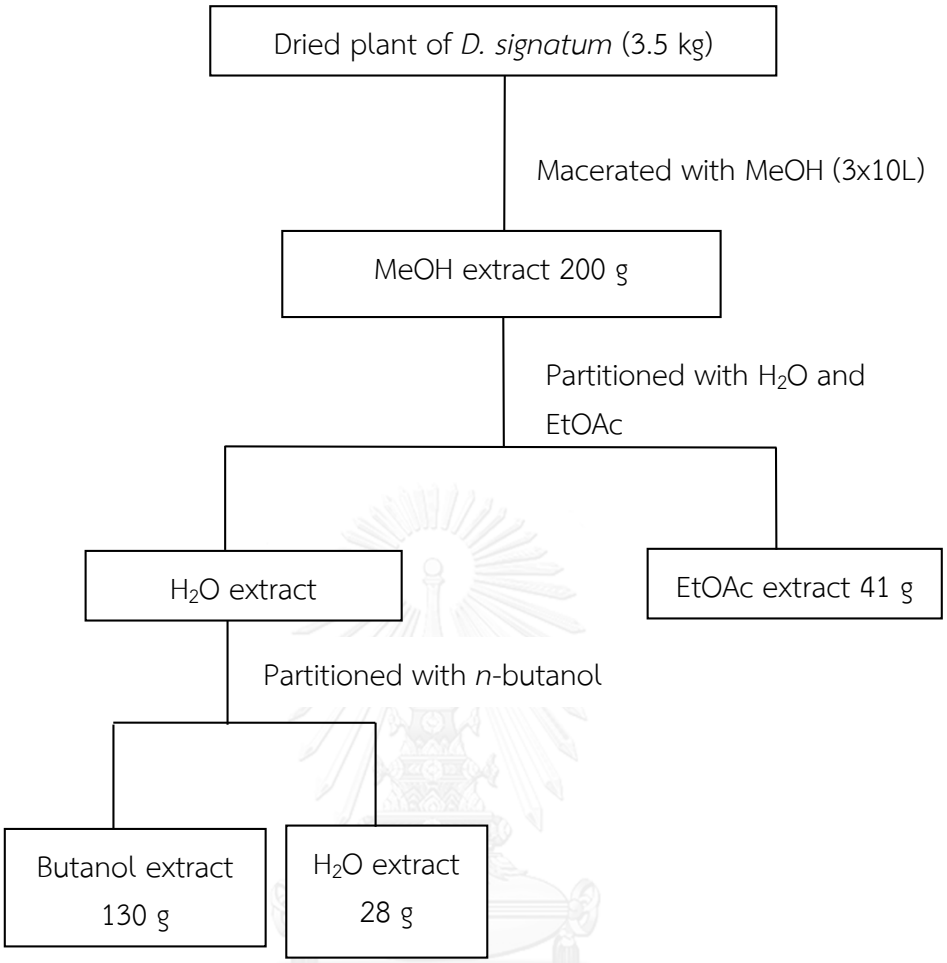
3.3 Separation of *n*-butanol extract

The *n*-BuOH extract (30 g) was separated on Diaion HP20 using a step gradient of H_2O-MeOH (1:0 to 0:1) and acetone-MeOH (1:0 to 0:1) as the mobile phase.

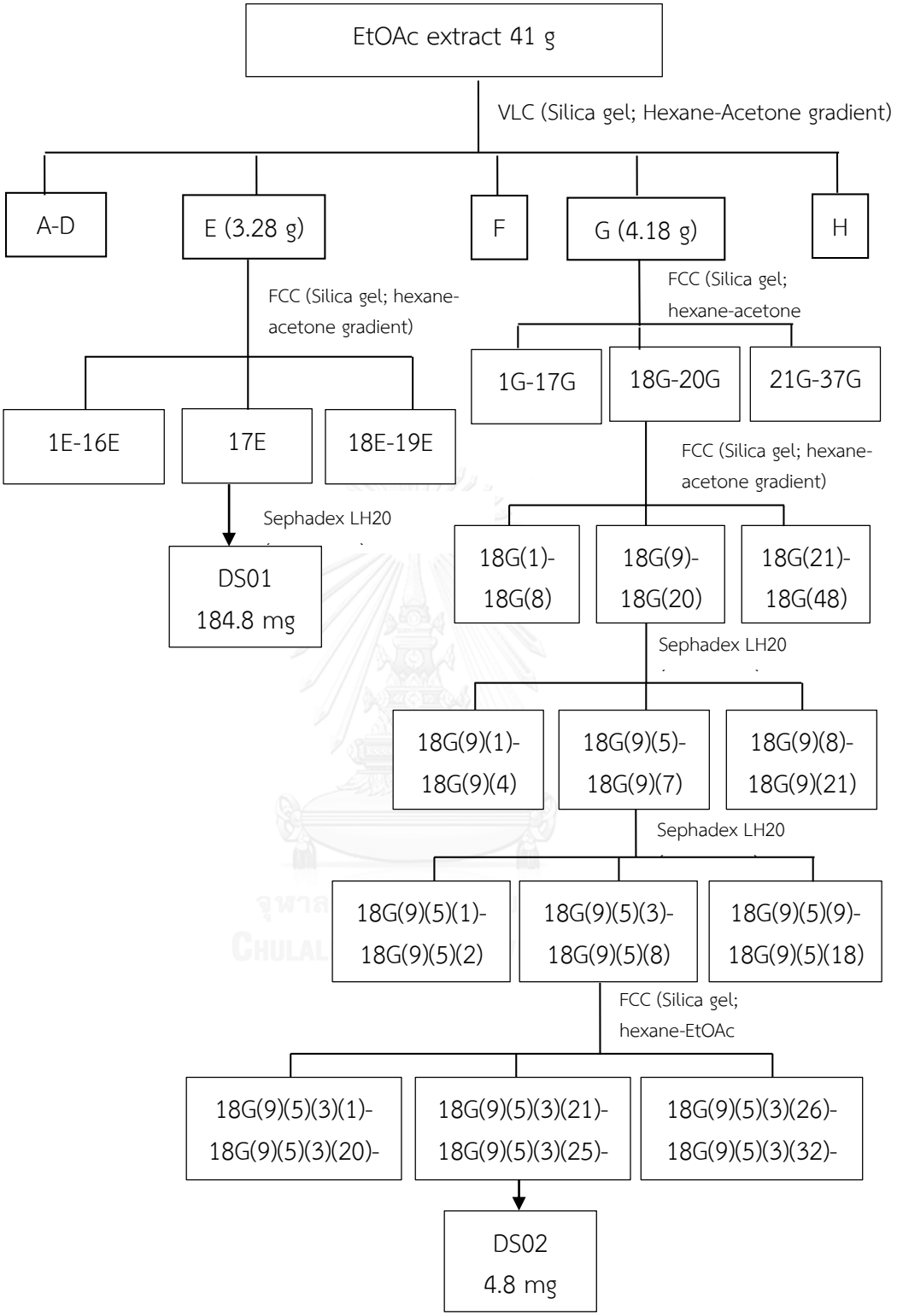
The eluates were collected about 500 mL per fraction and examined by TLC (silica gel, Hexane-EtOAc 1:1) to give 5 fractions: fractions 1 (3.7 g), 2 (3.0 g), 3 (3.4 g), 4 (7.2 g) and 5 (5.2 g).

3.3.1 Isolation of compounds DS03 (Dendrocandin I), DS04 (Dendrosignatol) and DS05 (Dendrofalconerol A)

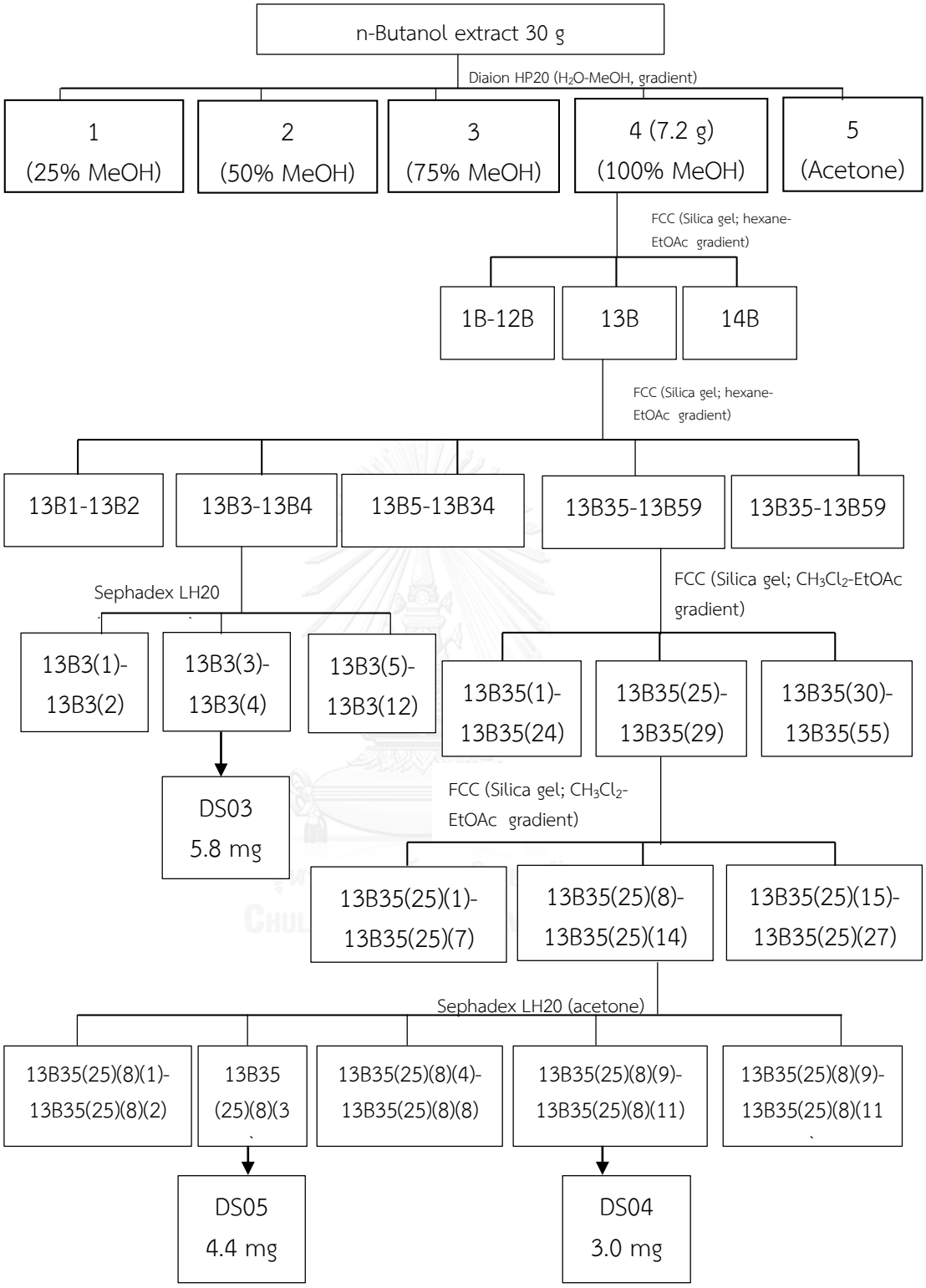
Fraction 4 (7.2 g) was separated by FCC using silica gel (No. 9385) as the stationary phase with a step gradient mixture of hexane-EtOAc gradient (1:0 to 0:1) to give 14 fractions: 1B-14B. Fraction 13B (302.4 mg) was subjected to repeated FCC (silica gel, Hexane : EtOAc gradient) to give 63 fractions: 13B1-13B63. Dendrocandin I (5.8 mg) was obtained from fractions 13B3(3)-13B3(4) (13.0 mg) after purification on Sephadex LH-20 (acetone). Fractions 13B35-13B59 (158.3 mg) were combined and then separated by FCC (silica gel, EtOAc-CH_2Cl_2, gradient) to yield 55 fractions: 13B35(1)-13B35(55). Fractions 13B35(25)- 13B35(29) (30.8 mg) were combined and further separated by FCC on silica gel (EtOAc-CH_2Cl_2, gradient) to give 27 fractions: . Purification of fractions 8-14 (13.5 mg) on Sephadex LH-20 (acetone) gave dendrosignatol (3.0 mg) and dendrofalconerol A (4.4 mg), respectively.



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



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



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

4. Physical and spectral data of isolated compounds

4.1 Compound DS01 (3,4-dihydroxy-5,4′dimethoxybibenzyl)

Compound DS01 was obtained as a red amorphous solid, soluble in acetone (184.8 mg, 5.28×10^{-3} % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 297.1103 ($C_{16}H_{18}O_4Na$); Figure 3

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see Table 2, Figure 4

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see Table 2, Figure 5

4.2 Compound DS02 (dendrocandin B)

Compound DS02 was obtained as a white powder, soluble in acetone (4.8 mg, 1.39×10^{-4} % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 505.1853 ($C_{27}H_{30}O_8Na$); Figure 7

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see Table 3, Figure 8

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see Table 3, Figure 9

4.3 Compound DS03 (dendrocandin I)

Compound DS03 was obtained as a brown amorphous solid, soluble in acetone (5.8 mg, 3.63×10^{-4} % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 567.2001 ($C_{32}H_{32}O_8Na$); Figure 12

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see Table 4, Figure 13

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see Table 4, Figure 14

4.4 Compound DS04 (dendrosignatol)

Compound DS04 was obtained as a red amorphous solid, soluble in acetone (3.0 mg, 8.57×10^{-5} % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 521.1585 ($C_{30}H_{26}O_7Na$); Figure 16

FT-IR : ν cm^{-1} (KBr) : 3367, 2917, 1510, 1467, 1246; Figure 17

UV : λ_{max} nm (log ε), in methanol: 227 (1.28), 283 (1.04); Figure 18

^{1}H NMR : δ ppm, 500 MHz, in acetone-d_6; see Table 5, Figure 19

^{13}C NMR : δ ppm, 125 MHz, in acetone-d_6; see Table 5, Figure 20

4.5 Compound DS05 (dendrofalconerol A)

Compound DS05 was obtained as a brown amorphous powder, soluble in acetone (4.0 mg, 7.11×10^{-5} % based on dried weight of whole plant).

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 567.2040 ($C_{32}H_{32}O_8Na$); Figure 24

^{1}H NMR : δ ppm, 300 MHz, in acetone-d_6; see Table 6, Figure 25

^{13}C NMR : δ ppm, 75 MHz, in acetone-d_6; see Table 6, Figure 26

5. Free radical scavenging activity

5.1 DPPH free radical scavenging assay

DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) free radical assay is an antioxidant activity evaluation method based on electron-transfer. Any substance that can donate a hydrogen atom (antioxidant) to the solution of DPPH can reduce the stable free radical. DPPH can produce a violet solution in methanol. This free radical is reduced in the presence of an antioxidant molecule, giving rise to a pale yellow MeOH solution (Likhitwitayawuid et al. 2006).

5.1.1 Materials and instruments

-DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) (Sigma-Aldrich, USA)

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

-Quercetin (Sigma-Aldrich, USA)

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

-Ultrasonic cleaner (Transsonic 570/H, Elma)

-Vortex mixer (Vortex-Genie2, Scientific industries)

5.1.2 Determination of DPPH free radical scavenging activity

DPPH was dissolved in MeOH to give a concentration of 0.5 mM. Samples were prepared in MeOH at the concentration of 0.0019-1.000 µg/ml. Trolox and quercetin were used as positive controls. The reaction of mixture consisted of 20 µl of sample and 180 µl of DPPH radical solution and was allowed to stand in the dark at room temperature for 30 min. The absorbance was then measured at 517 nm using a microplate reader (Wallac1420 Multilevel counter, Victor^3, PerkinElmer). The absorbance obtained was converted into free radical scavenging activity using the following formula;

$$\%\text{free radical scavenging activity} = [(A_{control} - A_{sample}) / A_{control}] \times 100$$

Where $A_{control}$ and A_{sample} are the absorbance. The experiment was performed in triplicate and each experiment consisted of three repetitions. MeOH was used as a negative control. Trolox and quercetin were used as positive controls and treated under the same condition as the samples.

5.2 Superoxide anion scavenging activity assay

Superoxide anion radical ($O_2^{\bullet-}$) is generated by four-electron reduction of molecule oxygen into water. This oxygen free radical is implicated in cell damage and can cause an indirect generation of hydroxyl radical ($OH^{\bullet}$). The measurement of superoxide anion scavenging activity is done through the reduction of nitroblue tetrazolium (NBT).

