FREE RADICAL SCAVENGERS FROM *DENDROBIUM VIRGINEUM*

Mr. Pongsawat Panuthai

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

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พงษ์สวัสดิ์ ปานอุทัย : สารที่มีฤทธิ์ต้านอนุมูลอิสระจากเอื้องนางชี. (FREE RADICAL SCAVENGERS FROM *DENDROBIUM VIRGINEUM*) อ.ที่ปรึกษาหลัก : รศ. ภก. ดร. บุญชู ศรีตุลารักษ์, อ.ที่ปรึกษาร่วม : ศ. ภก. ดร.กิตติศักดิ์ ลิขิตวิทยาวุฒิ

อนุมูลอิสระเป็นโมเลกุลที่ไม่เสถียรและไวต่อการเกิดปฏิกิริยาซึ่งเป็นต้นเหตุความผิดปกติต่าง ๆ ในร่างกาย เช่น ทำให้ยีนส์เกิดการกลายพันธุ์และเป็นสารก่อมะเร็ง งานวิจัยนี้ได้ศึกษาโครงสร้างทางเคมีของสารสกัดที่ได้จากเอื้องนางชี และนำมาทดสอบหาฤทธิ์ต้านอนุมูลอิสระ โดยสามารถแยกสารบริสุทธิ์ได้ทั้งหมด 9 สาร ซึ่งมีสารใหม่ 2 ชนิด ได้แก่ 2,8-dimethoxy-9,10-dihydro-4,5-phenanthrenediol และ 2,5-dimethoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone และสารที่เคยถูกค้นพบแล้ว 7 ชนิด ได้แก่ 2-methoxy-9,10-dihydro-4,5-phenanthrenediol, gigantol, 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone, *p*-coumaric acid, tristin, 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene และ 9,10-dihydro-2,4,7-phenanthrenetriol เมื่อนำสารบริสุทธิ์ทั้ง 9 ชนิดไปทดสอบฤทธิ์ต้านอนุมูลอิสระด้วยวิธี DPPH radical scavenging assay และ superoxide radical scavenging activity assay รวมถึง oxygen radical absorbance capacity assay พบว่า 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene มีฤทธิ์ต้านอนุมูลอิสระสูงที่สุด ซึ่งสารดังกล่าวมีศักยภาพที่จะนำไปศึกษาต่อเพื่อพัฒนาเป็นยารักษาโรคที่เกี่ยวข้องกับอนุมูลอิสระต่อไป

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สาขาวิชา เภสัชศาสตร์และเทคโนโลยี ลายมือชื่อนิสิต .....

ปีการศึกษา 2565 ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

ลายมือชื่อ อ.ที่ปรึกษาร่วม .....

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Pongsawat Panuthai : FREE RADICAL SCAVENGERS FROM *DENDROBIUM VIRGINEUM*. Advisor: Assoc. Prof. BOONCHOO SRITULARAK, Ph.D. Co-advisor: Prof. KITTISAK LIKHITWITAYAWUID, Ph.D.

Free radicals are unstable, highly reactive, molecules which can cause several degenerative diseases such as mutagenesis and carcinogenesis. This research aims to study the chemical constitutents of *Dendrobium virgineum* and their antioxidant activity in 3 different test models including DPPH radical scavenging assay, superoxide radical scavenging activity assay and oxygen radical absorbance capacity assay. Nine compounds were isolated and determined to be two new compounds named 2,8-dimethoxy-9,10-dihydro-4,5-phenanthrenediol and 2,5-dimethoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone, together with seven known compounds, which are 2-methoxy-9,10-dihydro-4,5-phenanthrenediol, gigantol, 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone, *p*-coumaric acid, tristin, 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene and 9,10-dihydro-2,4,7-phenanthrenetriol. The result obtained from the three testing models revealed that 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene showed strongest antioxidant activity. This compound has potential for further development as a preventive agent for free radical-related diseases.

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		Co-advisor's Signature .....

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Pongsawat Panuthai

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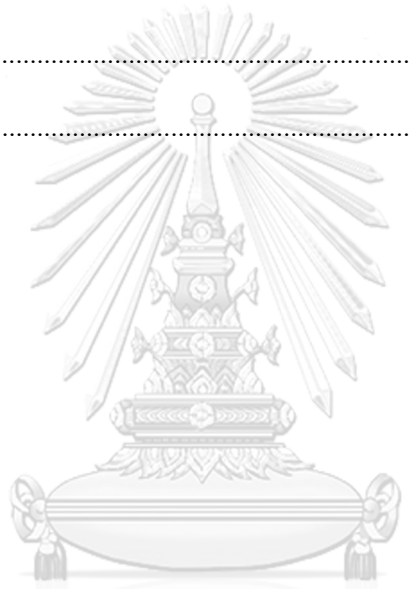

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ABBREVIATIONS AND SYMBOLS

AAPH	=	2,2′-Azobis(2-amidinopropane) dihydrochloride
Acetone-d_6	=	Deuterated acetone
AUC	=	Area under the curve
α	=	Alpha
β	=	Beta
brs	=	Broad singlet
^{13}C NMR	=	Carbon-13 nuclear magnetic resonance
°C	=	Degree Celsius
CD_3OD	=	Deuterated methanol
CAT	=	Catalase
$CDCl_3$	=	Deuterated chloroform
cm	=	Centimeter
d	=	Doublet (for NMR spectra)
D.	=	*Dendrobium*
dd	=	Doublet of doublets (for NMR spectra)
DOP	=	*Dendrobium officinale* polysaccharide
DW	=	Distilled water
DMSO	=	Dimethyl sulfoxide

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DPPH	=	2,2-Diphenyl-1-picrylhydrazyl
ε	=	Molar absorptivity
EDTA	=	Ethylene diamine tetra-acetic acid
ET	=	Electron transfer
EtOAc	=	Ethyl acetate
ɣ	=	Gamma
g	=	Gram
GPx	=	Glutathione peroxidase
GSH	=	Reduced glutathione
^{1}H NMR	=	Proton nuclear magnetic resonance
H_2O	=	Water
HAT	=	Hydrogen atom transfer
HMBC	=	Heteronuclear Multiple Bond Correlation
HR-ESI-MS	=	High-resolution electrospray ionisation mass spectrometry
HSQC	=	Heteronuclear Single Quantum Coherence
Hz	=	Hertz
IC_{50}	=	Half maximal inhibitory concentration
IR	=	Infrared
J	=	Coupling constant
kg	=	Kilogram

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L	=	Liter
LED	=	Light emitting diode
λ	=	Lambda
$[M+H]^+$	=	Hydrogen-adduct molecular ion
$[M-H]^-$	=	Hydrogen-deduct molecular ion
m	=	Multiplet (for NMR spectra)
MeOH	=	Methanol
mg	=	Milligram
MHz	=	Megahertz
min	=	Minute
mL	=	Milliliter
mM	=	Millimolar
MS	=	Mass spectroscopy
m/z	=	Mass to charge ratio
µg	=	Microgram
µL	=	Microlitre
µM	=	Micromolar
NBT	=	Nitro blue tetrazolium
nm	=	Nanometre
nM	=	Nanomolar

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NMR	=	Nuclear magnetic resonance
NOESY	=	Nuclear Overhauser Effect Spectroscopy
O_2	=	Oxygen
OMe	=	Methoxy group
ORAC	=	Oxygen radical absorbance capacity
ppm	=	Part per million
RSA	=	Radical scavenging activity
Rha	=	Rhamnose
ROS	=	Reactive oxygen species
RNS	=	Reactive nitrogen species
s	=	Singlet (for NMR spectra)
SOD	=	Superoxide dismutase
t	=	Triplet (for NMR spectra)
TE	=	Trolox® equivalent
δ	=	Chemical shift
TLC	=	Thin layer chromatography
Trolox®	=	6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid
UV	=	Ultraviolet
ν	=	Wave number

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CHAPTER I

INTRODUCTION

A free radical is atomic or molecular containing at least one unpaired electron. It is capable of existing in nature independently (Halliwell 2006). The existence of unpaired electron makes free radical unstable and highly reactive. It can either acting as an oxidant or a reductant by donating or receiving an electron from other molecules in order to stabilize themselves. Generally, the oxidants are called reactive oxygen species, ROS, or reactive nitrogen species, RNS and they can be categorized into two different types; radicals and non-radicals (Lobo et al. 2010; Phaniendra, Jestadi and Periyasamy 2015). Not only the free radicals can be endogenously produced in human body by general crucial metabolic process such as in mitochondria, xanthine oxidase and injury but they can also be exogenously acquired from many sources, for instance, X-Ray and air pollutants. The majority of free radicals produced by metabolic reaction are reactive oxygen species, ROS, derived from oxygen. They cause a host of degenerative diseases such as mutagenesis, carcinogenesis, cardiovascular disturbances and aging (Lobo et al. 2010; Kedare and Singh 2011; Phaniendra, Jestadi and Periyasamy 2015).

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Typically, endogenous antioxidants are produced to counteract the free radicals. Donating an electron from its molecule and terminating the chain reaction, an antioxidant molecule is able to neutralize a free radical at a time, resulting in slowing down or inhibiting oxidative damage of the target molecule. Ultimately, they can protect the body from various degenerative disorder (Sen et al. 2010). There are two different groups of endogenous antioxidants which are enzymatic and non-enzymatic. Enzymatic antioxidants are, for example, superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx). Non-enzymatic antioxidant included vitamin E, vitamin C and reduced glutathione (GSH) (Sen et al. 2010). Normally, even

though the mitochondria produce substantial amount of $O_2^{\bullet-}$ throughout electron transport chain, the animals possess superoxide dismutase enzyme, SOD, which can neutralize an O_2 into peroxide and oxygen (Halliwell 2006).

The antioxidants are not only produced endogenously, but also obtained exogenously by food and play significant role in protecting the body from oxidative damage. The researches have shown that free radical scavenging antioxidants originating from plant can alleviate the disease caused by oxidative stress (Sen et al. 2010).

Dendrobium is a genus in orchid family that has more than 1,500 species (Fan et al. 2020). They have been proven to have therapeutic properties and have been used as folk medicines for more than 2,300 years (Yeow, Chew and Sreeramanan 2020). The recent review reveals its major benefits as an anticancer, anti-inflammatory, antiangiogenic, immunoenhancing, antidiabetic, antioxidant, hepatoprotective, neuroprotective, antifungal, antimalarial, antiherpes simplex virus, hair growth-promoting, as well as submandibular gland activities (Teixeira da Silva and Ng 2017).

There are more than 150 *Dendrobium* species distributed in Thailand (Smitinand 2014) as shown in **table 1**.

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Table 1 Scientific name and Thai name of Dendrobium species found in Thailand

Scientific name	Thai name
D. acerosum Lindl.	**กล้วยไม้มือนาง** Kluai mai mue nang (Chumphon)
D. aciculare Lindl.	**เอื้องใบเข็ม**
D. acinaciforme Roxb.	**เอื้องยอดสร้อย** Ueang yot soi (Northern)
D. aduncum Lindl.	**N/A**
D. albosanguineum Lindl.	**เอื้องตางัว** Ueang ta ngua (Mae Hong Son)
D. aloifolium (Blume) Rchb.f.	**เอื้องมณี** Ueang mani (Bangkok)

Scientific name	Thai name
D. anceps Sw.	N/A
D. angulatum Lindl.	N/A
D. anosmum Lindl.	**เอื้องสาย** Ueang sai (Chiang Mai, Peninsular)
D. aphyllum (Roxb.) C.E.C. Fisch.	**เอื้องงวงช้าง** Ueang nguang chang (Mae Hong Son)
D. bellatulum Rolfe	**เอื้องแซะภู** Ueng sae phu
D. bensoniae Rchb.f.	**เอื้องสายดอกขาว** Ueng sai dok khaw
D. bicameratum Lindl.	**เอื้องเข็ม** Ueang khem (Northern)
D. bifarium Lindl.	N/A
D. bilobulatum Seidenf.	**กล้วยไม้ก้างปลา** Kluai mai kang pla (General)
D. blumei Lindl.	N/A
D. brevimentum Seidenf.	N/A
D. brymerianum Rchb.f.	**เอื้องคำฝอย** Ueang kham foi (Northern)
D. calicopis Ridl.	N/A
D. capillipes Rchb.f.	**เอื้องคำกิ่ว** Ueang kham kio (Lampang, Phrae)
D. cariniferum Rchb.f.	**เอื้องกาจก** Ueang kachok (Chiang Mai)
D. chittimae Seidenf.	**เอื้องจิตติมา** Ueang chittima (General)
D. christyanum Rchb.f.	**เอื้องแซะภูกระดึง** Ueang sae phu kradueng (Loei)
D. chrysanthum Lindl.	**เอื้องสายมรกต** Ueang sai morakot (Bangkok)
D. chrysotoxum Lindl.	**เอื้องคำ** Ueang kham (Northern)
D. ciliatilabellum Seidenf.	**หวายเขาเขียว** Wai khao khiao (General)
D. clavator Ridl.	N/A
D. compactum Rolfe ex Hackett	**เอื้องข้าวตอก** Ueang khao tok (Northern)
D. compressum Lindl.	**หวายแบนตะนาวศรี** Wai baen tanao si (General)
D. concinnum Miq.	**หางเปีย** Hang pia (Narathiwat)
D. confinale Kerr	N/A

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Scientific name	Thai name
D. cowenii P. O'Byrne & J.J. Verm.	N/A
D. crepidatum Lindl. & Paxton	**เอื้องสายน้ำเขียว** Ueang sai nam khiao (General)
D. cretaceum Lindl.	N/A
D. crocatum Hook.f.	**เอื้องนางนวล** Ueang nang nuan (Peninsular)
D. cruentum Rchb.f.	**เอื้องนกแก้ว** Ueang nok kaeo (Bangkok)
D. crumenatum Sw.	**หวายตะมอย** Wai tamoi (Central, Peninsular)
D. crystallinum Rchb.f.	**เอื้องนางฟ่อน** Ueang nang fon (Chiang Mai)
D. cumulatum Lindl.	**เอื้องสายสี่ดอก** Ueang sai si dok (Northern, Southeastern)
D. curviflorum Rolfe	N/A
D. cuspidatum Lindl.	**เอื้องข้าวตอกปากแหลม** Ueang khao tok pak leam
D. dantaniense Guillaumin	**เอื้องเข็ม** Ueang khem (Chiang Mai)
D. delacourii Guillaumin	**เอื้องดอกมะขาม** Ueang dok ma kham (General)
D. deltatum Seidenf.	N/A
D. denneanum Kerr	N/A
D. densiflorum Lindl.	**เอื้องมอนไข่** Ueang mon khai (Northern)
D. denudans D. Don	**เอื้องสายจำปา** Ueang sai champa (General)
D. devonianum Paxton	**เอื้องเมี่ยง** Ueang miang (Chiang Mai)
D. dickasonii L. O. Williams	**เอื้องเคี้ยะ** Ueang khia (Chiang Mai)
D. dixanthum Rchb.f.	**เอื้องเทียน** Ueang thian (Northern)
D. dixonianum Rolfe ex Downie	**เอื้องข้าวตอกเหลือง** Ueang khao tok lueang
D. draconis Rchb.f.	**เอื้องเงิน** Ueang ngoen (Northern)
D. elliottianum P. O'Byrne	**หวายเจดีย์** Wai chedi (Kanchanaburi)
D. ellipsophyllum Tang & Wang	**เอื้องทอง** Ueang thong (Genaeral)
D. erostelle Seidenf.	N/A
D. erosum (Blume) Lindl.	N/A

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Scientific name	Thai name
D. eserre Seidenf.	**N/A**
D. exile Schltr.	**เอื้องเสี้ยน** Ueang sian (General)
D. falconeri Hook.	**เอื้องสายวิสูตร** Ueang sai wisut (Bangkok)
D. farmeri Paxton	**เอื้องมัจฉานุ** Ueang matchanu (Bangkok)
D. fimbriatum Hook.	**เอื้องคำน้อย** Ueang kham noi (Chiang Mai)
D. findlayanum E.C.Parish & Rchb.f.	**พวงหยก** Phuang yok (Bangkok)
D. flexile Ridl.	**N/A**
D. formosum Roxb. ex Lindl.	**เอื้องเงินหลวง** Ueang ngoen luang (Chiang Mai)
D. friedericksianum Rchb.f.	**เอื้องเหลืองจันทบูร** Ueang lueang chantabun (Bangkok)
D. fuerstenbergianum Schltr.	**เอื้องแซะภูกระดึง** Ueang sae phukradueng (General)
D. fytchianum Bateman ex Rchb.f.	**หวายพม่า** Wai phama (General)
D. garrettii Seidenf.	**หวายการ์เร็ต** Wai karet (General)
D. gibsonii Paxton	**เอื้องคำสาย** Ueang kham sai (Northern)
D. grande Hook.f.	**เอื้องแผงใบใหญ่** Ueang pheang bai yai (Peninsular)
D. gratiotissimum Rchb.f.	**เอื้องกิ่งดำ** Ueang king dam (Bangkok)
D. gregulus Seidenf.	**เอื้องมะต่อม** Ueang ma tom (Chiang Mai)
D. griffithianum Lindl.	**เอื้องมัจฉาเหลือง** Ueang matcha lueang (Bangkok)
D. harveyanum Rchb.f.	**เอื้องคำฝอย** Ueang kham foi (Chiang Mai)
D. hendersonii Hawkes & Heller	**หวายตะมอยน้อย** Wai tamoi noi (Peninsular)
D. henryi Schltr.	**เอื้องสุริยัน** Ueang suriyan (Loei)
D. hercoglossum Rchb.f.	**เอื้องดอกมะเขือ** Ueang dok ma kuea (Bangkok)
D. heterocarpum Lindl.	**เอื้องสีตาล** Ueang si tan (Chiang Mai)

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Scientific name	Thai name
D. hymenanthum Rchb.f.	**เอื้องน้อยกลีบบาง** Ueang noi klip bang (Chiang Mai, Kanchanaburi)
D. hymenopterum Hook.f.	**N/A**
D. incurvum Lindl.	**N/A**
D. indivisum (Blume) Miq.	**ตานเสี้ยนไม้** Tan sian mai (Chumphon) var. *indivisum*
D. indivisum (Blume) Miq.	**N/A** var. *lampangense* Rolfe
D. indivisum (Blume) Miq.	**ก้างปลา** Kang pla (General) var. *pallidum* Seidenf.
D. indragiriense Schltr.	**N/A**
D. infundibulum Lindl.	**เอื้องตาเหิน** Ueang ta hoen (General)
D. intricatum Gagnep.	**เอื้องชมพู** Ueang chomphu (Chanthaburi)
D. jenkinsii Wall. ex Lindl.	**เอื้องผึ้งน้อย** Ueang phueng noi (Chiang Mai)
D. kanburiense Seidenf.	**หวายเมืองกาญจน์** Wai muang kan (Kanchanaburi)
D. keithii Ridl.	**หางเปีย** Hang pia (General)
D. kentrophyllum Hook.f.	**ก้างปลาใหญ่** Kang pla yai
D. kontumense Gagnep.	**เอื้องเงินวิลาศ** Ueang ngoen wilat (Northeastern)
D. kratense Kerr	**N/A**
D. lagarum Seidenf.	**N/A**
D. lanpongense J.J.Sm.	**N/A**
D. lamyaiae Seidenf.	**N/A**
D. leonis (Lindl.) Rchb.f.	**เอื้องตะขาบใหญ่** Ueang ta khap yai (General)
D. lindleyi Steud.	**เอื้องผึ้ง** Ueang phueng (Northern)
D. linguella Rchb.f.	**N/A**
D. lituiflorum Lindl.	**เอื้องสายม่วง** Ueang sai muang (Northern, Bangkok)
D. lueckelianum Fessel & Wolff	**N/A**

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Scientific name	Thai name
D. mannii Ridl.	**เอื้องหางปลา** Ueang hang pla (General)
D. metachilinum Rchb.f.	**N/A**
D. monticola Hunt & Summerh	**N/A**
D. moschatum (Buch.-Ham.) Sw.	**เอื้องจำปา** Ueang champa (Northern)
D. mucronatum Seidenf.	**N/A**
D. nanocompactum Seidenf.	**N/A**
D. nathanielis Rchb.f.	**เกล็ดนิ่ม** Klet nim (Chantaburi)
D. ochreatum Lindl.	**เอื้องตะขาบ** Ueang ta khap (Chiang Mai)
D. oligophyllum Gagnep.	**ข้าวตอกปราจีน** Khao tok prachin (General)
D. pachyglossum Parish & Rchb.f	**เอื้องขนหมู** Ueang khon mu (Mae Hong Son)
D. pachyphyllum (Kuntze) Bakh.f.	**เอื้องน้อย** Ueang noi (General)
D. palpebrae Lindl.	**เอื้องมัจฉา** Ueang matcha (Bangkok)
D. pandaneti Ridl.	**N/A**
D. panduriferum Hook.f.	**N/A**
D. parciflorum Rchb.f. ex Lindl.	**เอื้องดอกขาวใบแบน** Ueang dok khao bai baen (General)
D. parcum Rchb.f.	**เอื้องก้านกิ่ว** Ueang kan kio (Bangkok)
D. parishii Rchb.f.	**เอื้องครั่ง** Ueang khrang (Northern)
D. parvum Seidenf.	**N/A**
D. peguanum Lindl.	**หวายเปกู** Wai peku (General)
D. pendulum Roxb.	**เอื้องไม้เท้าฤษี** Ueang mai thao ruesi (Bangkok, Chiang Mai)
D. perpaulum Seidenf.	**เอื้องข้าวตอกอินทนนท์** Ueang khao tok inthanon (General)
D. planibulbe Lindl.	**N/A**
D. polyanthum Wall. ex Lindl.	**เอื้องสายประสาท** Ueang sai prasat (Bangkok)
D. porphyrochilum Lindl.	**เอื้องเฉวียน** Ueang chawian (General)
D. praecinctum Rchb.f.	**หวายภูหลวง** Wai phu luang (General)
D. proteranthum Seidenf.	**หวายน้อยภูหลวง** Wai noi phu luang (Loei)

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

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

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Dendrobium virgineum Rchb.f. has white petals and red lip flower. Generally, this particular orchid can be found in dry evergreen forest as well as mix deciduous forest in east and north-east part of Thailand. Furthermore, they also widely distribute in Myanmar, Laos, and Vietnam (Thaithong 2006). According to the research, *Dendrobium* polysaccharides can stop gastric cancer progress, thus, protecting against precancerous lesions of gastric cancer (Zhao et al. 2019). Another research found that *Dendrobium* alkaloids is capable of blocking janus kinase-signal transducer and activator of transcription signal, resulting in an alleviation of inflammation after oxidative injuries (Liu, Zhu, et al. 2020). The mechanism of those properties is associate

with reduced ROS. On the other hand, the prevention of ROS and phytochemical analysis of *Dendrobium virgineum* have never been studied. The objectives of this study included isolating, structure determining and evaluating antioxidant activity of chemical constituents in *Dendrobium virgineum*.

Figure 1 *Dendrobium virgineum* Rchb.f. (Sritularak 2019)

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CHAPTER II

LITERATURE REVIEW

1. Chemical constituents of *Dendrobium* species

Dendrobium species has been reported to have several kinds of chemical constituents which can be categorized into four groups, namely, stilbenoids, flavonoids, terpenoids, and miscellaneous compounds. The pure compounds isolated from *Dendrobium* species were concluded in **Table 2** - **Table 4** and **Figure 2** - **Figure 5**.

Table 2 Stilbenoids isolated from *Dendrobium* species.

Stilbenoids	Plant	Plant part	Reference
Aloifol I [**1**]	*D. longicornu*	Stem	Hu et al. 2008b
	D. williamsonii	Whole plant	Yang, Zhang, et al. 2018
	D. infundibulum	Whole plant	Na Ranong et al. 2019
	D. christyanum	Root	San et al. 2020
	D. gibsonii	Whole plant	Thant et al. 2020
	D. scabrilingue	Whole plant	Sarakulwattana et al. 2020
	D. senile	Whole plant	Pann Phyu et al. 2022
Amoenylin [**2**]	*D. amoenum*	Whole plant	Majumder, Guha and Sen 1999
	D. williamsonii	Whole plant	Yang, Zhang, et al. 2018
	D. heterocarpum	Whole plant	Warinhomhoun et al. 2022
Batatasin [**3**]	*D. longicornu*	Stem	Hu et al. 2008b
	D. plicatile	Stem	Yamaki and Honda 1996
Batatasin III [**4**]	*D. aphyllum*	Whole plant	Chen, Li, et al. 2008
		Stem	Yang et al. 2015
	D. cariniferum	Stem	Chen, Liu, et al. 2008
	D. rotundatum	Whole plant	Majumder and Pal 1992

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Stilbenoids	Plant	Plant part	Reference
Batatasin III [**4**] (continued)	*D. chrysotoxum*	Whole plant	Li, Qing, et al. 2009
	D. draconis	Stem	Sritularak, Anuwat and Likhitwitayawuid 2011
	D. formosum	Whole plant	Inthongkaew et al. 2017
	D. gratiosissimum	Stem	Zhang, Wang, et al. 2008
	D. loddigesii	Stem	Ito et al. 2010
	D. loddigesii	Stem	Ma, Yang, et al. 2019
	D. venustum	Whole plant	Sukphan et al. 2014
	D. scabrilingue	Whole plant	Sarakulwattana et al. 2020
	D. infundibulum	Whole plant	Na Ranong et al. 2019
	D. christyanum	Root	San et al. 2020
	D. delacourii	Whole plant	Thant et al. 2022
Brittonin A [**5**]	*D. secundum*	Stem	Sritularak, Duangrak and Likhitwitayawuid 2011
Chrysotobibenzyl [**6**]	*D. aurantiacum* var. *denneanum*	Stem	Yang, Wang and Xu 2006
	D. capillipes	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid 2012
	D. chrysanthum	Stem	Yang et al. 2006
	D. chryseum	Stem	Ma, Wang and Yin 1998
	D. chrysotoxum	Stem	Hu et al. 2012
	D. nobile	Stem	Zhang, Xu, et al. 2007
	D. pulchellum	Stem	Chanvorachote et al. 2013
	D. scabrilingue	Whole plant	Sarakulwattana et al. 2020

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Stilbenoids	Plant	Plant part	Reference
Chrysotoxine [**7**]	*D. aurantiacum* var. *denneanum*	Stem	Yang, Wang and Xu 2006
	D. chrysanthum	Stem	Yang et al. 2006
	D. chryseum	Stem	Ma, Wang and Yin 1998
	D. nobile	Stem	Zhang, Xu, et al. 2007
	D. pulchellum	Stem	Chanvorachote et al. 2013
	D. lindleyi	Whole plant	Khoonrit et al. 2020
Crepidatin [**8**]	*D. aurantiacum* var. *denneanum*	Whole plant	Ying et al. 2009
	D. capillipes	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid 2012,
	D. chrysanthum	Stem	Yang et al. 2006
	D. crepidatum	Whole plant	Majumder and Chatterjee 1989
	D. nobile	Stem	Zhang, Xu, et al. 2007
	D. pulchellum	Stem	Chanvorachote et al. 2013
	D. loddigesii	Stem	Ma, Yang, et al. 2019
Cumulatin [**9**]	*D. cumulatum*	Whole plant	Majumder and Pal 1993
Dendrobin A [**10**]	*D. nobile*	Stem	Wang, Zhao and Che 1985, Ye and Zhao 2002
3,3′-Dihydroxy-4,5-dimethoxybibenzyl [**11**]	*D. williamsonii*	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid 2014
	D. infundibulum	Whole plant	Na Ranong et al. 2019
3,4′-Dihydroxy-5-methoxybibenzyl [**12**]	*D. amoenum*	Whole plant	Majumder, Guha and Sen 1999

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Stilbenoids	Plant	Plant part	Reference
3,4′-Dihydroxy-5,5′-dimethoxydihydrostilbene [**13**]	*D. nobile*	Stem	Hwang et al. 2010
3,4-dihydroxy-5,4′-dimethoxybibenzyl [**14**]	*D. heterocarpum*	Whole plant	Warinhomhoun et al. 2022
4,5-Dihydroxy-3,3′-dimethoxybibenzyl [**15**]	*D. nobile*	Stem	Ye and Zhao 2002
Erianin [**16**]	*D. chrysotoxum*	Stem	Hu et al. 2012
Gigantol [**17**]	*D. aphyllum*	Whole plant	Chen, Li, et al. 2008
	D. aphyllum	Stem	Yang et al. 2015
	D. aurantiacum var. denneanum	Whole plant	Ying et al. 2009
	D. brymerianum	Whole plant	Klongkumnuankarn et al. 2015
	D. densiflorum	Stem	Fan et al. 2001
	D. devonianum	Whole plant	Sun et al. 2014
	D. draconis	Stem	Sritularak, Anuwat and Likhitwitayawuid 2011
	D. formosum	Whole plant	Inthongkaew et al. 2017
	D. gratiosissimum	Stem	Zhang, Wang, et al. 2008
	D. loddigesii	Whole plant	Ito et al. 2010
	D. longicornu	Stem	Hu et al. 2008a
	D. nobile	Stem	Zhang, Xu, et al. 2007
	D. officinale	Stem	Zhao et al. 2018
	D. polyanthum	Stem	Hu et al. 2009
	D. trigonopus	Stem	Hu et al. 2008b

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Stilbenoids	Plant	Plant part	Reference
Gigantol [**17**] (continued)	*D. venustum*	Whole plant	Sukphan et al. 2014
	D. scabrilingue	Whole plant	Sarakulwattana et al. 2020
	D. loddigesii	Stem	Ma, Yang, et al. 2019
	D. palpebrae	Whole plant	Kongkatitham et al. 2018
	D. lindleyi	Whole plant	Khoonrit et al. 2020
	D. christyanum	Root	San et al. 2020
	D. pachyglossum	Whole plant	Warinhomhoun et al. 2021
	D. delacourii	Whole plant	Thant et al. 2022
4-Hydroxy-3,5,3′-trimethoxybibenzyl [**18**]	*D. nobile*	Stem	Ye and Zhao 2002
5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl [**19**]	*D. secundum*	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid 2012
Isoamoenylin [**20**]	*D. amoenum*	Whole plant	Majumder, Guha and Sen 1999
Moniliformine [**21**]	*D. candidum*	Stem	Li et al. 2008
	D. signatum	Whole plant	Mittraphab et al. 2016
	D. tortile	Whole plant	Limpanit et al. 2016
	D. williamsonii	Whole plant	Yang, Zhang, et al. 2018
Moscatilin [**22**]	*D. amoenum*	Whole plant	Majumder, Guha and Sen 1999
	D. aurantiacum var. denneanum	Stem	Yang, Wang and Xu 2006
	D. brymerianum	Whole plant	Klongkumnuankarn et al. 2015
	D. chrysanthum	Stem	Yang et al. 2006

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Stilbenoids	Plant	Plant part	Reference
Moscatilin [**22**] (continued)	*D. densiflorum*	Stem	Fan et al. 2001
	D. ellipsophyllum	Whole plant	Tanagornmeatar et al. 2014
	D. formosum	Whole plant	Inthongkaew et al. 2017
	D. gratiosissimum	Stem	Zhang, Wang, et al. 2008
	D. loddigesii	Whole plant	Chen et al. 1994 Ito et al. 2010
	D. longicornu	Stem	Hu et al. 2008a
	D. moscatum	Whole plant	Majumder and Sen 1987
	D. nobile	Stem	Miyazawa et al. 1999
	D. polyanthum	Stem	Hu et al. 2009
	D. pulchellum	Stem	Chanvorachote et al. 2013
	D. secundum	Stem	Sritularak, Duangrak and Likhitwitayawuid 2011
	D. aphyllum	Stem	Yang et al. 2015
	D. williamsonii	Whole plant	Yang, Zhang, et al. 2018
	D. parishii	Whole plant	Kongkatitham et al. 2018
	D. loddigesii	Stem	Ma, Yang, et al. 2019
	D. palpebrae	Whole plant	Kongkatitham et al. 2018
	D. infundibulum	Whole plant	Na Ranong et al. 2019
	D. lindleyi	Whole plant	Khoonrit et al. 2020
	D. christyanum	Root	San et al. 2020
	D. pachyglossum	Whole plant	Warinhomhoun et al. 2021
	D. senile	Whole plant	Pann Phyu et al. 2022

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Stilbenoids	Plant	Plant part	Reference
3,3′,4-Trihydroxybibenzyl [**23**]	*D. longicornu*	Stem	Hu et al. 2008a
3,3′,5-Trihydroxy bibenzyl [**24**]	*D. cariniferum*	Whole plant	Liu et al. 2009
	D. loddigesii	Stem	Ma, Yang, et al. 2019
3,5,4′-Trihydroxybibenzyl [**25**]	*D. gratiosissimum*	Stem	Zhang, Wang, et al. 2008
4,5-Dihydroxy-3,3′,4′-trimethoxybibenzyl [**26**]	*D. lindleyi*	Whole plant	Khoonrit et al. 2020
4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl [**27**]	*D. secundum*	Stem	Sritularak, Duangrak and Likhitwitayawuid 2011
	D. ellipsophyllum	Whole plant	Tanagornmeatar et al. 2014
	D. parishii	Whole plant	Kongkatitham et al. 2018
	D. loddigesii	Stem	Ma, Yang, et al. 2019
	D. palpebrae	Whole plant	Kongkatitham et al. 2018
	D. pachyglossum	Whole plant	Warinhomhoun et al. 2021
Tristin [**28**]	*D. aphyllum*	Stem	Yang et al. 2015
	D. chrysotoxum	Stem	Hu et al. 2012
	D. densiflorum	Stem	Fan et al. 2001
	D. gratiosissimum	Stem	Zhang, Wang, et al. 2008
	D. longicornu	Stem	Hu et al. 2008a
	D. officinale	Stem	Zhao et al. 2018
	D. trigonopus	Stem	Hu et al. 2008b
	D. loddigesii	Stem	Ma, Yang, et al. 2019
Dendromoniliside E [**29**]	*D. moniliforme*	Stem	Zhao et al. 2003

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Stilbenoids	Plant	Plant part	Reference
5,4′-Dihydroxy-3,4,3′-trimethoxybibenzyl [**30**]	*D. infundibulum*	Whole plant	Na Ranong et al. 2019
4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl [**31**]	*D. parishii*	Whole plant	Kongkatitham et al. 2018
Dendrophenol [**32**]	*D. candidum*	Stem	Li et al. 2008
4,4′-Dihydroxy-3,5-dimethoxybibenzyl [**33**]	*D. candidum*	Stem	Li et al. 2008
	D. ellipsophyllum	Whole plant	Tanagornmeatar et al. 2014
	D. williamsonii	Whole plant	Yang, Zhang, et al. 2018
Loddigesiinol C [**34**]	*D. loddigesii*	Whole plant	Ito et al. 2010
3-O-Methylgigantol [**35**]	*D. candidum*	Stem	Li et al. 2008
	D. nobile	Stem	Hwang et al. 2010
	D. plicatile	Stem	Yamaki and Honda 1996
Dendrocandin A [**36**]	*D. candidum*	Stem	Li et al. 2008
4,5-Dihydroxy-3,3′,4′,α-tetramethoxybibenzyl [**37**]	*D. lindleyi*	Whole plant	Shang, Li and Xiao 2020
4,4′,5-Trihydroxy-3,3′,α-trimethoxybibenzyl [**38**]	*D. lindleyi*	Whole plant	Shang, Li and Xiao 2020
2,2′-Dihydroxy-3,3′,4,4′,7,7′-hexamethoxy-9,9′,10,10′-tetrahydro-1,1′- biphenanthrene [**39**]	*D. nobile*	Stem	Yang, Sung and Kim 2007,