5.2.1 Materials and instruments

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

(Sigma-Aldrich, USA)

-Nitroblue tetrazolium (NBT)

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

-Ultrasonic cleaner (Transsonic 570/H, Elma)

-Vortex mixer (Vortex-Genie2, Scientific Industries)

5.2.2 Determination of superoxide anion scavenging activity

The assay was based on the capacity of test sample to inhibit the reduction of nitroblue tetrazolium (NBT). The sample solution was prepared by dissolving the test sample in a solution of 30% MeOH in potassium phosphate buffer. Each 200 µl reaction mixture was prepared by adding 40 µl of sample solution and 20 µl of 750 µM NBT to a mixture of 20 µl of 50 mM potassium phosphate buffer, 100 µl of 266 µM riboflavin, and 20 µl of 1 mM EDTA in a 96-well microtiter plate. The production of blue formazan was followed by monitoring the increase in absorbance at 570 nm after 10 min illumination with a fluorescent lamp. A similar reaction mixture was enclosed in a box and kept in the dark and served as the blank. The percentage of O_2 radical scavenging activity was then calculated as follows :

$$\%\text{free radical scavenging activity} = [(A_{control} - A_{sample}) / A_{control}] \times 100$$

Where A is the absorbance. The experiment was performed in triplicate and each experiment consisted of three repetitions. MeOH was used as a negative control. Trolox® was used as a positive control and treated under the same condition as the sample.

CHAPTER IV

RESULTS AND DISCUSSION

In this study, the dried and powdered whole plants of *Dendrobium signatum* (3.5 kg) were macerated with methanol. The methanol extract was concentrated under reduced pressure to give 200 g of a crude extract. This methanol extract exhibited approximately 90 % free radical scavenging activity at a concentration of 100 µg/mL. It was further partitioned with EtOAc, H_2O and butanol. The EtOAc extract showed the most potent free radical scavenging activity with approximately 90% inhibition. The *n*-Butanol and H_2O extracts showed 70% and 60% inhibition, respectively. The EtOAc extract was further separated using several chromatographic techniques to give 2 bibenzyl compounds **(DS01 and DS02)**. Three compounds including, 2 bisbibenzyls **(DS03 and DS05)** and a bibenzyl-dihydrophenanthrene derivative **(DS04)**, were obtained from *n*-butanol extract after repeated chromatography. The structures of these compounds were determined by spectroscopic techniques, consisting of UV, IR, MS and NMR. They were also evaluated for their free radical scavenging activity.

1. Structure determination of isolated compounds

1.1 Structure determination of compound DS01

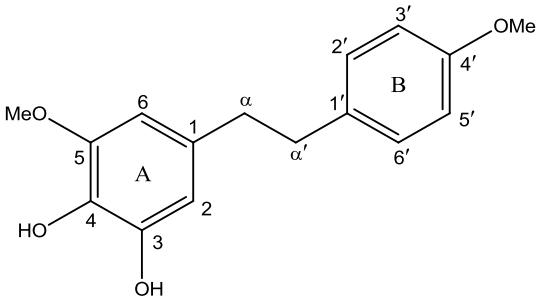
Compound DS01 was obtained as a red amorphous solid. Its IR spectrum exhibited absorption peaks at 3387 and 1611, 1512 cm^{-1} indicating hydroxyl and aromatic groups. (Ming *et al*., 2004). The HR-ESI mass spectrum (Figure 3) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 297.1103, suggesting the molecular formula $C_{16}H_{18}O_4$.

The ^{1}H-NMR spectrum (Figure 4 and Table 2) exhibited signals for two pairs of methylene protons at δ_H 2.79 (4H, m, H_2-α, H_2-α') and two singlets at 3.76 (3H, s, 3-OMe) and 3.74 (3H, s, OMe-4′) indicating two methoxyl groups. In the aromatic region of ring A, the ^{1}H NMR spectrum showed two doublet protons at δ_H 6.37 (1H, d, *J*=1.8 Hz, H-2) and δ_H 6.45 (1H, d, *J*=1.8 Hz, H-6). For ring B, the ^{1}H NMR spectrum showed four protons at δ_H 7.12 (2H, d, *J*=8.7 Hz, H-2′, H-6′) and δ_H 6.83 (2H, d, *J*=8.7 Hz, H-3′, H-5′). The locations of the two methoxyls were confirmed by a NOESY experiment (Figure 6). The first methoxyl at δ_H 3.74 was placed at C-4′ according to its NOESY correlation peaks with H-3′ and H-5′. The second methoxyl (δ_H 3.76) was located at C-5 based on its NOESY cross-peak with H-6.

The ^{13}C NMR spectrum (Figure 5 and Table 2) displayed sixteen carbon signals, including two signals for two methoxyl groups at δ_C 55.3 and 56.2. The other fourteen carbon signals of DS01 could be differentiated into two methylene carbon signals at 37.7 (C-α') and 38.6 (C-α) ppm; six methine carbon signals at 104.4 (C-2), 109.6 (C-6), 114.3 (C-3′), 114.3 (C-5′), 130.1 (C-2′) and 130.1 (C-6′) ppm and six quaternary carbon signals at 132.6 (C-1), 133.6 (C-1′), 134.6 (C-4), 145.9 (C-5), 148.6 (C-3) and 158.6 (C-4′) ppm.

From the above data and through comparison of its ^{1}H, ^{13}C NMR and MS with previously reported data (Ming *et al*., 2004), DS01 was identified as 3,4-dihydroxy-5,4′dimethoxybibenzyl [**39**]. The structure of the compound is shown below.

The presence of 3,4-dihydroxy-5,4′dimethoxybibenzyl in *Dendrobium* species has been previously reported in *D. moniliforme* (Zhi-Ming *et al.* 2004), *D. candidum* Yan (Li *et al.* 2008) and *D. officinale* (XiaoMei *et al.* 2012).



3,4-dihydroxy-5,4′dimethoxybibenzyl [**39**]

Table 2 NMR spectral data of compound DS01 (in acetone-d_6) and 3,4-dihydroxy-5,4′dimethoxybibenzyl (in $CDCl_3$)

Position	Compound DS01		3,4-dihydroxy-5,4′dimethoxybibenzyl[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	132.6	-	133.4
2	6.37 (d, 1.8)	104.4	6.20 (d, 1.3)	103.6
3	-	148.6	-	143.7
4	-	134.6	-	130.5
5	-	145.9	-	143.7
6	6.45 (d, 1.8)	109.6	6.44 (d, 1.3)	108.7
α	2.79 (m)	38.6	2.71 (m)	37.6
α′	2.79 (m)	37.7	2.71 (m)	36.7
1′	-	133.6	-	133.7
2′	7.12 (d, 8.7)	130.1	7.01 (d, 8.2)	129.3
3′	6.83 (d, 8.7)	114.3	6.78 (d, 8.2)	113.4
4′	-	158.6	-	157.3
5′	6.83 (d, 8.7)	114.3	6.78 (d, 8.2)	113.4
6′	7.12 (d, 8.7)	130.1	7.01 (d, 8.2)	129.3
3-OMe	3.76 (s)	56.2	3.66 (s)	55.7
4′-OMe	3.74 (s)	55.3	3.69 (s)	54.9

[a] Ming *et al*., 2004

1.2 Structure determination of compound DS02

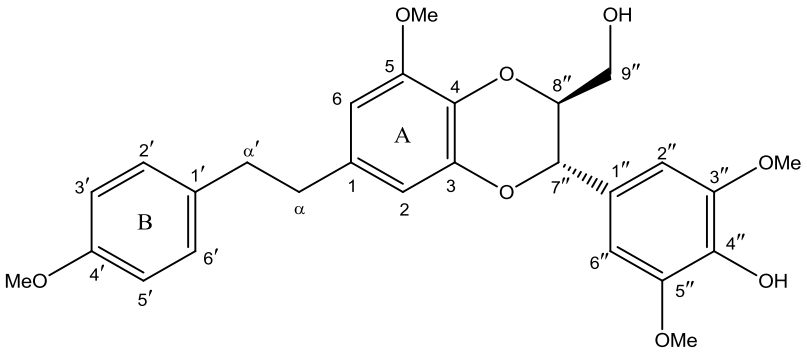
Compound DS02 was obtained as a white powder. Its specific optical rotation $[\alpha]_D^{20}$ was found to be -1.2° (c = 0.05, MeOH). The HR-ESI mass spectrum (Figure 7) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 505.1853, suggesting the molecular formula $C_{27}H_{30}O_8$.

The ^{1}H-NMR data (Figure 8 and Table 3) of DS02 showed bibenzyl signals similar to those of DS01 as well as additionals signals for a phenylpropanoid unit. In the aromatic region of ring A, the ^{1}H NMR spectrum showed protons at δ_H 6.42 (1H, d, *J*=1.8 Hz, H-2) and δ_H 6.45 (1H, d, *J*=1.8 Hz, H-6). For ring B, the ^{1}H NMR spectrum showed four protons at δ_H 7.15 (2H, d, *J*=8.4 Hz, H-2′, H-6′) and δ_H 6.83 (2H, d, *J*=8.4 Hz, H-3′, H-5′). Two pairs of methylene protons at δ_H 2.82 (2H, m, H_2-α) and δ_H 2.79 (2H, m, H_2-α') and three singlets at δ_H 3.83 (6H, s, 3′′,5′′-MeO), 3.78 (3H, s, 5-MeO) and 3.74 (3H, s, 4′-OMe) were observed.

The ^{13}C NMR spectrum (Figure 9 and Table 3) of DS02 revealed the presence of four methoxy groups (δ_C 54.5, 55.4 and 55.5), three methylene groups (δ_C 36.8, 37.7 and 61.0) and two oxygenated methine groups (δ_C 76.4 and 78.4).

The phenylpropanoid unit was linked to the B ring of the bibenzyl through a dioxane ring, as deduced from the appearance of signals for two aromatic protons of the phenyl propanoid at 6.81 (2H, s, H-2′′, H-6′′), the NOESY correlation (Figure 11) between H-8′′/H-2′′,H-6′′ and the HMBC correlation (Figure 10) between H-7′′/C-8′′ and between H-2′′,6′′/C-7′′.

Based on the above mentioned spectroscopic properties, compound DS02 was determined as dendrocandin B [**2**], which was first isolated from *Dendrobium candidum* (Yan LI *et al.* 2008).



Dendrocandin B [**2**]

Table 3 NMR spectral data of compound DS02 (in acetone-d_6) and dendrocandin B (in $CDCl_3$)

Position	Compound DS02		Dendrocandin B[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	133.9	-	134.5
2	6.42 (d, 1.8)	109.3	6.52 (d, 1.0)	109.5
3	-	144.3	-	144.1
4	-	131.6	-	131.0
5	-	148.8	-	148.4
6	6.45 (d, 1.8)	104.2	6.32 (d, 1.5)	104.8
1′	-	133.8	-	133.7
2′	7.15 (d, 8.4)	129.3	7.10 (d, 8.0)	129.4
3′	6.83 (d, 8.4)	113.6	6.83 (d, 8.0)	113.7
4′	-	158.0	-	160.1
5′	6.83 (d, 8.4)	113.6	6.83 (d, 8.0)	113.7
6′	7.15 (d, 8.4)	127.3	7.10 (d, 8.0)	129.4
α	2.82 (m)	37.7	2.82 (m)	38.0
α′	2.79 (m)	36.8	2.82 (m)	37.0
5-OMe	3.78 (s)	55.4	3.85 (s)	56.0
4′-OMe	3.74 (s)	54.5	3.79 (s)	55.3
1″	-	127.5	-	127.3
2″	6.81 (s)	105.2	6.68 (s)	104.0
3″	-	147.8	-	147.2
4″	-	136.4	-	135.2
5″	-	147.8	-	147.2
6″	6.81 (s)	105.2	6.68	104.0
7″	4.91 (d, 7.8)	76.4	4.96 (d, 8.5)	76.4
8″	4.00 (m)	78.4	3.98 (m, 8.0, 3.0, 3.0)	78.2
9″	3.50 (m)	61.0	3.55 (dd, 12.0, 3.0)	61.5
	3.83 (m)		3.90 (m)	
3″-OMe	3.83 (s)	55.5	3.92 (s)	56.4
5″-OMe	3.83 (s)	55.5	3.92 (s)	56.4

[a]Li et al., 2008

1.3 Structure determination of compound DS03

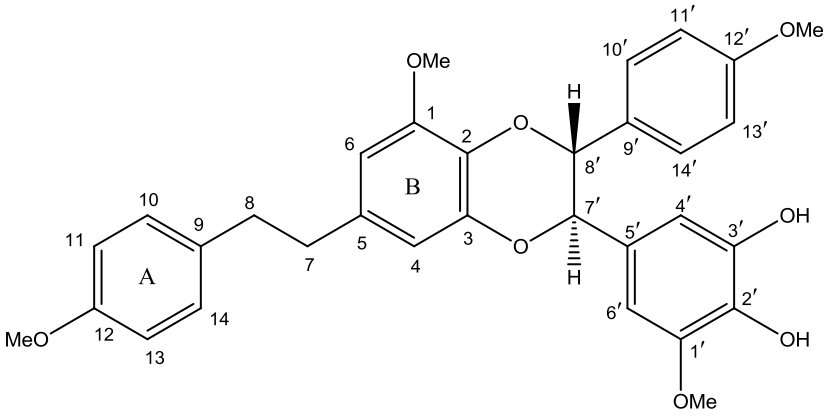
Compound DS03 was obtained as a brown amorphous solid. Its specific optical rotation $[\alpha]_D^{20}$ is -30.0° (c = 0.05, MeOH). The HR-ESI spectrum (Figure 12) showed a sodium-adduct molecular ion $[M+Na]^+$ *m/z* at 567.2001, and its molecular formula was determined as $C_{32}H_{32}O_8$.

The ^{1}H NMR spectrum of compound DS03 (Figure 13 and Table 4) exhibited four methoxyl groups at δ_H 3.67 (3H, s, 1′-MeO) and 3.74 (9H, s, 1-MeO, 12-MeO, 12′-MeO). Additional NMR signals were observed for two methylene groups at δ_H 2.83 (2H, m) and 2.83 (2H, m); two oxygenated methine protons at δ_H 4.85 (2H, d, 8.0); On ring A, the ^{1}H NMR spectrum showed four protons at δ_H 6.83 (2H, d, *J*=8.4 Hz, H-11, H-13) and δ_H 7.15 (2H, d, *J*=8.4 Hz, H-10, H-14). In the aromatic region of ring B, the ^{1}H NMR spectrum showed protons at δ_H 6.47 (2H, br s, H-4, H-6).

The ^{13}C NMR spectrum (Figure 14 and Table 4) showed 12 aromatic methines (δ_C 103.3, 105.0, 108.6, 109.2, 113.3, 113.6 and 129.3), 12 aromatic quaternary carbons (δ_C 127.6, 129.3, 132.1, 133.8, 134.1, 144.4, 145.0, 147.7, 148.9, 158.0 and 159.7 ppm), four methoxyls (δ_C 54.5, 54.5, 55.3 and 55.5), two aliphatic methylenes (δ_C 36.8 and 37.7) and two aliphatic methines (δ_C 79.6 and 80.3). The skeleton of compound DS03 was identified as a bisbibenzyl derivative with two hydroxyl and four methoxyl groups.

The HMBC correlations (Figure 15) at H-4/C-2, 3, 6, 7; H-4′/C-2′, 3′, 5′, 7′ and H-8′/C-7′, 10′, 14′ indicated that DS03 contained a 1,4-dioxane ring at C-2/C-8′ and C-3/C-7′. The relative configurations of the chiral centers of dioxane ring were deduced as *trans* form the coupling constant $J_{7',8'}$=8.0 Hz.

On basis of the ^{1}H- and ^{13}C-NMR data, coumpound DS03 was identified as dendrocandin I [**43**]. This compound was originally discovered from *Dendrobium candidum* (Li *et al.* 2009).



Dendrocandin I [**43**]

Table 4 NMR spectral data of compound DS03 (in acetone-d_6) and dendrocandin I (in CD_3OD)

Position	Compound DS03		Dendrocandin I[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	148.9	-	149.9
2	-	132.1	-	133.3
3	-	144.4	-	145.7
4	6.47 (br s)	109.2	6.45 (br s)	110.7
5	-	134.1	-	135.6
6	6.47 (br s)	105.0	6.36 (br s)	106.5
7	2.83 (m)	37.7	2.79 (m)	39.1
8	2.83 (m)	36.8	2.82 (m)	38.2
9	-	133.8	-	135.1
10	7.15 (d, 8.4)	129.3	7.08 (d, 8.5)	130.5
11	6.83 (d ,8.4)	113.3	6.81 (d, 8.5)	114.7
12	-	158.0	-	159.4
13	6.83 (d ,8.4)	113.3	6.81 (d, 8.5)	114.7
14	7.15 (d, 8.4)	129.3	7.08 (d, 8.5)	130.5
1′	-	147.7	-	149.2
2′	-	133.8	-	135.3
3′	-	145.0	-	146.3
4′	6.39 (br s)	108.6	6.30 (d, 1.5)	109.4
5′	-	127.6	-	128.7
6′	6.31 (br s)	103.3	6.13 (br s)	104.5
7′	4.85 (d, 8.0)	80.3	4.70 (d, 8.0)	82.0
8′	4.85 (d, 8.0)	79.6	4.70 (d, 8.0)	81.7
9′	-	129.3	-	130.3
10′	7.15 (d, 8.4)	129.3	7.04 (d, 8.5)	130.2
11′	6.81 (d, 8.4)	113.6	6.79 (d, 8.5)	114.5
12′	-	159.7	-	161.2
13′	6.81 (d, 8.4)	113.6	6.79 (d, 8.5)	114.5
14′	7.15 (d, 8.4)	129.3	7.04 (d, 8.5)	130.2
1-OMe	3.74 (s)	54.5	3.75 (s)	55.7
12-OMe	3.74 (s)	54.5	3.75 (s)	54.5
1′-OMe	3.67 (s)	55.5	3.64 (s)	55.5
12′-OMe	3.74 (s)	55.3	3.74 (s)	55.3

[a]Li et al., 2009

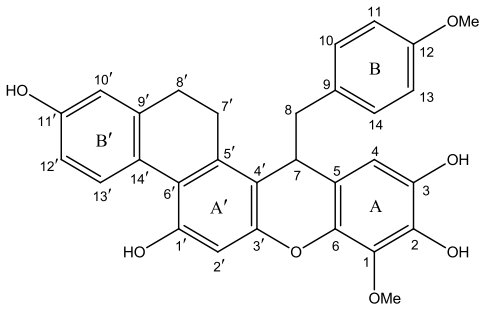
1.4 Structure elucidation of compound DS04

Compound DS04 was obtained as a red amorphous solid. Its specific optical rotation $[\alpha]_D^{20}$ is -11.3° (*c*=0.05, MeOH). The HR-ESI-MS of this compound (Figure 16) showed an $[M+Na]^+$ at *m/z* 521.1585, suggesting the molecular formula $C_{30}H_{26}O_7$. The IR spectrum (Figure 17) showed absorption bands for OH groups (3367 cm^{-1}), aromatic rings (2917,1510 cm^{-1}), methylene (1467 cm^{-1}) and ether (1246 cm^{-1}) functionalities. The UV absorptions (Figure 18) at 227 and 283 nm were suggestive of a bibenzyl-dihydrophenanthrene structure.

The ^1H NMR spectrum of compound DS04 (Figure 19 and Table 5) exhibited nine aromatic proton signals at δ_H 6.34 (1H, s, H-4), 6.55 (1H, s, H-2′), 6.57 (1H, d, *J*=8.5 Hz, H-10), 6.63 (1H, d, *J*=8.5 Hz, H-13), 6.69 (1H, dd, *J*=8.0,2.5 Hz, H-12′), 6.71 (br s) and 8.23 (1H, d, *J*=8.0 Hz, H-13′) and resonances for two methoxyls at δ_H 3.67 (3H, s, 12-MeO) and 3.76 (3H, s, 1-MeO). The aliphatic protons at δ_H 2.61 (2H, m, H-8′), 2.81 (2H, m, H-8), 2.61, 2.85 (1H each, m, H-7′) and 4.32 (1H, t, *J* = 6.0 Hz, H-7), which showed HSQC correlations to the carbon atoms (Figure 21) at δ_H 30.8 (C-8′), 45.1 (C-8), 25.9 (C-7′) and 39.0 (C-7), respectively, indicated a bibenzyl-dihydrophenanthrene skeleton. Comparison of the ^1H and ^{13}C NMR data of DS04 (Figures 19-20 and Table 5) with those of dendrofalconerol A (DS05), a bis-bibenzyl compound earlier isolated from *D. falconeri* (Sritularak and Likhitwitayawuid 2009), revealed that the bibenzyl unit (rings A and B) of DS04 was similar to that of DS05. Compound DS04 had ring A of the bibenzyl part connected to ring A′ of the dihydrophenanthrene part through a methane bridge and an ether linkage, as shown by the HMBC correlations (Figure 22

and Table 5) from H-7 to C-4 (δ_C 109.8), C-6 (δ_C 140.1), C-9 (δ_C 131.2), C-3′ (δ_C 152.3) and C-5′ (δ_C 138.3).

On ring A, H-4 (δ_H 6.34, 1H, s) showed a NOESY cross peak with H-7 (δ_H 4.32, 1H, *t*, *J* = 6 Hz) (Figure 23), and HMBC correlations with C-2 (δ_C 137.7), C-6 (δ_C 140.1) and C-7 (δ 39.0). The NMR signal for 1-MeO protons appeared at δ 3.76 (3H, s). For ring B, the ^{1}H NMR spectrum exhibited signals for a pair of doublets at δ_H 6.57 (2H, d, *J* = 8.5 Hz, H-10, H-14) and 6.63 (2H, d, *J* = 8.5 Hz, H-11, H-13). The presence of a methoxy group at C-12 (δ_C 3.67) was confirmed by its NOESY interaction with H-11 (H-13). With regard to ring B′ of the dihydrophenanthrene unit, an ABM splitting system consisting of a double doublet at δ_H 6.69 (*J* = 8.0, 2.5 Hz, H-12′), a doublet at δ_H 8.23 (*J* = 8.0 Hz, H-13′) and a broad singlet at δ 6.71, together with the HMBC correlation of H-10′ with C-8′ (δ_C 30.8), suggested the presence of a hydroxyl group at C-11′. This was supported by the NOESY correlation of H-10′ and H_2-8′ and the HMBC correlation of H-13′ with C-11′ (δ_C 156.3). The ^{1}H NMR resonance at δ_H 6.55 (s) was assigned to H-2′ of ring A′ on the basis of its 3-bond couplings to C-4′ (δ_C 114.7) and C-6′ (δ_C 118.7). Based on the above spectral evidence, the structure of DS04 was established as shown, and the compound was given the trivial name dendrosignatol [**259**]. (Mittraphab et al., 2016)



Dendrosignatol [**259**]

Table 5 NMR data of compound DS04 (in acetone-d_6)

Position	δ_H (mult., *J* in Hz)	δ_C	HMBC (correlation with ^{1}H)
1	-	136.7	1-OMe
2	-	137.7	4
3	-	141.8	4*
4	6.34 (s)	109.8	7
5	-	117.3	7*, 8
6	-	140.1	4, 7
7	4.32 (t, 6.0)	39.0	4, 8*
8	2.81 (m)	45.1	7*, 10, 14
9	-	131.2	7, 11, 13
10	6.57 (d, 8.5)	131.5	8, 14
11	6.63 (d, 8.5)	114.7	13
12	-	159.1	10, 11*, 13*, 14, 12-OMe
13	6.63 (d, 8.5)	114.7	11
14	6.57 (d, 8.5)	131.5	8, 10
1′	-	154.1	1′-OH, 2′*
2′	6.55 (s)	102.9	-
3′	-	152.3	2′*, 7
4′	-	114.7	2′, 7*, 8, 7′
5′	-	138.3	7, 8′
6′	-	118.7	1′-OH, 2′, 13′
7′	2.85 (m), 2.61 (m)	25.9	8′*
8′	2.61 (m)	30.8	7′*, 10′
9′	-	139.9	7′, 13′
10′	6.71 (br s)	114.6	8′, 12′
11′	-	156.3	13′
12′	6.69 (dd, 8.0, 2.5)	113.4	10′
13′	8.23 (d, 8.0)	130.4	-
14′	-	125.9	8′, 10′, 12′
1-MeO	3.76 (s)	61.2	-
12-MeO	3.67 (s)	55.3	-
1′-HO	8.60 (s)	-	-

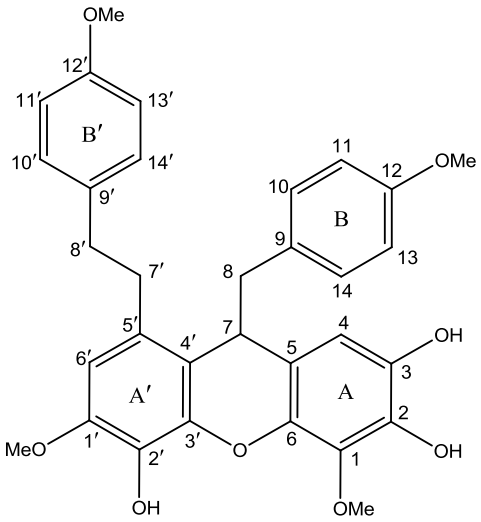
*Two-bonding coupling

1.5 Structure determination of compound DS05

Compound DS05 was obtained as a brown amorphous powder. Its HR-ESI-MS (Figure 24) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 567.2040, suggesting the molecular formula $C_{32}H_{32}O_8$.

In the aliphatic region of the ^{1}H-NMR spectrum (Figure 25 and Table 6), the following proton signals were observed: a methine proton at δ_H 4.09 (dd, *J* = 5.7, 6.9, H-7); three pairs of methylene groups at δ_H 2.74-2.83 (m, H-8), 2.65-2.71 (m, H-8), 2.87-2.90 (m, H-7′), 2.78-2.86 (m, H-7′) and 2.80-2.86 (m, H-8′); four methoxy groups at δ_H 3.70 (s, MeO-12), 3.73 (s, MeO-12′), 3.81 (s, MeO-1′) and 3.89 (s, MeO-1).

The ^{13}C-NMR (Figure 26 and Table 6) and DEPT 135 (Figure 29) spectra displayed 32 signals, corresponding to four aromatic methoxy groups, ten aromatic CH groups, three methylene groups, one aliphatic CH group, and 14 aromatic quaternary carbons. From the constitutional formula, compound DS05 was proposed to be a bis-bibenzyl structure with three OH and four MeO groups. On ring A the proton at δ_H4.09 (dd, *J* = 5.7, 6.9, H-7) displayed a NOESY interaction (Figure 28) with the proton at δ_H 6.13 (s, H-4). For ring A′, the proton at δ_H 6.65 (s, H-6′) displayed a NOESY cross peak with the proton at δ_H 3.81 (s, MeO-1′). The HMBC spectrum (Figure 27) showed correlations from the proton at δ_H 4.09 (dd, *J*=5.7, 6.9, H-7) to C-4, 5, 6 and 9. On basis of the ^{1}H- and ^{13}C-NMR data, coumpound DS03 was identified as dendrofalconerol A [**61**] which was previously reported from *Dendrobium falconeri* (Sritularak et al., 2009).



Dendrofalconerol A [**61**]

Table 6 NMR spectral data of compound DS05 (in acetone-d_6) and dendrofalconerol A (in acetone-d_6)

Position	Compound DS05		Dendrofalconerol A [a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	136.4	-	136.8
2	-	136.0	-	137.3
3	-	140.8	-	141.6
4	6.13 (s)	108.9	6.14 (s)	109.7
5	-	118.2	-	117.8
6	-	139.1	-	139.9
7	4.09 (dd, 5.7, 6.9)	38.7	4.09 (dd, 5.5,7.0)	39.6
8	2.74-2.83 (m)	44.5	2.76-2.82 (m)	45.4
	2.65-2.71 (m)		2.66-2.72 (m)	
9	-	131.6	-	131.6
10	6.60 (d, 8.4)	131.5	6.61 (d, 8.5)	131.3
11	6.68 (d, 8.4)	131.9	6.67 (d, 8.5)	113.9
12	-	158.2	-	159.1
13	6.68 (d, 8.4)	131.9	6.67 (d, 8.5)	113.9
14	6.60 (d, 8.4)	133.1	6.61 (d, 8.5)	131.3
1′	-	146.3	-	147.1
2′	-	133.8	-	134.0
3′	-	141.5	-	142.3
4′	-	118.2	-	119.1
5′	-	129.3	-	129.5
6′	6.65 (s)	107.6	6.65 (s)	108.5
7′	2.87-2.90 (m)	33.6	2.86-2.90 (m)	34.4
	2.78-2.86 (m)		2.79-2.85 (m)	
8′	2.80-2.86 (m)	36.7	2.73-2.84 (m)	37.5
9′	-	136.5	-	134.6
10′	7.13 (d, 8.4)	130.5	7.12 (d, 8.5)	130.2
11′	6.82 (d, 8.4)	113.1	6.82 (d, 8.5)	114.5
12′	-	158.1	-	158.9
13′	6.82 (d, 8.4)	113.1	6.82 (d, 8.5)	114.5
14′	7.13 (d, 8.4)	130.5	7.12 (d, 8.5)	130.2
1-MeO	3.89 (s)	60.3	3.89 (s)	61.2
1′-MeO	3.81 (s)	55.6	3.82 (s)	56.6
12-MeO	3.70 (s)	54.5	3.70 (s)	55.3
12′-MeO	3.73 (s)	54.5	3.73 (s)	55.4

[a]Sritularak et al., 2009

2. Free radical scavenging activity

The MeOH extract of *Dendrobium signatum* was found to possess significant antioxidant activity, showing 90% DPPH reduction at 100 µg/mL. The *n*-Butanol and H_2O extracts showed free radical scavenging activity with 70% and 60%, respectively. The free radical scavenging effects of the pure compounds were assessed in two assays, the DPPH radical scavenging activity assay (Likhitwitayawuid et al., 2006) and the superoxide radical scavenging activity assay (Chatsumpun et al., 2010). DPPH test is based on the ability of the sample to discolor 1,1,-diphenyl-2-picrylhydrazyl radical. Superoxide radical scavenging activity assay is based on the inhibition of photochemical reduction of nitroblue tetrazolium (NBT) in the riboflavin-light-NBT system. Each compound was first tested at a concentration of 100 µg/mL. An IC_{50} value was determined if the compound showed more than 50% inhibition. Quercetin (Sigma) and Trolox® were used as positive controls. The results are summarized in Table 7.

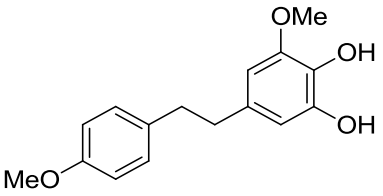
Table 7 Free radical scavenging activity of compounds isolated from *D. signatum*

Compounds	DPPH reduction		NBT reduction	
	%Inhibition at 100 µg/mL	IC_{50}(µM)	%Inhibition at 100 µg/mL	IC_{50}(µM)
MeOH extract	90	nd	80	nd
DS01 [**39**]	95.57	13.05 ± 1.28	81.27	51.17 ± 11.71
DS02 [**2**]	86.40	8.29 ± 0.71	74.67	13.85 ± 6.02
DS03 [**43**]	92.95	12.91 ± 2.89	66.50	58.23 ± 11.94
DS04 [**259**]	88.49	62.49 ± 4.04	88.37	9.30 ± 4.44
DS05 [**61**]	86.85	9.43 ± 0.62	81.78	15.32 ± 4.32
Quercetin	96.65	6.57 ± 0.03	nd	nd
Trolox®	97.93	10.95 ± 0.13	60.42	319.61 ±38.19

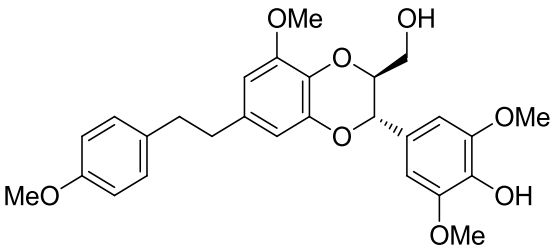
nd = not determined

As seen in Table 7, five pure compounds were evaluated for the ability to scavenge DPPH and superoxide radicals. Compounds DS01-DS05 exhibited DPPH radical scavenging activity with IC_{50} values 13.05, 8.29, 12.91, 62.49 and 9.43 µM, respectively, as compared with quercetin and Trolox® (IC_{50} values 6.57 and 10.95 µM, respectively). It can be seen that DS01-DS03 and DS05 exhibited DPPH radical scavenging activity in the same range as quercetin and Trolox®. In addition, these compounds also exhibited superoxide radical scavenging activity showing IC_{50} values of 51.17, 13.85, 58.23, 9.30 and 15.32 µM, respectively, with potency higher than that of Trolox® (IC_{50} values 319.61 µM). The result clearly showed that DS04 is the most efficient scavenger against the superoxide anion. DS01-DS05 all have several phenolic

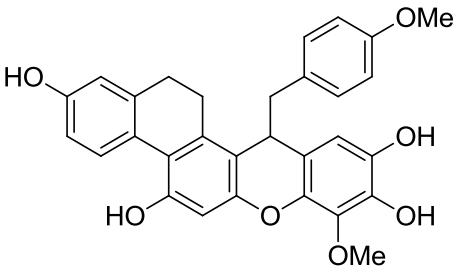
groups. This was in accordance with the previous report that indicated the phenolic groups played an important role in antioxidant activity (Zhang et al., 2007).