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Stilbenoids	Plant	Plant part	Reference
2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′- tetrahydro-1,1′- biphenanthrene [**40**]	*D. plicatile*	Stem	Yamaki and Honda 1996
	D. delacourii	Whole plant	Thant et al. 2022
Flavanthrin [**41**]	*D. aphyllum*	Whole plant	Chen, Li, et al. 2008
Coelonin [**42**]	*D. nobile*	Stem	Hwang et al. 2010
	D. aphyllum	Whole plant	Chen, Li, et al. 2008
	D. formosum	Whole plant	Inthongkaew et al. 2017
	D. nobile	Stem	Yang, Sung and Kim 2007
	D. scabrilingue	Whole plant	Sarakulwattana et al. 2020
9,10-Dihydromoscatin [**43**]	*D. polyanthum*	Stem	Hu et al. 2009
9,10-Dihydrophenanthrene-2,4,7-triol [**44**]	*D. polyanthum*	Stem	Hu et al. 2009
4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [**45**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar et al. 2014
	D. sinense	Whole plant	Chen et al. 2014
	D. pachyglossum	Whole plant	Warinhomhoun et al. 2021
4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene [**46**]	*D. chrysotoxum*	Stem	Hu et al. 2012
	D. devonianum	Stem	Wu et al. 2019

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Stilbenoids	Plant	Plant part	Reference
4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene [**47**]	*D. nobile*	Stem	Ye and Zhao 2002
4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene [**48**]	*D. nobile*	Stem	Yang, Sung and Kim 2007
	D. devonianum	Stem	Wu et al. 2019
	D. christyanum	Root	San et al. 2020
Lusianthridin [**49**]	*D. brymerianum*	Whole plant	Klongkumnuankarn et al. 2015
	D. nobile	Stem	Yang, Sung and Kim 2007 Hwang et al. 2010
	D. formosum	Whole plant	Inthongkaew et al. 2017
	D. plicatile	Stem	Yamaki and Honda 1996
	D. venustum	Whole plant	Sukphan et al. 2014
	D. scabrilingue	Whole plant	Sarakulwattana et al. 2020
	D. palpebrae	Whole plant	Kongkatitham et al. 2018
	D. gibsonii	Whole plant	Thant et al. 2020
	D. delacourii	Whole plant	Thant et al. 2022
Bulbophyllanthrin [**50**]	*D. nobile*	Stem	Yang, Sung and Kim 2007
5-Hydroxy-2,4-dimethoxyphenanthrene [**51**]	*D. loddigesii*	Whole plant	Ito et al. 2010
3-Hydroxy-2,4,7-trimethoxyphenanthrene [**52**]	*D. nobile*	Stem	Yang, Sung and Kim 2007

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Stilbenoids	Plant	Plant part	Reference
Dendrocandin C [**53**]	*D. candidum*	Stem	Li, Wang, Wang, Guo, et al. 2009
Dendrocandin D [**54**]	*D. candidum*	Stem	Li, Wang, Wang, Guo, et al. 2009
Dendrocandin E [**55**]	*D. candidum*	Stem	Li, Wang, Wang, Guo, et al. 2009
	D. parishii	Whole plant	Kongkatitham et al. 2018
Dendrocandin B [**56**]	*D. candidum*	Stem	Li et al. 2008
	D. signatum	Whole plant	Mittraphab et al. 2016
Dendrocandin F [**57**]	*D. candidum*	Stem	Li, Wang, Wang, Wang, et al. 2009
Dendrocandin G [**58**]	*D. candidum*	Stem	Li, Wang, Wang, Wang, et al. 2009
Dendrocandin H [**59**]	*D. candidum*	Stem	Li, Wang, Wang, Wang, et al. 2009
Dendroscabrol B **[60]**	*D. scabrilingue*	Whole plant	Sarakulwattana et al. 2020
2,2′,7,7′-tetrahydroxy-4,4′-dimethoxy-1,1′-biphenanthrene [**61**]	*D. senile*	Whole plant	Pann Phyu et al. 2022
Bleformin G [**62**]	*D. senile*	Whole plant	Pann Phyu et al. 2022
Dendropachol [**63**]	*D. pachyglossum*	whole plant	Warinhomhoun et al. 2021
2,5,7-trihydroxy-4-methoxyphenanthrene [**64**]	*D. senile*	whole plant	Pann Phyu et al. 2022
Dengraol A [**65**]	*D. gratiosissimum*	Stem	Zhang, Wang, et al. 2008

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Stilbenoids	Plant	Plant part	Reference
Dendrosinen A [**66**]	*D. sinense*	Whole plant	Chen et al. 2014
Dengraol B [**67**]	*D. gratiosissimum*	Stem	Zhang, Wang, et al. 2008
Dendrosinen B [**68**]	*D. sinense*	Whole plant	Chen et al. 2014
	D. infundibulum	Whole plant	Na Ranong et al. 2019
	D. christyanum	Root	San et al. 2020
Dendrosinen C [**69**]	*D. sinense*	Whole plant	Chen et al. 2014
Dendrosinen D [**70**]	*D. sinense*	Whole plant	Chen et al. 2014
Loddigesiinol B [**71**]	*D. loddigesii*	Whole plant	Ito et al. 2010
Dendrocandin I [**72**]	*D. candidum*	Stem	Li, Wang, Wang, Wang, et al. 2009
	D. signatum	Whole plant	Mittraphab et al. 2016
Dendrocandin L [**73**]	*D. candidum*	Stem	Li, Wang, et al. 2014
Dendrocandin J [**74**]	*D. candidum*	Stem	Li, Wang, et al. 2014
Dendrocandin K [**75**]	*D. candidum*	Stem	Li, Wang, et al. 2014
Dendrocandin M [**76**]	*D. candidum*	Stem	Li, Wang, et al. 2014
Dendrocandin N [**77**]	*D. candidum*	Stem	Li, Wang, et al. 2014
Dendrocandin O [**78**]	*D. candidum*	Stem	Li, Wang, et al. 2014
Densiflorol A [**79**]	*D. densiflorum*	Stem	Fan et al. 2001
	D. loddigesii	Stem	Ma, Yang, et al. 2019
Dendrocandin P [**80**]	*D. candidum*	Stem	Li, Wang, et al. 2014
Dendrocandin Q [**81**]	*D. candidum*	Stem	Li, Wang, et al. 2014
Longicornuol A [**82**]	*D. longicornu*	Stem	Hu et al. 2008a
Trigonopol B [**83**]	*D. chrysotoxum*	Stem	Hu et al. 2012
	D. trigonopus	Stem	Hu et al. 2008b
	D. aphyllum	Stem	Yang et al. 2015

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Stilbenoids	Plant	Plant part	Reference
Trigonopol A [**84**]	*D. trigonopus*	Stem	Hu et al. 2008b
Crepidatuol A [**85**]	*D. crepidatum*	Stem	Li et al. 2013
Dencryol A [**86**]	*D. crystallinum*	Stem	Wang et al. 2009
Crepidatuol B [**87**]	*D. crepidatum*	Stem	Li et al. 2013
Dencryol B [**88**]	*D. crystallinum*	Stem	Wang et al. 2009
Loddigesiinol D [**89**]	*D. loddigesii*	Whole plant	Ilto et al. 2010
Dendrosignatol [**90**]	*D. signatum*	Whole plant	Mittraphab et al. 2016
4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol [**91**]	*D. longicornu*	Stem	Hu et al. 2008a
Nobilin A [**92**]	*D. nobile*	Stem	Zhang et al. 2006
Nobilin B [**93**]	*D. nobile*	Stem	Zhang et al. 2006
Nobilin C [**94**]	*D. nobile*	Stem	Zhang et al. 2006
Nobilin D [**95**]	*D. nobile*	Stem	Zhang, Xu, et al. 2007
Dendrofalconerol A [**96**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid 2009
	D. signatum	Whole plant	Mittraphab et al. 2016
	D. tortile	Whole plant	Limpanit et al. 2016
	D. heterocarpum	Whole plant	Warinhomhoun et al. 2022
Nobilin E [**97**]	*D. nobile*	Stem	Zhang, Xu, et al. 2007
Dendrofalconerol B [**98**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid 2009
Phoyunnanin C [**99**]	*D. venustum*	Whole plant	Sukphan et al. 2014
	D. delacourii	Whole plant	Thant et al. 2022

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Stilbenoids	Plant	Plant part	Reference
Phoyunnanin E [**100**]	*D. venustum*	Whole plant	Sukphan et al. 2014
	D. delacourii	Whole plant	Thant et al. 2022
Amoenumin [**101**]	*D. amoenum*	Whole plant	Veerraju et al. 1989
Crystalltone [**102**]	*D. crystallinum*	Stem	Wang et al. 2009
Confusarin [**103**]	*D. chryseum*	Stem	Ma, Wang and Yin 1998
	D. chrysotoxum	Stem	Hu et al. 2012
	D. formosum	Whole plant	Inthongkaew et al. 2017
	D. nobile	Stem	Zhang, Tu, et al. 2008
	D. officinale	Stem	Zhao et al. 2018
Chrysotoxol A [**104**]	*D. chrysotoxum*	Stem	Hu et al. 2012
Denthyrsinin [**105**]	*D. densiflorum*	Stem	Fan et al. 2001
	D. thyrsiforum	Stem	Zhang et al. 2005
	D. palpebrae	Whole plant	Kongkatitham et al. 2018
Chrysotoxol B [**106**]	*D. chrysotoxum*	Stem	Hu et al. 2012
Dendropalpebrone [**107**]	*D. palpebrae*	Whole plant	Kongkatitham et al. 2018
Dendrochrysanene [**108**]	*D. chrysanthum*	Stem	Yang et al. 2006
Cypripedin [**109**]	*D. densiflorum*	Stem	Fan et al. 2001
	D. lindleyi	Whole plant	Khoonrit et al. 2020
Densiflorol B **[110**]	*D. densiflorum*	Stem	Fan et al. 2001
	D. venustum	Whole plant	Sukphan et al. 2014
Denbinobin [**111**]	*D. moniliforme*	Stem	Lin et al. 2001
	D. nobile	Stem	Yang, Sung and Kim 2007
Fimbriatone [**112**]	*D. nobile*	Stem	Zhang, Tu, et al. 2008
	D. pulchellum	Stem	Chanvorachote et al. 2013
Dendroscabrol A [**113**]	*D. scabrilingue*	Whole plant	Sarakulwattana et al. 2020

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Stilbenoids	Plant	Plant part	Reference
densifloral B [**114**]	*D. delacourii*	Whole plant	Thant et al. 2022
Moniliformin [**115**]	*D. moniliforme*	Stem	Lin et al. 2001
Moscatin [**116**]	*D. aphyllum*	Whole plant	Chen, Li, et al. 2008
	D. chrysanthum	Stem	Yang et al. 2006
	D. chrysotoxum	Whole plant	Li, Qing, et al. 2009
	D. densiflorum	Stem	Fan et al. 2001
	D. polyanthum	Stem	Hu et al. 2009
	D. rotundatum	Whole plant	Majumder and Pal 1992
	D. senile	Whole plant	Pann Phyu et al. 2022
	D. delacourii	Whole plant	Thant et al. 2022
Dendrononе [**117**]	*D. cariniferum*	Whole plant	Chen, Liu, et al. 2008
	D. longicornu	Stem	Hu et al. 2008a
Ephemeranthoquinone [**118**]	*D. plicatile*	Stem	Yamaki and Honda 1996
	D. delacourii	Whole plant	Thant et al. 2022
5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone [**119**]	*D. draconis*	Stem	Sritularak, Anuwat and Likhitwitayawuid 2011
	D. formosum	Whole plant	Inthongkaew et al. 2017
Aphyllone A [**120**]	*D. aphyllum*	Stem	Yang et al. 2015
2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene [**121**]	*D. rotundatum*	Whole plant	Majumder and Pal 1992

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Stilbenoids	Plant	Plant part	Reference
2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**122**]	*D. nobile*	Stem	Yang, Sung and Kim 2007
4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene [**123**]	*D. sinense*	Whole plant	Chen et al. 2013
Ephemeranthol A [**124**]	*D. nobile*	Stem	Yang, Sung and Kim 2007, Hwang et al. 2010
	D. officinale	Stem	Zhao et al. 2018
	D. infundibulum	Whole plant	Na Ranong et al. 2019
	D. gibsonii	Whole plant	Thant et al. 2020
Ephemeranthol C [**125**]	*D. nobile*	Stem	Hwang et al. 2010
Erianthridin [**126**]	*D. formosum*	Whole plant	Inthongkaew et al. 2017
	D. nobile	Stem	Hwang et al. 2010, Yang, Sung and Kim 2007
	D. plicatile	Stem	Yamaki and Honda 1996
Flavanthridin [**127**]	*D. nobile*	Stem	Hwang et al. 2010
Hircinol [**128**]	*D. nobile*	Stem	Hwang et al. 2010
	D. aphyllum	Stem	Yang et al. 2015
	D. draconis	Stem	Sritularak, Anuwat and Likhitwitayawuid 2011,
	D. formosum	Whole plant	Inthongkaew et al. 2017
	D. delacourii	Whole plant	Thant et al. 2022

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Stilbenoids	Plant	Plant part	Reference
3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene [**129**]	*D. nobile*	Stem	Yang, Sung and Kim 2007
7-Hydroxy-2,3,4-trimethoxy-9,10-dihydrophenanthrene [**130**]	*D. hainanense*	Aerial part	Zhang, Wang, et al. 2019
Dendroinfundin A [**131**]	*D. infundibulum*	Whole plant	Na Ranong et al. 2019
Dendroinfundin B [**132**]	*D. infundibulum*	Whole plant	Na Ranong et al. 2019
3,4-Dimethoxy-1-(methoxymethyl)-9,10-dihydrophenanthrene-2,7- diol [**133**]	*D. hainanense*	Aerial part	Zhang, Wang, et al. 2019
2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene [**134**]	*D. nobile*	Stem	Yang, Sung and Kim 2007
7-Methoxy-9,10-dihydrophenanthrene- 2,4,5-triol [**135**]	*D. draconis*	Stem	Sritularak, Anuwat and Likhitwitayawuid 2011
2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene [**136**]	*D. formosum*	Whole plant	Inthongkaew et al. 2017
Plicatol C [**137**]	*D. plicatile*	Stem	Honda and Yamaki 2000
Rotundatin [**138**]	*D. rotundatum*	Whole plant	Majumder and Pal 1992

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Stilbenoids	Plant	Plant part	Reference
2,5-Dihydroxy-3,4 dimethoxyphenanthrene [**139**]	*D. nobile*	Stem	Yang, Sung and Kim 2007
2,5-Dihydroxy-4,9-dimethoxyphenanthrene [**140**]	*D. nobile*	Stem	Zhang, Tu, et al. 2008
	D. palpebrae	Whole plant	Kongkatitham et al. 2018
	D. senile	Whole plant	Pann Phyu et al. 2022
2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene [**141**]	*D. nobile*	Stem	Yang, Sung and Kim 2007
Epheranthol B [**142**]	*D. chrysotoxum*	Stem	Hu et al. 2012
	D. plicatile	Stem	Yamaki and Honda 1996
Fimbriol B [**143**]	*D. nobile*	Stem	Yang, Sung and Kim 2007, Hwang et al. 2010
Flavanthrinin [**144**]	*D. brymerianum*	Whole plant	Klongkumnuankarn et al. 2015
	D. nobile	Stem	Zhang, Tu, et al. 2008
	D. venustum	Whole plant	Sukphan et al. 2014
	D. parishii	Whole plant	Kongkatitham et al. 2018
Loddigesiinol A [**145**]	*D. loddigesii*	Whole plant	Ito et al. 2010
Nudol [**146**]	*D. formosum*	Whole plant	Inthongkaew et al. 2017
	D. nobile	Stem	Yang, Sung and Kim 2007
	D. rotundatum	Whole plant	Majumder and Pal 1992
Plicatol A [**147**]	*D. nobile*	Stem	Yang, Sung and Kim 2007
	D. plicatile	Stem	Honda and Yamaki 2000
Plicatol B [**148**]	*D. plicatile*	Stem	Honda and Yamaki 2000

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Stilbenoids	Plant	Plant part	Reference
2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene [**149**]	*D. nobile*	Stem	Yang, Sung and Kim 2007
3,4,8-Trimethoxy phenanthrene-2,5-diol [**150**]	*D. nobile*	Stem	Hwang et al. 2010
2,4,5,9S-Tetrahydroxy-9,10-dihydro phenanthrene [**151**]	*D. fimbriatum*	Stem	Xu et al. 2014
1,5,7-Trimethoxy phenanthren-2-ol [**152**]	*D. nobile*	Stem	Kim et al. 2015
1,5-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene [**153**]	*D. moniliforme*	Whole plant	Zhao et al. 2016
2,5,9S-Trihydroxy-9,10-dihydrophenanthrene-4-O-β-D-glucopyranoside [**154**]	*D. primulinum*	Whole plant	Ye et al. 2016
Loddigesiinol G [**155**]	*D. loddigesii*	Stem	Lu et al. 2014
Aphyllal D [**156**]	*D. aphyllum*	Stem	Yang et al. 2015
Loddigesiinol H [**157**]	*D. loddigesii*	Stem	Lu et al. 2014
Aphyllal E [**158**]	*D. aphyllum*	Stem	Yang et al. 2015
Loddigesiinol I [**159**]	*D. loddigesii*	Stem	Lu et al. 2014
Loddigesiinol J [**160**]	*D. loddigesii*	Stem	Lu et al. 2014

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Stilbenoids	Plant	Plant part	Reference
Dendrowillol A [**161**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018
Dendrocandin P1 [**162**]	*D. officinale*	Stem	Zhao et al. 2018
Dendrocandin P2 [**163**]	*D. officinale*	Stem	Zhao et al. 2018
Orchinol [**164**]	*D. officinale*	Stem	Zhao et al. 2018
2,4,7-Trihydroxy-9,10-Dihydrophenanthrene [**165**]	*D. officinale*	Stem	Zhao et al. 2018
4-Methoxy-5,9R-dihydroxy-9,10-dihydro phenanthrene-2-O-β-D-glucopyranoside [**166**]	*D. nobile*	Stem	Zhou et al. 2017
Dihydroresveratrol [**167**]	*D. aphyllum*	Stem	Yang et al. 2015
Aphyllone B [**168**]	*D. aphyllum*	Stem	Yang et al. 2015
Aphyllal C [**169**]	*D. aphyllum*	Stem	Yang et al. 2015
	D. loddigesii	Stem	Ma, Yang, et al. 2019
(-)-Dendroparishiol [**170**]	*D. parishii*	Whole plant	Kongkatitham et al. 2018
(R)-4,5,4′-Trihydroxy-3,3′,α-trimethoxybibenzyl [**171**]	*D. loddigesii*	Stem	Ma, Yang, et al. 2019
Dendrofindlaphenol B [**172**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2018
Dendrofindlaphenol A [**173**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2018
Dendrofindlaphenol C [**174**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2018

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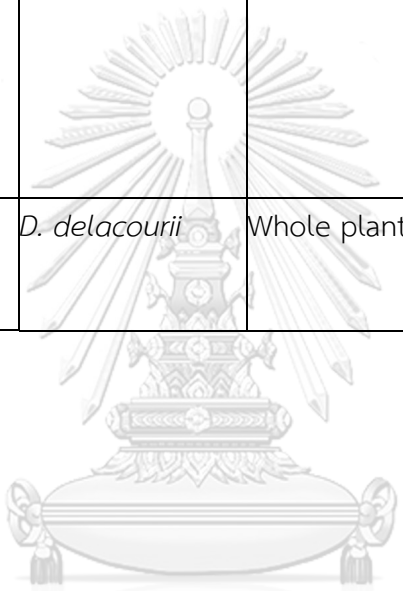
Stilbenoids	Plant	Plant part	Reference
6″-De-O-methyl dendrofindlaphenol A [**175**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2018
Dendrodevonin A [**176**]	*D. devonianum*	Stem	Wu et al. 2019
Dendrodevonin B [**177**]	*D. devonianum*	Stem	Wu et al. 2019
4,4′,8,8′-tetramethoxy[1,1′-biphenanthrene]-2,2′,7,7′-tetrol [**178**]	*D. senile*	Whole plant	Pann Phyu et al. 2022
4,9-dimethoxy-2,5-phenanthrenediol [**179**]	*D. delacourii*	Whole plant	Thant et al. 2022



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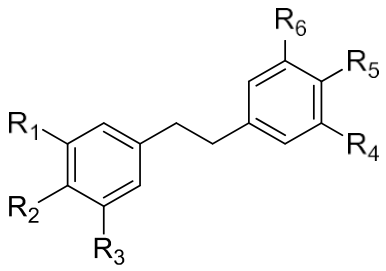

	R_1	R_2	R_3	R_4	R_5	R_6
[**1**] Aloifol I	OMe	OH	OMe	OH	H	H
[**2**] Amoenylin	OMe	OH	OMe	H	OMe	H
[**3**] Batatasin	OMe	H	H	OH	H	OH
[**4**] Batatasin III	OH	H	OMe	H	H	OH
[**5**] Brittonin A	OMe	OMe	OMe	OMe	OMe	OMe
[**6**] Chrysotobibenzyl	OMe	OMe	OMe	OMe	OMe	H
[**7**] Chrysotoxine	OMe	OH	OMe	OMe	OMe	H
[**8**] Crepidatin	OMe	OMe	OMe	OMe	OH	H
[**9**] Cumulatin	OMe	OMe	OH	OH	OMe	OMe
[**10**] Dendrobin A	OH	OH	OMe	H	H	OMe
[**11**] 3,3′-Dihydroxy-4,5-dimethoxybibenzyl	OMe	OMe	OH	H	H	OH
[**12**] 3,4′-Dihydroxy-5-methoxybibenzyl	OH	H	OMe	H	OH	H
[**13**] 3,4′-Dihydroxy-5,5′-dimethoxydihydrostilbene	OH	H	OMe	OMe	OH	H
[**14**] 3,4-dihydroxy-5,4′-dimethoxybibenzyl	OMe	OH	OMe	H	OMe	H

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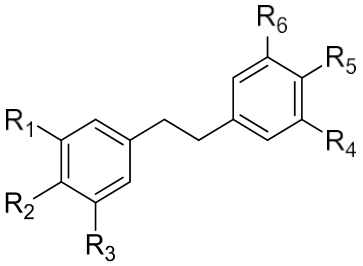
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



	R_1	R_2	R_3	R_4	R_5	R_6
[**15**] 4,5-Dihydroxy-3,3′-dimethoxybibenzyl	OMe	OH	OH	H	H	OMe
[**16**] Erianin	OMe	OMe	OMe	H	OMe	OH
[**17**] Gigantol	OMe	H	OH	H	OH	OMe
[18] 4-Hydroxy-3,5,3′-trimethoxybibenzyl	OMe	OH	OMe	H	H	OMe
[**19**] 5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl	OMe	OMe	OH	OMe	OMe	OMe
[**20**] Isoamoenylin	OMe	OMe	OMe	H	H	OH
[**21**] Moniliformine	OH	OH	OMe	H	OMe	H
[**22**] Moscatilin	OMe	OH	OMe	H	OH	OMe
[**23**] 3,3′,4-Trihydroxybibenzyl	OH	OH	H	H	H	OH
[**24**] 3,3′,5-Trihydroxybibenzyl	OH	H	OH	H	H	OH
[**25**] 3,5,4′-Trihydroxybibenzyl	OH	H	OH	H	OH	H
[**26**] 4,5-Dihydroxy-3,3′,4′-trimethoxybibenzyl	OMe	OH	OH	OMe	OMe	H

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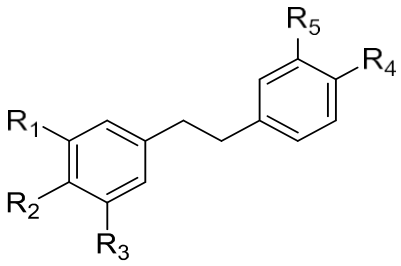
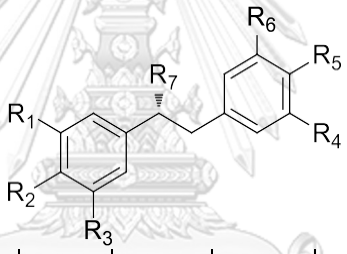
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



	R_1	R_2	R_3	R_4	R_5
[**27**] 4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl	OMe	OH	OH	OH	OMe
[**28**] Tristin	OH	H	OH	OH	OMe
[**29**] Dendromoniliside E	OGlc	OGlc	OMe	OMe	H
[**30**] 5,4′-Dihydroxy-3,4,3′-trimethoxybibenzyl	OH	OMe	OMe	OH	OMe
[**31**] 4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	OH	OH



	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**32**] Dendrophenol	OMe	OH	OMe	OH	OH	H	H
[**33**] 4,4′-Dihydroxy-3,5-dimethoxybibenzyl	OMe	OH	OMe	H	OH	H	H
[**34**] Loddigesiinol C	OMe	OH	OMe	H	OH	OMe	OMe
[**35**] 3-*O*-Methylgigantol	OMe	H	OH	OMe	OMe	H	H
[**36**] Dendrocandin A	OMe	OH	OH	H	OMe	H	OMe
[**37**] 4,5-Dihydroxy-3,3′,4′,α-tetramethoxybibenzyl	OMe	OH	OH	OMe	OMe	H	OMe
[**38**] 4,4′,5-Trihydroxy-3,3′,α-trimethoxybibenzyl	OMe	OH	OH	OMe	OH	H	OMe

Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.

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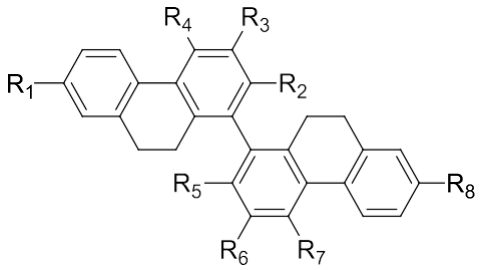

	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
[**39**] 2,2′-Dihydroxy-3,3′,4,4′,7,7′-hexamethoxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OMe	OH	OMe	OMe	OH	OMe	OMe	OMe
[**40**] 2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OH	OMe	H	OH	OMe	H	OH	OH
[**41**] Flavanthrin	OH	OH	H	OMe	OH	H	OMe	OH

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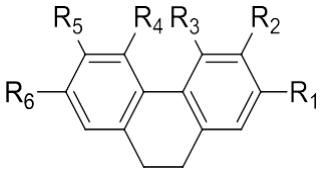
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



	R_1	R_2	R_3	R_4	R_5	R_6
[**42**] Coelonin	OH	H	OMe	H	H	OH
[**43**] 9,10-Dihydromoscatin	H	H	OH	OMe	H	OH
[**44**] 9,10-Dihydrophenanthrene-2,4,7-triol	OH	H	OH	H	H	OH
[**45**] 4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	OH	H	H
[**46**] 4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	OMe	H
[**47**]4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene	H	OMe	OH	OH	H	OMe
[**48**] 4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene	OMe	H	OH	OH	H	H
[**49**] Lusianthridin	OMe	H	OH	H	H	OH

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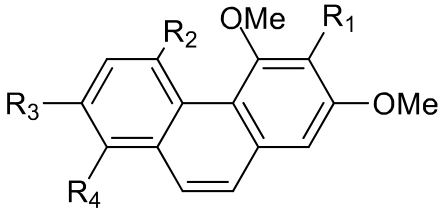
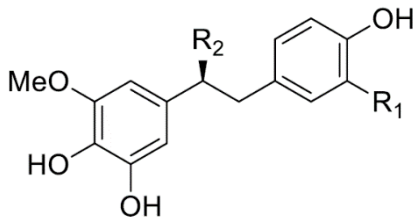
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species**.**



	R_1	R_2	R_3	R_4
[**50**] Bulbophyllanthrin	OH	OH	H	H
[**51**] 5-Hydroxy-2,4-dimethoxyphenanthrene	H	OH	H	H
[**52**] 3-Hydroxy-2,4,7-trimethoxyphenanthrene	OH	H	OMe	H



	R_2
[**53**] Dendrocandin C	OMe
[**54**] Dendrocandin D	OEt
[**55**] Dendrocandin E	H

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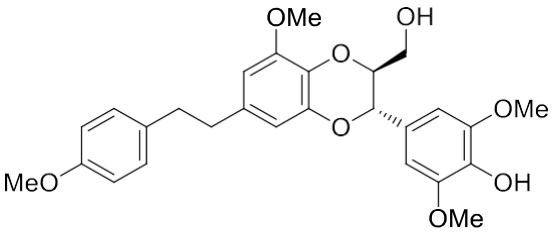
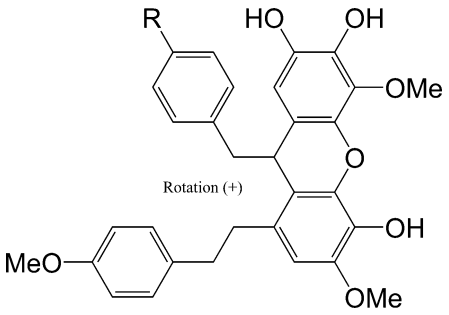
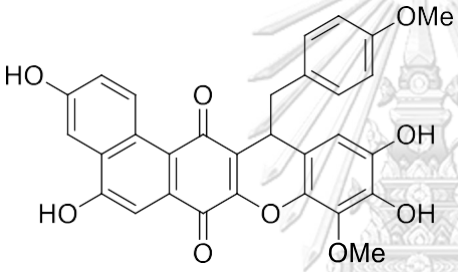
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



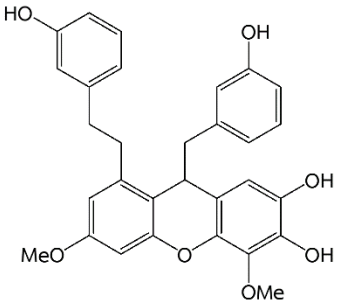
[**56**] Dendrocandin B



	R
[**57**] Dendrocandin F	OMe
[**58**] Dendrocandin G	OH



[59] Dendrocandin H



[**60**] Dendroscabrol B

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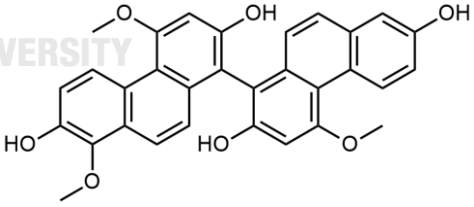
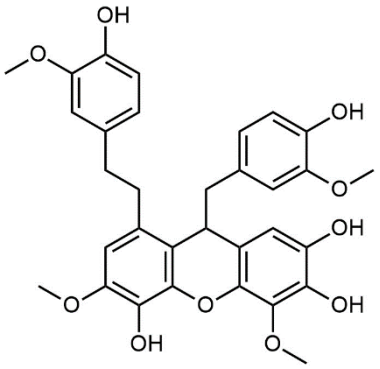
[**61**] 2,2′,7,7′-tetrahydroxy-4,4′-dimethoxy-1,1′-biphenanthrene

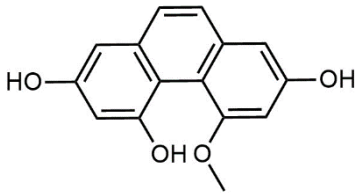


[**62**] Bleformin G

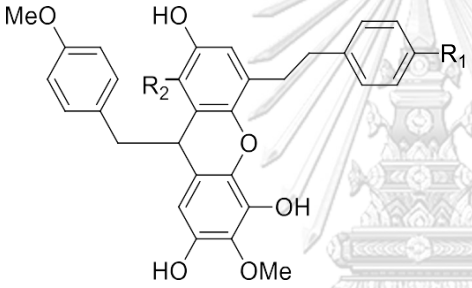
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.

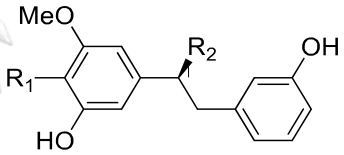


[**63**] Dendropachol



[**64**] 2,5,7-trihydroxy-4-methoxyphenanthrene





	R_1	R_2		R_1	R_2
[**65**] Dengraol A	OH	OH	[**66**] Dendrosinen A	OMe	OH
[**67**] Dengraol B	OMe	OMe	[**68**] Dendrosinen B	OH	H

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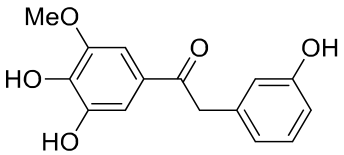
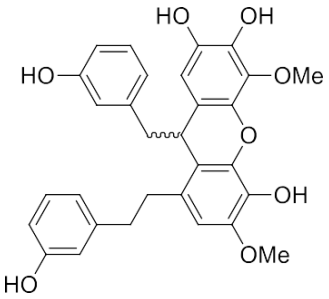
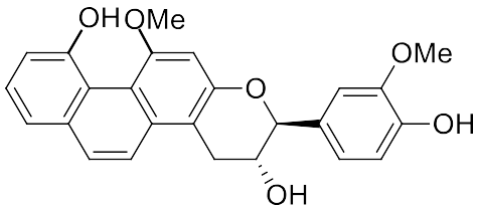


[**69**] Dendrosinen C

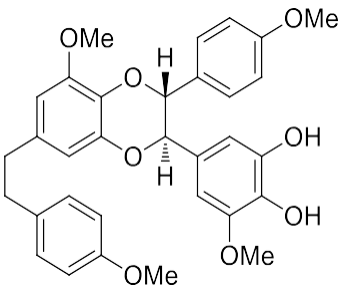


[**70**] Dendrosinen D

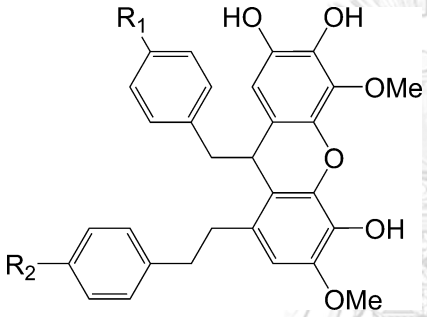
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



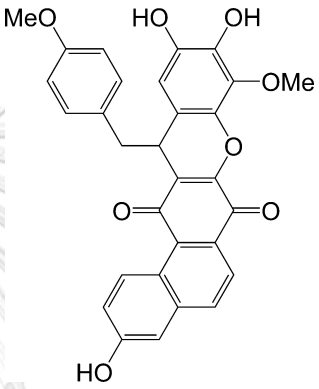
[**71**] Loddigesiinol B



[**72**] Dendrocandin I



	R_1	R_2
[**74**] Dendrocandin J	OMe	OH
[**75**] Dendrocandin K	OH	OH



[**73**] Dendrocandin L

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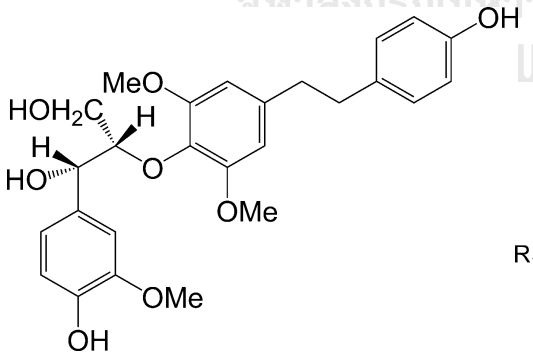
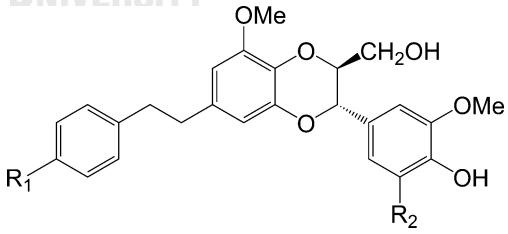
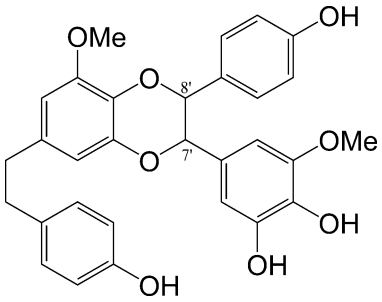


[**76**] Dendrocandin M

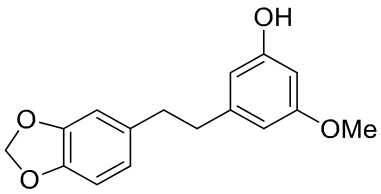


	R_1	R_2
[**77**] Dendrocandin N	OH	H
[**78**] Dendrocandin O	OH	OH

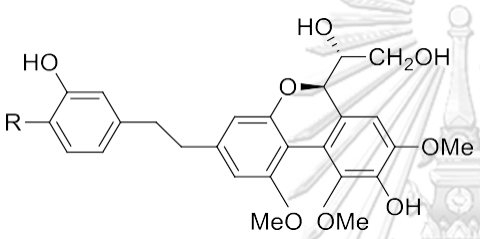
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



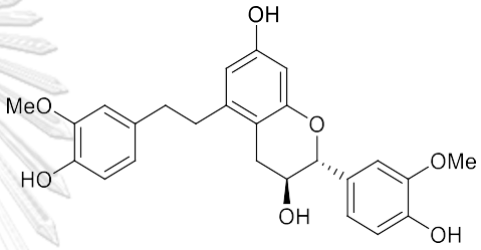
	H-7′, 8′
[**80**] Dendrocandin P	*cis*
[**81**] Dendrocandin Q	*trans*



[**79**] Densiflorol A



	R
[**82**] Longicornuol A	H
[**84**] Trigonopol A	OMe



[**83**] Trigonopol B

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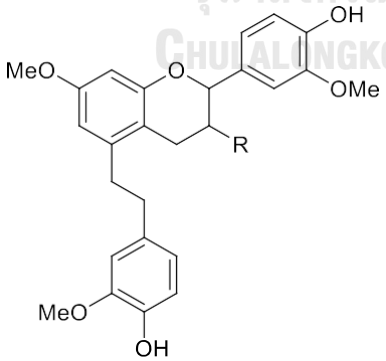
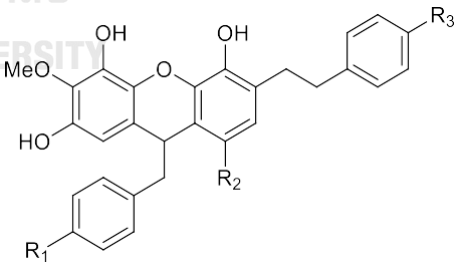
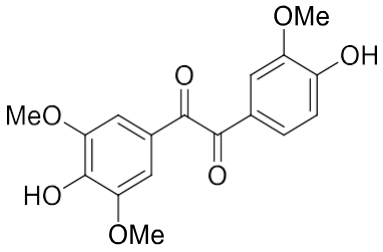


	R
[**85**] Crepidatuol A	H
[**87**] Crepidatuol B	OH

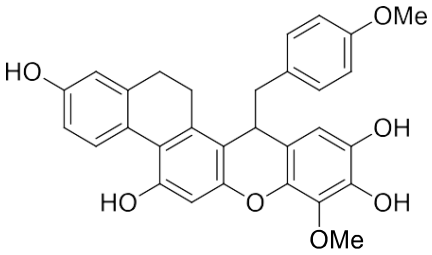


	R_1	R_2	R_3
[**86**] Dencryol A	OMe	OH	OH
[**88**] Dencryol B	OH	OMe	OMe

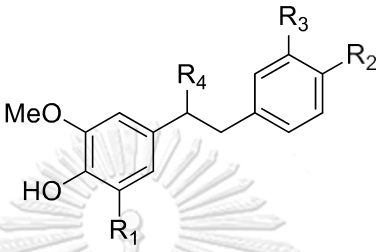
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



[**89**] Loddigesiinol D



[**90**] Dendrosignatol



	R_1	R_2	R_3	R_4
[**91**] 4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol	OMe	H	OH	OMe
[**92**] Nobilin A	OH	H	OMe	OMe
[**93**] Nobilin B	OMe	OH	OMe	OMe
[**94**] Nobilin C	OMe	OMe	OMe	OMe
[**95**] Nobilin D	OMe	OH	OMe	OH

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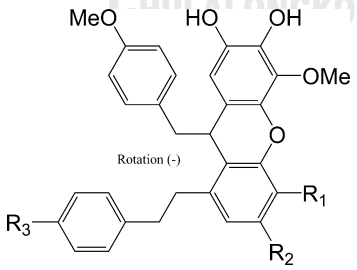
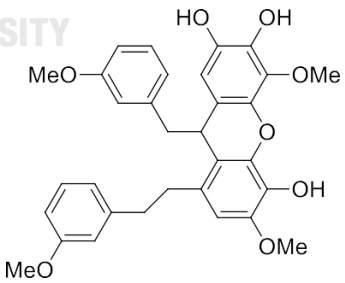
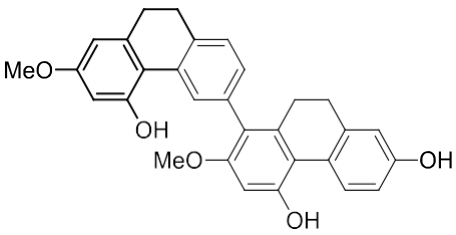


	R_1	R_2	R_3
[**96**] Dendrofalconerol A	OH	OMe	OMe
[**98**] Dendrofalconerol B	H	OH	OH

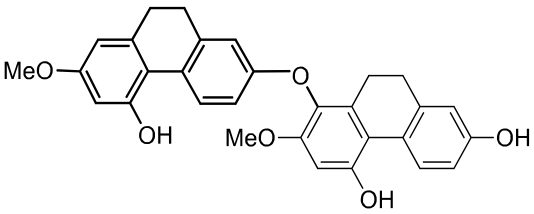


[**97**] Nobilin E

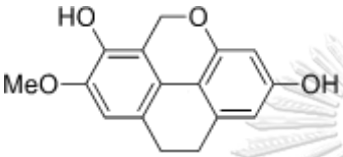
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



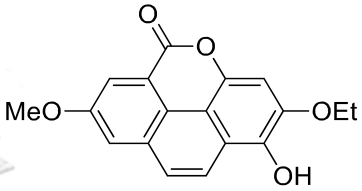
[**99**] Phoyunnanin C



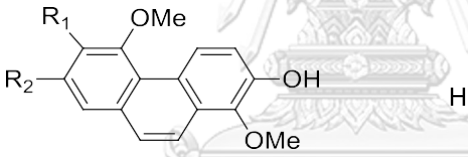
[**100**] Phoyunnanin E

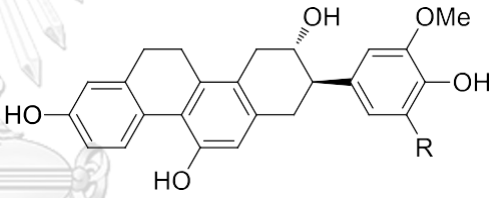


[**101**] Amoenumin



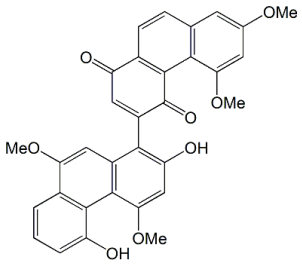
[**102**] Crystalltone



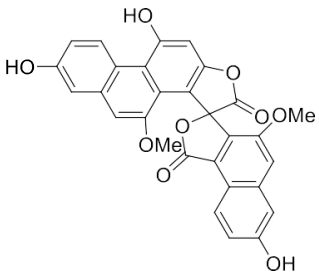


	R_1	R_2
[**103**] Confusarin	OMe	OH
[**105**] Denthyrsinin	OH	OMe

	R
[**104**] Chrysotoxol A	H
[**106**] Chrysotoxol B	OMe

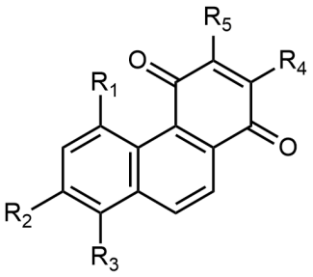


[**107**] Dendropalpebrone

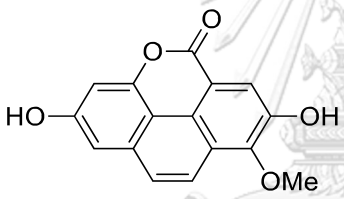


[**108**] Dendrochrysanene

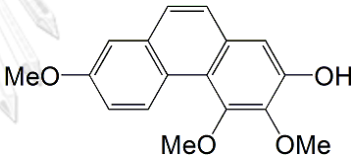
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



	R_1	R_2	R_3	R_4	R_5
[**109**] Cypripedin	H	OH	OMe	OMe	H
[**110**] Densiflorol B	H	OH	H	OMe	H
[**111**] Denbinobin	OH	OMe	H	H	OMe



[**112**] Fimbriatone



[**113**] Dendroscabrol A

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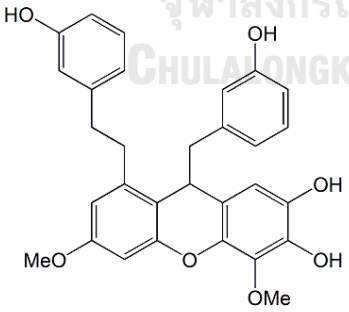
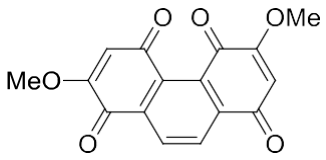
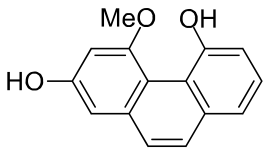


[**114**] Dendroscabrol B

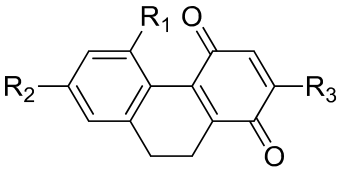


[**115**] Moniliformin

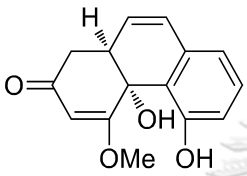
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



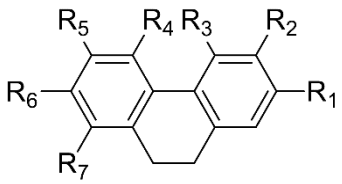
[**116**] Moscatin



	R_1	R_2	R_3
[**117**] Dendronone	OH	OMe	H
[**118**] Ephemeranthoquinone	H	OH	OMe
[**119**] 5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone	OMe	OH	H



[**120**] Aphyllone A



	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**121**] 2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**122**] 2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene	OH	OMe	OMe	H	H	OMe	OH
[**123**] 4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OH	H	OMe	OH	H

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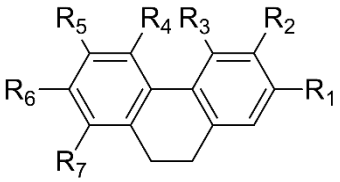
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**124**] Ephemeranthol A	OH	H	H	OH	OMe	OMe	H
[**125**] Ephemeranthol C	OH	OH	OMe	OH	H	H	H
[**126**] Erianthridin	OH	OMe	OMe	H	H	OH	H
[**127**] Flavanthridin	OH	H	H	OMe	OH	OMe	H
[**128**] Hircinol	OH	H	OMe	OH	H	H	H
[**129**] 3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene	OMe	OH	OMe	H	H	OMe	H
[**130**] 7-Hydroxy-2,3,4-trimethoxy-9,10-dihydrophenanthrene	OH	H	H	OMe	OMe	OMe	H
[**131**] Dendroinfundin A	OMe	OMe	OH	H	H	OMe	H
[**132**] Dendroinfundin B	OMe	OMe	OH	OH	H	H	OMe
[**133**] 3,4-Dimethoxy-1-(methoxymethyl)-9,10-dihydrophenanthrene-2,7-diol	OH	H	H	OMe	OMe	OH	$-CH_2OMe$

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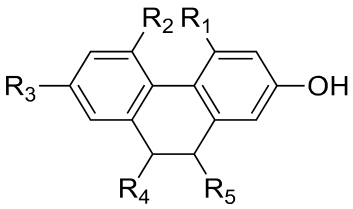
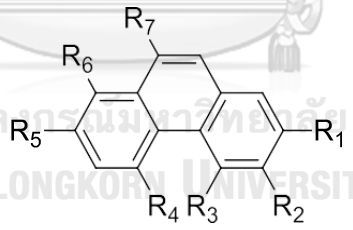
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



	R_1	R_2	R_3	R_4	R_5
[**134**] 2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenanthrene	OMe	H	OMe	H	H
[**135**] 7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol	OH	OH	OMe	H	H
[**136**] 2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene	OMe	OH	OH	H	H
[**137**] Plicatol C	H	OMe	OH	H	OMe
[**138**] Rotundatin	H	OMe	OH	H	OH



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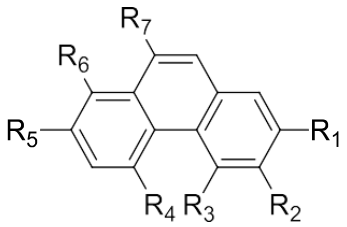
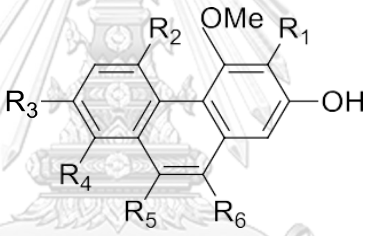
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**139**] 2,5-Dihydroxy-3,4-dimethoxyphenanthrene	OH	OMe	OMe	OH	H	H	H
[**140**] 2,5-Dihydroxy-4,9-dimethoxyphenanthrene	OH	H	OMe	OH	H	H	OMe

Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**141**] 2,8-Dihydroxy-3,4,7-trimethoxyphenanthrene	OH	OMe	OMe	H	OMe	OH	H
[**142**] Epheranthol B	H	H	OMe	OH	OMe	H	H
[**143**] Fimbriol B	OH	OMe	OH	H	H	H	H
[**144**] Flavanthrinin	OH	H	OMe	H	OH	H	H



	R_1	R_2	R_3	R_4	R_5	R_6
[**145**] Loddigesiinol A	H	OMe	H	H	OH	H
[**146**] Nudol	OMe	H	OH	H	H	H
[**147**] Plicatol A	H	OH	H	H	OMe	OMe
[**148**] Plicatol B	H	OH	H	H	H	H
[**149**] 2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene	OH	OH	H	H	OMe	H
[**150**] 3,4,8-Trimethoxyphenanthrene-2,5-diol	OMe	OH	H	OMe	H	H

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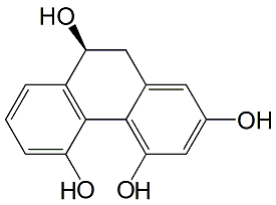
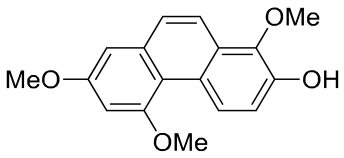
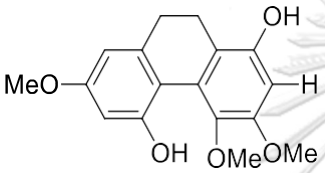
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



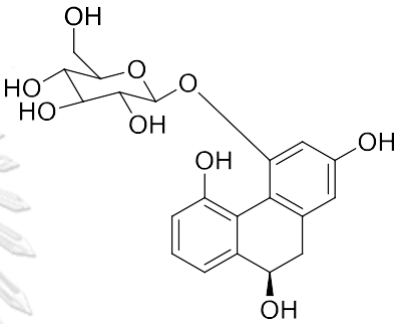
[**151**] 2,4,5,9S-Tetrahydroxy-9,10-dihydrophenanthrene



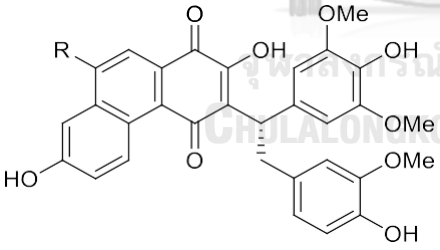
[**152**] 1,5,7-Trimethoxyphenanthren-2-ol

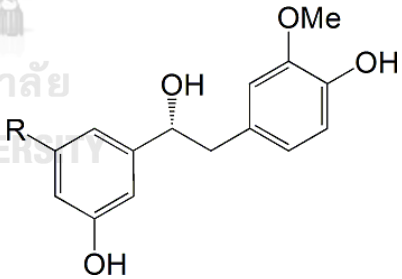


[**153**] 1,5-Dihydroxy-3,4,7-trimethoxy-9,10-dihydrophenanthrene



[**154**] 2,5,9S-Trihydroxy-9,10-dihydrophenanthrene-4-O-β-D-glucopyranoside





	R
[**155**] Loddigesiinol G	H
[**157**] Loddigesiinol H	OH

	R
[**156**] Aphyllal D	OH
[**158**] Aphyllal E	OMe

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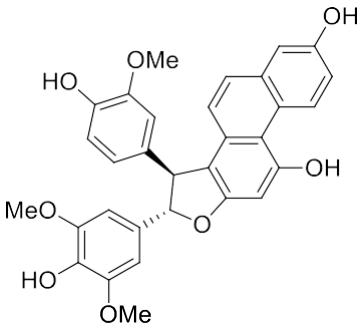
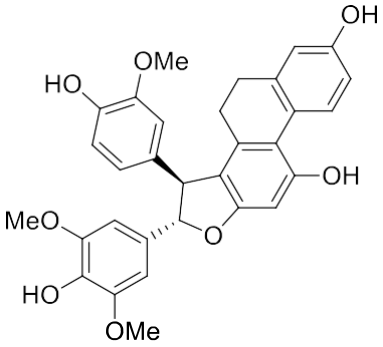
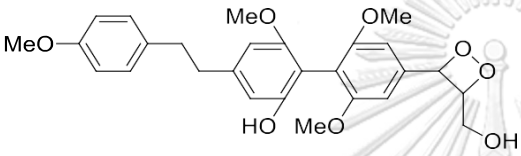
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



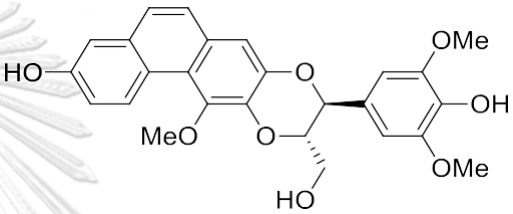
[**159**] Loddigesiinol I



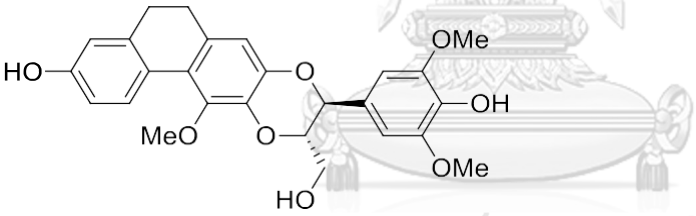
[**160**] Loddigesiinol J



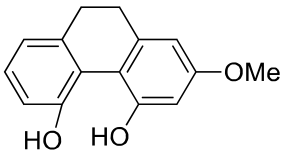
[**161**] Dendrowillol A



[**162**] Dendrocandin P1



[**163**] Dendrocandin P2



[**164**] Orchinol

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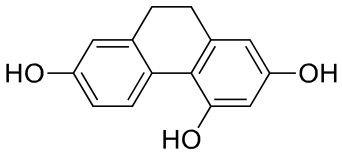
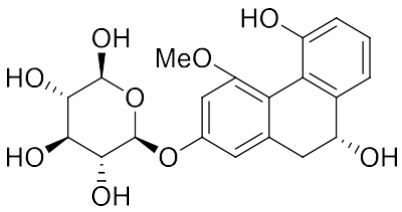
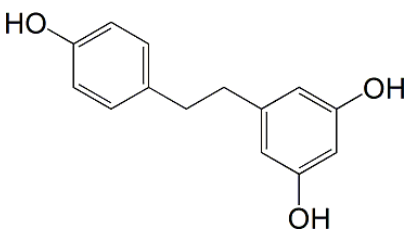


[**165**] 2,4,7-Trihydroxy-9,10-dihydrophenanthrene

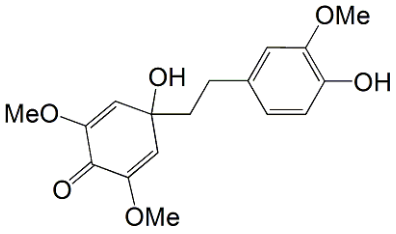


[**166**] 4-Methoxy-5,9R-dihydroxy-9,10-dihydrophenanthrene-2-O-β-D-glucopyranoside

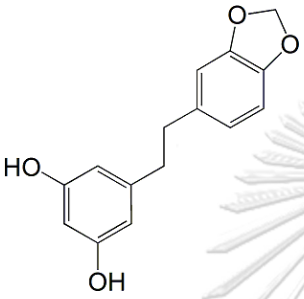
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



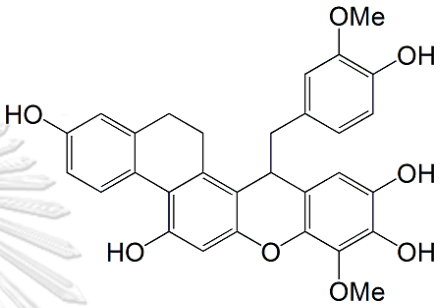
[**167**] Dihydroresveratrol



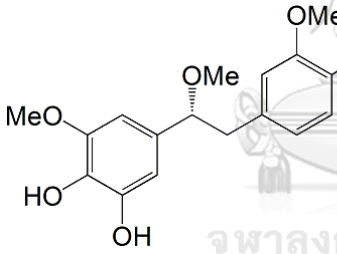
[**168**] Aphyllone B



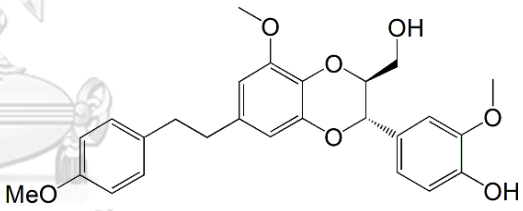
[**169**] Aphyllal C



[**170**] (-)-Dendroparishiol



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



[**172**] Dendrofindlaphenol *B*

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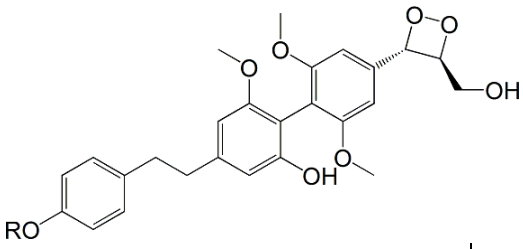
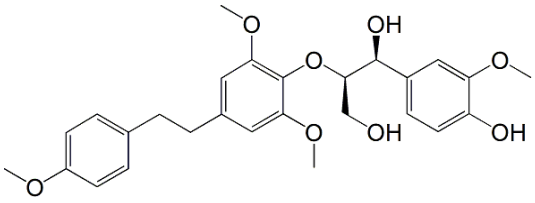
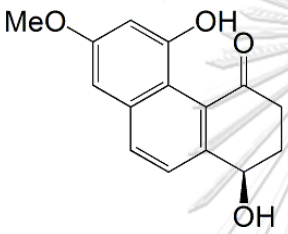
Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.



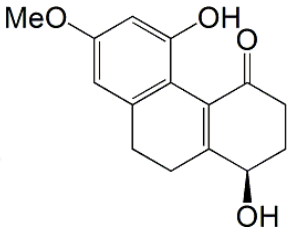
	R
[**173**] Dendrofindlaphenol A	Me
[**175**] 6″-De-*O*-methyldendrofindlaphenol A	H



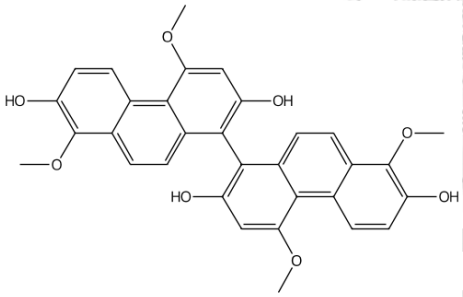
[**174**] Dendrofindlaphenol C



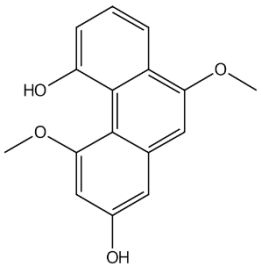
[**176**] Dendrodevonin A



[**177**] Dendrodevonin B



[**178**] 4,4′,8,8′-tetramethoxy[1,1′-biphenanthrene]-2,2′,7,7′-tetrol



[**179**] 4,9-dimethoxy-2,5-phenanthrenediol

Figure 2 Structure of Stilbenoids isolated from *Dendrobium* species.

Table 3 Flavonoids isolated from *Dendrobium* species

Flavonoids	Plant	Plant part	Reference
(2S)-Homoeriodictyol [**180**]	*D. densiflorum*	Stem	Fan et al. 2001
	D. ellipsophyllum	Whole plant	Tanagornmeatar et al. 2014
Naringenin [**181**]	*D. aurantiacum var.d enneanum*	Stem	Yang, Wang and Xu 2006
	D. densiflorum	Stem	Fan et al. 2001
	D. longicornu	Stem	Hu et al. 2008a
(2S)-Eriodictyol [**182**]	*D. trigonopus*	Stem	Hu et al. 2008b
	D. ellipsophyllum	Whole plant	Tanagornmeatar et al. 2014
	D. tortile	Whole plant	Limpanit et al. 2016
Vicenin II [**183**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al. 2013
Apigenin [**184**]	*D. crystallinum*	Stem	Wang et al. 2009
	D. williamsonii	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid 2014
5,6-Dihydroxy-4′-methoxyflavone [**185**]	*D. chrysotoxum*	Stem	Hu et al. 2012
Chrysoeriol [**186**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar et al. 2014

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Flavonoids	Plant	Plant part	Reference
Luteolin [**187**]	*D. aurantiacum var. denneanum*	Whole plant	Ying et al. 2009
	D. ellipsophyllum	Whole plant	Tanagornmeatar et al. 2014
6-*C*-(α-Arabino pyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-galactopyranosyl] apigenin [**188**]	*D. huoshanense*	Aerial part	Chang et al. 2010
6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl) –β-glucopyranosyl] apigenin [**189**]	*D. huoshanense*	Aerial part	Chang et al. 2010
6‴-Glucosyl-vitexin [**190**]	*D. crystallinum*	Stem	Wang et al. 2009
Isoschaftoside [**191**]	*D. huoshanense*	Aerial part	Chang et al. 2010
Isoviolanthin [**192**]	*D. crystallinum*	Stem	Wang et al. 2009
6-*C*-[(2-*O*-α-Rhamno pyranosyl)-β-glucopyranosyl]-8-*C*-(α-arabinopyranosyl) apigenin [**193**]	*D. huoshanense*	Aerial part	Chang et al. 2010

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Flavonoids	Plant	Plant part	Reference
6-*C*-(β-Xylopyranosyl)-8-*C*- [(2-*O*-α-rhamnopyranosyl)-β-glucopyranosyl] apigenin [**194**]	*D. huoshanense*	Aerial part	Chang et al. 2010
Kaempferol[**195**]	*D. aurantiacum* var. *denneanum*	Stem	Yang, Wang and Xu 2006
Kaempferol-3-*O*-α-L-rhamnopyranoside [**196**]	*D. secundum*	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid 2012
Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside [**197**]	*D. secundum*	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid 2012
Kaempferol-3-O-α-L-rhamnopyranosyl-(1→2)-β- D-glucopyranoside [**198**]	*D. capillipes*	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid 2012
Kaempferol-3-O-α-L-rhamnopyranosyl-(1→2)-β- D-xylopyranoside [**199**]	*D. capillipes*	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid 2012
Quercetin-3-O-α-L-rhamnopyranoside [**200**]	*D. secundum*	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid 2012

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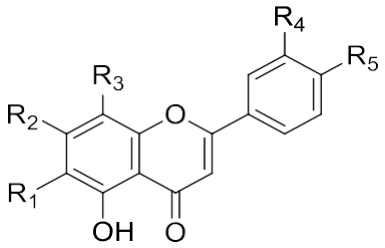
Flavonoids	Plant	Plant part	Reference
Quercetin-3-O-α-L-rhamnopyranosyl-(1→2)-β- D-xylopyranoside [**201**]	*D. capillipes*	Stem	Phechrmeekha, Sritularak and Likhitwitayawuid 2012
5-Hydroxy-3-methoxyflavone-7-O-[β-D- apiosyl-(1→6)]-β-D- glucoside [**202**]	*D. devonianum*	Stem	Sun et al. 2014
Isorhamnetin-3-O-β-D-rutinoside [**203**]	*D. nobile*	Stem	Zhou et al. 2017
(S)-5,5′,7-Trihydroxy-3′,4′-dimethoxyflavanone [**204**]	*D. loddigesii*	Stem	Ma, Yang, et al. 2019

	R
[**180**] (2S)-Homoeriodictyol	OMe
[**181**] Naringenin	H
[**182**] (*2S*)-Eriodictyol	OH

[**183**]Vicenin II

Figure 3 Structure of Flavonoids isolated from *Dendrobium* species



	R_1	R_2	R_3	R_4	R_5
[**184**] Apigenin	H	OH	H	H	OH
[**185**] 5,6-Dihydroxy-4′-methoxyflavone	OH	H	H	H	OMe
[**186**] Chrysoeriol	H	OH	H	OMe	OH
[**187**] Luteolin	H	OH	H	OH	OH
[**188**] 6-C-(α-Arabinopyranosyl)-8-C-[(2-O-α-rhamnopyranosyl)-β-galactopyranosyl] apigenin	-Ara	OH	-Gal -Rha	H	OH
[**189**] 6-C-(α -Arabinopyranosyl)-8-C-[(2-O- α -rhamnopyranosyl)-β-glucopyranosyl] apigenin	-Ara	OH	-Glc -Rha	H	OH

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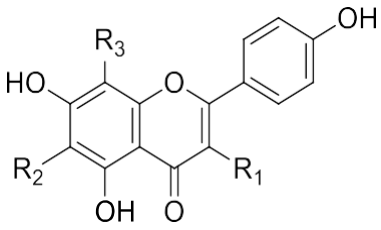
Figure 3 Structure of Flavonoids isolated from *Dendrobium*



	R_1	R_2	R_3
[**190**] 6‴-Glucosyl-vitexin	H	H	-Glc
[**191**] Isoschaftoside	H	-Ara	-Glc
[**192**] Isoviolanthin	H	-Rha	-Glc
[**193**] 6-C-[(2-O-α-Rhamnopyranosyl)-β-glucopyranosyl]-8-C-(α-arabinopyranosyl) apigenin	H	-Glc -Rha	-Ara
[**194**] 6-C-(β-Xylopyranosyl)-8-C-[(2-O-α-rhamnopyranosyl)-β-glucopyranosyl] apigenin	H	-Xyl	-Glc -Rha
[**195**] Kaempferol	OH	H	H

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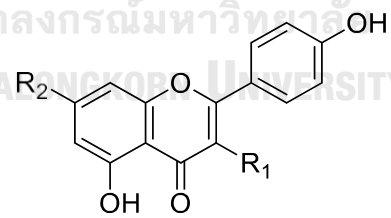
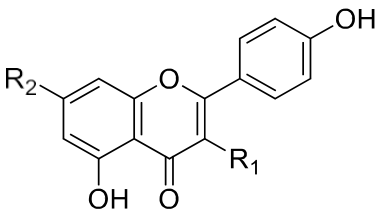
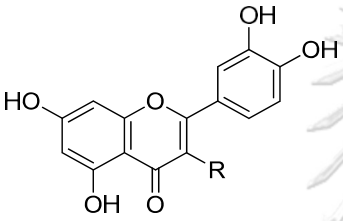


	R_1	R_2
[**196**] Kaempferol-3-O-α-L-rhamnopyranoside	O-Rha	OH
[**197**] Kaempferol-3,7-O-di- α -L-rhamnopyranoside	O-Rha	O-Rha

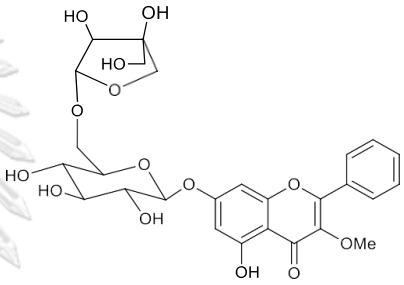
Figure 3 Structure of Flavonoids isolated from *Dendrobium* species