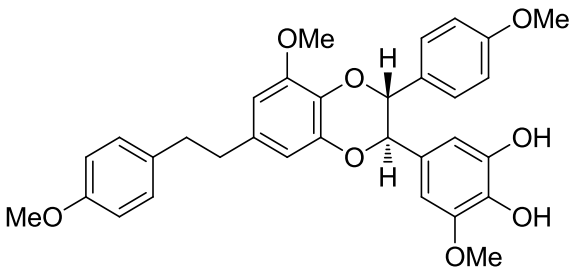
DS01 [**39**]



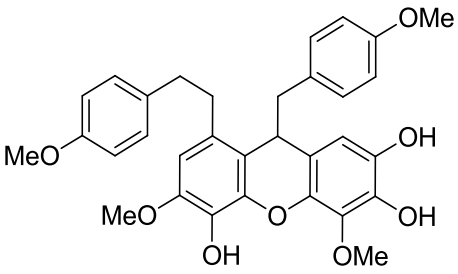
DS02 [**2**]



DS04 [**259**]



DS03 [**43**]

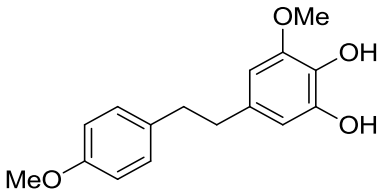


DS05 [**61**]

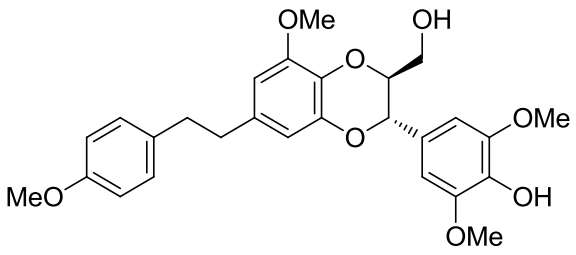
CHAPTER V

CONCLUSION

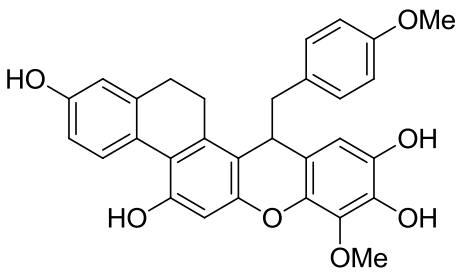
In this study, a new bibenzyl dihydrophenanthrene derivative named dendrosignatol [**259**] and four known compounds, which included 3,4-dihydroxy-5,4′ dimethoxybibenzyl [**39**], dendrocandin B [**2**], dendrocandin I [**43**] and dendrofalconerol A [**61**], were isolated from the MeOH extract of *Dendrobium signatum* Rchb.f. (Orchidaceae). These isolated compounds were evaluated for free radical scavenging activity. All compounds exhibited significant activity against both DPPH and superoxide free radicals.



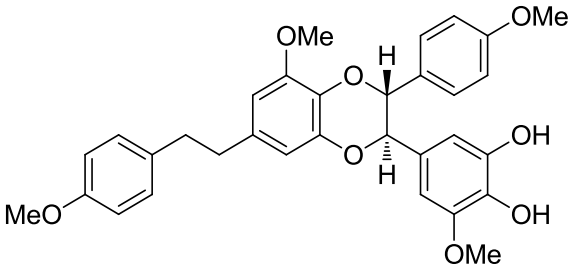
3,4-dihydroxy-5,4′ dimethoxybibenzyl [**39**]



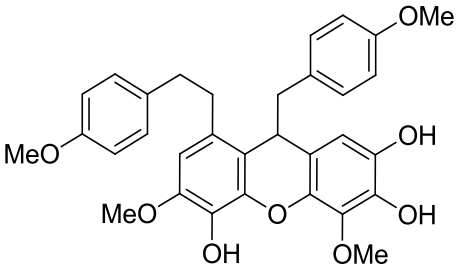
Dendrocandin B [**2**]



Dendrosignatol [**259**]



Dendrocandin I [**43**]



Dendrofalconerol A [**61**]

Regarding the chemical structures of the isolates, it should be noted that all of them contain a 3,4,5,4′-tetraoxygenated bibenzyl unit, appearing as a monomer [**39**], dimers [**43**, **61** and **259**] and a monomer with a phenylpropanoid unit [**2**]. The chemical data obtained in this study should be useful for further chemotaxonomic studies of *Dendrobium* plants.

When the DPPH free radical scavenging activities of these compounds [**2**, **39**, **43**, **61** and **259**] were compared, it was found that the new compound dendrosignatol [**259**] showed the lowest activity. This weak antioxidant property might result from the ring cyclization of one of the bibenzyl units. However, this partial structure seemed to enhance the superoxide scavenging activity of [**259**]. It is interesting to note that all of the bibenzyl compounds isolated in this study showed stronger superoxide scavenging activity than Trolox. Compound [**39**] and its dimer [**43**] exhibited lower activity than rfthe other bibenzyls for unclear reasons. Nevertheless, the free radical scavenging activities observed in this investigation indicated that *D. signatum* is a potential source of natural antioxidants.

APPENDIX

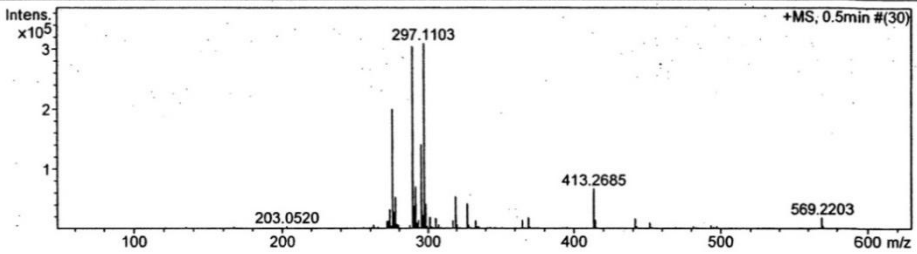
Mass Spectrum List Report

Analysis Info

Analysis Name	OSCUBS570805005.d	Acquisition Date	8/5/2014 3:36:42 PM
Method	MKE_tune_low_positive_20130204.m	Operator	Administrator
Sample Name	DS01	Instrument	micrOTOF 72
	DS01		

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Corrector Fill	79 V
Scan Range	n/a	Capillary Exit	180.0 V	Set Pulsar Pull	406 V
Scan Begin	50 m/z	Hexapole RF	90.0 V	Set Pulsar Push	388 V
Scan End	3000 m/z	Skimmer 1	45.5 V	Set Reflector	1300 V
		Hexapole 1	25.0 V	Set Flight Tube	9000 V
				Set Detector TOF	1910 V



#	m/z	I	I %	S/N	FWHM	Res.
1	271.1296	12971	4.2	184.6	0.0423	6413
2	272.1269	14116	4.6	199.6	0.0416	6540
3	273.1433	32637	10.6	458.7	0.0440	6215
4	275.1607	199709	64.6	2771.9	0.0433	6362
5	276.1639	27886	9.0	384.5	0.0394	7016
6	277.1730	53250	17.2	729.8	0.0430	6446
7	278.1767	8261	2.7	112.4	0.0439	6342
8	289.1416	304515	98.5	3884.9	0.0448	6453
9	290.1450	38912	12.6	493.4	0.0432	6722
10	291.1564	70223	22.7	885.5	0.0436	6678
11	292.1592	10706	3.5	134.1	0.0454	6429
12	293.1708	14662	4.7	182.6	0.0472	6214
13	295.0949	140920	45.6	1737.9	0.0438	6742
14	296.0984	23349	7.5	286.2	0.0434	6820
15	297.1103	309286	100.0	3772.0	0.0451	6589
16	298.1134	42104	13.6	510.5	0.0441	6758
17	301.1411	19938	6.4	237.7	0.0444	6784
18	305.1471	17918	5.8	209.1	0.0708	4309
19	317.1736	14325	4.6	157.1	0.0461	6885
20	319.0935	53983	17.5	586.9	0.0450	7087
21	320.0967	7732	2.5	83.5	0.0461	6938
22	327.1209	41899	13.5	438.1	0.0457	7162
23	333.1622	14089	4.6	143.1	0.0562	5933
24	365.1073	14947	4.8	158.7	0.0512	7128
25	369.1325	19203	6.2	206.8	0.0513	7201
26	413.2685	67237	21.7	854.0	0.0566	7299
27	414.2706	14703	4.8	187.2	0.0564	7350
28	441.2994	17174	5.6	245.7	0.0613	7202
29	451.3213	10173	3.3	152.3	0.0670	6734
30	569.2203	18963	6.1	545.3	0.0882	6456

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Figure 3 Mass spectrum of compound DS01

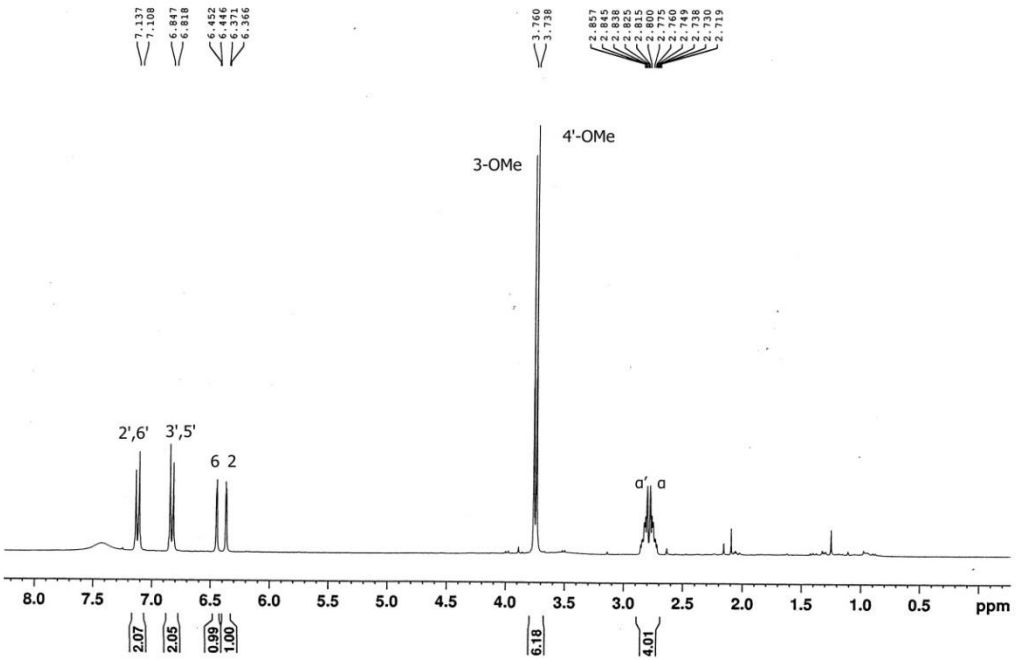


Figure 4 ^{1}H-NMR (300 MHz) spectrum of compound DS01 (in acetone-d_6)

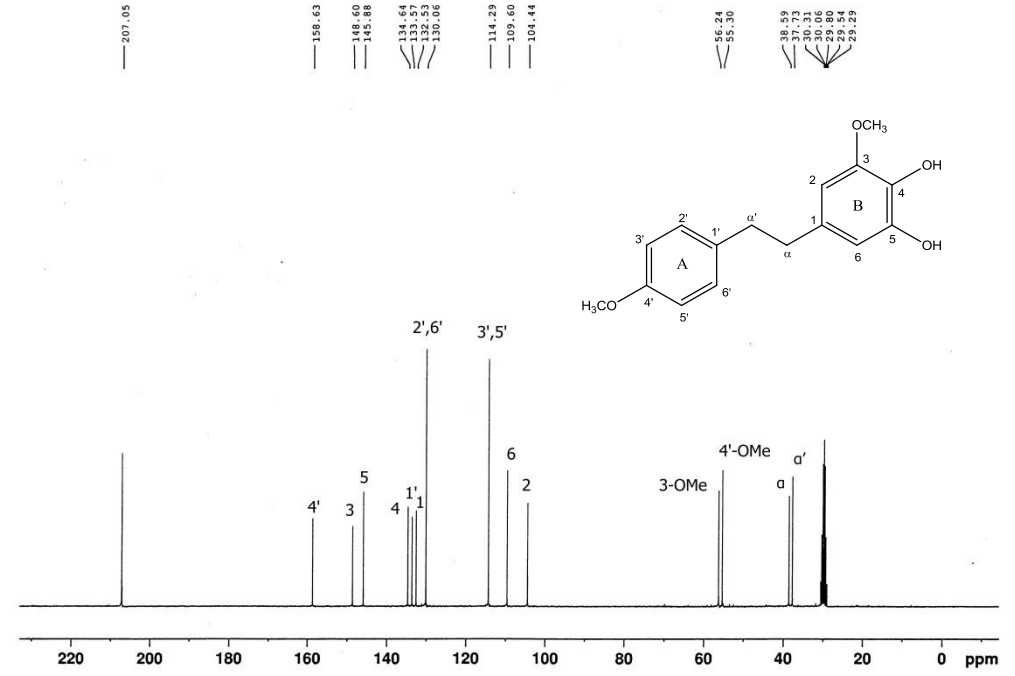


Figure 5 ^{13}C-NMR (75 MHz) spectrum of compound DS01 (in acetone-d_6)

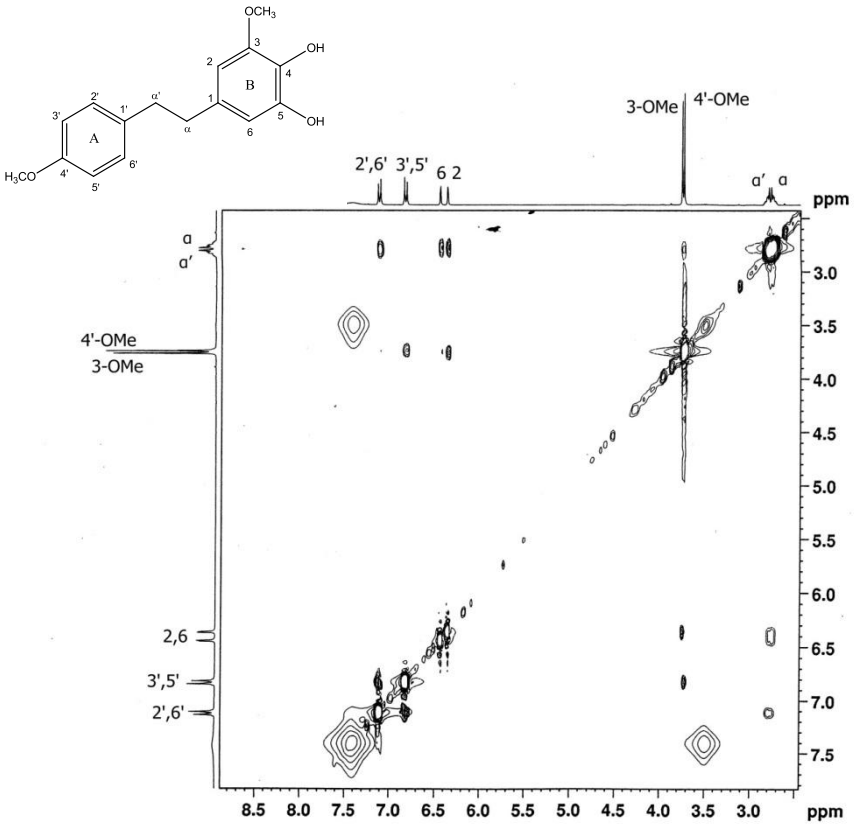


Figure 6 NOESY spectrum of compound DS01 (in acetone-d_6)

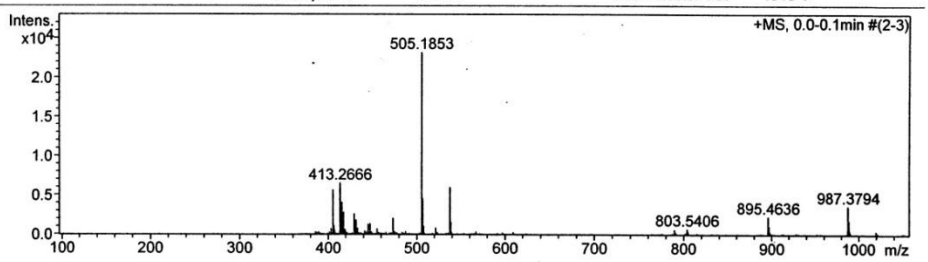
Mass Spectrum List Report

Analysis Info

Analysis Name	OSCUBS571223001.d	Acquisition Date	12/23/2014 12:30:30 PM
Method	Natee20130403.m	Operator	Administrator
Sample Name	DS02	Instrument	micrOTOF 72
	DS02		

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Corrector Fill	79 V
Scan Range	n/a	Capillary Exit	150.0 V	Set Pulsar Pull	406 V
Scan Begin	50 m/z	Hexapole RF	400.0 V	Set Pulsar Push	388 V
Scan End	3000 m/z	Skimmer 1	54.4 V	Set Reflector	1300 V
		Hexapole 1	21.4 V	Set Flight Tube	9000 V
				Set Detector TOF	1910 V



#	m/z	I	I %	S/N	FWHM	Res.
1	403.2066	732	3.2	143.3	0.0492	8193
2	405.1545	5638	24.4	1093.5	0.0455	8907
3	406.1584	1107	4.8	213.3	0.0426	9538
4	413.2666	6513	28.1	1208.1	0.0437	9459
5	414.2707	1448	6.3	266.9	0.0410	10110
6	415.2109	4054	17.5	744.1	0.0445	9326
7	416.2152	836	3.6	152.5	0.0437	9514
8	417.2242	2818	12.2	511.6	0.0445	9378
9	418.2270	677	2.9	122.2	0.0424	9861
10	419.2280	583	2.5	104.7	0.0724	5787
11	429.1897	2582	11.2	440.9	0.0468	9165
12	430.1927	610	2.6	103.4	0.0432	9963
13	431.2026	1805	7.8	305.2	0.0465	9277
14	433.2155	749	3.2	125.2	0.0511	8473
15	445.1845	1251	5.4	197.8	0.0459	9708
16	447.2003	1360	5.9	213.1	0.0470	9511
17	455.2054	691	3.0	104.4	0.0463	9837
18	473.1807	2062	8.9	288.8	0.0498	9502
19	505.1853	23148	100.0	2871.0	0.0509	9931
20	506.1885	4553	19.7	562.4	0.0503	10056
21	507.1945	1054	4.6	129.6	0.0578	8777
22	521.1650	829	3.6	96.9	0.0567	9195
23	537.2092	5981	25.8	664.9	0.0546	9848
24	538.2125	1586	6.9	175.8	0.0528	10199
25	789.3506	624	2.7	103.3	0.0813	9703
26	803.5406	697	3.0	113.4	0.0680	11820
27	895.4636	2275	9.8	331.9	0.0788	11371
28	896.4643	1066	4.6	155.1	0.0844	10621
29	987.3794	3600	15.6	547.0	0.0820	12048
30	988.3840	1768	7.6	268.8	0.0843	11726

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Figure 7 Mass spectrum of compound DS02

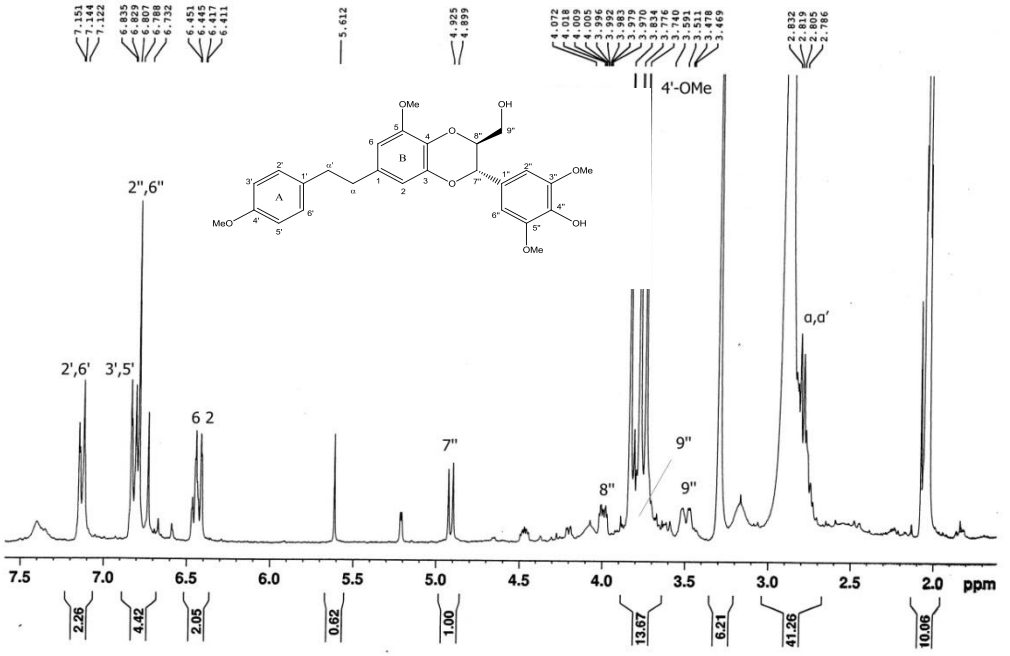


Figure 8 ^{1}H-NMR (300 MHz) spectrum of compound DS02 (in acetone-d_6)

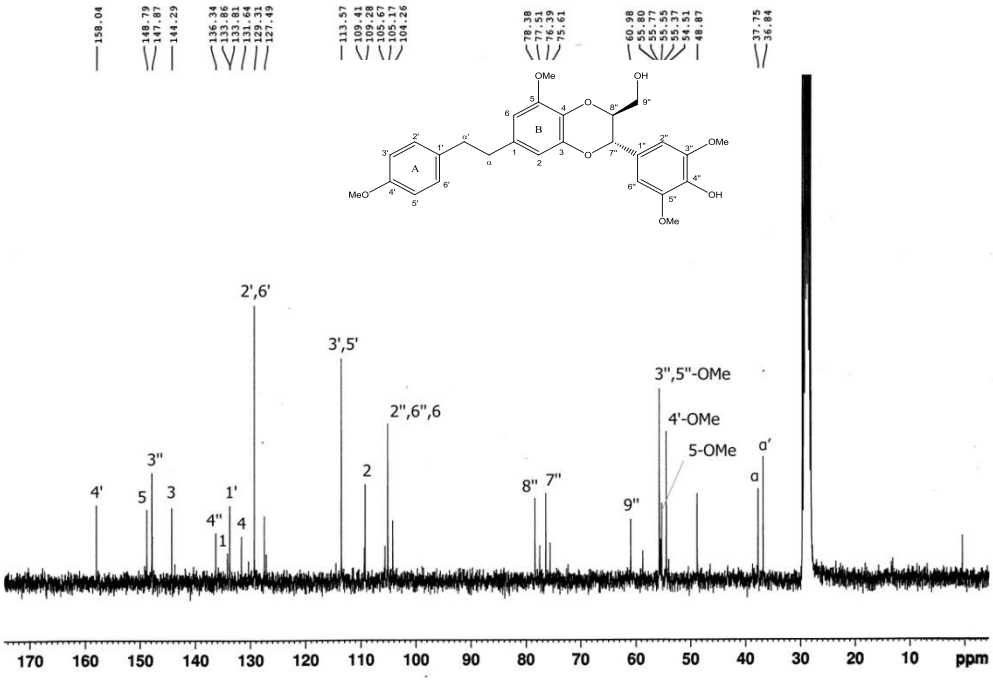


Figure 9 ^{13}C-NMR (75 MHz) spectrum of compound DS02 (in acetone-d_6)

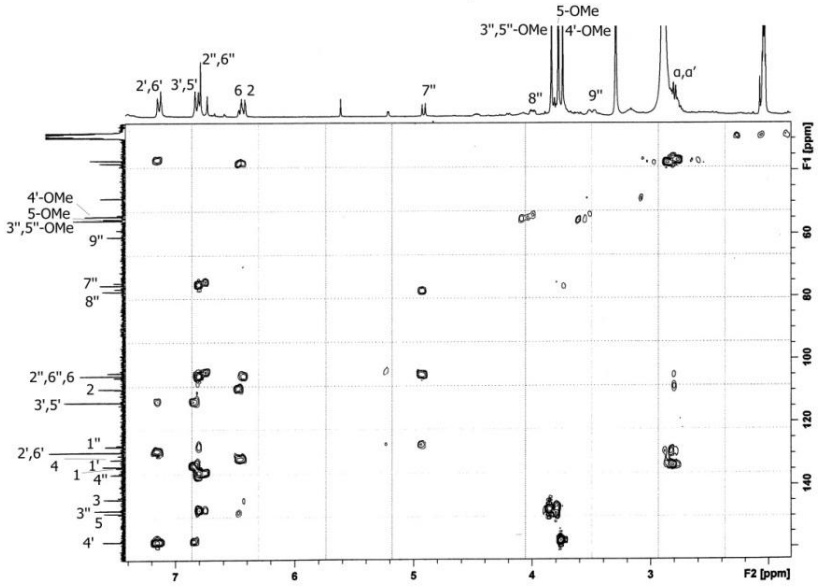


Figure 10 HMBC spectrum of compound DS02 (in acetone-d_6)

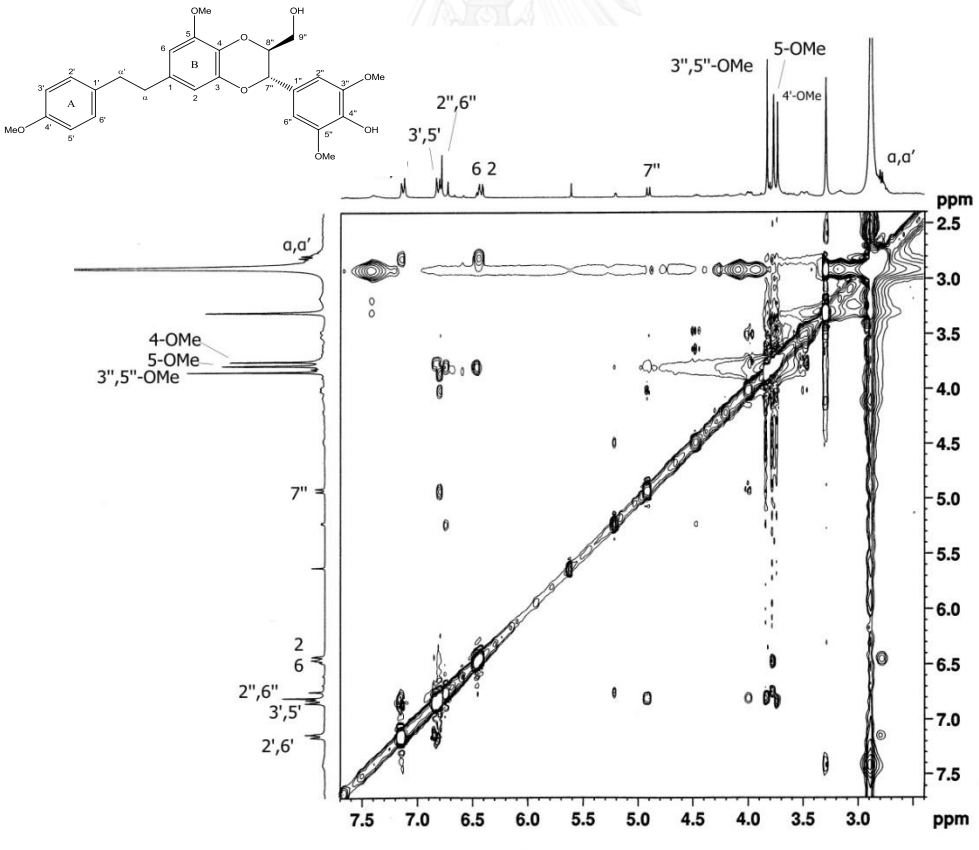


Figure 11 NOESY spectrum of compound DS02 (in acetone-d_6)

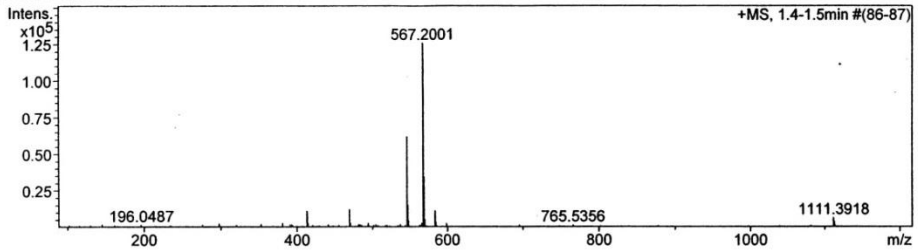
Mass Spectrum List Report

Analysis Info

Analysis Name	OSCU5810050011.d	Acquisition Date	10/5/2015 10:35:23 AM
Method	MKE_tune_wide_20130204.m	Operator	Administrator
Sample Name	DS03	Instrument	micrOTOF 72
	DS03		

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Corrector Fill	92 V
Scan Range	n/a	Capillary Exit	150.0 V	Set Pulsar Pull	409 V
Scan Begin	50 m/z	Hexapole RF	400.0 V	Set Pulsar Push	391 V
Scan End	3000 m/z	Skimmer 1	54.4 V	Set Reflector	1300 V
		Hexapole 1	22.3 V	Set Flight Tube	9000 V
				Set Detector TOF	1980 V



#	m/z	I	I %	S/N	FWHM	Res.
1	196.0487	1830	1.5	26.8	0.0118	16678
2	297.6841	1923	1.5	26.0	0.0137	21742
3	353.2663	2385	1.9	30.1	0.0573	6165
4	381.2956	2925	2.3	34.2	0.0535	7132
5	391.1609	1994	1.6	22.6	0.0721	5427
6	393.2956	2204	1.8	24.9	0.0536	7338
7	413.2695	11383	9.1	123.5	0.0635	6510
8	414.2716	2958	2.4	31.8	0.0643	6447
9	441.3125	2063	1.6	20.7	0.1050	4202
10	469.3318	12416	9.9	118.8	0.0726	6463
11	470.3354	3120	2.5	29.5	0.0822	5719
12	481.3597	2178	1.7	19.9	0.0758	6354
13	483.3438	2017	1.6	18.4	0.0788	6131
14	494.2547	3024	2.4	27.1	0.0708	6980
15	504.4833	2020	1.6	17.6	0.0160	31480
16	536.3050	2161	1.7	17.7	0.0841	6376
17	545.2176	62225	49.5	529.3	0.0808	6746
18	546.2212	15551	12.4	132.2	0.0918	5947
19	547.2151	4731	3.8	39.9	0.0848	6454
20	565.1847	3093	2.5	27.0	0.0938	6028
21	567.2001	125692	100.0	1122.8	0.0869	6527
22	568.2020	34570	27.5	309.1	0.0870	6534
23	569.2070	5643	4.5	50.1	0.0887	6420
24	583.1755	11462	9.1	105.7	0.0862	6764
25	584.1853	3833	3.0	35.1	0.0875	6677
26	598.2760	2815	2.2	26.5	0.0913	6554
27	1111.3918	6578	5.2	109.8	0.1702	6531
28	1112.3881	4247	3.4	70.8	0.1662	6692
29	2351.9357	2660	2.1	54.8	0.0314	74845
30	2352.2873	3119	2.5	64.3	0.0328	71612

Figure 12 Mass spectrum of compound DS03

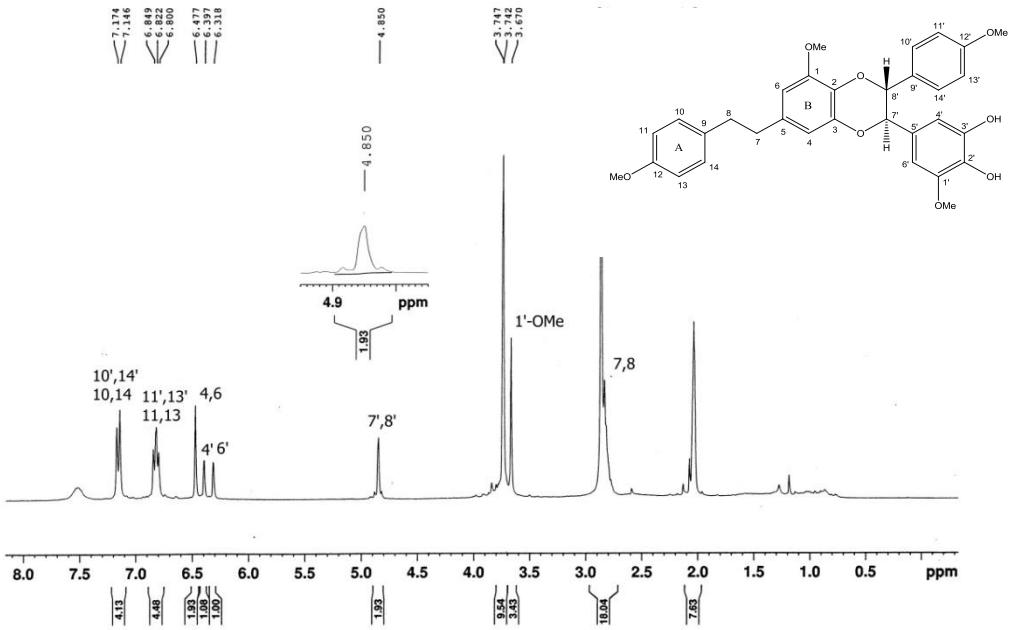


Figure 13 ^{1}H-NMR (300 MHz) spectrum of compound DS03 (in acetone-d_6)