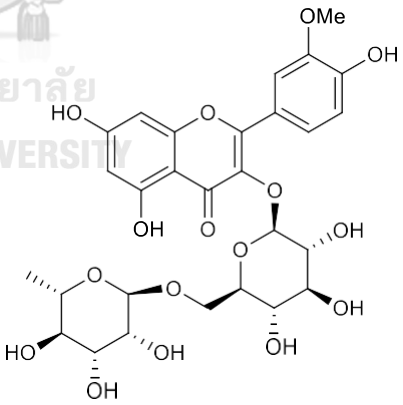
	R_1	R_2
[**198**] Kaempferol-3-O-α-L-rhamnopyranosyl-(1→2)-β-D-glucopyranoside	O-Glc-Rha	OH
[**199**] Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1→2)-β-D-xylopyranoside	O-Xyl-Rha	OH



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



[**202**] 5-Hydroxy-3-methoxyflavone-7-O-[β-D-apiosyl-(1→6)]-β-D-glucoside



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

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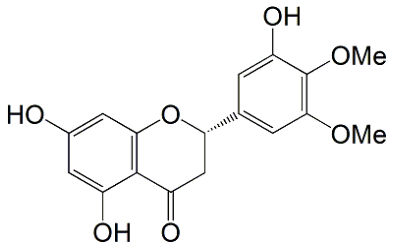
Figure 3 Structure of Flavonoids isolated from *Dendrobium* species



[**204**] (*S*)-5,5′,7-Trihydroxy-3′,4′-dimethoxyflavanone

Figure 3 Structure of Flavonoids isolated from *Dendrobium* species

Table 4 Terpenoids isolated from *Dendrobium* species

Terpenoids	Plant	Plant part	Reference
1,4-trans-12-hydroxycalamenene-12-O-β-glucoside [**205**]	*D. nobile*	Stem	Chen et al. 2023
Dendronobin [**206**]	*D. nobile*	Stem	Chen et al. 2023
dendrobilin L [**207**]	*D. nobile*	Stem	Chen et al. 2023
N-Isopentenyldendrobinium [**208**]	*D. nobile*	Stem	Wang et al. 2016
6-Hydroxy-dendroxine [**209**]	*D. findlayanum*	Stem	Yang et al. 2020
Aduncin [**210**]	*D. aduncum*	Whole plant	Gawell and Leander 1976
Amoenin [**211**]	*D. amoenum*	Whole plant	Dahmén and Leander 1978, Majumder, Guha and Sen 1999
Amotin [**212**]	*D. amoenum*	Whole plant	Majumder, Guha and Sen 1999, Dahmén and Leander 1978

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Terpenoids	Plant	Plant part	Reference
α-Dihydropicrotoxinin [**213**]	*D. moniliforme*	Stem	Bi, Wang and Xu 2004
Dendrobane A **[214]**	*D. nobile*	Stem	Zhang, Xu, et al. 2007
Dendrofindline A [**215**]	*D. findlayanum*	Stem	Liu, Tan, et al. 2020
Dendrofindline B [**216**]	*D. findlayanum*	Stem	Liu, Tan, et al. 2020
Dendronobilin A [**217**]	*D. nobile*	Stem	Zhang, Liu, et al. 2007
Dendronobilin B [**218**]	*D. nobile*	Stem	Zhang, Liu, et al. 2007
Dendronobilin C [**219**]	*D. nobile*	Stem	Zhang, Liu, et al. 2007
Dendronobilin D [**220**]	*D. nobile*	Stem	Zhang, Liu, et al. 2007
Dendronobilin E [**221**]	*D. nobile*	Stem	Zhang, Liu, et al. 2007
Dendronobilin F [**222**]	*D. nobile*	Stem	Zhang, Liu, et al. 2007
Dendronobilin G [**223**]	*D. nobile*	Stem	Zhang, Liu, et al. 2007
Dendronobilin H [**224**]	*D. nobile*	Stem	Zhang, Liu, et al. 2007
Dendronobilin I [**225**]	*D. nobile*	Stem	Zhang, Liu, et al. 2007
	D. findlayanum	Stem	Yang, Cheng, et al. 2019
Dendronobilin J [**226**]	*D. nobile*	Stem	Zhang, Xu, et al. 2007
Dendronobilin K [**227**]	*D. nobile*	Stem	Zhang, Tu, et al. 2008
Dendronobilin L [**228**]	*D. nobile*	Stem	Zhang, Tu, et al. 2008
Dendronobilin M [**229**]	*D. nobile*	Stem	Zhang, Tu, et al. 2008
Dendronobilin N [**230**]	*D. nobile*	Stem	Zhang, Tu, et al. 2008
	D. findlayanum	Stem	Yang, Cheng, et al. 2019
Dendrowardol A [**231**]	*D. wardianum*	Stem	Fan et al. 2013
Dendrowardol B [**232**]	*D. wardianum*	Stem	Fan et al. 2013
Dendrowardol C [**233**]	D. wardianum	Stem	Fan et al. 2013
Dihydronobilonine [**234**]	*D. findlayanum*	Stem	Yang et al. 2020

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Terpenoids	Plant	Plant part	Reference
Corchoionoside C [**235**]	*D. polyanthum*	Stem	Hu et al. 2009
Crystallinin [**236**]	*D. crystallinum*	Stem	Wang et al. 2009
	D. findlayanum	Whole plant	Qin et al. 2011
Findlayanin [**237**]	*D. findlayanum*	Whole plant	Qin et al. 2011
3-Hydroxy-2-oxodendrobine [**238**]	*D. nobile*	Stem	Wang, Zhao and Che 1985
Findlayine A **[239]**	*D. findlayanum*	Stem	Yang, Cheng, et al. 2018
Findlayine B [**240**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2018
Dendrobine [**241**]	*D. nobile*	Stem	Wang, Zhao and Che 1985
	D. findlayanum	Stem	Yang, Cheng, et al. 2018
	D. nobile	Stem	Chen et al. 2023
2-Hydroxydendrobine [**242**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2018
Findlayine C [**243**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2018
Findlayine D [**244**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2018
Findlayine E [**245**]	*D. findlayanum*	Stem	Yang et al. 2020
Findlayine F [**246**]	*D. findlayanum*	Stem	Yang et al. 2020
Dendromoniliside A [**247**]	*D. nobile*	Stem	Zhao et al. 2003
Dendromoniliside B [**248**]	*D. moniliforme*	Stem	Zhao et al. 2003
Dendromoniliside C [**249**]	*D. moniliforme*	Stem	Zhao et al. 2003
Dendromoniliside D [**250**]	*D. moniliforme*	Stem	Zhao et al. 2003,
	D. nobile	Stem	Daopeng et al. 2023

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Terpenoids	Plant	Plant part	Reference
Dendronobiloside A [**251**]	*D. nobile*	Stem	Zhao et al. 2001, Daopeng et al. 2023
Dendronobiloside B [**252**]	*D. nobile*	Stem	Zhao et al. 2001
Dendronobiloside C [**253**]	*D. nobile*	Stem	Zhao et al. 2001, Ye and Zhao 2002, Daopeng et al. 2023
Dendronobiloside D [**254**]	*D. nobile*	Stem	Zhao et al. 2001, Ye and Zhao 2002, Daopeng et al. 2023
Dendronobiloside E [**255**]	*D. nobile*	Stem	Zhao et al. 2001, Ye and Zhao 2002, Daopeng et al. 2023
Dendroside A [**256**]	*D. moniliforme*	Stem	Zhao et al. 2003
	D. nobile	Stem	Zhao et al. 2001
	D. nobile	Stem	Ye and Zhao 2002
	D. findlayanum	Stem	Yang, Cheng, et al. 2019
Dendroside B [**257**]	*D. nobile*	Stem	Ye and Zhao 2002
Dendroside C [**258**]	*D. moniliforme*	Stem	Zhao et al. 2003
	D. nobile	Stem	Ye and Zhao 2002
Dendroside D [**259**]	*D. nobile*	Stem	Ye and Zhao 2002
Dendroside E [**260**]	*D. nobile*	Stem	Ye, Qin and Zhao 2002, Daopeng et al. 2023
Dendroside F [**261**]	*D. moniliforme*	Stem	Ye and Zhao 2002
Dendroside G [**262**]	*D. nobile*	Stem	Ye, Qin and Zhao 2002
Dendrowillin A [**263**]	*D. williamsonii*	Whole plant	Yang, Chen, et al. 2019

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Terpenoids	Plant	Plant part	Reference
Dendrowillin B [**264**]	*D. williamsonii*	Whole plant	Yang, Chen, et al. 2019
(-)-Picrotin [**265**]	*D. williamsonii*	Whole plant	Yang, Chen, et al. 2019
10β,12,14-Trihydroxyaromadendrane [**266**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2019
10β,13,14-Trihydroxyaromadendrane [**267**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2019
Dendrofindlayanoside A [**268**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2019
Dendrofindlayanoside B [**269**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2019
Dendrofindlayanoside C [**270**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2019
Dendrofindlayanobilin [**271**]	*D. findlayanum*	Stem	Yang, Cheng, et al. 2019
(+)-(1*R*,2*S*,3*R*,4*S*,5*R*,6*S*,9*R*)-3,11,12-Trihydroxypicrotoxane- 2(15)-lactone [**272**]	*D. nobile*	Stem	Ma, Meng, et al. 2019
(-)-(1*S*,2*R*,3*S*,4*R*,5*S*,6*R*, 9*S*,12*R*)-3,11,13-Trihydroxypicrotoxane -2(15)-lactone [**273**]	*D. nobile*	Stem	Ma, Meng, et al. 2019
(+)-(1R,5R,6S,8R,9R)-8,12-Dihydroxycopacamphan-3-en- 2-one [**274**]	*D. nobile*	Stem	Ma, Meng, et al. 2019
Dendroterpene A [**275**]	*D. nobile*	Stem	Wang et al. 2019

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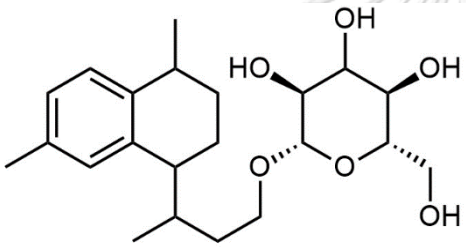
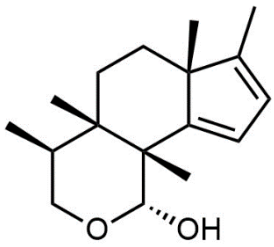
Terpenoids	Plant	Plant part	Reference
Dendroterpene B [**276**]	*D. nobile*	Stem	Wang et al. 2019
Dendroterpene C [**277**]	*D. nobile*	Stem	Wang et al. 2019
Dendroterpene D [**278**]	*D. nobile*	Stem	Wang et al. 2019
Dendroterpene E [**279**]	*D. nobile*	Stem	Wang et al. 2022
Nobiline [**280**]	*D. findlayanum*	Stem	Yang et al. 2020
	D. nobile	Stem	Chen et al. 2023



[**205**] 1,4-trans-12-hydroxycalamenene-12-O-β—glucoside



[**206**] Dendronobin

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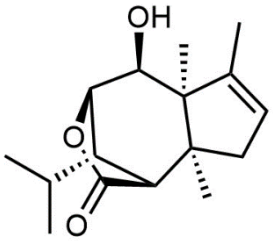
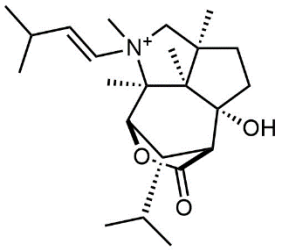
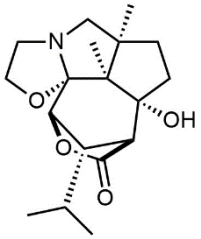
Figure 4 Structure of Terpenoids isolated from *Dendrobium* species



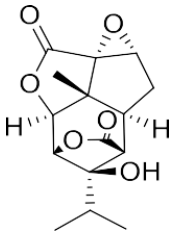
[**207**] dendrobilin L



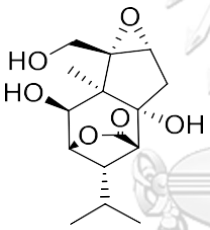
[**208**] N-Isopentenyldendrobinium



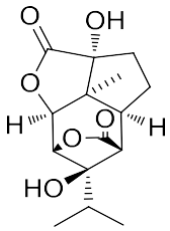
[**209**] 6-Hydroxy-dendroxine



[**210**] Aduncin



[**211**] Amoenin



[**212**] Amotin

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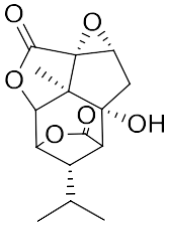
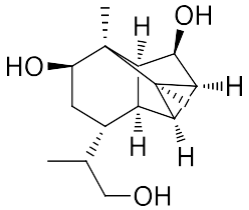
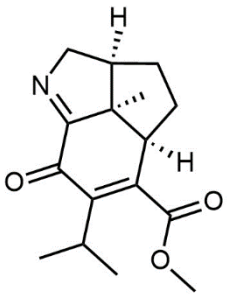


[**213**] α-Dihydropicrotoxinin

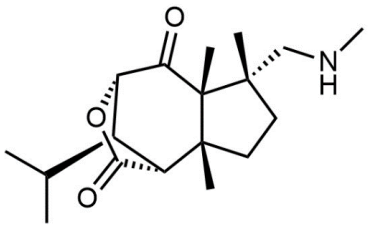


[**214**] Dendrobane A

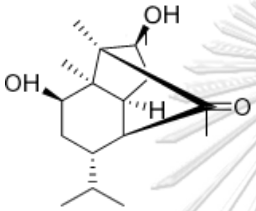
Figure 4 Structure of Terpenoids isolated from *Dendrobium* species



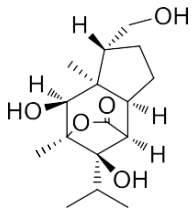
[**215**] Dendrofindline A



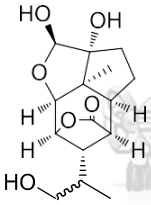
[**216**] Dendrofindline B



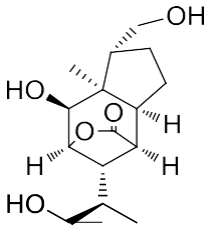
[**217**] Dendronobilin A



[**218**] Dendronobilin B



[**219**] Dendronobilin C



[**220**] Dendronobilin D

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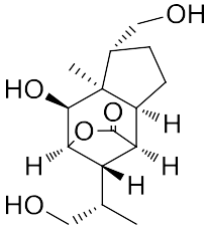
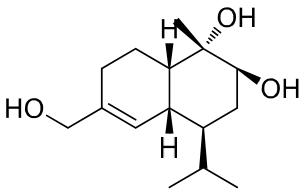


[**221**] Dendronobilin E



[**222**] Dendronobilin F

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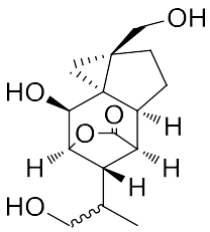
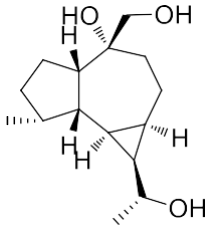
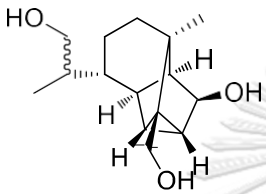


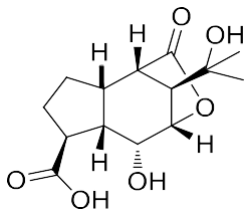
[**223**] Dendronobilin G



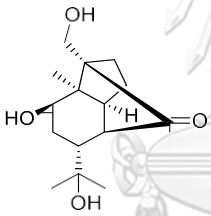
[**224**] Dendronobilin H



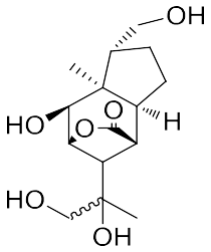
[**225**] Dendronobilin I



[**226**] Dendronobilin J



[**227**] Dendronobilin K



[**228**] Dendronobilin L

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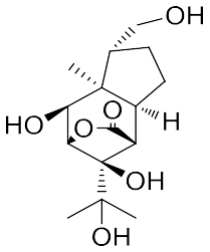
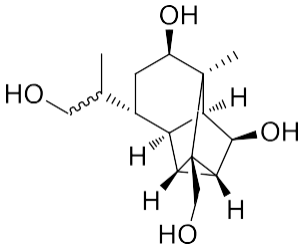
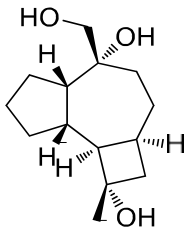


[**229**] Dendronobilin M

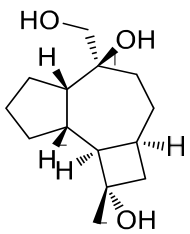


[**230**] Dendronobilin N

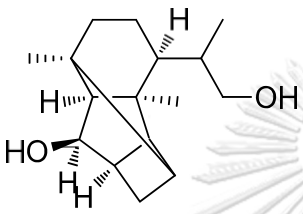
Figure 4 Structure of Terpenoids isolated from *Dendrobium* species



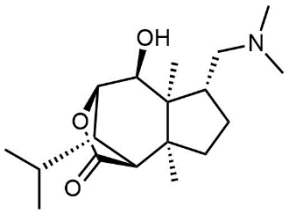
[**231**] Dendrowardol A



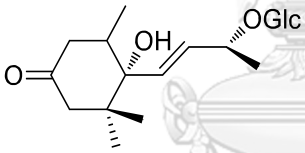
[**232**] Dendrowardol B



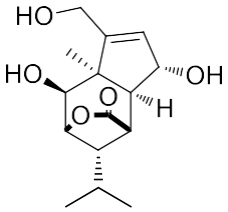
[**233**] Dendrowardol C



[**234**] Dihydronobilonine



[**235**] Corchoionoside C



[**236**] Crystallinin

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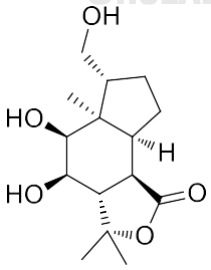
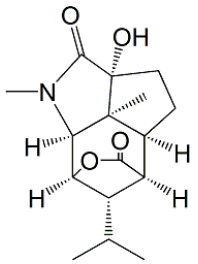


[**237**] Findlayanin



[**238**] 3-Hydroxy-2-oxodendrobine

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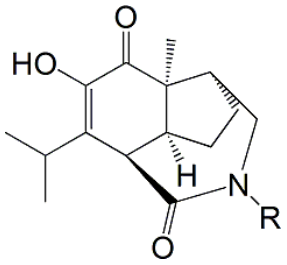
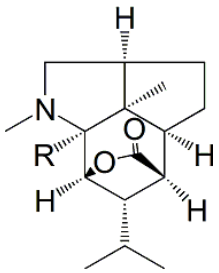
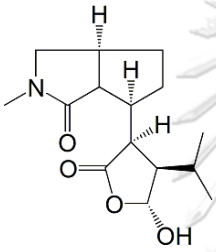


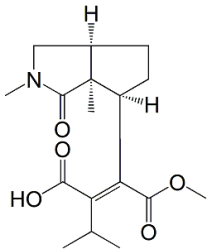
	R
[**239**] Findlayine A	Me
[**240**] Findlayine B	H



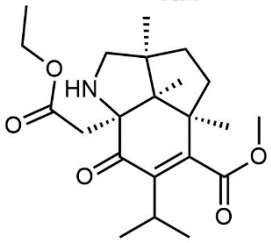
	R
[**241**] Dendrobine	H
[**242**] 2-Hydroxydendrobine	OH



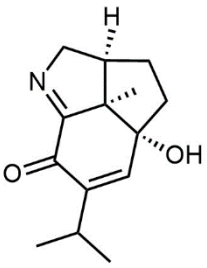
[**243**] Findlayine C



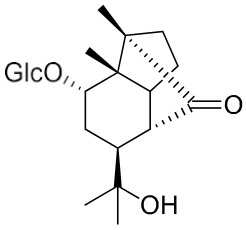
[**244**] Findlayine D



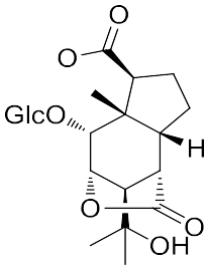
[**245**] Findlayine E



[**246**] Findlayine F



[**247**] Dendromoniliside A



[**248**] Dendromoniliside B

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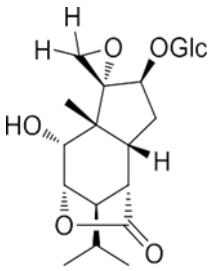
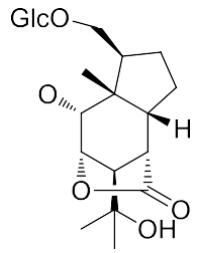
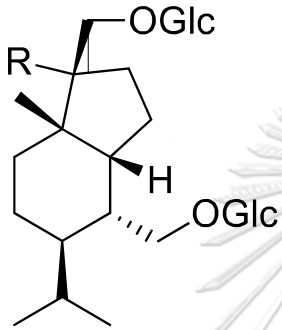


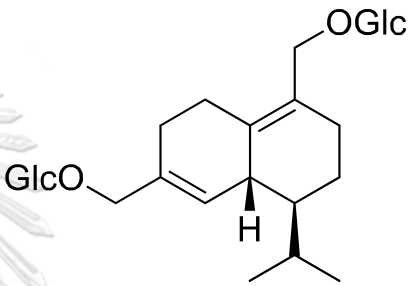
[**249**] Dendromoniliside C



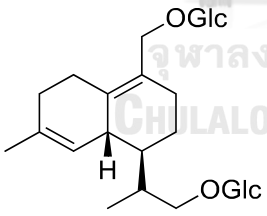
[**250**] Dendromoniliside D



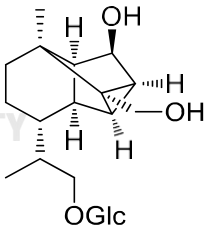
	R
[**251**] Dendronobiloside A	H
[**252**] Dendronobiloside B	OH



[**253**] Dendronobiloside C



[**254**] Dendronobiloside D



[**255**] Dendronobiloside E

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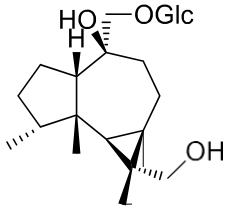
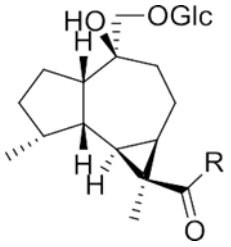
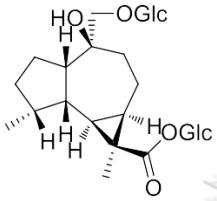
Figure 4 Structure of Terpenoids isolated from *Dendrobium* species



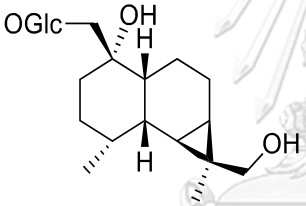
[**256**] Dendroside A



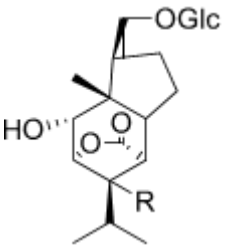
	R
[**257**] Dendroside B	O-Glc
[**258**] Dendroside C	OH



[**259**] Dendroside D



[**260**] Dendroside E



	R
[**261**] Dendroside F	H
[**262**] Dendroside G	OH

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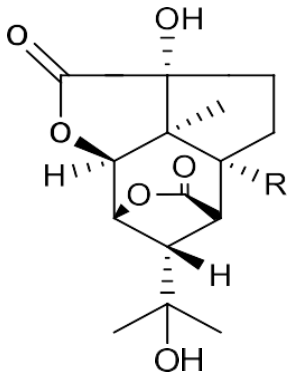
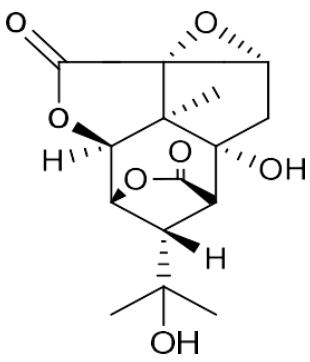
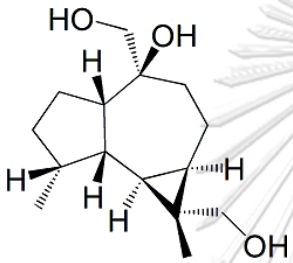
Figure 4 Structure of Terpenoids isolated from *Dendrobium* species



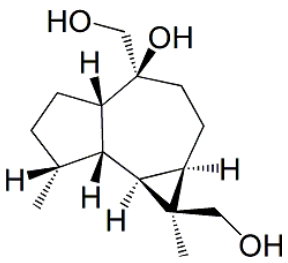
	R
[**263**] Dendrowillin A	OH
[**264**] Dendrowillin B	H



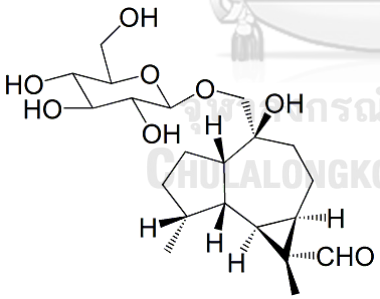
[**265**] (-)-Picrotin



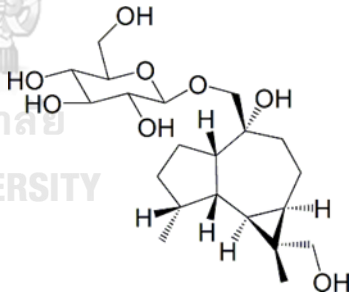
[**266**] 10β,12,14-Trihydroxyaromadendrane



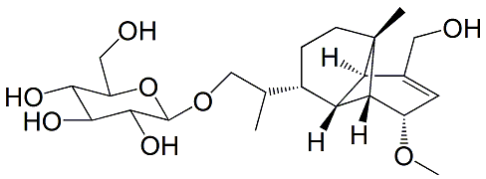
[**267**] 10β,13,14-Trihydroxyaromadendrane



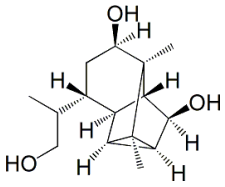
[**268**] Dendrofindlayanoside A



[**269**] Dendrofindlayanoside B



[**270**] Dendrofindlayanoside C



[**271**] Dendrofindlayanobilin

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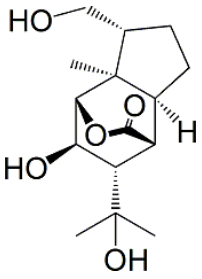
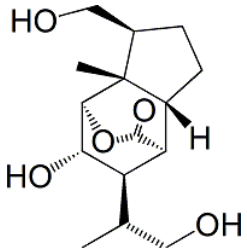
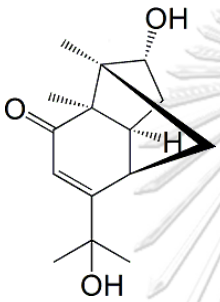


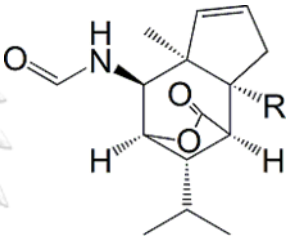
[**272**] (+)-(1*R*,2*S*,3*R*,4*S*,5*R*,6*S*,9*R*)- 3,11,12-Trihydroxypicrotoxane-2(15)-lactone



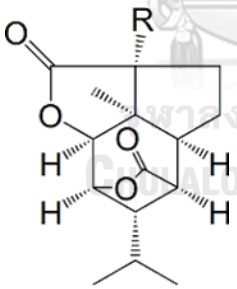
[**273**] (-)-(1*S*,2*R*,3*S*,4*R*,5*S*,6*R*,9*S*,12*R*)-3,11,13-Trihydroxypicrotoxane-2(15)-lactone



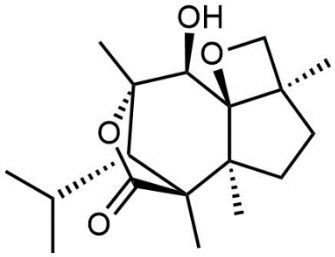
[**274**] (+)-(1*R*,5*R*,6*S*,8*R*,9*R*)- 8,12-Dihydroxycopacamphan-3-en-2-one



	R
[**275**] Dendroterpene A	H
[**276**] Dendroterpene B	OH



	R
[**277**] Dendroterpene C	H
[**278**] Dendroterpene D	OH



[**279**] Dendroterpene E

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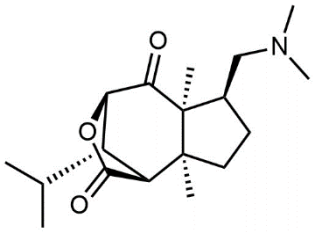
Figure 4 Structure of Terpenoids isolated from *Dendrobium* species



[**280**] Nobiline

Figure 4 Structure of Terpenoids isolated from *Dendrobium* species

Table 5 Miscellaneous compounds isolated from *Dendrobium* species

Categories and compounds	Plant	Plant part	Reference
Aliphatic acid derivatives			
Malic acid [**281**]	*D. huoshanense*	Aerial part	Chang et al. 2010
Dimethyl malate [**282**]	*D. huoshanense*	Aerial part	Chang et al. 2010
Aliphatic acids [**283**]	*D. clavatum* var. *aurantiacum*	Stem	Chang, Lin and Chen 2001
Aliphatic alcohols [**284**]	*D. clavatum* var. *aurantiacum*	Stem	Chang, Lin and Chen 2001
(-)-Shikimic acid [**285**]	*D. fuscescens*	Whole plant	Talapatra, Das and Talapatra 1989
	D. huoshanense	Aerial part	Chang et al. 2010
	D. longicornu	Stem	Hu et al. 2008a
	D. pulchellum	Stem	Chanvorachote et al. 2013
Isopentyl butyrate [**286**]	*D. huoshanense*	Aerial part	Chang et al. 2010
Dendrodevonic acid A [**287**]	*D. devonianum*	Stem	Wu et al. 2019

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Categories and compounds	Plant	Plant part	Reference
Dendrodevonic acid B [**288**]	*D. devonianum*	Stem	Wu et al. 2019
Benzoic acid derivatives and phenolic compounds			
methyl 3-(4-hydroxyphenyl) propionate [**289**]	*D. heterocarpum*	Whole plant	Warinhomhoun et al. 2022
Diorcinolic acid [**290**]	*D. christyanum*	Root	San et al. 2020
3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid [**291**]	*D. crystallinum*	Stem	Wang et al. 2009
Salicylic acid [**292**]	*D. huoshanense*	Aerial part	Chang et al. 2010
	D. williamsonii	Whole plant	Yang, Zhang, et al. 2018
Vanilloloside[**293**]	*D. denneanum*	Stem	Pan et al. 2012
	D. moniliforme	Stem	Zhao et al. 2003
Gallic acid [**294**]	*D. longicornu*	Whole plant	Li, Yin, et al. 2009
Syringic acid [**295**]	*D. crystallinum*	Stem	Wang et al. 2009
Vanillic acid [**296**]	*D. chrysotoxum*	Whole plant	Li, Qing, et al. 2009
	D. williamsonii	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid 2014
Protocatechuic acid [**297**]	*D. nobile*	Stem	Ye and Zhao 2002
Antiarol [**298**]	*D. chrysotoxum*	Stem	Hu et al. 2012

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Categories and compounds	Plant	Plant part	Reference
p-Hydroxybenzaldehyde [**299**]	*D. devonianum*	Whole plant	Sun et al. 2014
	D. falconeri	Stem	Sritularak and Likhitwitayawuid 2009
	D. tortile	Whole plant	Limpanit et al. 2016
	D. williamsonii	Whole plant	Yang, Chen, et al. 2019
Methyl β-orsellinate [**300**]	*D. longicornu*	Stem	Hu et al. 2008b
Methyl haematommate [**301**]	*D. christyanum*	Root	San et al. 2020
Ethylhaematommate [**302**]	*D. longicornu*	Whole plant	Li, Yin, et al. 2009
Tachioside [**303**]	*D. denneanum*	Stem	Pan et al. 2012
p-Hydroxyphenethyl trans-ferulate [**304**]	*D. loddigesii*	Stem	Ma, Yang, et al. 2019
Alkyl 4′-hydroxy trans-cinnamates [**305**]	*D. clavatum var. aurantiacum*	Stem	Chang, Lin and Chen 2001
Alkyl trans-ferulates [**306**]	*D. clavatum var. aurantiacum*	Stem	Chang, Lin and Chen 2001
	D. scabrilingue	Whole plant	Sarakulwattana et al. 2020
Defuscin [**307**]	*D. fuscescens*	Whole plant	Talapatra, Das and Talapatra 1989
	D. aurantiacum var. denneanum	Stem	Yang, Wang and Xu 2006

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Categories and compounds	Plant	Plant part	Reference
n-Octacosyl ferulate [**308**]	*D. aurantiacum var. denneanum*	Stem	Yang, Wang and Xu 2006
	D. moniliforme	Stem	Bi, Wang and Xu 2004
n-Triacontyl-p-hydroxy cis-cinnamate [**309**]	*D. moniliforme*	Stem	Bi, Wang and Xu 2004
Tetratriacontanyl trans-p-coumarate [**310**]	*D. williamsonii*	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid 2014
n-Docosyl trans-ferulate [**311**]	*D. longicornu*	Whole plant	Li, Yin, et al. 2009
	D. williamsonii	Whole plant	Rungwichaniwat, Sritularak and Likhitwitayawuid 2014
trans-Tetracosyl ferulate [**312**]	*D. tortile*	Whole plant	Limpanit et al. 2016
cis-Hexacosanoyl ferulate [**313**]	*D. tortile*	Whole plant	Limpanit et al. 2016
Ferulaldehyde [**314**]	*D. longicornu*	Whole plant	Li, Yin, et al. 2009
Ferulic acid [**315**]	*D. secundum*	Stem	Sritularak, Duangrak and Likhitwitayawuid 2011
2-(p-Hydroxyphenyl) ethyl p-coumarate [**316**]	*D. falconeri*	Stem	Sritularak and Likhitwitayawuid 2009

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Categories and compounds	Plant	Plant part	Reference
Dihydroconiferyl dihydro-p-coumarate [**317**]	*D. formosum*	Whole plant	Inthongkaew et al. 2017
	D. loddigesii	Stem	Ma, Yang, et al. 2019
	D. devonianum	Stem	Wu et al. 2019
	D. hainanense	Aerial part	Zhang, Wang, et al. 2019
1-[4-(β-D-Glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone [**318**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al. 2013
3-Hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl)-1-propanone [**319**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018
2-Hydroxy-3-(4-hydroxy-3-methoxyphenyl)-3-methoxypropyl-3-(4-hydroxylphenyl) propanoate [**320**]	*D. hainanense*	Aerial part	Zhang, Wang, et al. 2019
Coniferyl alcohol [**321**]	*D. trigonopus*	Stem	Hu et al. 2008b
	D. christyanum	Root	San et al. 2020
(E)-Coniferyl aldehyde [**322**]	*D. hainanense*	Aerial part	Zhang, Wang, et al. 2019
Coniferyl aldehyde [**323**]	*D. christyanum*	Root	San et al. 2020
Sinapicaldehyde [**324**]	*D. hainanense*	Aerial part	Zhang, Wang, et al. 2019
Decumbic acid A [**325**]	*D. nobile*	Stem	Zhou et al. 2016
Decumbic acid B [**326**]	*D. nobile*	Stem	Zhou et al. 2016
(-)-Decumbic acid [**327**]	*D. nobile*	Stem	Zhou et al. 2016