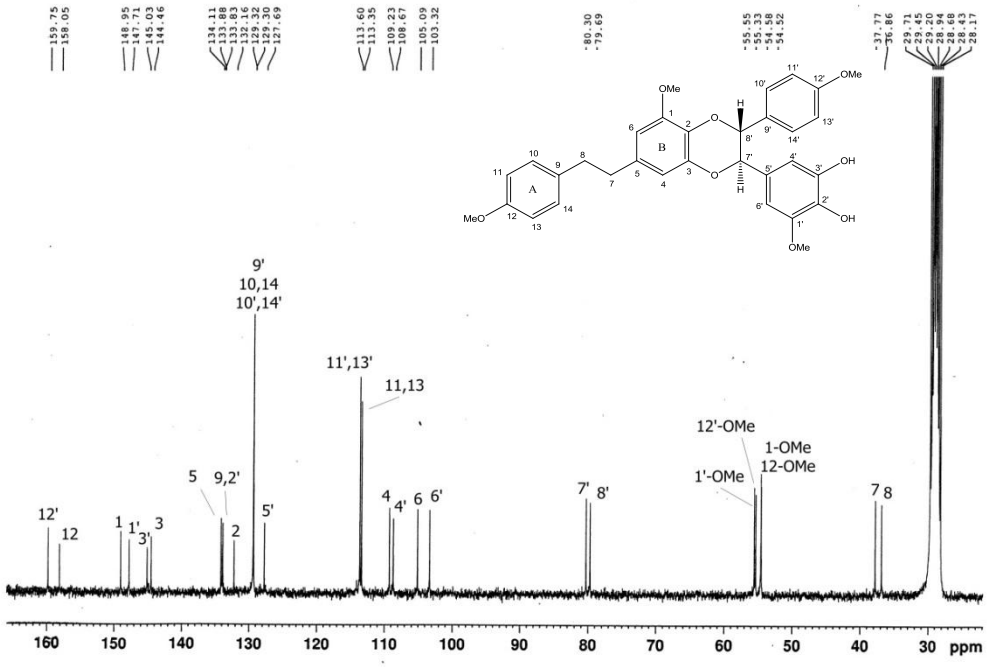


Figure 14 ^{13}C-NMR (75 MHz) spectrum of compound DS03 (in acetone-d_6)

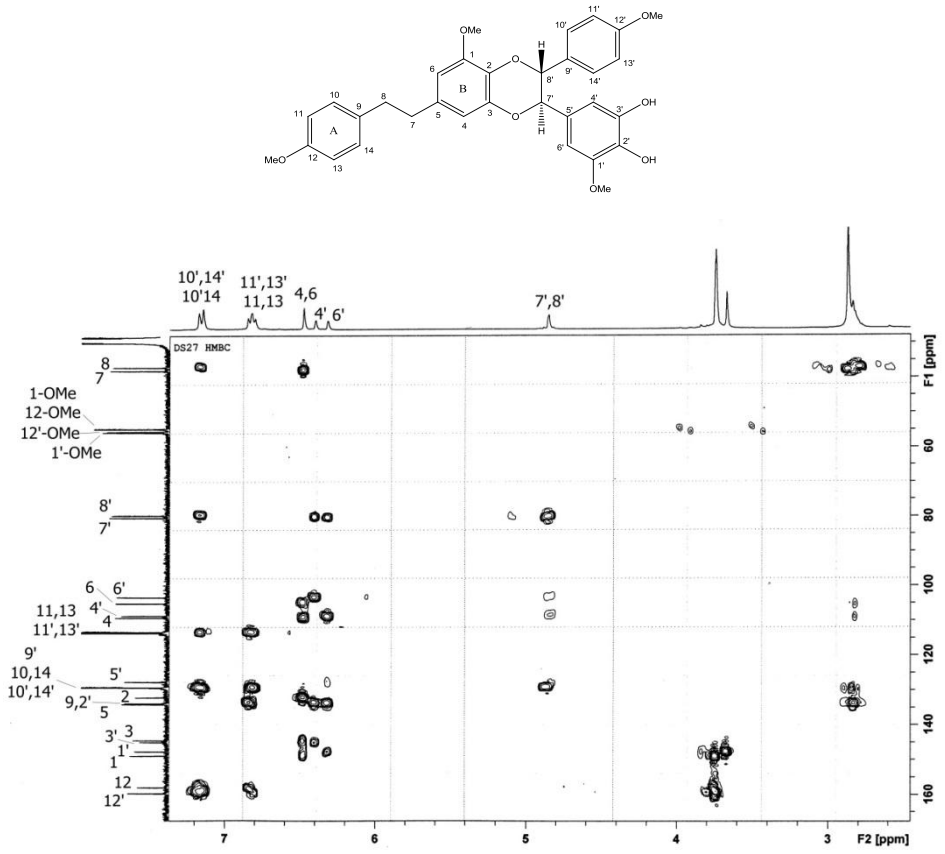


Figure 15 HMBC spectrum of compound DS03 (in acetone-d_6)

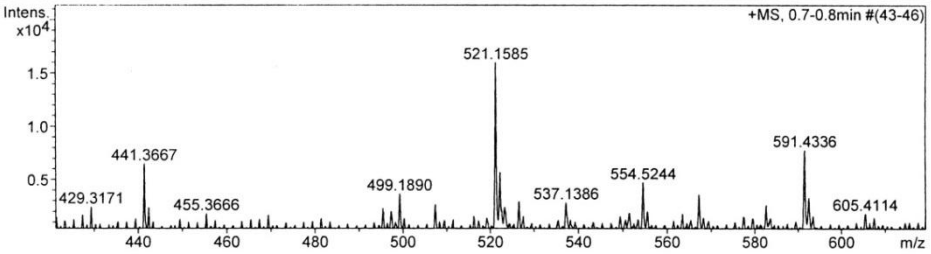
Mass Spectrum List Report

Analysis Info

Analysis Name	OSCU581224001_4.d	Acquisition Date	12/24/2015 3:02:56 PM
Method	MKE_tune_low_positive_20130204.m	Operator	Administrator
Sample Name	DS04	Instrument	micrOTOF 72
	DS04		

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Corrector Fill	50 V
Scan Range	n/a	Capillary Exit	180.0 V	Set Pulsar Pull	337 V
Scan Begin	50 m/z	Hexapole RF	90.0 V	Set Pulsar Push	337 V
Scan End	3000 m/z	Skimmer 1	45.5 V	Set Reflector	1300 V
		Hexapole 1	25.0 V	Set Flight Tube	9000 V
				Set Detector TOF	2300 V



#	m/z	I	I %	S/N	FWHM	Res.
1	421.3989	990	6.4	12.0	0.2527	1668
2	425.3293	805	5.2	9.8	0.1374	3096
3	429.3171	2010	12.9	24.4	0.2132	2013
4	441.3667	6068	39.0	73.7	0.2334	1891
5	451.3384	615	4.0	7.5	0.1513	2983
6	455.3666	1816	11.7	16.9	0.2049	2222
7	465.3873	831	5.3	10.1	0.2193	2122
8	469.3624	1267	8.1	15.4	0.1808	2597
9	481.3576	881	5.7	10.7	0.1424	3381
10	487.3073	406	2.6	4.9	0.1227	3972
11	495.3613	1809	11.6	22.1	0.2127	2329
12	499.1890	2978	19.1	36.3	0.2819	1771
13	507.3005	2245	14.4	27.4	0.2833	1791
14	511.4017	762	4.9	9.3	0.1528	3346
15	516.1920	1149	7.4	14.0	0.1932	2672
16	521.1585	15551	100.0	190.2	0.3066	1700
17	522.1630	5279	33.9	64.6	0.3267	1598
18	527.5282	1159	7.5	14.2	0.2058	2563
19	537.1386	2435	15.7	29.8	0.3755	1430
20	547.3137	519	3.3	6.4	0.1290	4244
21	554.5244	4304	27.7	53.1	0.2896	1915
22	563.4321	1401	9.0	17.4	0.2065	2728
23	569.3618	739	4.7	9.2	0.1794	3174
24	577.3950	996	6.4	12.4	0.0150	38392
25	587.4490	440	2.8	5.5	0.1636	3592
26	591.4336	7357	47.3	92.3	0.3569	1657
27	605.4114	1356	8.7	17.1	0.2990	2025
28	609.3946	400	2.6	5.1	0.1976	3085
29	617.4603	620	4.0	7.9	0.1767	3494
30	619.4514	11155	71.7	141.7	0.3557	1741

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Figure 16 Mass spectrum of compound DS04

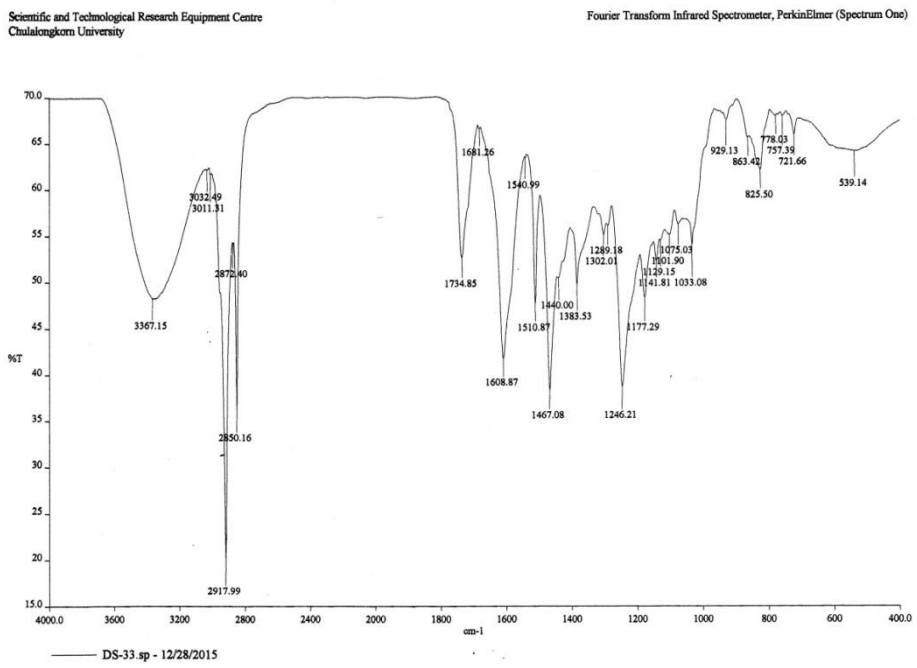


Figure 17 IR spectrum of compound DS04

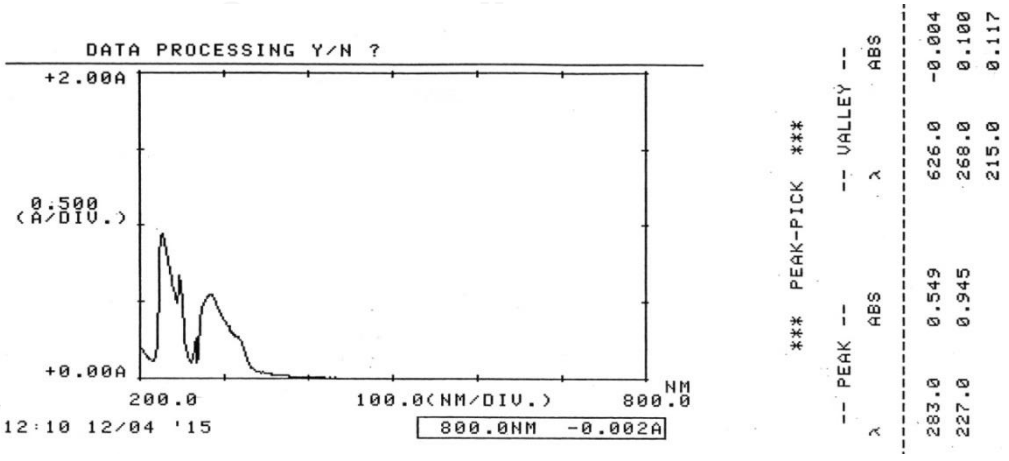


Figure 18 UV spectrum of compound DS04

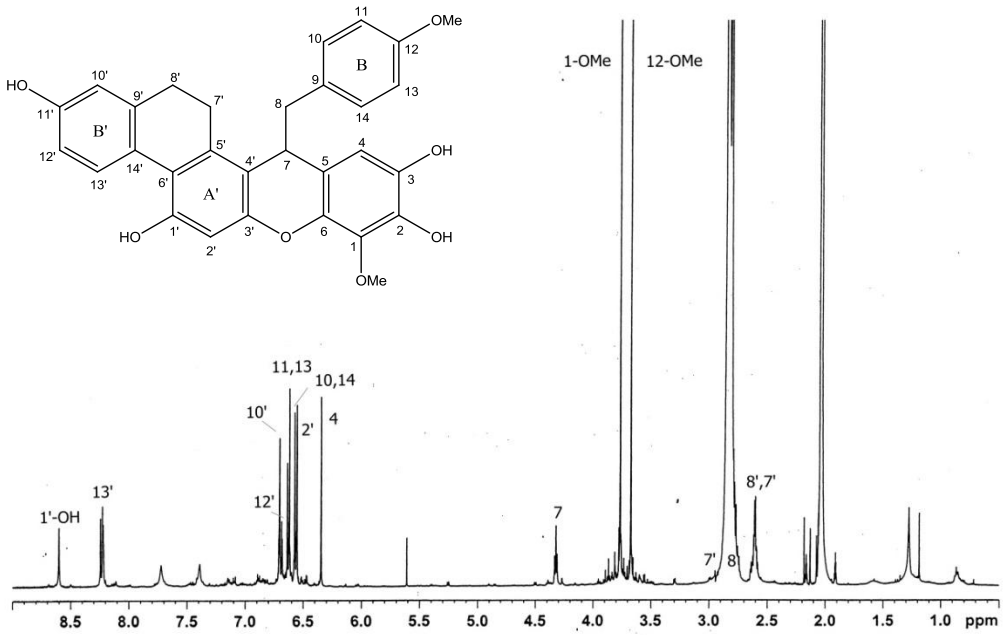


Figure 19 ^{1}H-NMR (500 MHz) spectrum of compound DS04 (in acetone-d_6)

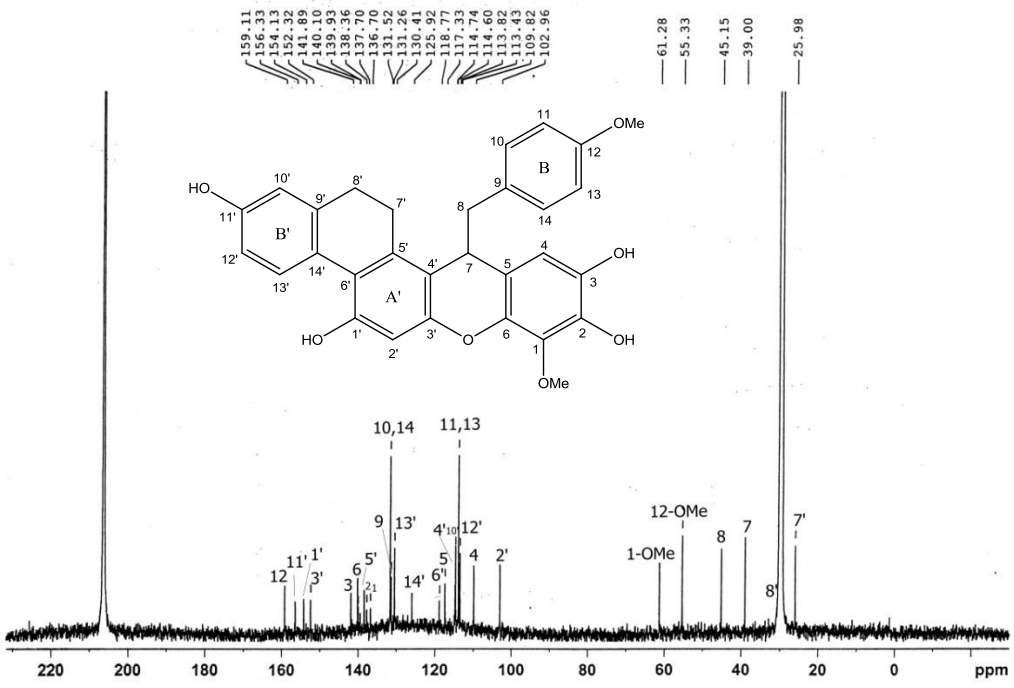


Figure 20 ^{13}C-NMR (125 MHz) spectrum of compound DS04 (in acetone-d_6)

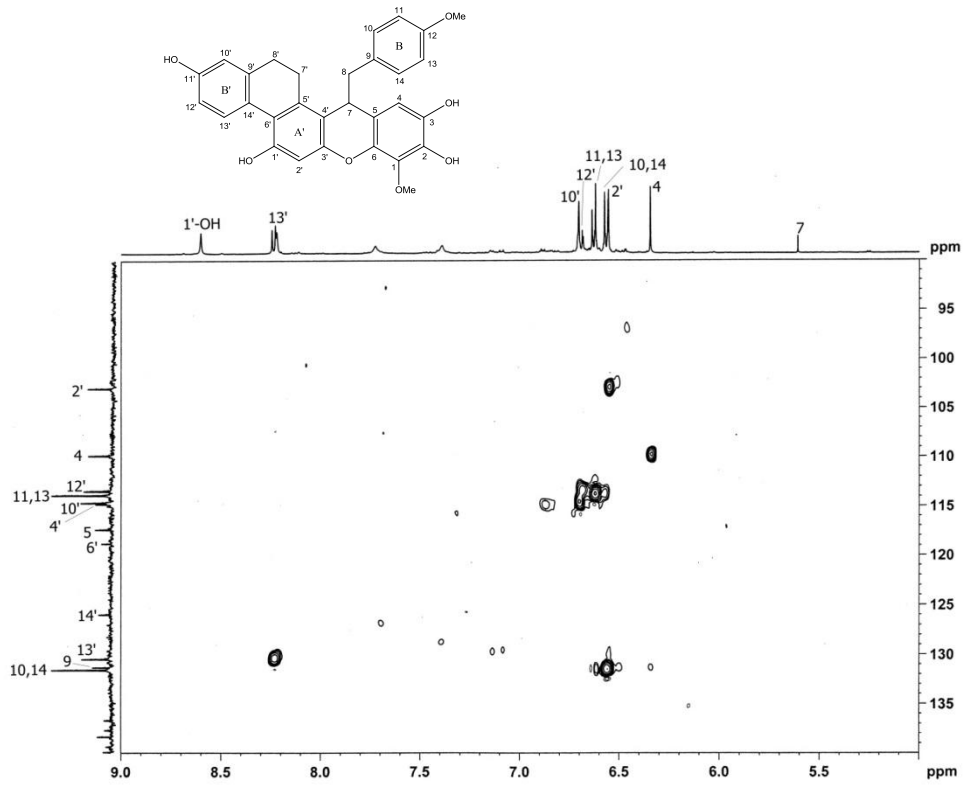


Figure 21 HSQC spectrum of compound DS04 (in acetone-d_6)

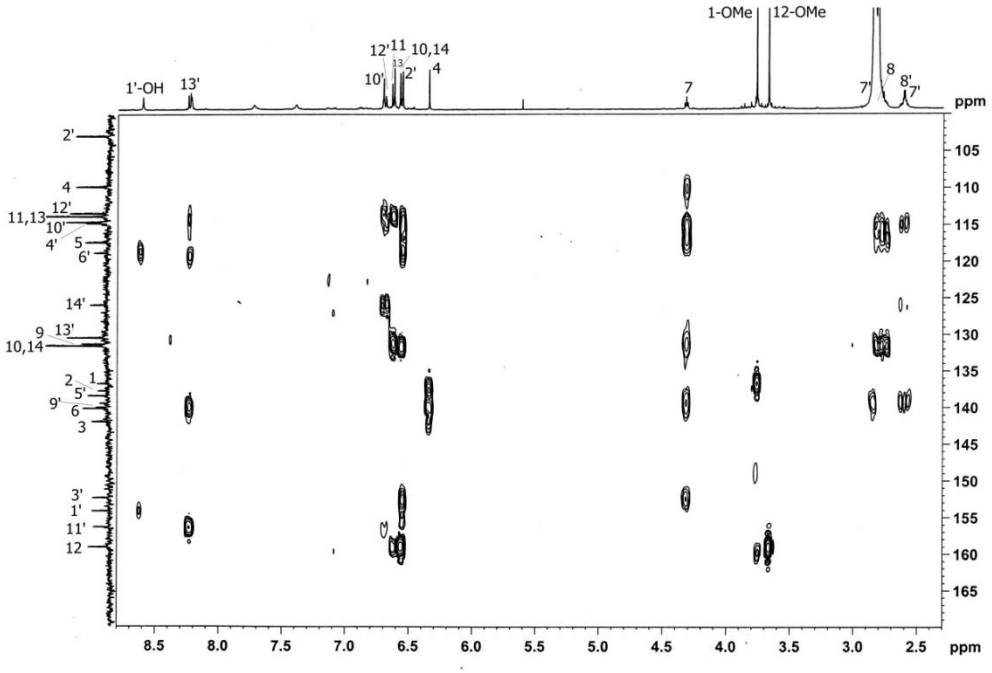


Figure 22 HMBC spectrum of compound DS04 (in acetone-d_6)

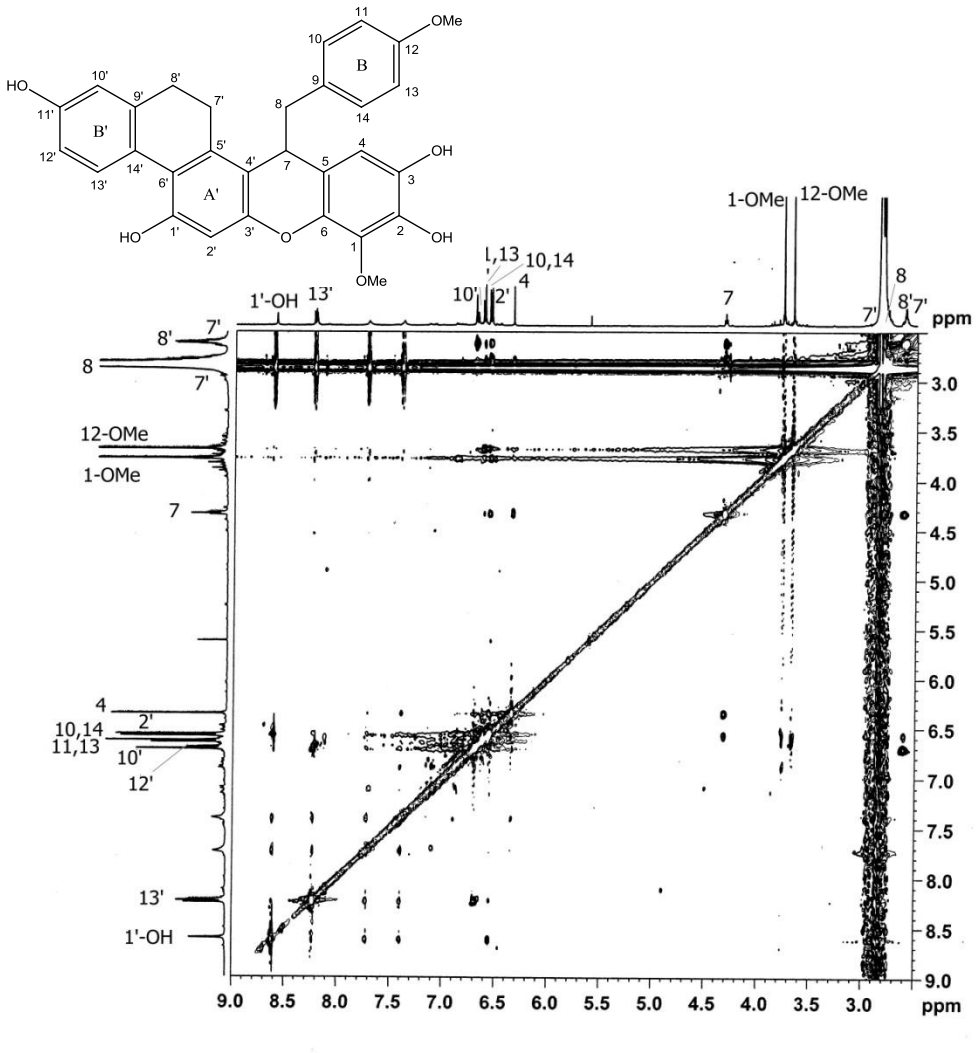


Figure 23 NOESY spectrum of compound DS04 (in acetone-d_6)

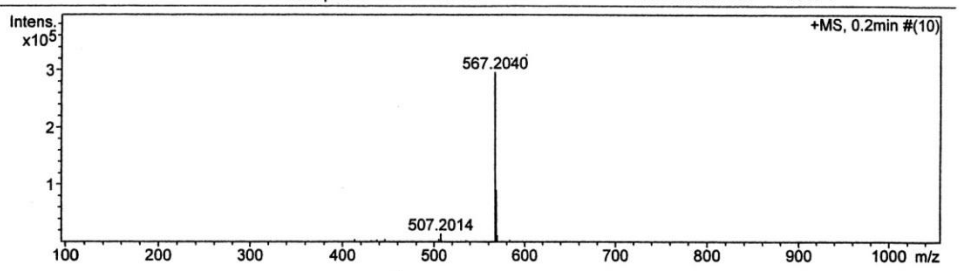
Mass Spectrum List Report

Analysis Info

Analysis Name	OSCUBS5712230051.d	Acquisition Date	12/23/2014 12:48:56 PM
Method	MKE_tune_wide_20130204.m	Operator	Administrator
Sample Name	DS05	Instrument	micrOTOF 72
	DS05		

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Corrector Fill	79 V
Scan Range	n/a	Capillary Exit	180.0 V	Set Pulsar Pull	406 V
Scan Begin	50 m/z	Hexapole RF	400.0 V	Set Pulsar Push	388 V
Scan End	3000 m/z	Skimmer 1	45.0 V	Set Reflector	1300 V
		Hexapole 1	25.0 V	Set Flight Tube	9000 V
				Set Detector TOF	1910 V



#	m/z	I	I %	S/N	FWHM	Res.
1	413.2688	4113	1.4	347.1	0.0399	10349
2	414.2719	874	0.3	73.0	0.0439	9442
3	431.1140	2627	0.9	196.5	0.0463	9306
4	437.1597	3221	1.1	232.1	0.0454	9620
5	438.1656	718	0.2	51.2	0.0469	9348
6	446.1357	4441	1.5	303.5	0.0470	9496
7	447.1401	988	0.3	66.9	0.0478	9358
8	469.3307	1162	0.4	69.8	0.0515	9113
9	473.1700	674	0.2	39.6	0.0555	8524
10	475.1754	1491	0.5	87.0	0.0491	9685
11	477.1888	1554	0.5	89.8	0.0432	11042
12	505.1858	4987	1.7	254.0	0.0509	9933
13	506.1899	1119	0.4	56.5	0.0543	9325
14	507.2014	14641	4.9	739.9	0.0501	10122
15	508.2053	3017	1.0	151.6	0.0536	9475
16	535.1958	2416	0.8	108.8	0.0521	10276
17	536.2002	681	0.2	30.4	0.0560	9576
18	537.2099	2297	0.8	102.7	0.0570	9422
19	538.2124	678	0.2	30.0	0.0525	10255
20	565.1862	1306	0.4	64.0	0.0584	9672
21	567.2040	296211	100.0	14686.5	0.0653	8691
22	568.2065	90144	30.4	4486.2	0.0594	9573
23	569.2080	11662	3.9	582.3	0.0563	10117
24	570.2089	1287	0.4	64.2	0.0496	11503
25	583.1779	3538	1.2	186.3	0.0570	10222
26	584.1823	1095	0.4	57.7	0.0554	10554
27	597.2109	1556	0.5	86.6	0.0609	9812
28	623.2274	718	0.2	44.7	0.0565	11037
29	1111.4118	2531	0.9	441.5	0.0936	11877
30	1112.4144	1624	0.5	283.0	0.0838	13272

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Figure 24 Mass spectrum of compound DS05

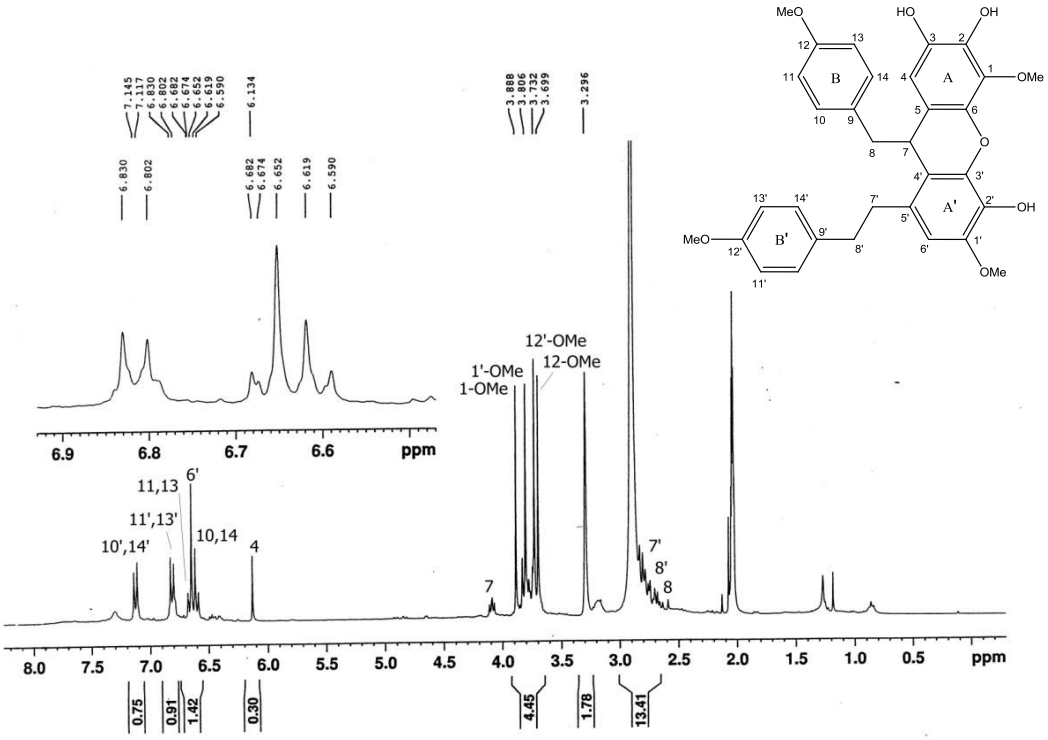

Figure 25 ^{1}H-NMR (300 MHz) spectrum of compound DS05 (in acetone-d_6)

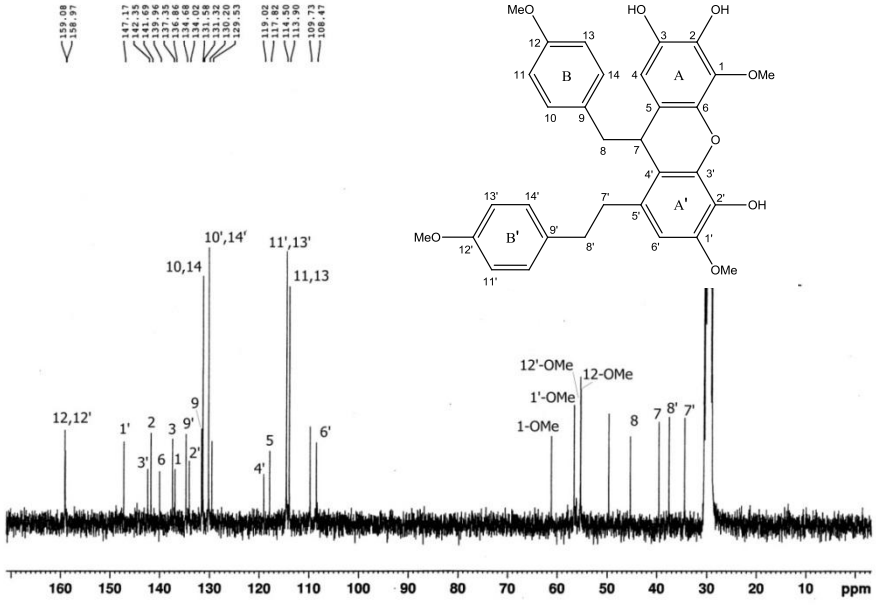

Figure 26 ^{13}C-NMR (75 MHz) spectrum of compound DS05 (in acetone-d_6)