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Categories and compounds	Plant	Plant part	Reference
(+)-Dendrolactone [**328**]	*D. nobile*	Stem	Zhou et al. 2016
4-(3-Hydroxyphenyl)-2-butanone [**329**]	*D. nobile*	Stem	Zhou et al. 2016
3-Hydroxy-1-(3-methoxy-4-hydroxyphenyl)-propan-1- one [**330**]	*D. nobile*	Stem	Zhou et al. 2016
3′,4′,5′-Trimethoxy cinnamyl acetate [**331**]	*D. nobile*	Stem	Zhou et al. 2016
Alatusol A [**332**]	*D. hainanense*	Aerial part	Zhou et al. 2016
p-Hydroxyphenyl propionic methyl ester [**333**]	*D. aphyllum*	Whole plant	Chen, Li, et al. 2008
Phloretic acid [**334**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar et al. 2014
Dihydroconiferyl alcohol [**335**]	*D. longicornu*	Stem	Hu et al. 2008a
	D. nobile	Stem	Zhang et al. 2006; Wang 2021
Salidrosol [**336**]	*D. chrysotoxum*	Stem	Hu et al. 2012
Shashenoside I [**337**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al. 2013
Syringin [**338**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al. 2013
cis-Melilotoside [**339**]	*D. aurantiacum var. denneanum*	Stem	Yang et al. 2007
trans-Melilotoside [**340**]	*D. aurantiacum var. denneanum*	Stem	Yang et al. 2007

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Categories and compounds	Plant	Plant part	Reference
Dihydromelilotoside [**341**]	*D. aurantiacum var. denneanum*	Stem	Yang et al. 2007
Tetracosyl (*Z*)-p-coumarate [**342**]	*D. falconeri*	Whole plant	Sritularak and Likhitwitayawuid 2009
(7*S*,8*R*)-Dehydrodiconiferyl alcohol 9′-β-D-glucopyranoside [**343**]	*D. nobile*	Stem	Zhou et al. 2017
Koaburaside [**344**]	*D. nobile*	Stem	Zhou et al. 2017
Juniperoside [**345**]	*D. nobile*	Stem	Zhou et al. 2017
Dehydrodiconiferyl alcohol-4-β-D-glucoside [**346**]	*D. nobile*	Stem	Zhou et al. 2017
(3*R*,3′*S*,4*R*,4′*S*)-3,3′,4,4′-Tetrahydro-6,6′-dimethoxy[3,3′-bi-2H-benzopyran]-4,4′-diol [**347**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018
threo-7-O-Ethyl-9-O-(4-hydroxyphenyl) propionyl-guaiacylglycerol [**348**]	*D. loddigesii*	Stem	Ma, Yang, et al. 2019
Methyl 2,4-dihydroxy-3,6-dimethylbenzoate [**349**]	*D. christyanum*	Root	San et al. 2020
n-Docosyl 4-hydroxy-*trans*-cinnamate [**350**]	*D. christyanum*	Root	San et al. 2020

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Categories and compounds	Plant	Plant part	Reference
n-Eicosyl *trans*-ferulate [**351**]	*D. christyanum*	Root	San et al. 2020
Vanillin [**352**]	*D. christyanum*	Root	San et al. 2020
Coumarin			
Ayapin [**353**]	*D. densiflorum*	Stem	Fan et al. 2001
Coumarin [**354**]	*D. aurantiacum* var. *denneanum*	Stem	Yang, Wang and Xu 2006
	D. clavatum var. *aurantiacum*	Stem	Chang, Lin and Chen 2001
Denthyrsin [**355**]	*D. thyrsiflorum*	Stem	Zhang et al. 2005
Scoparone [**356**]	*D. densiflorum*	Stem	Fan et al. 2001
	D. thyrsiflorum	Stem	Zhang et al. 2005
	D. williamsonii	Whole plant	Yang, Zhang, et al. 2018
	D. palpebrae	Whole plant	Kyokong et al. 2019
Scopoletin [**357**]	*D. densiflorum*	Stem	Fan et al. 2001
Lignans and neolignans			
Episyringaresinol [**358**]	*D. chrysotoxum*	Stem	Hu et al. 2012
	D. longicornu	Stem	Hu et al. 2008a
	D. nobile	Stem	Zhang, Tu, et al. 2008
Episyringaresinol 4″-O-β-D- glucopyranoside [**359**]	*D. moniliforme*	Stem	Zhao et al. 2003

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Categories and compounds	Plant	Plant part	Reference
(-)-(7S,8R,7′E)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′- oxyneolign-7′-ene-7,9′-bis- O-β-D-glucopyranoside [**360**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al. 2013
5-methoxy-(+)-isolariciresinol [**361**]	*D. nobile*	Stem	Chen et al. 2023
Lyoniresinol [**362**]	*D. chrysanthum*	Stem	Ye, Zhao and Qin 2004
	D. nobile	Stem	Chen et al. 2023
erythro-1-(4-O-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol [**363**]	*D. longicornu*	Stem	Hu et al. 2008a
(-)-Syringaresinol-4,4′-bis-O-β-D-glucopyranoside [**364**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al. 2013
Syringaresinol-4-O-D-monoglucopyranoside [**365**]	*D. aurantiacum var. denneanum*	Stem	Xiong et al. 2013
Dendrocoumarin [**366**]	*D. nobile*	Stem	Zhou et al. 2018
Itolide A [**367**]	*D. nobile*	Stem	Zhou et al. 2018

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Categories and compounds	Plant	Plant part	Reference
Syringaresinol [**368**]	*D. nobile*	Stem	Zhang, Tu, et al. 2008
	D. secundum	Stem	Sritularak, Duangrak and Likhitwitayawuid 2011
	D. williamsonii	Whole plant	Yang, Zhang, et al. 2018
	D. heterocarpum	Whole plant	Warinhomhoun et al. 2022
Acanthoside B [**369**]	*D. chrysanthum*	Stem	Ye, Zhao and Qin 2004
Liriodendrin [**370**]	*D. brymerianum*	Whole plant	Chen, Yu and Liu 2014
(-)-Medioresinol [**371**]	*D. loddigesii*	Whole plant	Ito et al. 2010
	D. nobile	Stem	Zhang, Tu, et al. 2008
(-)-Pinoresinol [**372**]	*D. loddigesii*	Whole plant	Ito et al. 2010
	D. nobile	Stem	Zhang, Tu, et al. 2008
(+)-Pinoresinol [**373**]	*D. devonianum*	Stem	Wu et al. 2019
	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 [**374**]	*D. auranticum var. denneanum*	Stem	Li, Guo, et al. 2014

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Categories and compounds	Plant	Plant part	Reference
(-)-(8S,7′E)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′- oxyneolign-7′-ene-9,9′-diol 4,9-bis-O-β-D-glucopyranoside [**375**]	*D. auranticum var. denneanum*	Stem	Li, Guo, 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 [**376**]	*D. auranticum var. denneanum*	Stem	Li, Guo, et al. 2014
Fluorenones			
Denchrysan B [**377**]	*D. brymerianum*	Whole plant	Klongkumnuankarn et al. 2015
	D. chrysotoxum	Whole plant	Li, Qing, et al. 2009
Dendrogibsol [**378**]	*D. gibsonii*	Whole plant	Thant et al. 2020
Denchrysan A [**379**]	*D. chrysotoxum*	Whole plant	Li, Qing, et al. 2009
	D. gibsonii	Whole plant	Thant et al. 2020
Dendroflorin [**380**]	*D. aurantiacum* var. *denneanum*	Stem	Yang, Wang and Xu 2006
	D. brymerianum	Whole plant	Klongkumnuankarn et al. 2015
	D. palpebrae	Whole plant	Kyokong et al. 2019

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Categories and compounds	Plant	Plant part	Reference
Dengibsin [**381**]	*D. aurantiacum var. denneanum*	Stem	Yang, Wang and Xu 2006
	D. chrysanthum	Stem	Yang et al. 2006
	D. chrysotoxum	Whole plant	Li, Qing, et al. 2009
Dengibsinin [**382**]	*D. gibsonii*	Whole plant	Thant et al. 2020
Nobilone [**383**]	*D. brymerianum*	Whole plant	Klongkumnuankarn et al. 2015
	D. nobile	Stem	Zhang, Liu, et al. 2007
	D. palpebrae	Whole plant	Kyokong et al. 2019
	D. gibsonii	Whole plant	Thant et al. 2020
1,4,5-Trihydroxy-7-methoxy-9H-fluoren-9-one [**384**]	*D. chrysotoxum*	Whole plant	Li, Qing, et al. 2009
2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone [**385**]	*D. chrysotoxum*	Stem	Yang et al. 2004
4-Methoxy-9H-fluorene-2,5,9-triol [**386**]	*D. gibsonii*	Whole plant	Thant et al. 2020
Dihydrodengibsinin [**387**]	*D. gibsonii*	Whole plant	Thant et al. 2020

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Categories and compounds	Plant	Plant part	Reference
Others			
3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one [**388**]	*D. chrysotoxum*	Stem	Hu et al. 2012
Palmarumycin JC2 [**389**]	*D. crystallinum*	Stem	Wang et al. 2009
Dehydrovomifoliol [**390**]	*D. loddigesii*	Whole plant	Ito et al. 2010
2,6-Dimethoxybenzoquinone [**391**]	*D. chryseum*	Stem	Ma, Wang and Yin 1998
4-(2-Hydroxypropyl)-2(5H)-furanone [**392**]	*D. tortile*	Whole plant	Limpanit et al. 2016
5,7-Dihydroxychromen-4-one [**393**]	*D. ellipsophyllum*	Whole plant	Tanagornmeatar et al. 2014
Balanophonin [**394**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018
Ergosta-8(9),22-diene-3,5,6,7-tetraol [**395**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018
Stigmast-4-en-3α,6β-diol [**396**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018
3β-Hydroxy-5α,8α-epidioxyergosta-6,9,22-triene [**397**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018
Betulin [**398**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018
Anosmine [**399**]	*D. parishii*	Whole plant	Hemscheidt and Spenser 1991
β-Sitosterol [**400**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018

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Categories and compounds	Plant	Plant part	Reference
Daucosterol [**401**]	*D. williamsonii*	Whole plant	Yang, Zhang, et al. 2018
Asiatic acid [**402**]	*D. parishii*	Whole plant	Klongkumnuankarn et al. 2015
Di-p-hydroxyphenylpropionic acidic-*p*-coumaric acid lactone [**403**]	*D. chrysanthum*	Whole plant	Cai et al. 2018
RF-3192C [**404**]	*D. scabrilingue*	Whole plant	Sarakulwattana et al. 2020
Crepidatumine C [**405**]	*D. crepidatum*	Stem	Xu et al. 2019
Crepidatumine D [**406**]	*D. crepidatum*	Stem	Xu et al. 2019
Crepidine [**407**]	*D. crepidatum*	Stem	Xu et al. 2019
Isocrepidamine [**408**]	*D. crepidatum*	Stem	Xu et al. 2019
Crepidamine [**409**]	*D. crepidatum*	Stem	Xu et al. 2019
5,7-Dimethyl-octahydroindolizine (Dendroprimine) [**410**]	*D. primulinum*	Whole plant	Lüning et al. 1965; Mou et al. 2021
Hygrine [**411**]	*D. primulinum*	Whole plant	Lüning et al. 1965; Mou et al. 2021
Pierardine [**412**]	*D. pierardii*	Whole plant	Elander, Leander and Luning 1969
2,3,4,9-Tetrahydro-1*H*-pyrido[3,4-b]indole-3-carboxylic acid [**413**]	*D. devonianum*	Stem	Mou et al. 2021
Shihunidine[**414**]	*D. loddigesii*	Stem	Li et al. 1991

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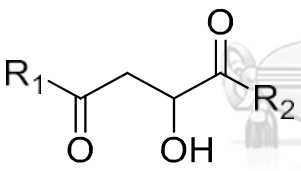
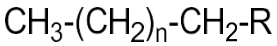
Categories and compounds	Plant	Plant part	Reference
Shihunine[**415**]	*D. loddigesii*	Stem	Li et al. 1991; Mou et al. 2021
N-cis-p-coumaroyltyramine [**416**]	*D. devonianum*	Stem	Mou et al. 2021
N-cis-feruloyltyramine [**417**]	*D. devonianum*	Stem	Mou et al. 2021





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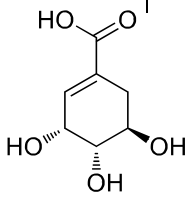
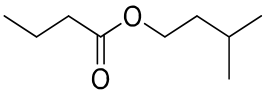
	R_1	R_2
[**281**] Malic acid	OH	OH
[**282**] Dimethyl malate	OMe	OMe

	R	n
[**283**] Aliphatic acids	COOH	19-31
[**284**] Aliphatic alcohols	OH	22-32

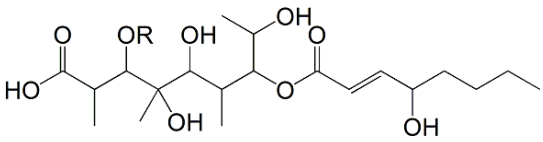


[**285**] (-)-Shikimic acid

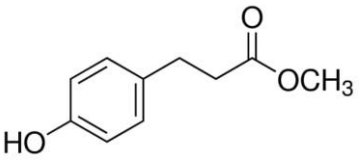


[**286**] Isopentyl butyrate

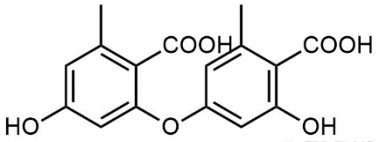
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



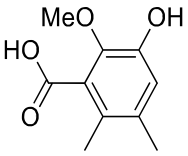
	R
[**287**] Dendrodevonic acid A	H
[**288**] Dendrodevonic acid B	Acetyl



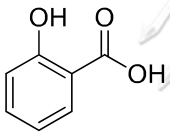
[**289**] methyl 3-(4-hydroxyphenyl) propionate



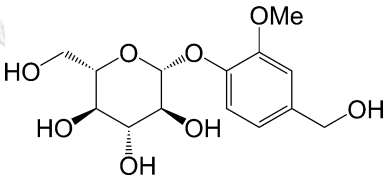
[**290**] Diorcinolic acid



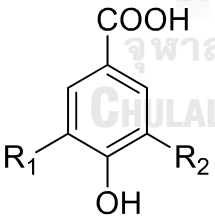
[**291**] 3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid



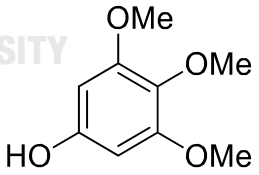
[**292**] Salicylic acid



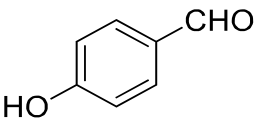
[**293**] Vanilloloside



	R_1	R_2
[**294**] Gallic acid	OH	OH
[**295**] Syringic acid	OMe	OMe
[**296**] Vanillic acid	H	OMe
[**297**] Protocatechuic acid	H	OH



[**298**] Antiarol



[**299**] p-Hydroxybenzaldehyde

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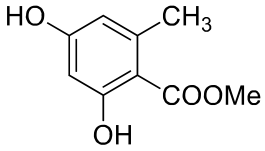
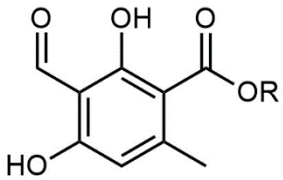
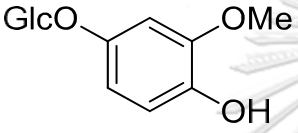
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



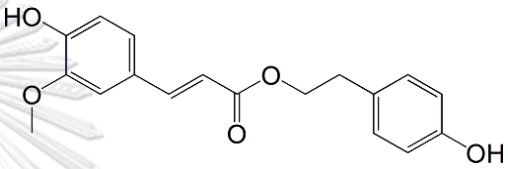
[**300**] Methyl β-orsellinate



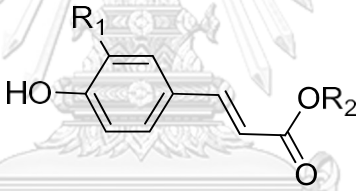
	R_1
[**301**] Methyl haematommate	Me
[**302**] Ethylhaematommate	Et



[**303**] Tachioside



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



	R_1	R_2	n
[**305**] Alkyl 4′-hydroxy trans-cinnamates	H	C_nH_{2n+1}	22-32
[**306**] Alkyl trans-ferulates	OMe	C_nH_{2n+1}	18-28, 30
[**307**] Defuscin	OMe	$(CH_2)_{27}CH_3$	-
[**308**] n-Octacosyl ferulate	OMe	$(CH_2)_{28}CH_3$	-
[**309**] n-Triacontyl-p-hydroxy cis-cinnamate	H	$C_{30}H_{61}$	-
[**310**] Tetratriacontanyl trans-p-coumarate	H	$(CH_2)_{33}CH_3$	

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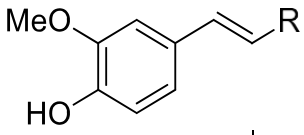
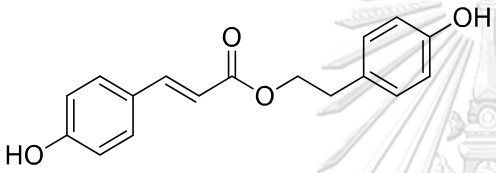
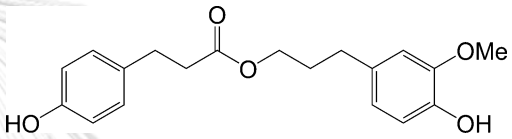
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



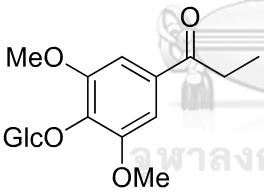
	R
[**311**] n-Docosyl trans-ferulate	$COOCH_2(CH_2)_{20}CH_3$
[**312**] *trans*-Tetracosyl ferulate	$COOCH_2(CH_2)_{22}CH_3$
[**313**] *cis*-Hexacosanoyl ferulate	$COOCH_2(CH_2)_{24}CH_3$
[**314**] Ferulaldehyde	CHO
[**315**] Ferulic acid	COOH



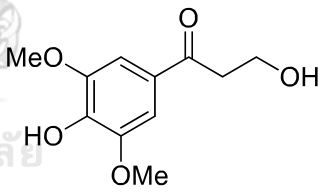
[**316**] 2-(p-Hydroxyphenyl) ethyl p-coumarate



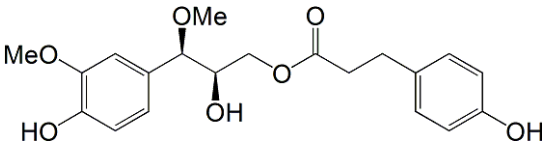
[**317**] Dihydroconiferyl dihydro-*p*-coumarate



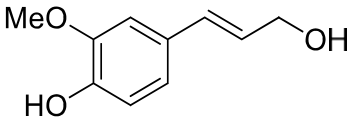
[**318**] 1-[4-(β-D-Glucopyranosyloxy)-3,5-dimethoxyphenyl)-1-propanone



[**319**] 3-Hydroxy-1-(4-hydroxy-3,5-dimethoxyphenyl]-1-propanone

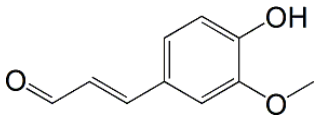


[**320**] 2-Hydroxy-3-(4-hydroxy-3 methoxyphenyl)-3-methoxypropyl-3-(4-hydroxylphenyl) propanoate

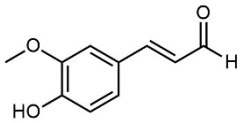


[**321**] Coniferyl alcohol

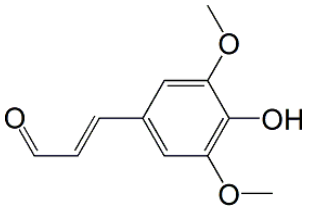
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



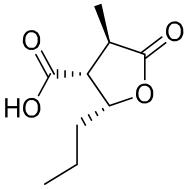
[**322**] (E)-Coniferyl aldehyde



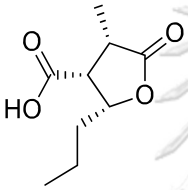
[**323**] Coniferyl aldehyde



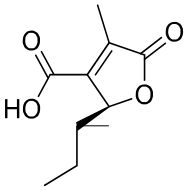
[**324**] Sinapicaldehyde



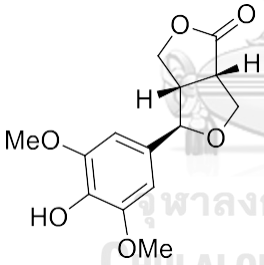
[**325**] Decumbic acid A



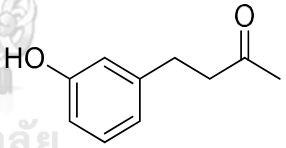
[**326**] Decumbic acid B



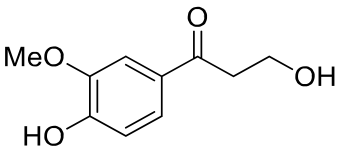
[**327**] (-)-Decumbic acid



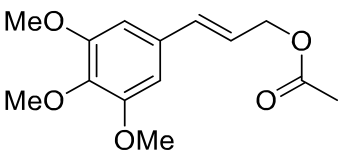
[**328**] (+)-Dendrolactone



[**329**] 4-(3-Hydroxyphenyl)-2-butanone



[**330**] 3-Hydroxy-1-(3-methoxy-4-hydroxyphenyl)-propan-1-one



[**331**] 3′,4′,5′-Trimethoxy cinnamyl acetate

Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species

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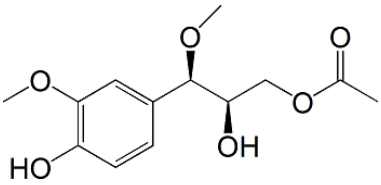
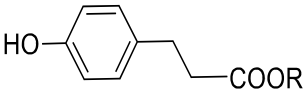
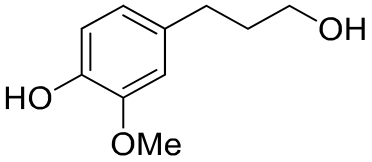


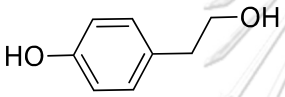
[**332**] Alatusol A



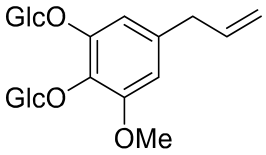
	R
[**333**] p-Hydroxyphenyl propionic methyl ester	Me
[**334**] Phloretic acid	OH



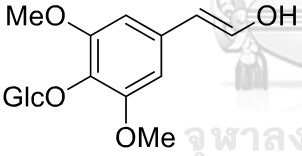
[**335**] Dihydroconiferyl alcohol



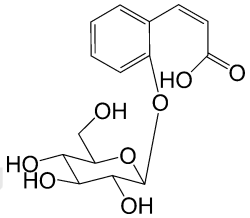
[**336**] Salidrosol



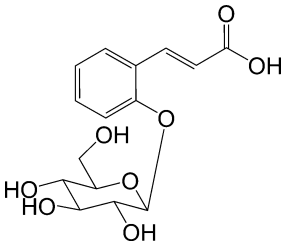
[**337**] Shashenoside I



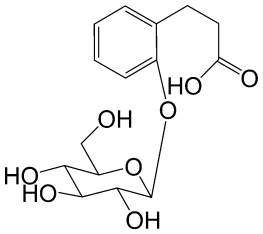
[**338**] Syringin



[**339**] *cis*-Melilotoside



[**340**] trans-Melilotoside



[**341**] Dihydromelilotoside

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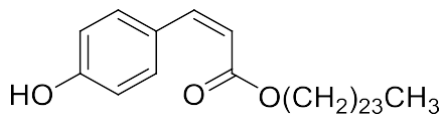
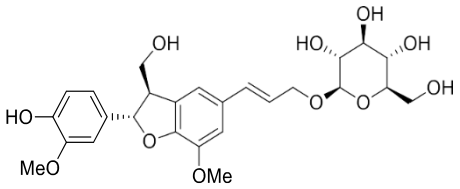
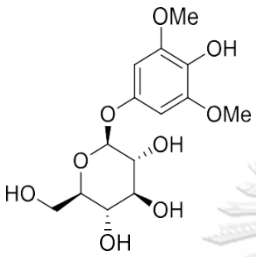
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



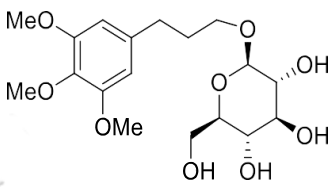
[**342**] Tetracosyl (*Z*)-*p*-coumarate



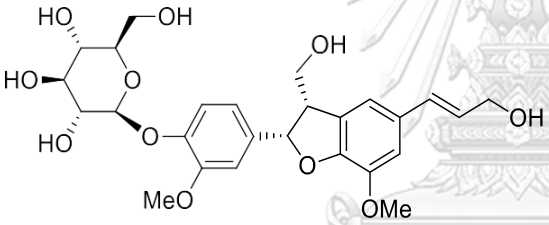
[**343**] (7*S*,8*R*)-Dehydrodiconiferyl alcohol 9′-β-D-glucopyranoside



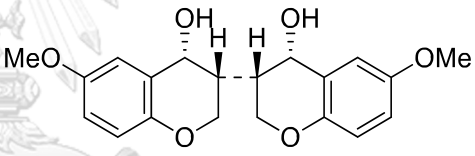
[**344**] Koaburaside



[**345**] Juniperoside



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



[**347**] (3*R*,3′*S*,4*R*,4′*S*)-3,3′,4,4′-Tetrahydro-6,6′-dimethoxy[3,3′- bi-2H-benzopyran]-4,4′-diol

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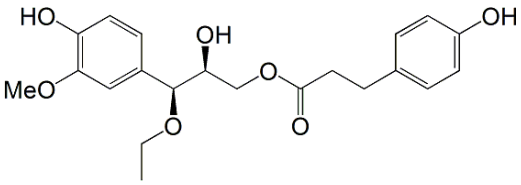
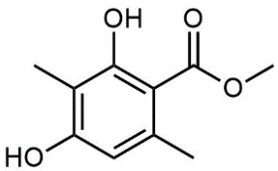
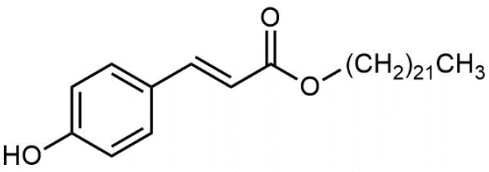


[**348**] threo-7-O-Ethyl-9-O-(4-hydroxyphenyl) propionyl-guaiacylglycerol

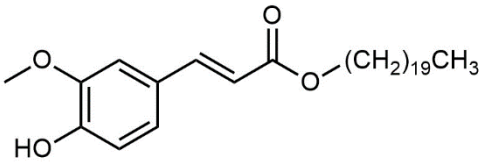


[**349**] Methyl 2,4-dihydroxy-3,6-dimethylbenzoate

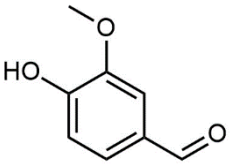
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



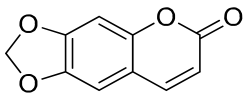
[**350**] n-Docosyl 4-hydroxy-trans-cinnamate



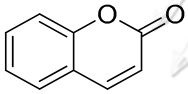
[**351**] n-Eicosyl trans-ferulate



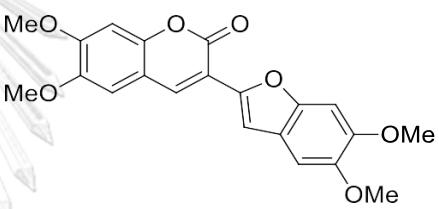
[**352**] Vanillin



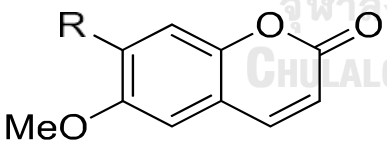
[**353**] Ayapin



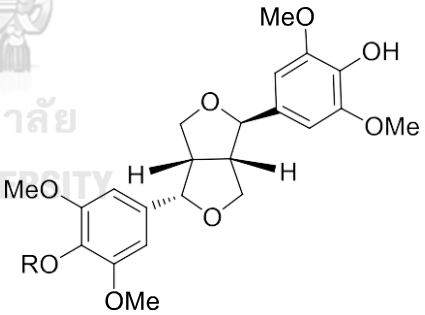
[**354**] Coumarin



[**355**] Denthyrsin



	R
[**356**] Scoparone	OMe
[**357**] Scopoletin	OH



	R
[**358**] Episyringaresinol	H
[**359**] Episyringaresinol 4″-*O*-β-D-glucopyranoside	β-D-glucose

Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species

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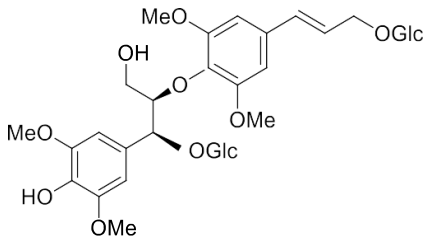
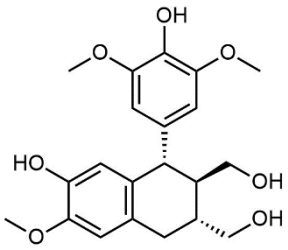
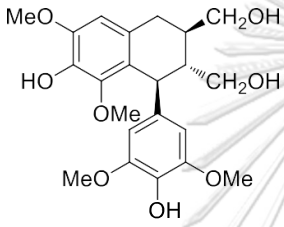


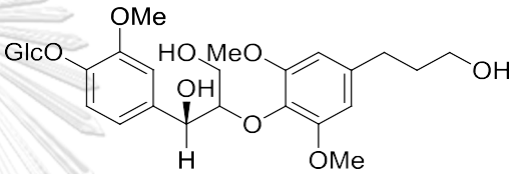
[**360**] *(-)-(7S,8R,7′E)-4*-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign- 7′-ene-7,9′-bis-O-β-D-glucopyranoside



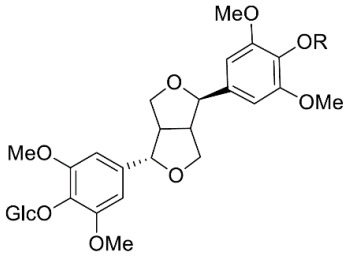
[**361**] 5-methoxy-(+)-isolariciresinol



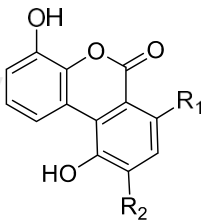
[**362**] Lyoniresinol



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

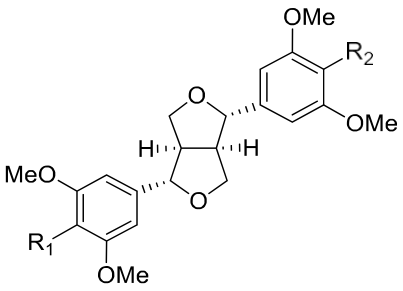


	R
[**364**] (-)-Syringaresinol-4,4′-bis-O-β-D-glucopyranoside	Glc
[**365**] Syringaresinol-4-O-D-monoglucopyranoside	H

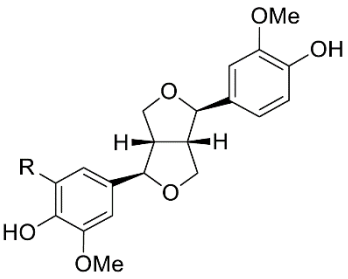


	R_1	R_2
[**366**] Dendrocoumarin	H	OH
[**367**] Itolide A	OH	H

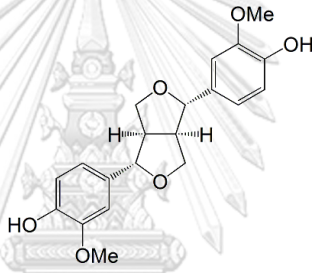
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



	R_1	R_2
[**368**] Syringaresinol	OH	OH
[**369**] Acanthoside B	OGlc	OH
[**370**] Liriodendrin	OGlc	OGlc



	R
[**371**] (-)-Medioresinol	OMe
[**372**] (-)-Pinoresinol	H



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

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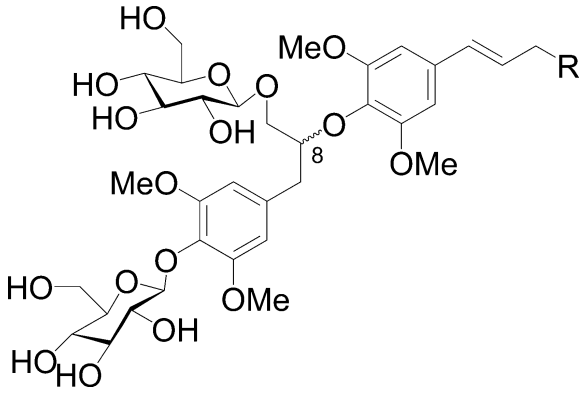
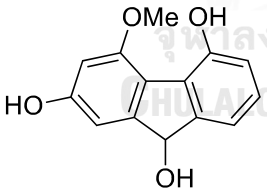
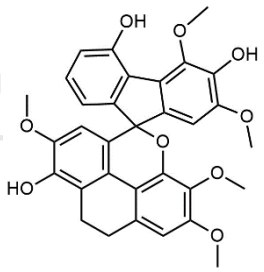
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



	R_1	8
[**374**] (-)-(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	OH	*R*
[**375**] (-)-(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	OH	*S*
[**376**] (-)-(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	OMe	*R*



[**377**] Denchrysan B



[**378**] Dendrogibsol

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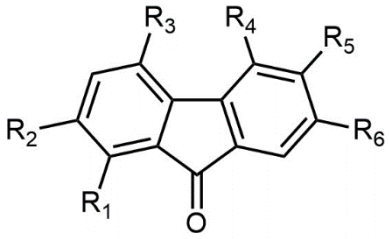
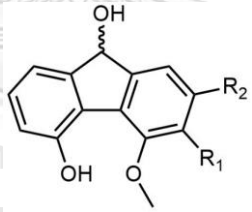
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



	R_1	R_2	R_3	R_4	R_5	R_6
[**379**] Denchrysan A	H	OH	OH	OMe	H	OH
[**380**] Dendroflorin	OH	OH	H	OH	H	OMe
[**381**] Dengibsin	H	OH	OMe	OH	H	H
[**382**] Dengibsinin	H	H	OH	OMe	OH	OMe
[**383**] Nobilone	H	OH	H	OMe	H	OH
[**384**] 1,4,5-Trihydroxy-7-methoxy-9H-fluoren-9-one	OH	H	OH	OH	H	OMe
[**385**] 2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone	OMe	OH	OH	OMe	H	OH



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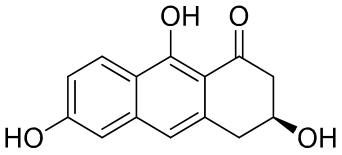
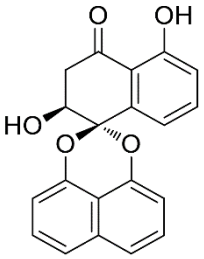
	R_1	R_2
[**386**] 4-Methoxy-9H-fluorene-2,5,9-triol	H	OH
[**387**] Dihydrodengibsinin	OH	OMe

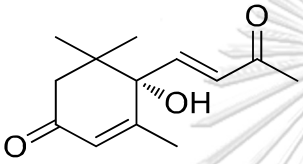
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



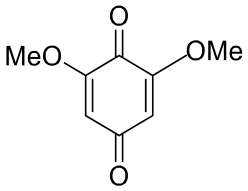
[**388**] 3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2H)-one



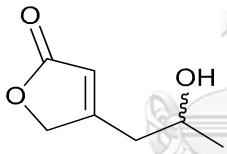
[**389**] Palmarumycin JC2



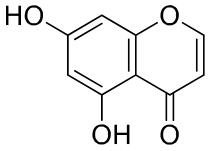
[**390**] Dehydrovomifoliol



[**391**] 2,6-Dimethoxybenzoquinone



[**392**] 4-(2-Hydroxypropyl)-2(5*H*)-furanone



[393] 5,7-Dihydroxychromen-4-one

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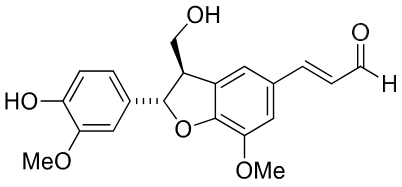
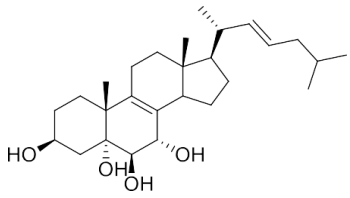
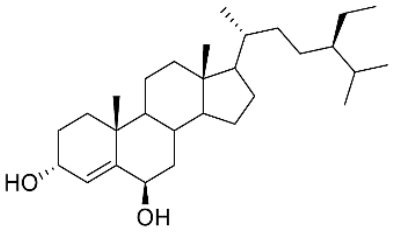


[**394**] Balanophonin

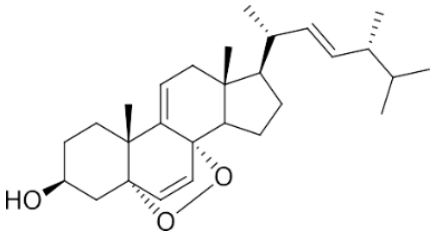


[**395**] Ergosta-*8(9),22*-diene-*3,5,6,7*-tetraol

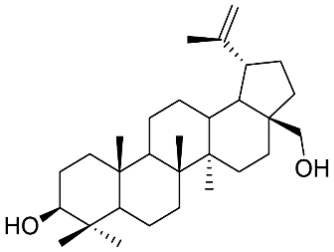
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



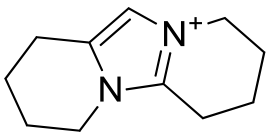
[**396**] Stigmast-4-en-3α,6β-diol



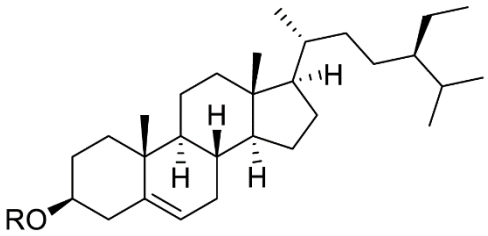
[**397**] 3β-Hydroxy-5α,8α-epidioxyergosta-6,9,22-triene



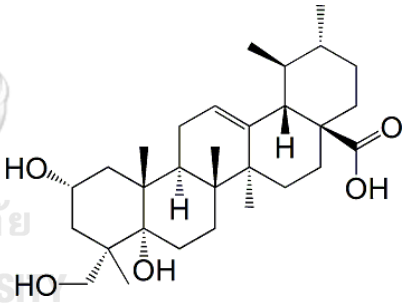
[**398**] Betulin



[**399**] Anosmine



	R
[**400**] β-Sitosterol	H
[**401**] Daucosterol	Glc



[**402**] Asiatic acid

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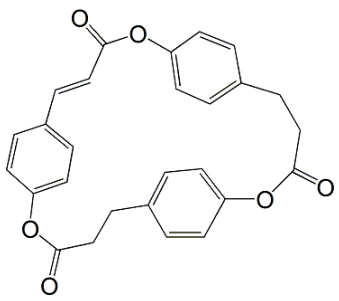
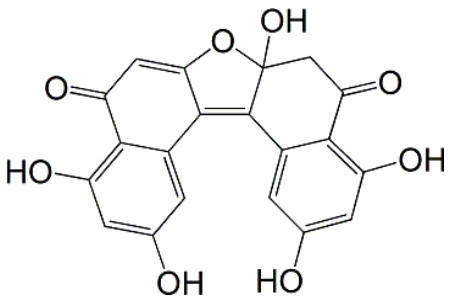
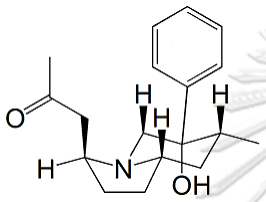
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



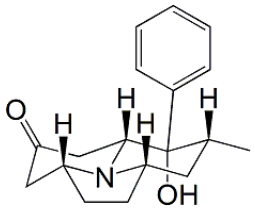
[**403**] Di-p-hydroxyphenylpropionic acidic-p-coumaric acid lactone



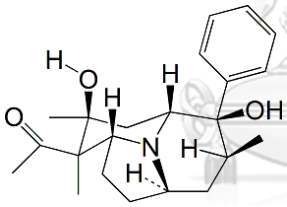
[**404**] RF-3192C



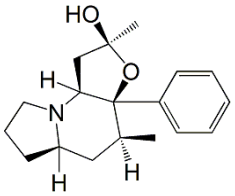
[**405**] Crepidatumine C



[**406**] Crepidatumine D



[**407**] Crepidine



[**408**] Isocrepidamine

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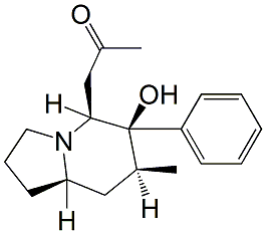
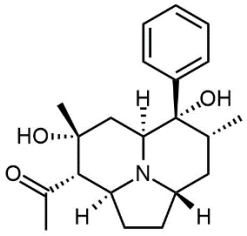
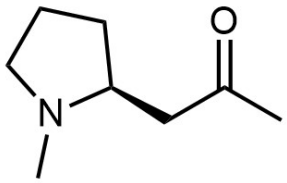


[**409**] Crepidamine

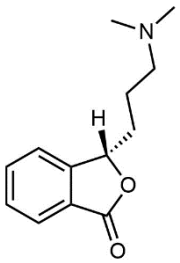


[**410**] 5,7-Dimethyl-octahydroindolizine (Dendroprimine)*

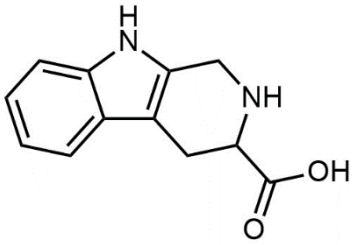
Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species



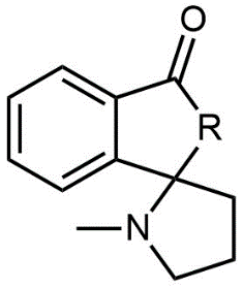
[**411**] Hygrine



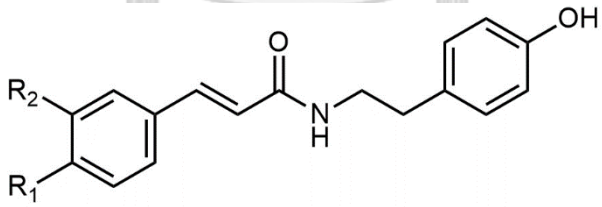
[**412**] Pierardine



[**413**] 2,3,4,9-Tetrahydro-1H-pyrido[3,4-b]indole-3-carboxylic acid



	R
[**414**] Shihunidine	NH
[**415**] Shihunine	O



	R_1	R_2
[**416**] *N-cis-p*-coumaroyltyramine	OH	J
[**417**] *N-cis*-feruloyltyramine	OH	OMe

Figure 5 Structure of Miscellaneous compounds isolated from *Dendrobium* species

2. Free radical scavenging properties of *Dendrobium* species

A number of compounds extracted from the plants in *Dendrobium* species has been proven to have free radical scavenging properties by several research. The active compounds extracted from the plants were concluded in **Table 6**.

Table 6 Radical scavenging compounds from *Dendrobium* species

Source	Substance	Method and results*		Reference
Dendrobium catenatum	3,4′,5-Trihydroxy-3′-methoxybibenzyl	DPPH	34.45 ± 1.07 mM	Zhu et al. 2021
D. longicornu	Methanol extract	DPPH	117.56 mg/mL	Paudel et al. 2020
D. crepidatum	Hexane extract	DPPH	306.77 ± 51.14 µg/mL	Zhang, Zhang, et al. 2019
	Chloroform extract	DPPH	277.08 ± 27.80 µg/mL	
	Acetone extract	DPPH	99.35 ± 2.40 µg/mL	
	Ethanol extract	DPPH	74.00 ± 5.75 µg/mL	
	Methanol extract	DPPH	186.39 ± 72.79 µg/mL	
D. officinale	(*Dendrobium officinale* polysaccharide) DOP-70**	DPPH	2081.7 µg/ml	Xing et al. 2018; Z. 2014
	DOP-40**	DPPH	2837.7 µg/ml	

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Source	Substance	Method and results*		Reference
D. officinale (continued)	DOP-60**	DPPH	3385.3 μg/ml	Xing et al. 2018; Zhu 2014
	DOP-50**	DPPH	5803.8 μg/ml	
	Acetone extract	ORAC	193.39 ± 51.2 μmol/g	
	Ethanol extract	ORAC	299.79 ± 99.3 μmol/g	
D. moniliforme	Hexane extract	DPPH	52.68 μg/ml	Paudel et al. 2018
	Chloroform extract	DPPH	42.39 μg/ml	
	Acetone extract	DPPH	49.56 μg/ml	
	Ethanol extract	DPPH	58.77 μg/ml	
	Methanol extract	DPPH	223.15 μg/ml	
D. macrostachyum	Ethanol extracts	DPPH	10.21 μg/ml	Sukumaran and Yadav 2016
D. secundum	4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl	DPPH	15.87 ± 1.48 μM	Sritularak, Duangrak and Likhitwitayawuid 2011
	Moscatilin	DPPH	5.14 ± 0.18 μM	
	Syringaresinol	DPPH	11.38 ± 0.24 μM	
	Ferulic acid	DPPH	37.52 ± 0.47 μM	
D. draconis	5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone	DPPH	283.3 ± 13.7 μM	Sritularak, Anuwat and

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Source	Substance	Method and results*		Reference
D. draconis (continued)	Hircinol	DPPH	22.3 ± 1.0 μM	Likhitwitayawuid 2011 Sritularak, Anuwat and Likhitwitayawuid 2011
	Gigantol	DPPH	17.7 ± 0.5 μM	
	7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol	DPPH	10.2 ± 0.1 μM	
D. nobile	4,4′,α-Trihydroxy-3,3′,5-trimethoxybibenzyl	DPPH	19.9 ± 0.8 μM	Zhang, Xu, et al. 2007
		ORAC	0.274 ± 0.006 μM^{-1}	
	Bisbibenzyl derivative (nobilin E)	DPPH	21.0 ± 0.4 μM	
		ORAC	0.031 ± 0.001 μM^{-1}	
	2,7-Dihydroxy-4-methoxy-9-fluorenone	DPPH	>200 μM	
		ORAC	0.432 ± 0.005 μM^{-1}	
	Crepidatin	DPPH	21.8 ± 0.4 μM	
		ORAC	0.299 ± 0.008 μM^{-1}	
	Chrysotobibenzyl	DPPH	>200 μM	
		ORAC	0 μM^{-1}	

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Source	Substance	Method and results*		Reference
D. nobile (continued)	Dendrobin	DPPH	40.3 ± 0.1 μM	Zhang, Xu, et al. 2007
		ORAC	0.090 ± 0.001 μM^{-1}	
	Chrysotoxine	DPPH	14.0 ± 0.1 μM	
		ORAC	0.280 ± 0.005 μM^{-1}	
	Moscatilin	DPPH	14.5 ± 0.3 μM	
		ORAC	0.625 ± 0.013 μM^{-1}	
	Gigantol	DPPH	56.4 ± 0.9 μM	
		ORAC	0.234 ± 0.005 μM^{-1}	
	Dendroflorin	DPPH	16.2 ± 0.2 μM	
		ORAC	0.596 ± 0.003 μM^{-1}	
D. parishii	4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl	ORAC	~400 μmol/g	Kongkatitham et al. 2018
	(–)-dendroparishiol	ORAC	~500 μmol/g	
	Flavanthrinin	ORAC	~450 μmol/g	

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Source	Substance	Method and results*		Reference
D. parishii (continued)	Moscatilin	ORAC	~450 μmol/g	Kongkatitham et al. 2018
	4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl	ORAC	~450 μmol/g	
	Dendrocandin E	ORAC	~450 μmol/g	
	Asiatic acid	ORAC	~250 μmol/g	

Remark: * DPPH assay was evaluated and shown as IC_{50} and ORAC assay was evaluated and shown as Trolox® equivalent.

**DOP obtained by extraction using hot water, then precipitated in ethanol, after that, separated and collected a polysaccharide fractions

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Chapter III

EXPERIMENTAL METHODS

1. Source of plant materials

The whole plant of *Dendrobium virgineum* Rchb.f. was purchased from Chatuchak market, Bangkok, in September 2020. It was authenticated by Assoc. Prof. Boonchoo Sritularak and compared with a herbarium specimen at the Botanical Garden Organization. Its voucher specimen has been deposited at the Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University.

2. General techniques

2.1 Thin-layer chromatography (TLC)

Technique: One-dimensional ascending

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

Layer thickness: 0.2 mm

Distance: 6.5 cm at room temperature.

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

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2.2 Adsorption column chromatography

2.2.1 Vacuum liquid column chromatography

Absorbent: Silica gel 60 (No. 7734, E. Merck)

Particle size: 0.063-0.200 mm

Packing: Dry packing

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

2.2.2 Flash column chromatography

Absorbent: Silica gel 60 (No. 9385, E. Merck)

Particle size: 0.040-0.063 mm

Packing: Dry packing

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

2.2.3 Gel filtration chromatography

Absorbent: Sephadex LH-20 (GE Healthcare)

Packing: Wet packing

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

2.3 Spectrometry and spectroscopy

2.3.1 Mass spectrometry (MS)

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

2.3.2 Nuclear magnetic resonance (NMR) spectroscopy

One dimensional NMR (^{1}H NMR, 300 MHz and ^{13}C NMR, 75 MHz) and 2-dimensional NMR spectroscopy (NOESY, HSQC and HMBC) were performed using a Bruker Avance DPX 300 MHz FT-NMR spectrometer (Faculty of Pharmaceutical Sciences, Chulalongkorn University) or Bruker Avance III HD/OXFORD 500 MHz FT-NMR spectrometer (Scientific and Technological Research Equipment Centre, Chulalongkorn University). Deuterated acetone (acetone-d_6) was used as solvents. Chemical shifts were stated in ppm scale.

2.3.3 Ultraviolet (UV) spectroscopy

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

2.3.4 Infrared (IR) spectroscopy

IR spectra were recorded on a BRUKER LUMOS-II (Scientific and Technology Research Equipment Center, Chulalongkorn University).

2.4 Solvents

Commercial grade organic solvents were used throughout the experiments and were purified by re-distillation before experiments.

3. Extraction

The whole plant of *D. virgineum* (2.7 kg) was dried and ground into fine powder. The powder was then macerated in methanol at room temperature for a week before collection of the extract. The maceration was repeated two times, all extracts were then mixed. The combined extract was filtered and evaporated under reduced pressure using a rotary evaporator to give 297.4 g of methanol extract. The methanol extract was suspended in distilled water and partitioned with ethyl acetate (EtOAc), yielding 95.1 g of EtOAc extract, and aqueous extract (**Figure 6**).

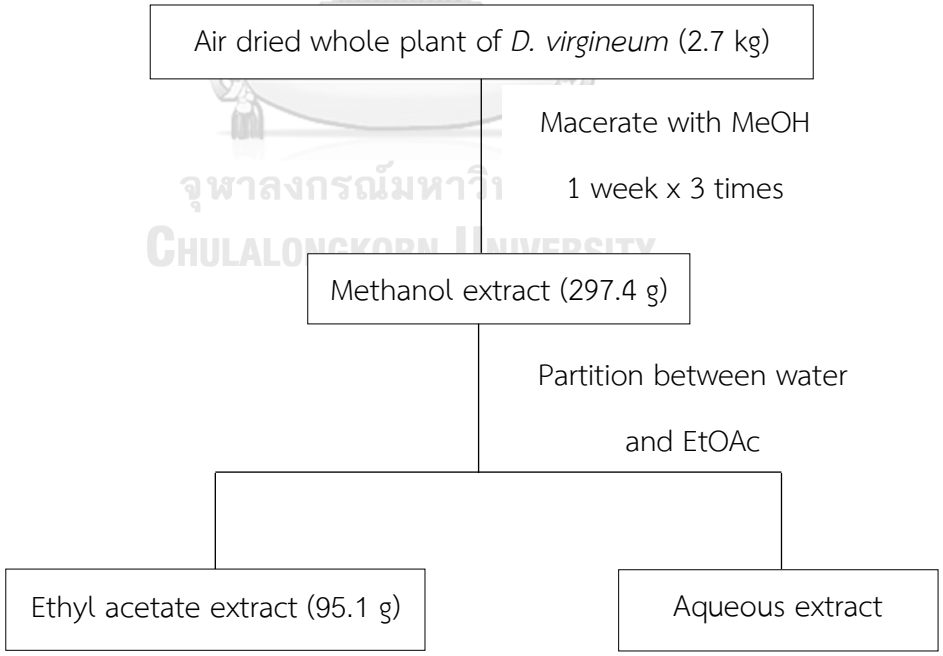

Figure 6 Extraction of *D. virgineum*

4. Isolation

The EtOAc extract was fractioned by adsorption chromatography using a silica gel column (EtOAc-hexane, gradient) as described in section 2.2.1, yielding 10 fractions labeled as A-F.

4.1 Isolation of 2,8-Dimethoxy-9,10-dihydro-4,5-phenanthrenediol

Fraction B (12.34 g) was divided into 30 fractions (B1-B30) by adsorption chromatography (silica gel, Acetone-hexane, gradient). Fraction B7 (2.50 g) was divided into 10 fractions (B7.1-B7.10) by size-exclusion chromatography (MeOH). Fraction B7.6 (21.7 mg) was fractionated by adsorption chromatography (silica gel, Acetone-hexane, gradient) to yield **compound 1** (2,8-Dimethoxy-9,10-dihydro-4,5-phenanthrenediol, 5.6 mg). Additionally, Fraction B8 (553 mg) was fractionated by size-exclusion chromatography (MeOH) to yield **compound 1** (2,8-Dimethoxy-9,10-dihydro-4,5-phenanthrenediol, 17.9 mg) (**Figure 7**).

4.2 Isolation of 2,5-Dimethoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone

Fraction C (8.678 g) was divided into 9 fractions (C1-C9) by adsorption chromatography (silica gel, Acetone-hexane, gradient). After that, fraction C5 (2.04 g) was divided into 30 fractions (C5.1-C5.30) by size-exclusion chromatography (MeOH). Then, fraction C5.7 (206 mg) was divided into 31 fractions (C5.7.1-C5.7.31) by adsorption chromatography (silica gel, EtOAc-hexane, gradient). Next, fraction C5.7.14-C5.7.17 (33.9 mg) was divided into 5 fractions (C5.7.14.1-C5.7.14.5) by adsorption chromatography (silica gel, Acetone-hexane, gradient). Fraction C5.7.14.3 (10.8 g) was then fractionated by size-exclusion chromatography (MeOH) to yield **compound 2** (2,5-Dimethoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone, 5.8 mg) (**Figure 8**).

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4.3 Isolation of 2-Methoxy-9,10-dihydro-4,5-phenanthrenediol

Fraction B (12.34 g) was divided into 30 fractions (B1-B30) by adsorption chromatography (silica gel, Acetone-hexane, gradient). Then, fraction B7 (2.50 g) was

divided into 10 fractions (B7.1-B7.10) by size-exclusion chromatography (MeOH). Fraction B7.6 (21.7 mg) was then fractionated by adsorption chromatography (silica gel, Acetone-hexane, gradient) to yield **compound 3** (2-Methoxy-9,10-dihydro-4,5-phenanthrenediol, 4.7 mg) (**Figure 7**).

4.4 Isolation of Gigantol

After Fraction B (12.34 g) was divided into 30 fractions (B1-B30) by adsorption chromatography (silica gel, Acetone-hexane, gradient), fraction B9 (612 mg) was fractionated by size-exclusion chromatography (MeOH) to yield compound 4 (Gigantol, 228 mg). In addition, Fraction B10 (635 mg) was fractionated by size-exclusion chromatography (MeOH) to yield compound 4 (Gigantol, 313.5 mg) (**Figure 7**).

4.5 Isolation of 5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone

After fraction C (8.678 g) was divided into 9 fractions (C1-C9) by adsorption chromatography (silica gel, Acetone-hexane, gradient), fraction C5 (2.04 g) was divided into 30 fractions (C5.1-C5.30) by size-exclusion chromatography (MeOH). Then, fraction C5.8 (117 mg) was divided into 23 fractions (C5.8.1-C5.8.23) by adsorption chromatography (silica gel, EtOAc-hexane, gradient). Next, fraction C5.8.14 (36.6 mg) was fractionated by adsorption chromatography (silica gel, Acetone-hexane, gradient) to yield **compound 5** (2,5-Dimethoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone, 4.3 mg) (**Figure 8**).

4.6 Isolation of *p*-Coumaric acid

Fraction C (8.678 g) was divided into 9 fractions (C1-C9) by adsorption chromatography (silica gel, Acetone-hexane, gradient). Then, fraction C6 (1.326 g) was divided into 77 fractions (C6.1-C6.77) by size-exclusion chromatography (MeOH). After that, fraction C6.7 (106 mg) was divided into 9 fractions (C6.7.1-C6.7.9) by size-exclusion chromatography (Actone). Next, fraction C6.7.5 (39.1 mg) was fractionated by

adsorption chromatography (silica gel, EtOAc-hexane, gradient) to yield **compound 6** (*p*-Coumaric acid, 9.1 mg) (**Figure 9**).

4.7 Isolation of Tristin

Fraction C (8.678 g) was divided into 9 fractions (C1-C9) by adsorption chromatography (silica gel, Acetone-hexane, gradient). After that, fraction C6 (1.326 g) was divided into 77 fractions (C6.1-C6.77) by size-exclusion chromatography (MeOH). Fraction C6.8 (237 mg) was then fractionated by adsorption chromatography (silica gel, EtOAc-hexane, gradient) to yield **compound 7** (Tristin, 101.6 mg) (**Figure 9**).

4.8 Isolation of 2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene

Fraction C (8.678 g) was divided into 9 fractions (C1-C9) by adsorption chromatography (silica gel, Acetone-hexane, gradient). After that, fraction C6 (1.326 g) was divided into 77 fractions (C6.1-C6.77) by size-exclusion chromatography (MeOH). Then, fraction C6.12-C6.14 (237 mg) was fractionated by adsorption chromatography (silica gel, EtOAc-hexane, gradient) to yield **compound 8** (2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene, 116.9 mg) (**Figure 9**).

4.9 Isolation of 9,10-Dihydro-2,4,7-phenanthrenetriol

Fraction C (8.678 g) was divided into 9 fractions (C1-C9) by adsorption chromatography (silica gel, Acetone-hexane, gradient). Then, fraction C6 (1.326 g) was divided into 77 fractions (C6.1-C6.77) by size-exclusion chromatography (MeOH). After that, fraction C6.15 (11.7 mg) was fractionated by adsorption chromatography (silica gel, EtOAc-hexane, gradient) to yield **compound 9** (9,10-Dihydro-2,4,7-phenanthrenetriol, 5.5 mg) (**Figure 9**).

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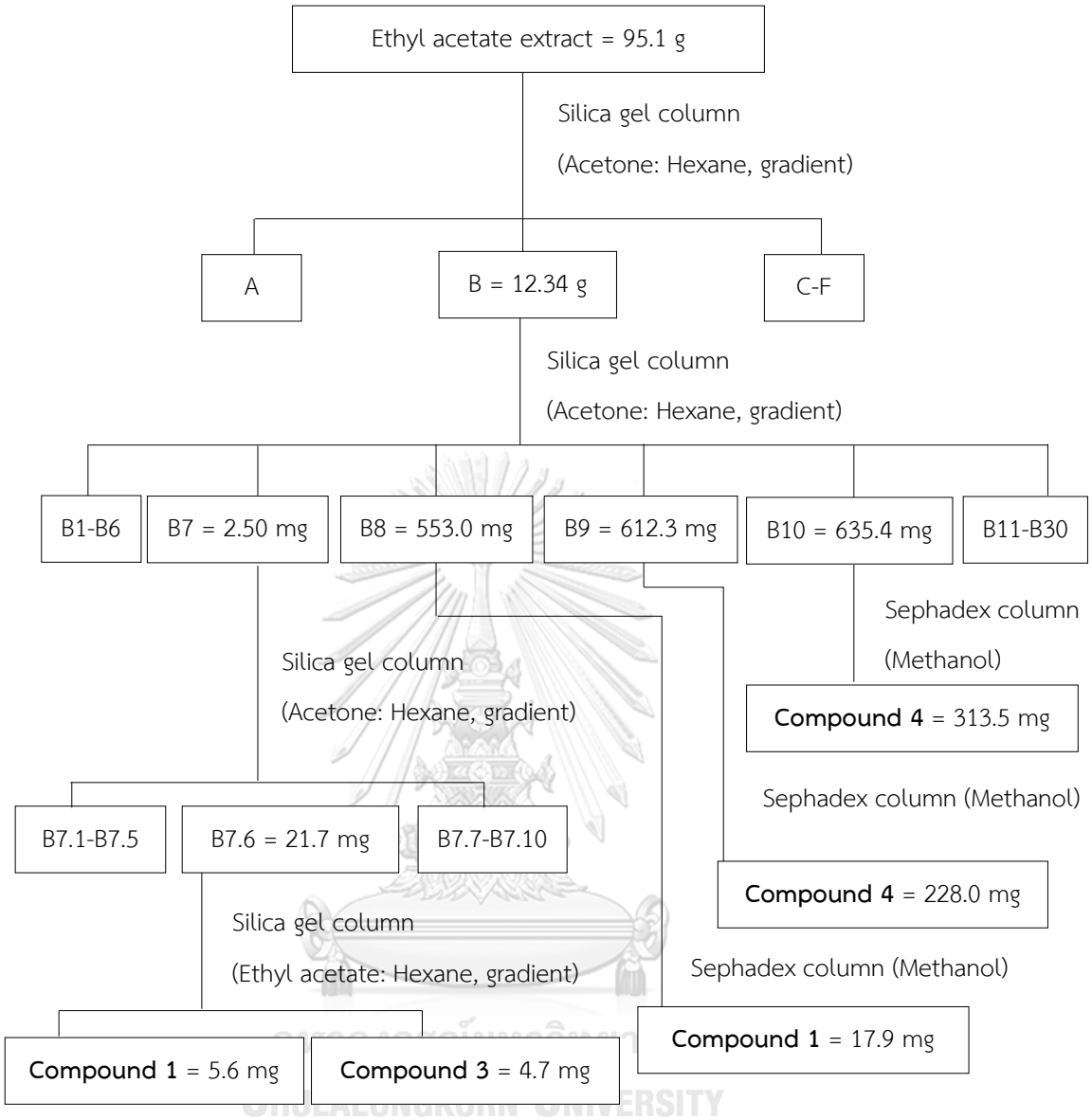


Figure 7 Extraction of fraction B

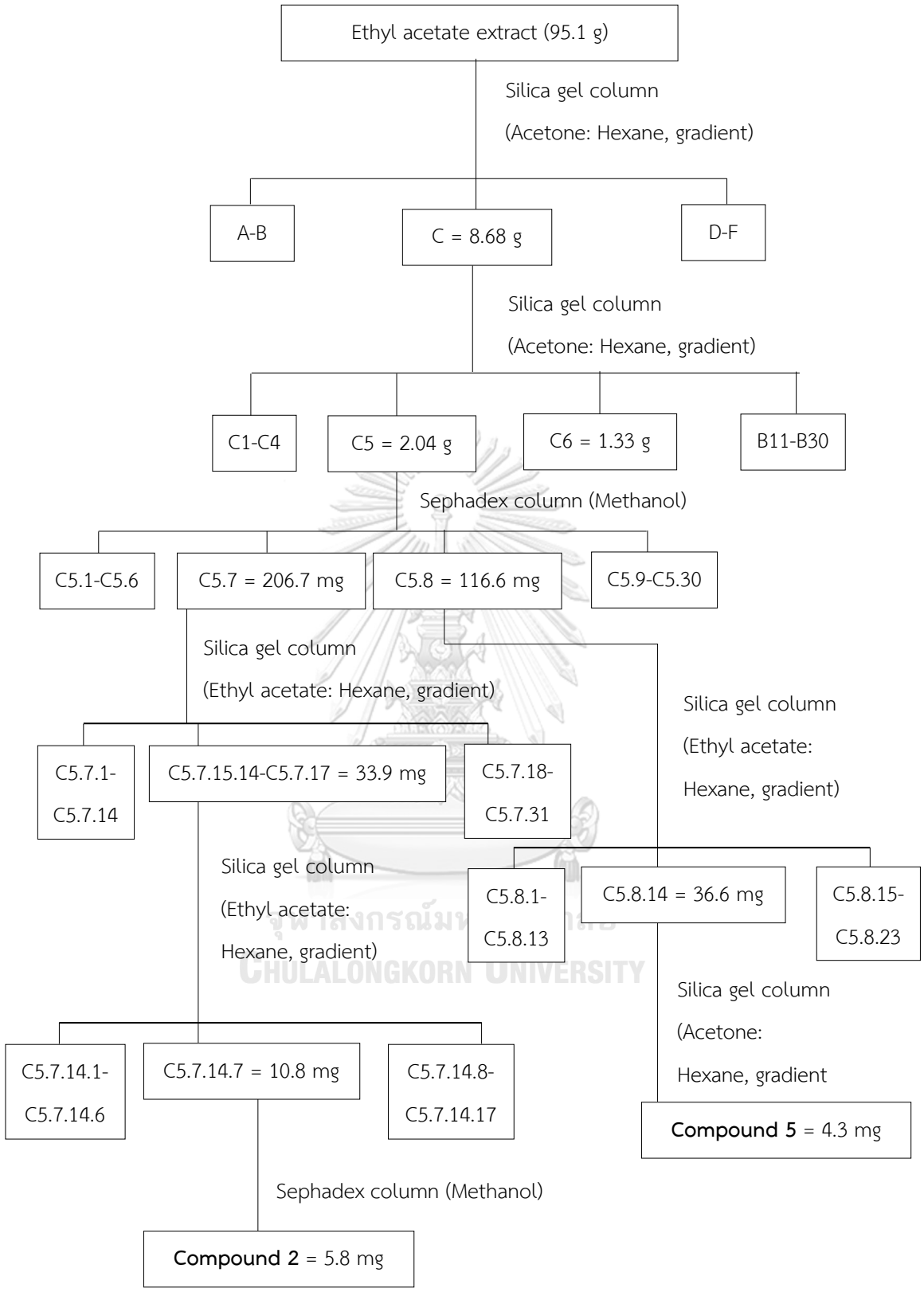


Figure 8 Extraction of fraction C5

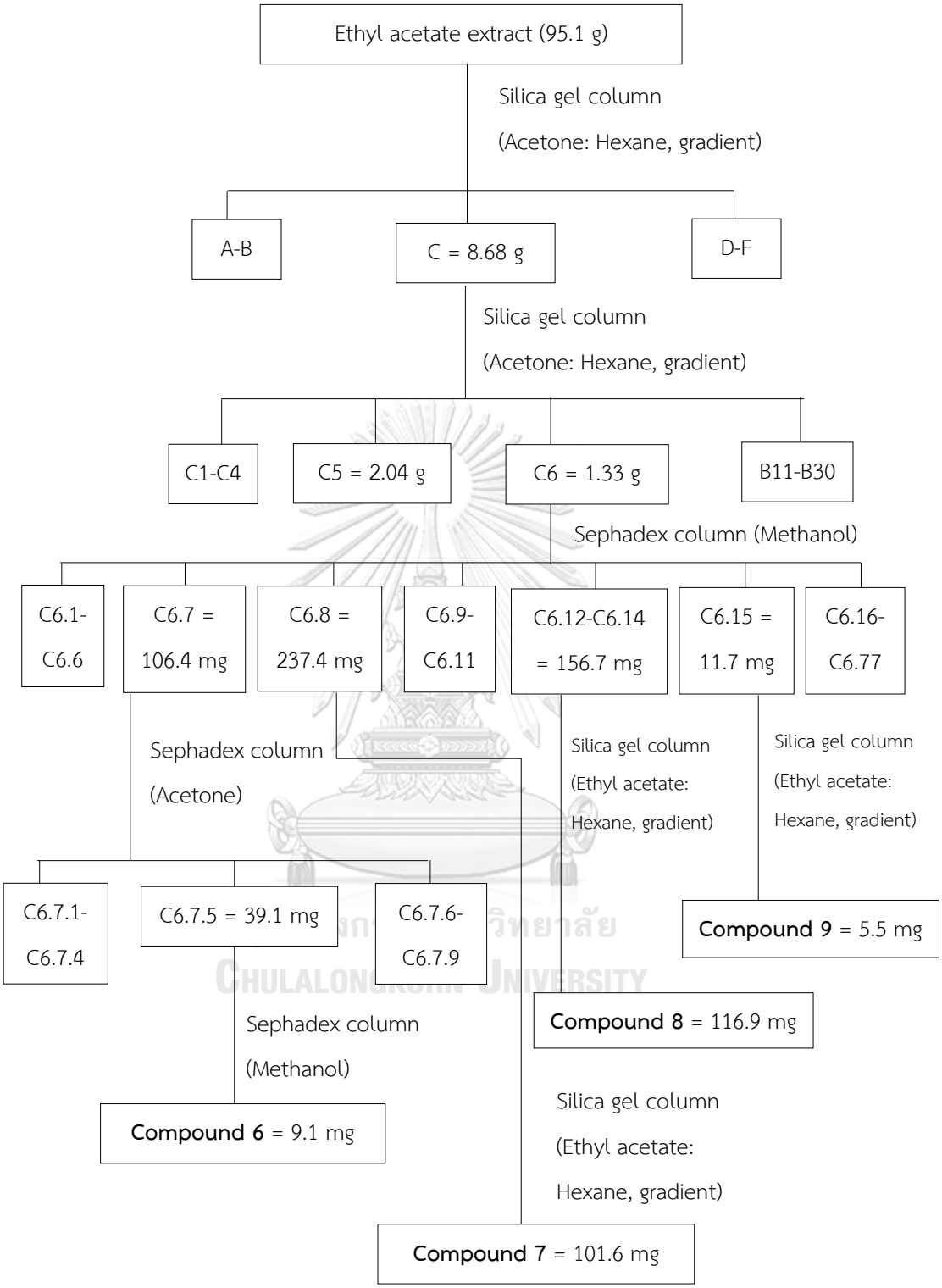


Figure 9 Extraction of fraction C6

5. Physical and spectral data of isolated compounds

5.1 Compound 1 (2,8-Dimethoxy-9,10-dihydro-4,5-phenanthrenediol)

Compound 1 was obtained as brown amorphous solid, soluble in methanol (23.5 mg, 0.00087% based on dried weight of whole plant).