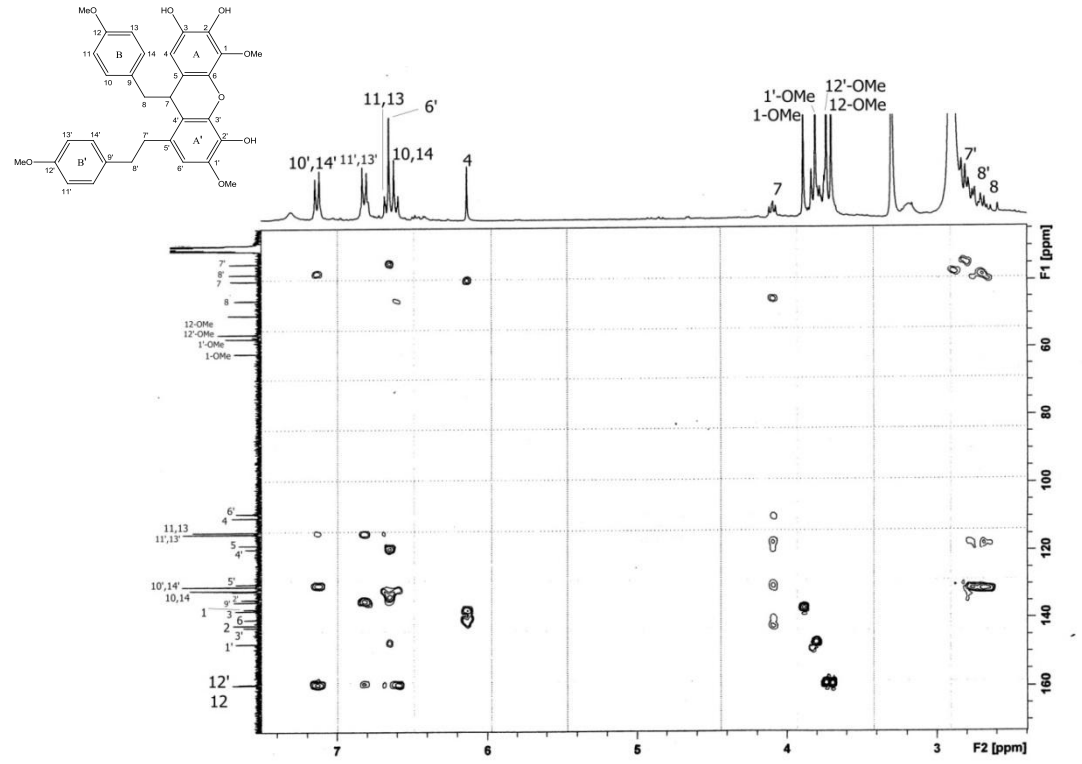

Figure 27 HMBC spectrum of compound DS05 (in acetone-d_6)

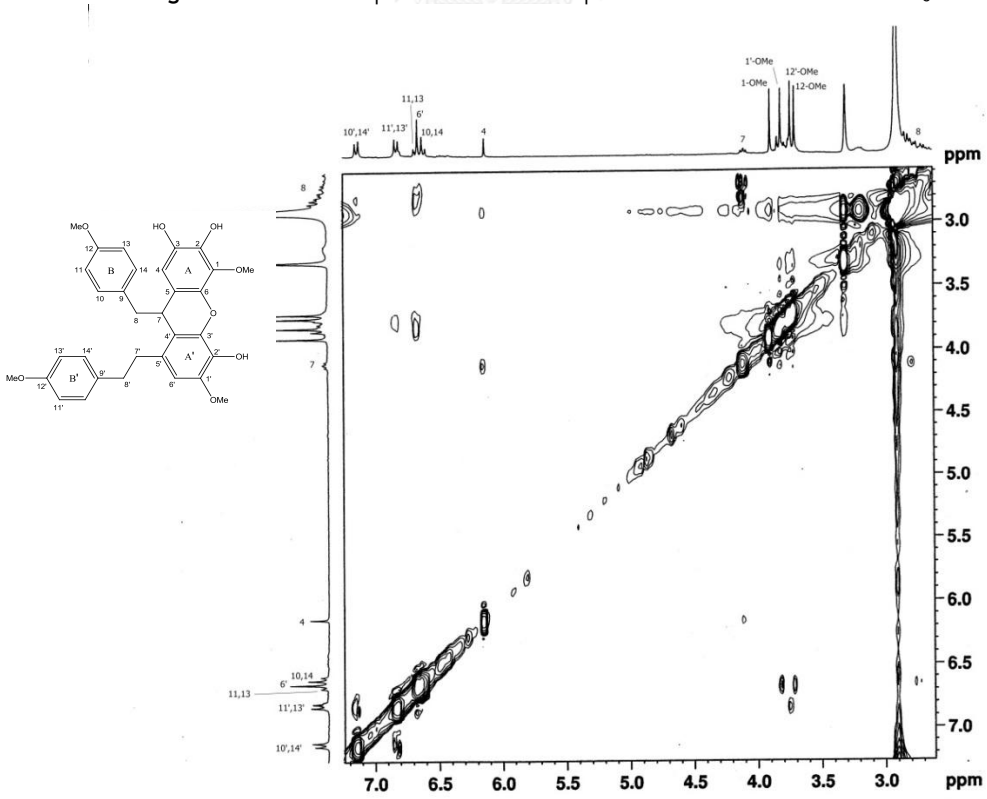

Figure 28 NOESY spectrum of compound DS05 (in acetone-d_6)

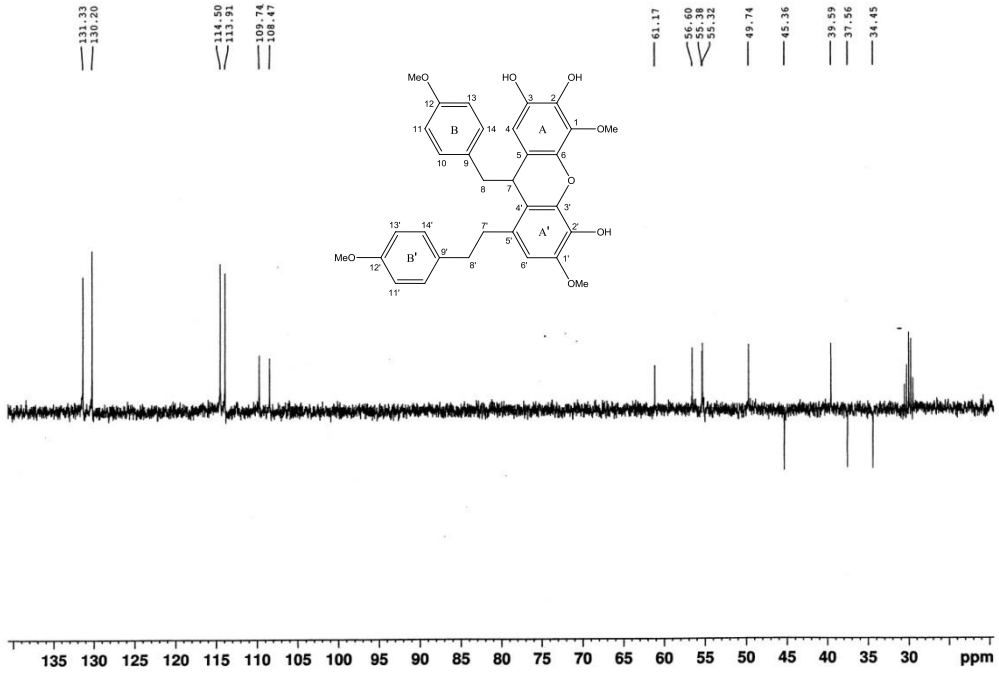

Figure 29 DEPT135 spectrum of compound DS05 (in acetone-d_6)

REFERENCES

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

Blade, A., Claeys, M., Pieters L.A., Wray, V., Vlietinck, A.J. (1991). "Ferulic acid esters from stem bark of *Pavetta owarienis*." Phytochemistry **3**: 1024-1026.

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

Chang, S. J., T.H., and Chen, C.C. (2001). "Constituents from the stems of *Dendrobium clavatum* var. *auranteacum*." Journal of Chinese Medicine **12**: 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**: 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**: 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**: 67-70.

Chen, Y., *et al.* (2008d). "Cytotoxic phenolics from *Bulbophyllum odoratissimum*." Food Cemistry **107**: 169-173.

Chen, Y., Li, J., Wang, L., and Liu, Y. (2008). "Aromatic compounds from *Dendrobium aphyllum*."

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

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

Do, T. D. T., D. Cozzolino, B. Muhlhausler, A. Box and Able, A. J. (2015). "Antioxidant capacity and vitamin E in barley: Effect of genotype and storage." Food Chemistry **187**: 65-74.

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

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

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

Guanghua, Z., Zhanhe, J., Wood, H.P. (2009). "*Dendrobium Swartz.*" Flora of China **25**: 367.

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." 2007 **9**: 165-174.

Gutiérrez, R. M. P. (2010). "Orchids: A review of uses in traditional medicine, its phytochemistry and pharmacology." Journal of Medicinal Plants Research **4**: 592-638.

Ho, C. K., and Chen, C.C. (2003). "Moscatilin from the orchid *Dendrobium loddigesii* is a potential anticancer agent." Cancer Investigation **21**: 729-736.

Honda, C., and Yamaki, M. (2000). "Phenanthrenes from *Dendrobium plicatile*." Phytochemistry **53**: 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**: 535-539.

Hossain, M. M. (2011). "Therapeutic orchids: traditional uses and recent advances." Fitoterapia **82**: 102-140.

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

Hu, J. M., J. J. Chen, H. Yu, Y. X. Zhao and Zhou, J. (2008b). "Two novel bibenzyls from *Dendrobium trigonopus*." Journal of Asian Natural Products Research **10**(7-8): 653-657.

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

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

Hwang, J. S., *et al*. (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**: 3785-3787.

Ito, M., K. Matsuzaki, J. Wang, A. Daikonya, N.-L. Wang, X.-S. Yao and Kitanaka, S. (2010). "New Phenanthrenes and Stilbenes from *Dendrobium loddigesii*." Chem Pharm Bull **58**: 628-633.

Juneja, R. K., Sharma, S.C., and Tandon, J.S. (1985). "A substituted 1,2-diarylethane from *Cymbidium giganteum*." Phytochemistry **24**: 321-324.

Klongkumnuankarn, P., K. Busaranon, P. Chanvorachote, B. Sritularak, V. Jongbunprasert and K. Likhitwitayawuid (2014). "Cytotoxic and Antimigratory Activities of Phenolic Compounds from *Dendrobium brymerianum*." Evidence-Based Complementary and Alternative Medicine **2015**: 1-9.

Lam, Y., T. B. Ng, R. M. Yao, J. Shi, K. Xu, S. C. W. Sze and K. Y. Zhang (2015). "Evaluation of Chemical Constituents and Important Mechanism of Pharmacological

Biology in *Dendrobium* Plants." Evidence-Based Complementary and Alternative Medicine **2015**: 1-25.

Lee, Y. H., Park, J.D., Baek, N.I., Kim, S.I., and Ahn, B.Z. (1995). "*In vitro* and *in vivo* antitumoral phenanthrenes from the aerial parts of *Dendrobium nobile*." Planta Medica **61**: 178-180.

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

Li, Y., W. ChunLan, Y. J. Wang, S.-X. Guo, J.-S. Yang, X.-M. Chen and Xiao, P.-G. (2009). "Three New Bibenzyl Derivatives from *Dendrobium candidum*." Chemical and pharmaceutical bulletin **57**: 218-219.

Li, Y., Wang, C.L., Guo, S.X., Yang, J.S., and Xiao, P.G. (2008). "Two new compounds from *Dendrobium candinum*." Chemical & Pharmaceutical Bulletin **56**: 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., Y. J. Wang, S.-X. Guo, J.-S. Yang, X.-M. Chen and Xiao, P.-G (2009a). "Three new bibenzyl derivatives from *Dendrobium candidum*." Chinese Pharmaceutical Journal **57**(2): 218—219.

Li, Y., Wang, C. L., Y. J. Wang, S.-X. Guo, J.-S. Yang, X.-M. Chen and Xiao, P.-G (2009b). "Four new bibenzyl derivatives from *Dendrobium candidum*." Chemical & 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**: 414-416.

Likhitwitayawuid, K., Klongsiriwet, C., Jongbunprasert, V., Sritularak, B. and Wongseripipatana, S. (2006). "Flavones with Free Radical Scavenging Activity from *Goniothalamus tenuifolius* " Archives of Pharmacal Research **29**: 199-202.

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.

Lu, Y., 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**: 8544-8555.

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

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

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

Majumder, P. L. and Pal, S. (1993). "Cumulatin and tristin, two bibenzyl derivatives from the orchids *Dendrobium cumulatum* and *Bulbophyllum triste*." Phytochemistry **32**: 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**: 657-659.

Ono, M., Ito, Y., Masuoka, C., Koga, H., and Nohara, T. (1995). "Antioxidative constituents from Dendrobii Herba (Stems of *Dendrobium* spp.)." Food Science Technology International **2**: 115-120.

Pan, H., Chen, B., Li, F., and Wang, M. (2012). "Chemical constituents of *Dendrobium denneanum*." Chinese Journal Application Environmental Biology **18**: 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**: 748-754.

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

Shu, Y., Zhang, D.M., and Guo, S.X. (2004). "A new sesquiterpene glycoside from *Dendrobium nobile* Lindl." Journal of Asian Natural Products Research **6**: 311-314.

Singh, S., Singh, A.K., Kumar, M., Pandey, P.K., and Singh, M.C.K. (2012). "Medicinal properties and uses of orchids: a concise review." Elixir Applied Botany **52**: 11627-11634.

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**: 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 Chemica Acta **92**: 740-744.

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

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

Tarapatra, S. K., Rose, S., and Mallik, A.K. (1994). "A new fluorenone derivative from *Dendrobium densiforum*." Journal of Indian Chemistry Society **61**: 1010-1012.

Vaddhanaphuti, N. (2005). A field guide to the wild orchids of Thailand fourth and expanded edition. Chiang Mai, Silkworm Books**:** 125.

Valko, M., C. J. Rhodes, J. Moncol, M. Izakovic and M. Mazur (2006). "Free radicals, metals and antioxidants in oxidative stress-induced cancer." Chemico-Biological Interactions **160**: 1-40.

Wang, H., Zhao, T., and Che, C.T. (1985). "Dendrobine and 3-hydroxy-2-oxodendrobine from *Dendrobium nobile*." Journal of Natural Products **48**: 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**: 903-911.

XiaoMei, C., W. FangFei, W. YunQiang, L. XueLan, W., ChunLan, W. and ShunXing, G. (2012). "Discrimination of the rare medicinal plant *Dendrobium officinale* based on naringenin, bibenzyl, and polysaccharides
" Life Sciences **55**: 1092-1099.

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.

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

Yan Li, Chun-Lun Wang, Shun-Xing Guo, Jun-Shan Yang and P.-G. Xiao (2008). "Two New Compounds from *Dendrobium candidum*." Chemical and pharmaceutical bulletin **56**: 1477-1479.

Yan LI, C.-L. WANG, S.-X. GUO, J.-S. YANG and P.-G. XIAO (2008). "Two New Compounds from *Dendrobium candidum*." Chemical and pharmaceutical bulletin **56**: 1477-1479.

Yang, D., Liang-YanLiu, Z.-Q. Cheng, Feng-QingXu, W.-W. Fan, C.-T. Zi, Fa-WuDong, J. Zhou, Z.-T. Ding and J.-M. Hu (2015). "Five new phenolic compounds from *Dendrobium aphyllum*." Fitoterapia **100**: 11-18.

Yang, H., G. X. Chou, Z. T. Wang, Y. W. Guo, Z. B. Hu and L. S. Xu (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 phenanthrene of *Dendrobium nobile* stems." Journal of Natural Products **70**: 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, Y., Wang, Z., and Xu, L. (2006a). "Phenols and a triterpene from *Dendrobium auranticum* var. *denneanum* (Orchidaceae)." Biochemical Systematics and Ecology **34**: 658-660.

Ye, Q., Qin, G. and Zhao, W. (2002b). "Immunomodulatory sesquiterpene glycosides from *Dendrobium nobile*." Phytochemistry **61**: 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., W. M. Zhao and G. W. Qin (2004). "Lignans from *Dendrobium chrysanthum*." Journal of Asian Natural Products Research **6**(1): 39-43.

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**: 952-956.

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

Zhang, X., 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 & 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.

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 Activit." Journal of Natural Products **64**: 1196-1200.

Zhi-Ming, B., Zheng-Tao W. and Luo-Shan X. (2004). "Chemical Constituents of *Dendrobium moniliforme*." Acta Botanica Sinica **46**: 124-126.

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อาภาพร มิตรภาพ, กิตติศักดิ์ ลิขิตวิทยาวุฒิ, และบุญชู ศรีตุลารักษ์. (2558). องค์ประกอบที่มีฤทธิ์ต้านอนุมูลอิสระจากเอื้องเค้ากิ่ว. การประชุมนำเสนอผลงานวิจัยบัณฑิตศึกษาระดับชาติ มหาวิทยาลัยราชภัฏอุดรธานี ครั้งที่ 9 ประจำปีการศึกษา 2558, วันที่ 19-20 กันยายน 2558; จังหวัดอุดรธานี