HR-ESI-MS: $[M-H]^-$ at *m/z* 271.0960 (calcd. for 271.0970, $C_{16}H_{15}O_4$)

UV (MeOH): λ_{max} (log ε): 222 (7.78), 273 (2.59), 305 (1.80) nm

IR (film): ν_{max}: 3167, 2937, 2838, 1616, 1463, 1435, 1250, 1152, 1104 cm^{-1}

^{1}H NMR: δ ppm, 500 MHz, acetone-d_6; **(see chapter IV)**

^{13}C NMR: δ ppm, 125 MHz, acetone-d_6; **(see chapter IV)**

5.2 Compound 2 (2,5-Dimethoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone)

Compound 2 was obtained as brown amorphous solid, soluble in methanol (5.8 mg, 0.00022% based on dried weight of whole plant).

HR-ESI-MS: $[M-H]^-$ at *m/z* 285.0752 (calcd. for 285.0763, $C_{16}H_{13}O_5$)

UV (MeOH): λ_{max} (log ε): 222 (6.53), 260 (2.45), 334 (1.60), 490 (1.29) nm

IR (film): ν_{max}: 3416, 2940, 2922, 1658, 1606, 1561, 1213, 1160, 1045, 847 cm^{-1}

^{1}H NMR: δ ppm, 500 MHz, acetone-d_6; **(see chapter IV)**

^{13}C NMR: δ ppm, 125 MHz, acetone-d_6; **(see chapter IV)**

5.3 Compound 3 (2-Methoxy-9,10-dihydro-4,5-phenanthrenediol)

Compound 3 was obtained as brown amorphous solid, soluble in methanol (4.7 mg, 0.00017% based on dried weight of whole plant).

HR-ESI-MS: $[M+H]^+$ at *m/z* 243.1026 (calcd. for 243.1021, $C_{15}H_{15}O_3$)

^{1}H NMR: δ ppm, 500 MHz, acetone-d_6; **(see chapter IV)**

^{13}C NMR: δ ppm, 125 MHz, acetone-d_6; **(see chapter IV)**

5.4 Compound 4 (Gigantol)

Compound 4 was obtained as brown amorphous solid, soluble in methanol (541.5 mg, 0.020% based on dried weight of whole plant).

HR-ESI-MS: $[M+H]^+$ at *m/z* 275.1218 (calcd. for 275.1283, $C_{16}H_{19}O_4$)

^{1}H NMR: δ ppm, 500 MHz, acetone-d_6; **(see chapter IV)**

^{13}C NMR: δ ppm, 125 MHz, acetone-d_6; **(see chapter IV)**

5.5 Compound 5 (5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone)

Compound 5 was obtained as brown amorphous solid, soluble in methanol (4.3 mg, 0.00016% based on dried weight of whole plant).

HR-ESI-MS: $[M-H]^-$ at *m/z* 255.0659 (calcd. for 255.0657, $C_{15}H_{11}O_4$)

^{1}H NMR: δ ppm, 500 MHz, acetone-d_6; **(see chapter IV)**

^{13}C NMR: δ ppm, 125 MHz, acetone-d_6; **(see chapter IV)**

5.6 Compound 6 (*p*-Coumaric acid)

Compound 6 was obtained as brown amorphous solid, soluble in methanol (9.1 mg, 0.00033% based on dried weight of whole plant).

HR-ESI-MS: $[M+H]^+$ at *m/z* 165.0554 (calcd. for 165.0552, $C_9H_9O_3$)

^{1}H NMR: δ ppm, 300 MHz, acetone-d_6; **(see chapter IV)**

^{13}C NMR: δ ppm, 75 MHz, acetone-d_6; **(see chapter IV)**

5.7 Compound 7 (Tristin)

Compound 7 was obtained as brown amorphous solid, soluble in methanol (101.6 mg, 0.0038% based on dried weight of whole plant).

HR-ESI-MS: $[M+H]^+$ at *m/z* 261.1150 (calcd. for 261.1127, $C_{15}H_{17}O_4$)

^{1}H NMR: δ ppm, 300 MHz, acetone-d_6; **(see chapter IV)**

^{13}C NMR: δ ppm, 75 MHz, acetone-d_6; **(see chapter IV)**

5.8 Compound 8 (2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene)

Compound 8 was obtained as brown amorphous solid, soluble in methanol (116.9 mg, 0.0043% based on dried weight of whole plant).

HR-ESI-MS: $[M+H]^+$ at *m/z* 259.0969 (calcd. for 259.0970, $C_{15}H_{15}O_4$)

^{1}H NMR: δ ppm, 300 MHz, acetone-d_6; **(see chapter IV)**

^{13}C NMR: δ ppm, 75 MHz, acetone-d_6; **(see chapter IV)**

5.9 Compound 9 (9,10-Dihydro-2,4,7-phenanthrenetriol)

Compound 9 was obtained as brown amorphous solid, soluble in methanol (5.5 mg, 0.00020% based on dried weight of whole plant).

HR-ESI-MS: $[M+H]^+$ at *m/z* 229.0888 (calcd. for 229.0865, $C_{14}H_{13}O_3$)

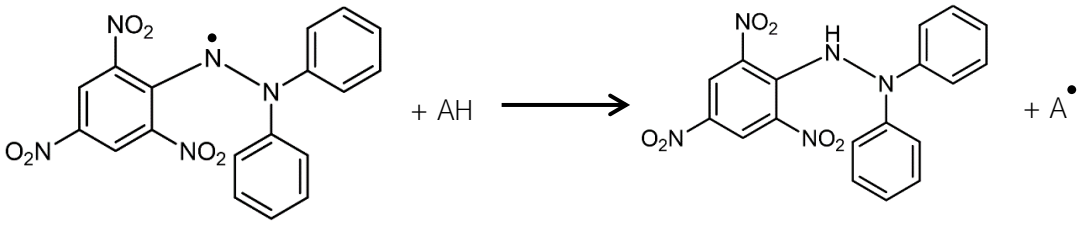
^{1}H NMR: δ ppm, 300 MHz, acetone-d_6; **(see chapter IV)**

^{13}C NMR: δ ppm, 75 MHz, acetone-d_6; **(see chapter IV)**

6. Free radical scavenging activity assays

6.1 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay

The DPPH assay screens substances having radical scavenging activity using single electron transfer (ET) mechanism. It is a stable radical with deep purple colour that can change into yellow when it is changed into a reduced form by accepting either a hydrogen atom or an electron from a substance with antioxidant properties (Zhong and Shahidi 2015). The chemical reaction was shown below (Bibi S. et al. 2020).



2,2-dipheny-1-picrylhydrazyl (radical, purple)

2,2-dipheny-1-picrylhydrazyl (nonradical, yellow)

Figure 10 The reaction between DPPH and antioxidant

6.1.1 Materials and instruments

- DPPH (Sigma-Aldrich)
- Trolox® (Sigma-Aldrich)
- Microplate reader (PerkinElmer)

6.1.2 DPPH assay method

The assay was carried out according to a method modified from the protocol of Kongkatitham et al (2018). Firstly, samples were dissolved and diluted to desired concentration in 50% DMSO in DW. After that, each sample solution was filled in 96-well microplate with the reagent according to the table below (Kongkatitham et al. 2018);

Table 7 Reagent's volume filled in 96-well microplate for DPPH assay

Order	Reagent	Volume
1	Samples	20 µL
2	150 uM DPPH in MeOH	180 µL
	Total volume	200 µL

Then, the samples were shaken gently and kept in the dark at room temperature for 30 minutes. The absorbance at 517 nm was measured by microplate reader. % Radical scavenging activity (RSA) was calculated by below equation;

$$\%RSA = \frac{(\text{absorbance of blank} - \text{absorbance of sample}) \times 100}{\text{absorbance of blank}}$$

6.2 Oxygen radical absorbance capacity (ORAC) assay

The ORAC assay is used for screening for substances with radical scavenging activity using hydrogen atom transfer (HAT) mechanism. This test can measure the degree of antioxidant that can terminate peroxyl radical induced oxidation which was created by heating azo compounds. The peroxyl radical quench

the fluorescent probe as illustrate in below figure. This reaction can be terminated by antioxidants and can be monitored by measuring fluorescence intensity.

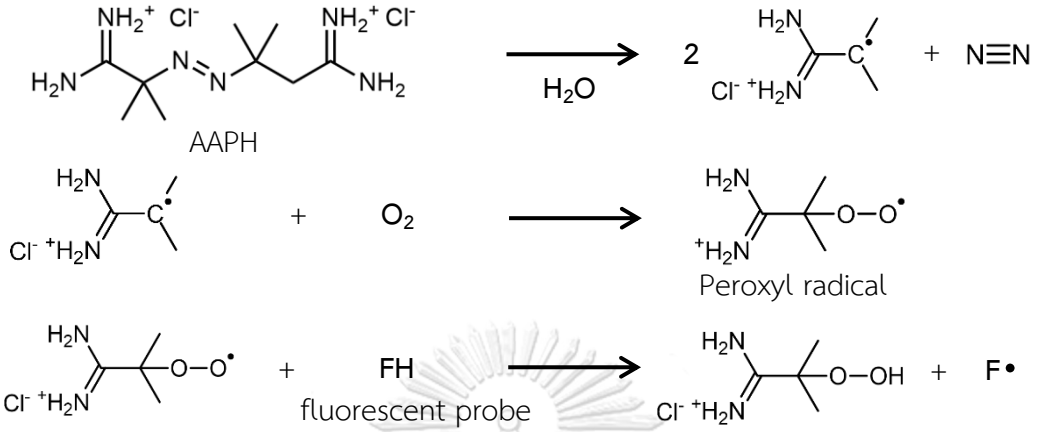


Figure 11 The principle of ORAC assay

6.2.1 Materials and instruments

- DPPH (Sigma-Aldrich)
- Trolox® (Sigma-Aldrich)
- Microplate reader (PerkinElmer)

6.2.2 ORAC assay method

The assay was carried out according to a method modified from the protocol of Huang, Ou et al (2002). Firstly, the samples were dissolved in DMSO and diluted to several concentrations with 75 mM potassium phosphate buffer (pH 7.4). The samples and reagent were then filled in 96-well microplate according to below table (Huang et al. 2002);

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Table 8 Reagent's volume filled in 96-well microplate for ORAC assay

Order	Reagent	Volume
1	Samples	25 µL
2	13.2 nM fluorescein in Buffer*	150 µL
incubated at 37 °C for 10 minutes		
3	240 mM AAPH in Buffer*	25 µL
	Total volume	200 µL

*Buffer = 75 mM potassium phosphate buffer (pH 7.4)

The plate was incubated at 37 °C for 30 minutes along with shaking for 1.5 minutes every 5 minutes. After that, 25 microliter of 240 mM AAPH was filled to each well of the microplate. The microplate was then measured for fluorescence intensity by microplate reader. The excitation and emission wavelengths were set at 485 nm and 520 nm, respectively. The microplate was shaken for 5 seconds in the microplate reader, then, its fluorescence intensity was measured every 15 minutes for 360 minutes. The results of fluorescence intensity were plotted against sample concentration and were calculated for area under the curve, AUC. The Trolox® equivalent per gram of sample was evaluated by comparing net AUC of the sample and Trolox® standard curve.

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6.3 Nitroblue tetrazolium (NBT) assay

Superoxide radical scavenging activity can be measured by NBT assay. Generally, superoxide radical can be produced by cell respiration as mentioned in chapter 1. Therefore, this test can represent the antioxidant activity that occurred in human body. To begin with, riboflavin underwent photodegradation to produce superoxide which then reacted with NBT, a pale-yellow water-soluble salt. When NBT was reduced by superoxide at pH 7.4, it then changed into the blue colour of water

insoluble diformazan as shown in chemical reaction below. when the antioxidant was added, the antioxidant scavenged superoxide radical and stop the reaction. Therefore, the blue colour will not appear.

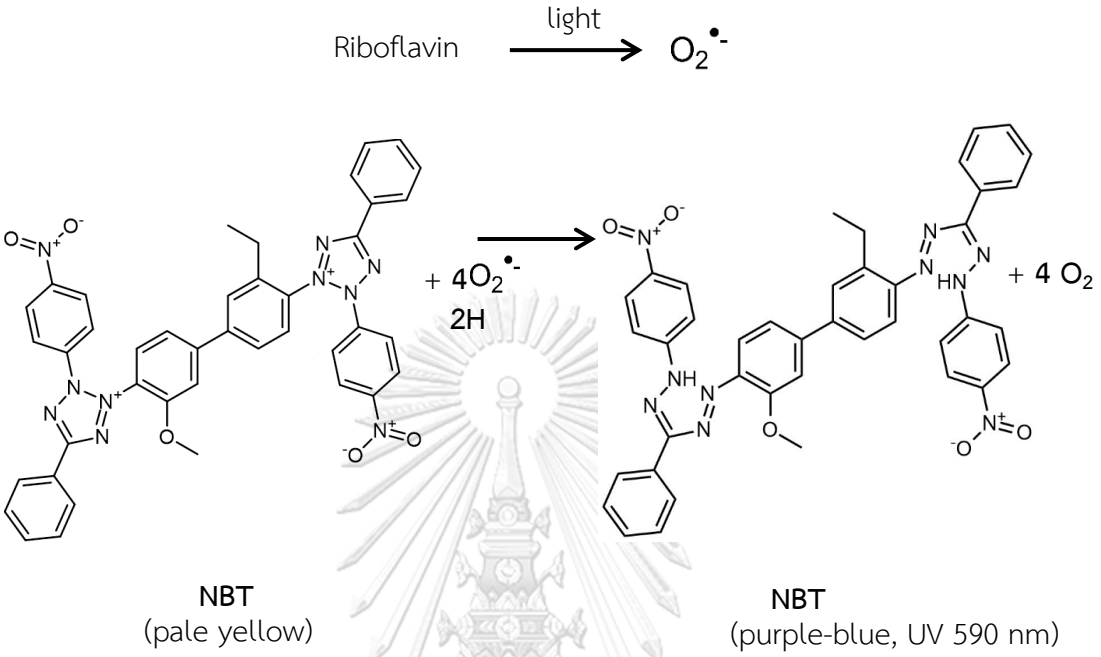

Figure 12 The reaction of NBT assay

6.3.1 Materials and instruments

- Methionine (Sigma-Aldrich)
- Riboflavin (Sigma-Aldrich)
- Nitro blue tetrazolium (NBT) (Sigma-Aldrich)
- Trolox® (Sigma-Aldrich)
- EDTA (Merck)
- Polystyrene 96-well microplates (SPL Life Sciences)
- Microplate reader (BMG Labtech)
- 18-watt fluorescent LED lamp

6.3.2 NBT assay method

The assay was carried out according to a method modified from the protocol of Bagul, Ravishankara et al (2003) and Anandjiwala et al (2008). Firstly, the

sample were dissolved with DMSO and diluted to desired concentration with 50 mM potassium phospate buffer (pH 7.4). Then, the sample and the reagents were added in 96-well micropate according to the table below (Bagul et al. 2003; Anandjiwala et al. 2008);

Table 9 Reagent's volume filled in 96-well microplate for NBT assay

Order	Reagent	Volume
1	50 mM potassium phosphate buffer (pH 7.4)	10 µL
2	200 mM methionine	10 µL
3	30 µM riboflavin	100 µL
4	100 mM EDTA	20 µL
5	Samples	40 µL
6	400 µM NBT	20 µL
	Total volume	200 µL

The plate was duplicated into 2 sets. One of them was exposed to fluorescent lamp for 10 minutes. The other plate was kept in the dark. The absorbance was measured at 570 nm by microplate reader and was calculated for %RSA using equation below;

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$$\%RSA = \frac{(\text{absorbance of blank} - \text{absorbance of sample}) \times 100}{\text{absorbance of blank}}$$

CHAPTER IV

RESULTS AND DISCUSSION

2.7 kg of *Dendrobium virgineum* Rchb.f was extracted with methanol. The dried methanol extract was suspended in distilled water then partitioned with ethyl acetate. Ethyl acetate extracted and distilled water extracted were screened for antioxidant activity by spraying the TLC plate with DPPH reagent. The purple colour of the reagent was changed into yellow in ethyl acetate extract. Therefore, ethyl acetate extract was selected to purify by chromatography where 9 pure compounds were found and their structure were confirmed by UV spectroscopy, IR spectroscopy, MS and NMR spectroscopy techniques. In order to evaluate antioxidant activity, those compounds were tested by several methods.

1. Identification of isolated compounds

1.1 Identification of compound 1 (2,8-Dimethoxy-9,10-dihydro-4,5-phenanthrenediol)

The negative HR-ESI-MS showed a deprotonated molecular ion $[M-H]^-$ at *m/z* 271.0960 (calcd. for $C_{16}H_{15}O_4$, 271.0970) (**Figure 14**), suggesting the molecular formula $C_{16}H_{16}O_4$.

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The IR spectrum (**Figure 15**) exhibited absorption bands for hydroxyl (3167 cm^{-1}), aromatic ring (1616, 1574 cm^{-1}) and methoxy (1152, 1104 cm^{-1}) groups.

The UV absorption (**Figure 16**) peaks at 222, 273 and 305 nm were indicative of a phenanthrene derivative (Sarakulwattana et al. 2020).

A phenanthrene ring was confirmed by two multiplets in ^{1}H NMR spectrum (**Figure 17**) at δ_H 2.58-2.65 ppm, twelve aromatic carbons presented in ^{13}C NMR spectrum (**Figure 18**) at δ_C 102.4-160.7 ppm and two methylene carbons at δ_C 23.0 and 31.6 ppm. An absence of adjacent proton at C-1 and C-3 was confirmed by two doublets presented in ^{1}H NMR spectrum at δ_H 6.45 (*J* = 2.5 Hz, H-3), and 6.49 (*J* =

2.5 Hz, H-1) ppm, HMBC correlation (**Figure 20)** of H-1 with C-3, C-4a and C-10, as well as correlation of H-3 with C-1 and C-4a. An absence of substitution at C-6 and C-7 was assigned due to two doublets shown in ^{1}H NMR spectrum at δ_H 6.84 (*J* = 8.5 Hz, H-7) and 6.88 (*J* = 8.5 Hz, H-6) ppm, and HMBC correlation of H-6 with C-8 and C-4b and H-7 with C-8a and C-5. Two singlets at δ_H 3.77 and 3.78 ppm presented in ^{1}H NMR spectrum and chemical shifts signaled in ^{13}C NMR spectrum at δ_C 55.4 and 56.6 ppm confirmed two methoxy group substitution in the structure. The assignment of methoxy group at C-2 and C-8 was confirmed by NOESY interaction (**Figure 21**) of MeO-2 with H-1 and H-3, and MeO-8 with H-7, respectively. Hydroxy group substitutions at C-4 and C-5 were determined by δ_C 155.6 and 146.8 ppm, respectively.

The HSQC spectrum displays peaks that correspond to the correlations between the protons and carbons in the molecule (**Figure 19)**.

In conclusion, according to obtained spectral data, **compound 1** was characterized as a new phenanthrene derivative, namely, 2,8-dimethoxy-9,10-dihydro-4,5-phenanthrenediol. Its structured was illustrated in **Figure 13**.

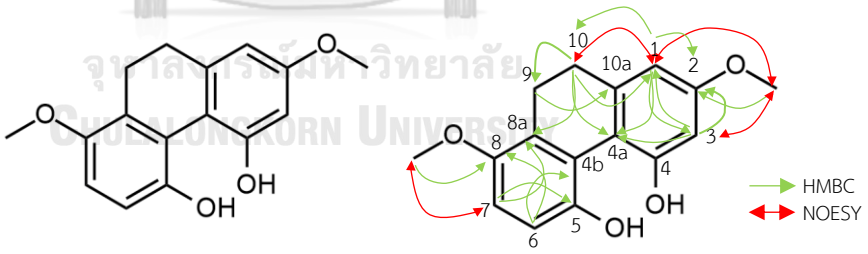

Figure 13 Structure of 2,8-Dimethoxy-9,10-dihydro-4,5-phenanthrenediol (**compound 1**)

Table 10 Chemical shift of ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz), and correlation of HMBC spectrum of **compound 1** in acetone-d_6

Position	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	HMBC (correlation with ^{1}H)
1	6.49 (*d*, 2.5)	107.1	3, 10
2	-	160.7	1*, 3*, MeO-2
3	6.45 (*d*, 2.5)	102.4	1
4	-	155.6	3*
4a	-	114.8	1, 3, 10
4b	-	123.3	6
5	-	146.8	7
6	6.88 (*d*, 8.5)	116.1	-
7	6.84 (*d*, 8.5)	111.7	-
8	-	150.9	6, MeO-8
8a	-	129.3	7, 10
9	2.58-2.65 (*m*)	23.0	10*
10	2.58-2.65 (*m*)	31.6	1
10a	-	143.4	9
MeO-2	3.77 (*s*)	55.4	-
MeO-8	3.78 (*s*)	56.6	-

*Two-bond coupling

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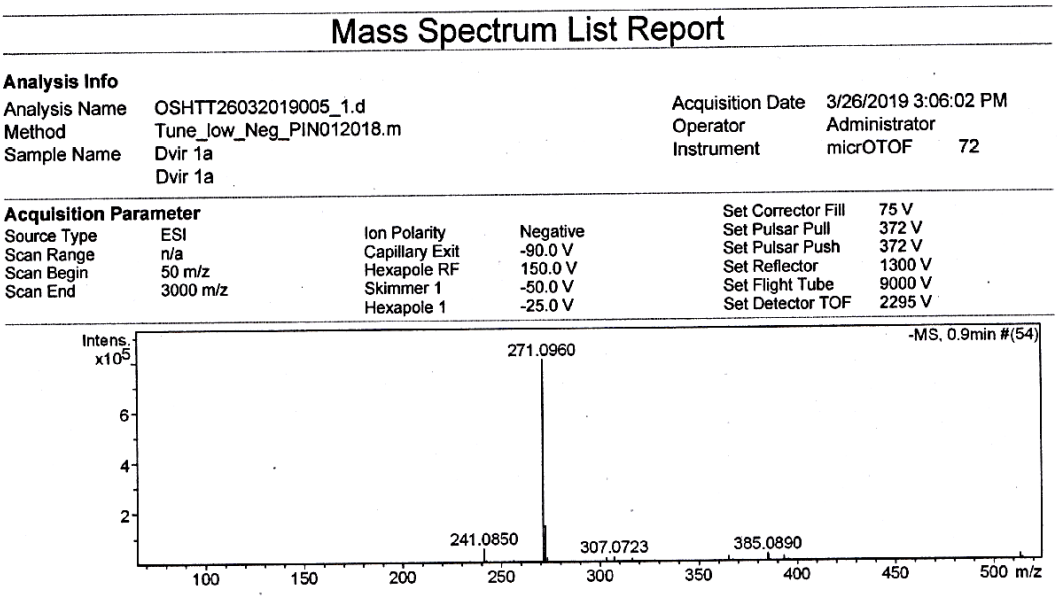

Figure 14 HR-ESI-MS spectrum of **compound 1**

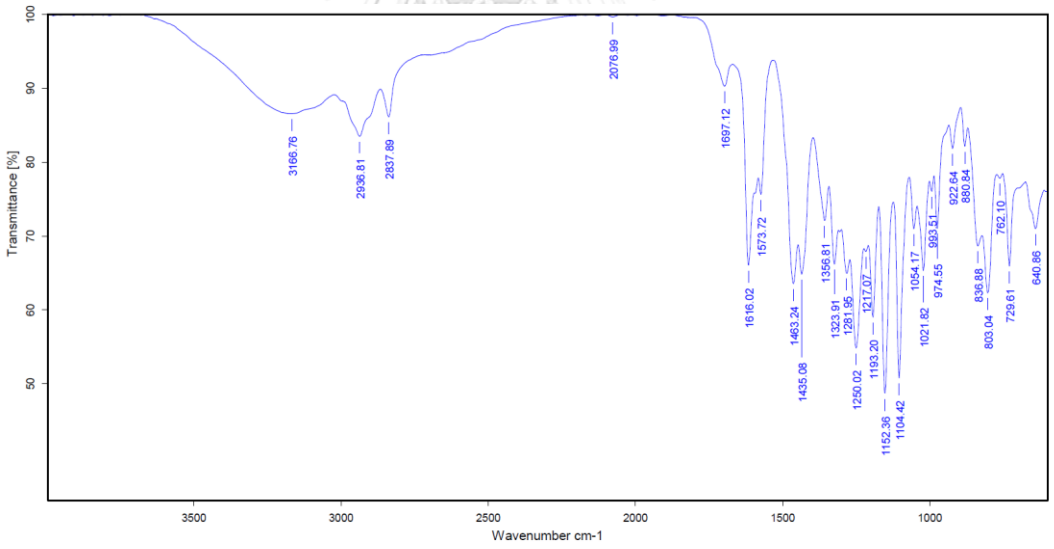

Figure 15 IR spectrum of **compound 1**

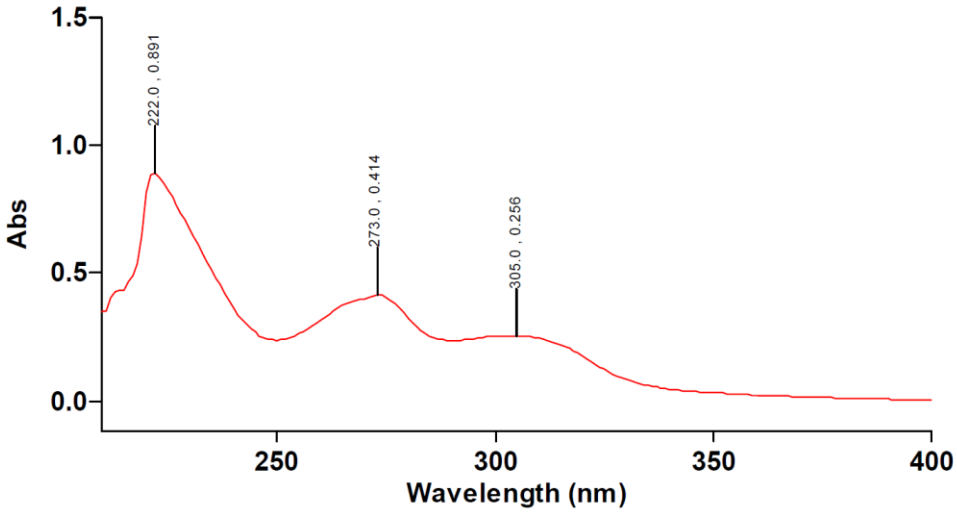

Figure 16 UV spectrum of **compound 1**

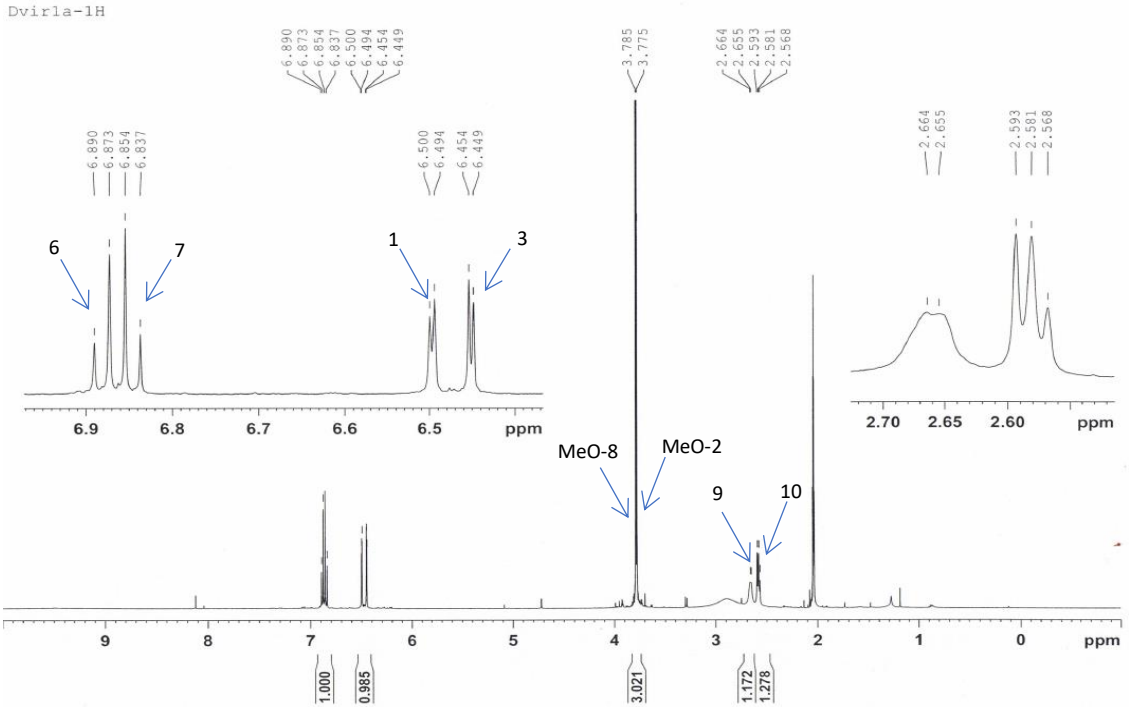

Figure 17 ^{1}H NMR spectrum of **compound 1** (500 MHz) in acetone-d_6

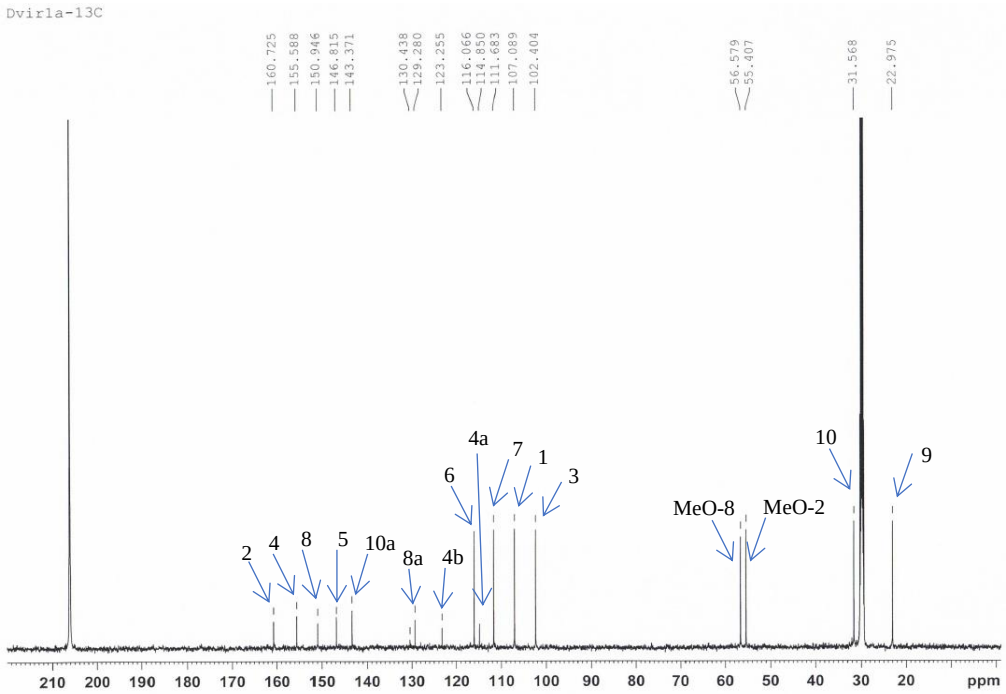

Figure 18 ^{13}C NMR spectrum of **compound 1** (125 MHz) in acetone-d_6

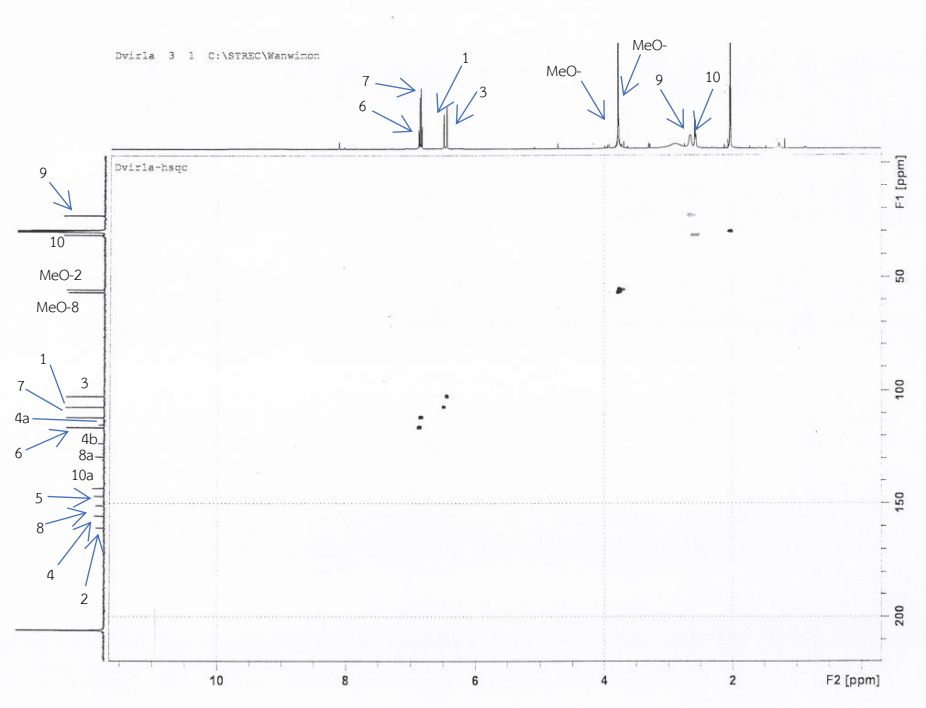

Figure 19 HSQC spectrum of **compound 1** in acetone-d_6

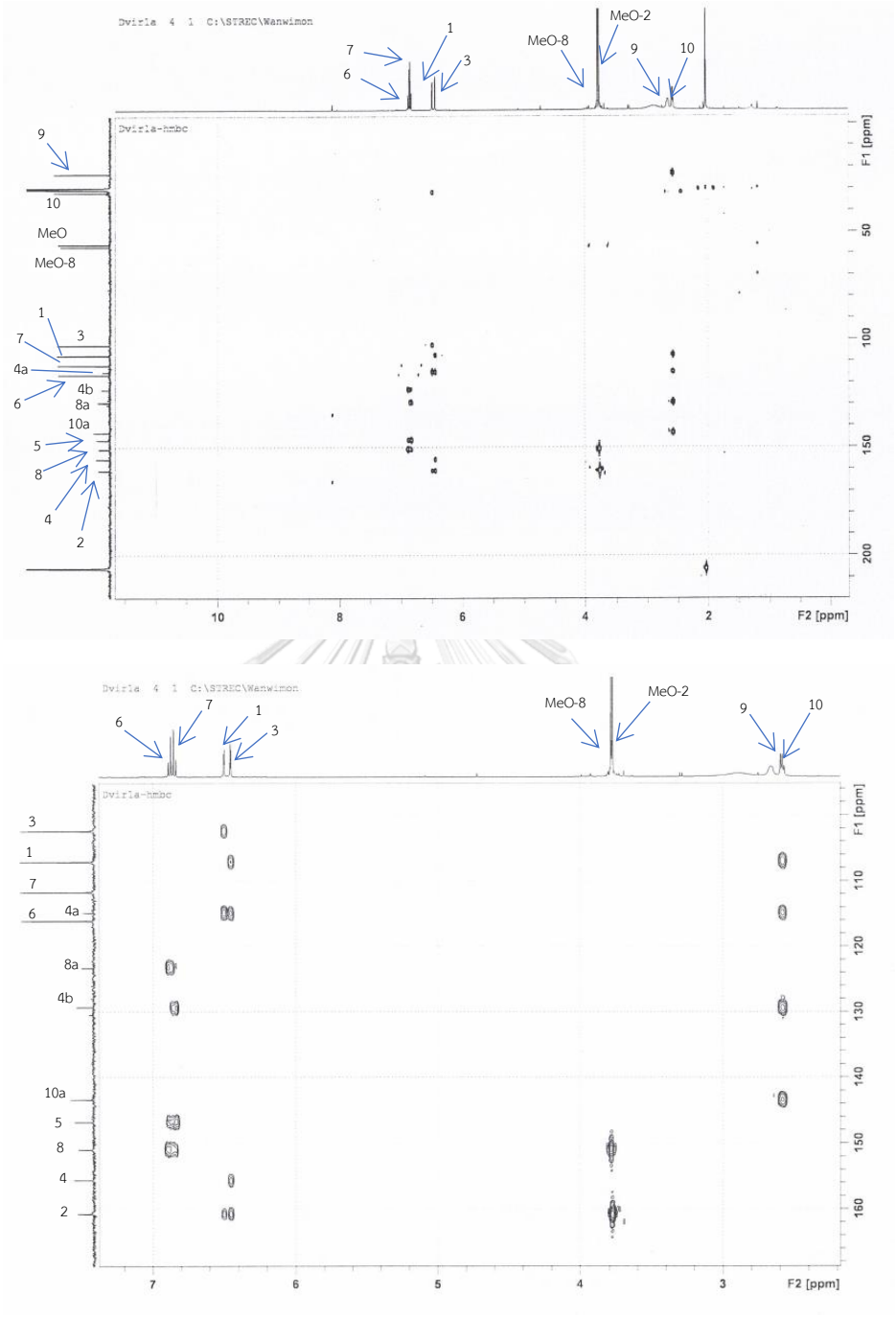

Figure 20 HMBC spectrum of **compound 1** in acetone-d_6

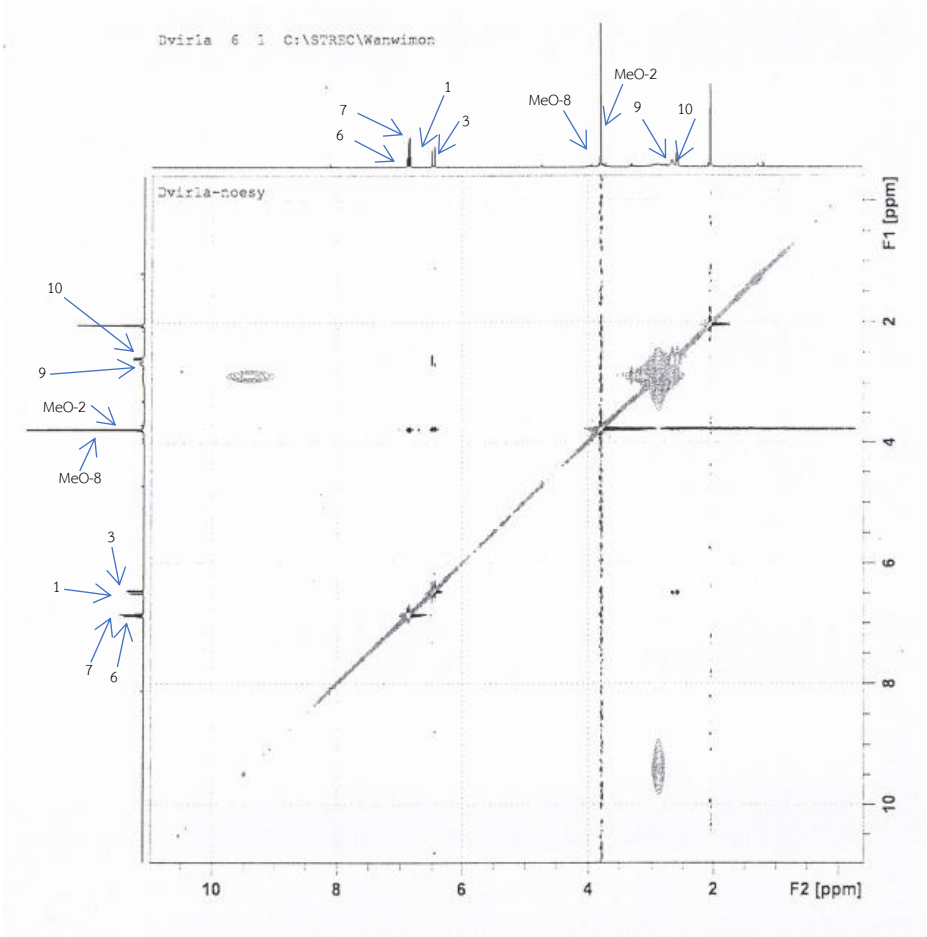

Figure 21 NOESY spectrum of **compound 1** in acetone-d_6

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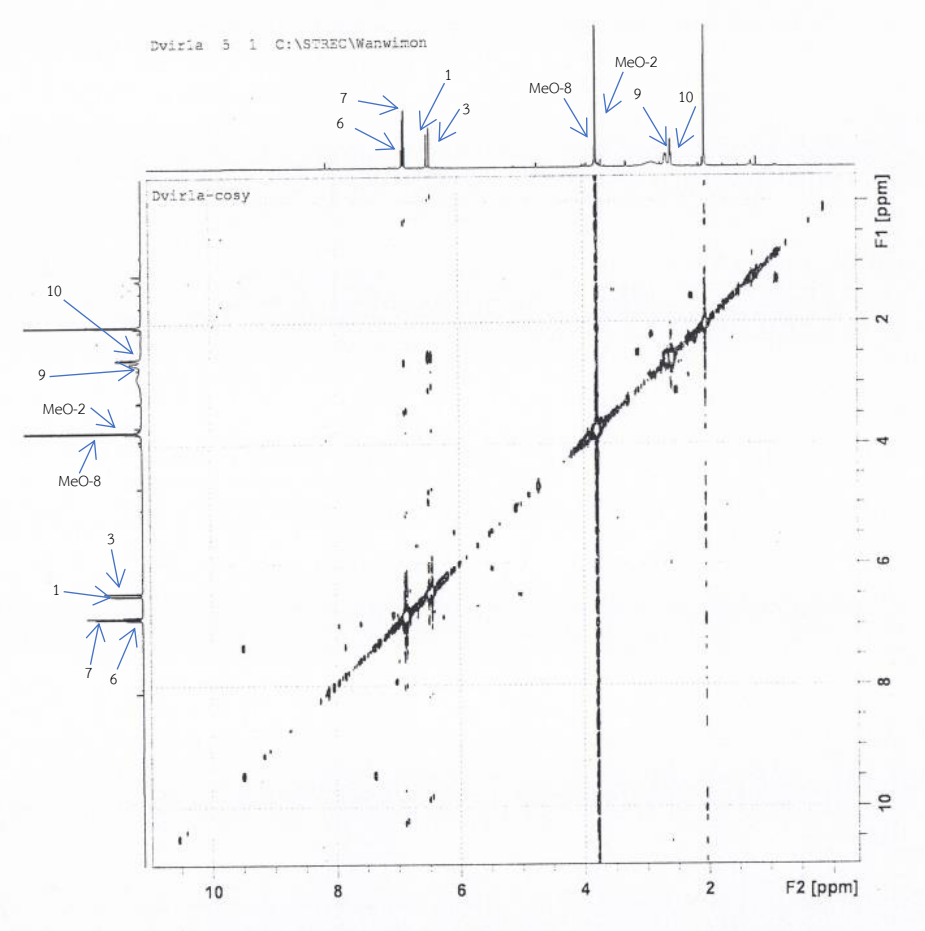

Figure 22 COSY spectrum of **compound 1** in acetone-d_6

1.2 Identification of compound 2 (2,5-Dimethoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone)

The negative HR-ESI-MS showed a deprotonated molecular ion $[M-H]^-$ at *m/z* 285.0752 (calcd. for $C_{16}H_{13}O_5$, 285.0763) (**Figure 24**), suggesting the molecular formula $C_{16}H_{14}O_5$.

The IR spectrum (**Figure 25**) exhibited absorption bands for hydroxyl (3416 cm^{-1}), aromatic ring (1658, 1606 cm^{-1}), ketone (1723 cm^{-1}) and methoxy (1213, 1160 cm^{-1}) groups.

The UV absorption (**Figure 26**) peaks at 222, 260, 334 and 490 nm were indicative of a phenanthrene derivative (Sarakulwattana et al. 2020).

An assignment of 9,10-dihydro-1,4-phenanthrenequinone was confirmed by a board singlet shown in ^{1}H NMR spectrum (**Figure 27**) at δ_H 2.46 ppm (H-10), a triplet at δ_H 2.58 (*J* = 7.0 Hz, H-9) ppm, twelve aromatic carbons shown in ^{13}C NMR spectrum (**Figure 28**) at δ_C 99.5-180.7 ppm, two methylene carbons at δ_C 20.6 and 29.3 ppm, and a ketone carbon at δ_C 180.7 and 185.1 ppm. The determination of two methoxy groups at C-2 and C-5 was confirmed by singlet peaks presented in ^{1}H NMR at δ_H 3.82 and 3.69 ppm, two methoxy carbons shown in ^{13}C NMR spectrum at δ_C 56.3 and 56.0 ppm, and NOESY (**Figure 31**) correlation of MeO-2 with H-3 and MeO-5 with H-6. The absence of substitution at C-6 and C-8 was confirmed by two doublets presented in ^{1}H-NMR spectrum at δ_H 6.41 (*J* = 2.0 Hz, H-8) and 6.43 (*J* = 2.0 Hz, H-6) ppm, and HMBC correlation (**Figure 30**) of H-6 with C-4b and C-8, H-8 with C-6, C-4b, and C-9. Moreover, the assignment of hydroxy group at C-7 was confirmed by δ_C 161.5 ppm.

The HSQC spectrum (**Figure 29**) displayed peaks that correspond to the correlations between the protons and carbons in the molecule.

In conclusion, referring to above spectral information, the structure was confirmed as a new phenanthrene derivative, 2,5-dimethoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone (**compound 2**), Its structure was illustrated in **Figure 23**.

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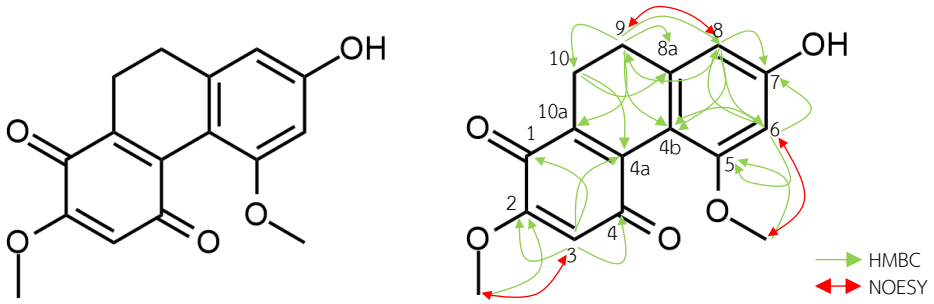

Figure 23 Structure of 2,5-Dimethoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone (**compound 2**)

Table 11 Chemical shift of ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz), and correlation of HMBC spectrum of **compound 2** in acetone-d_6

Position	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	HMBC (correlation with ^{1}H)
1	-	180.7	3
2	-	158.9	3*, MeO-2
3	5.95 (*s*)	108.0	-
4	-	185.1	3*
4a	-	142.1	3
4b	-	112.6	6, 8, 9
5	-	160.4	6, MeO-5
6	6.43 (*d*, 2.0)	99.5	8
7	-	161.5	6*, 8*
8	6.41 (*d*, 2.0)	108.2	6, 9
8a	-	143.9	9*, 10
9	2.58 (*t*, 7.0)	29.3	8
10	2.46 (*brs*)	20.6	9*
10a	-	137.6	9
MeO-2	3.82 (*s*)	56.3	-
MeO-5	3.69 (*s*)	56.0	-

*Two-bond coupling

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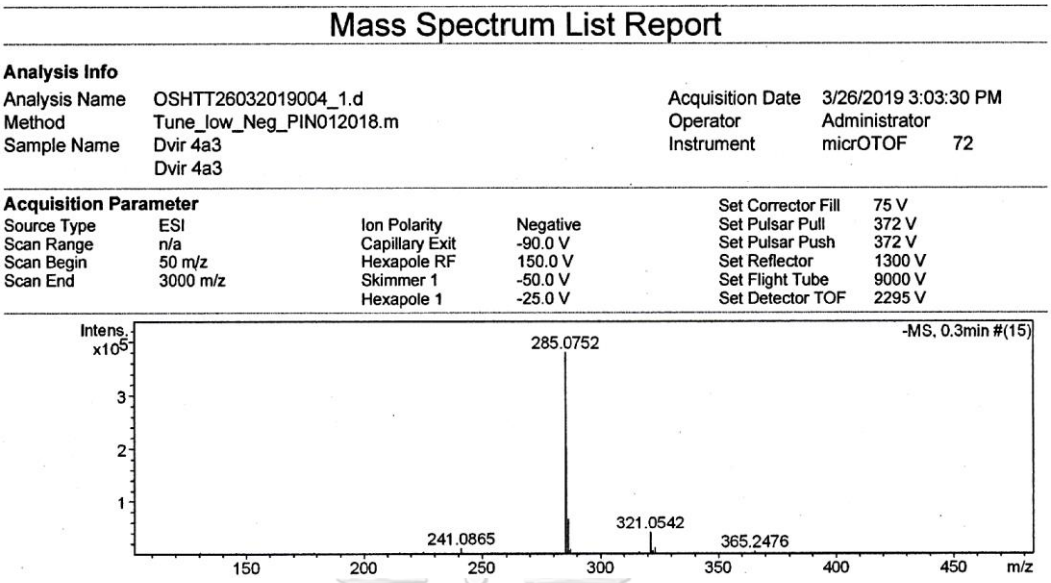

Figure 24 HR-ESI-MS spectrum of **compound 2**

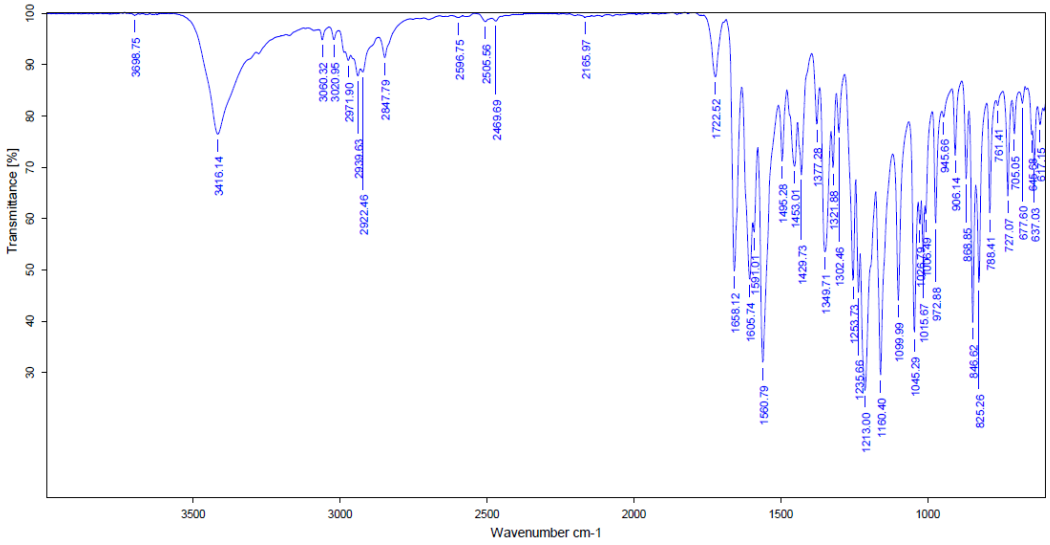

Figure 25 IR spectrum of **compound 2**

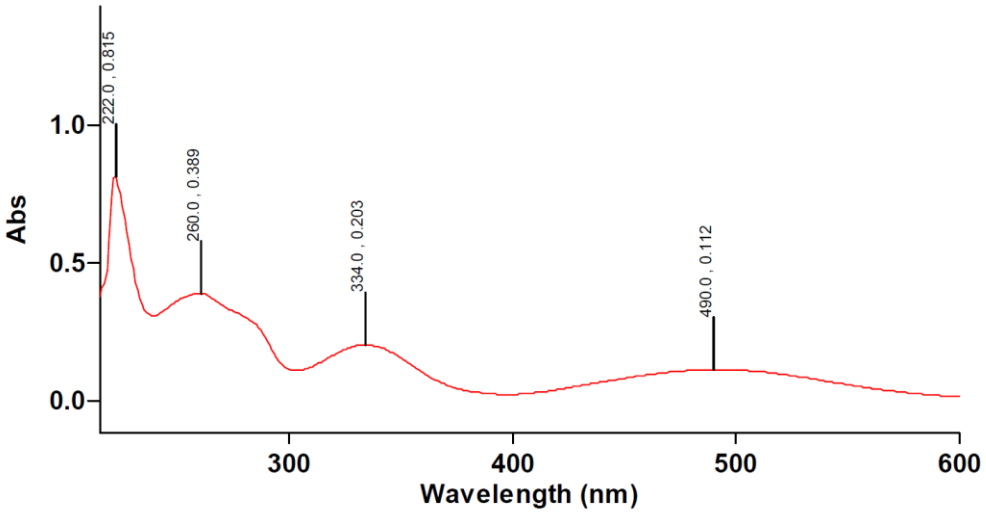

Figure 26 UV spectrum of **compound 2**

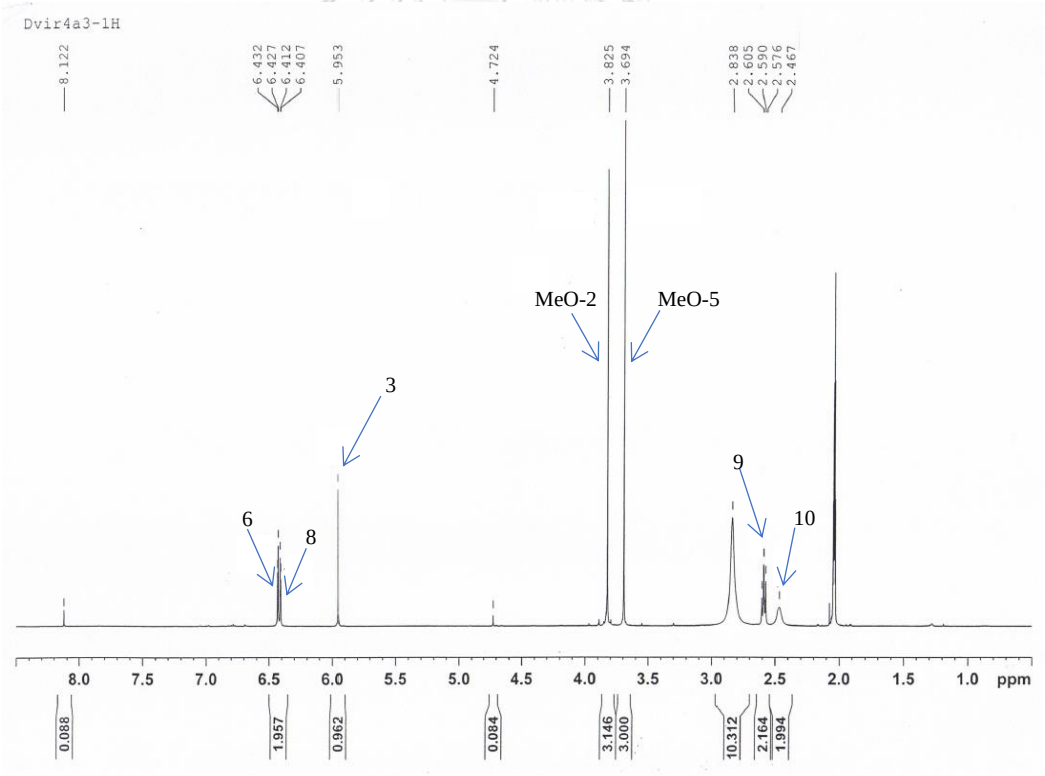

Figure 27 ^{1}H NMR spectrum of **compound 2** (500 MHz) in acetone-d_6

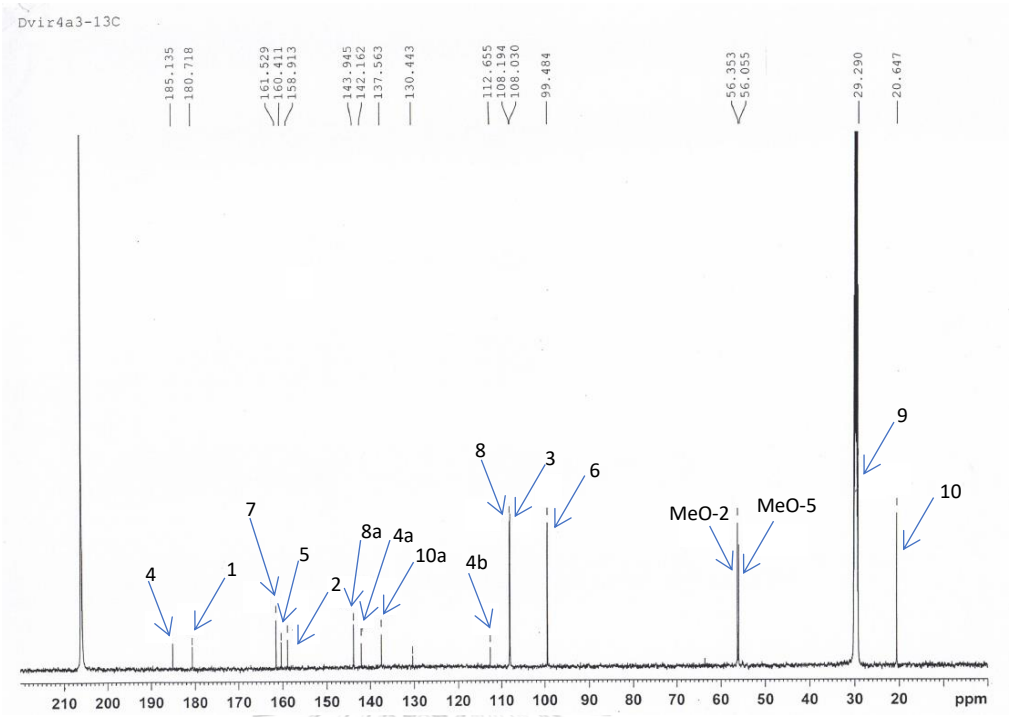

Figure 28 ^{13}C NMR spectrum of **compound 2** (125 MHz) in acetone-d_6

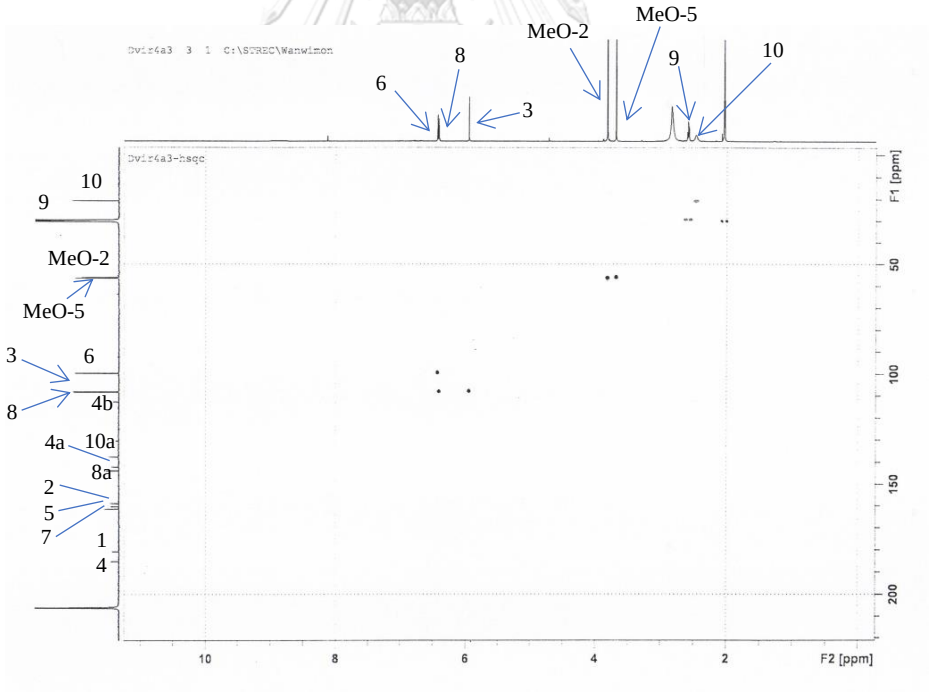

Figure 29 HSQC spectrum of **compound 2** in acetone-d_6

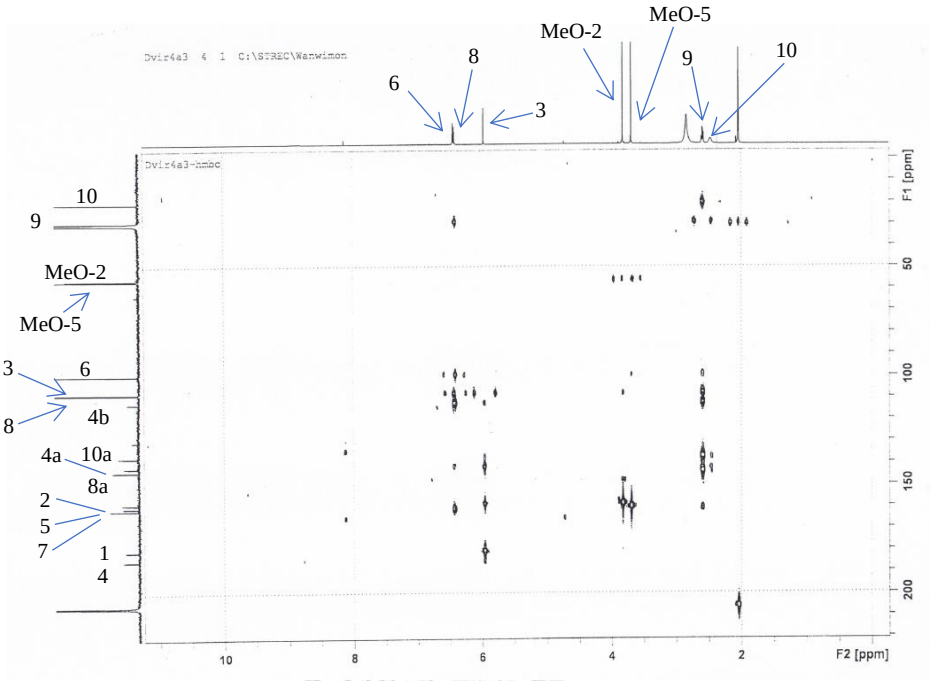

Figure 30 HMBC spectrum of **compound 2** in acetone-d_6

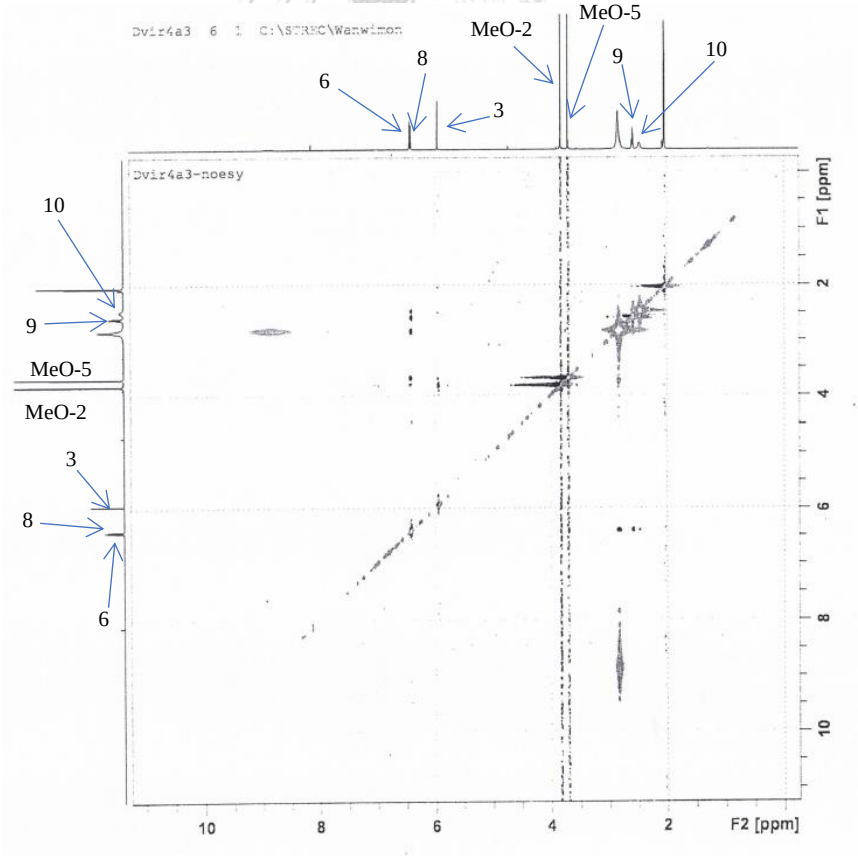

Figure 31 NOESY spectrum of **compound 2** in acetone-d_6

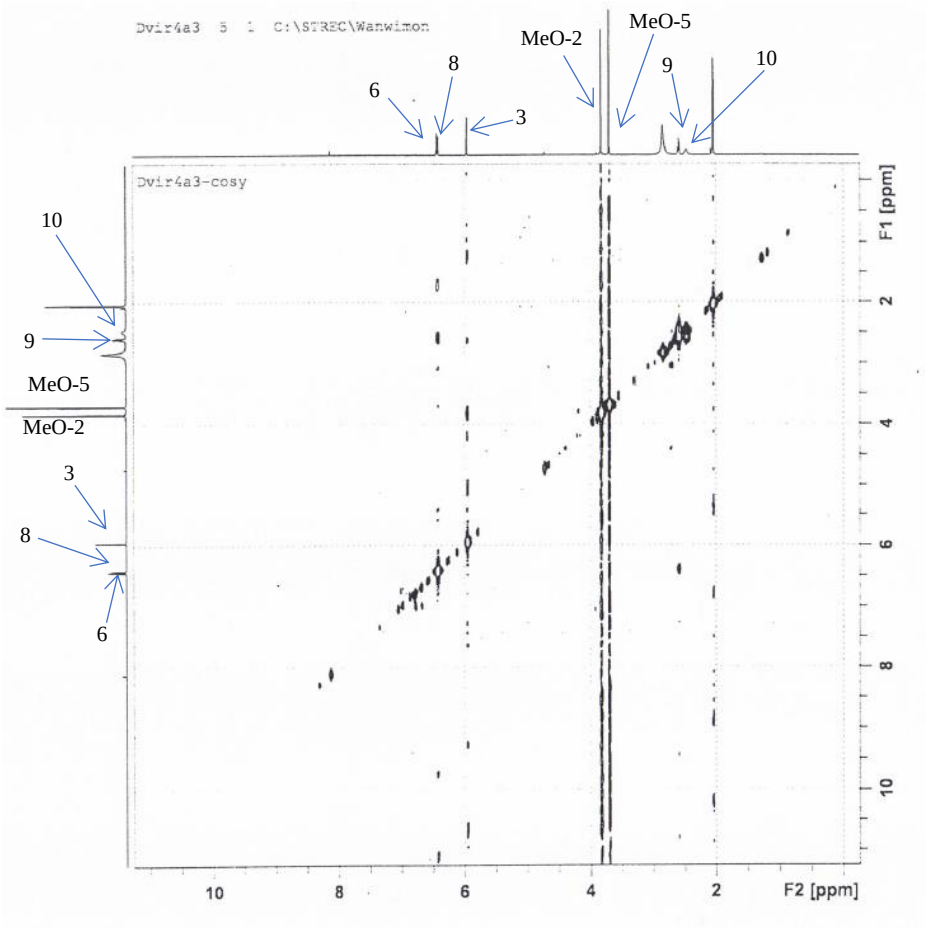

Figure 32 COSY spectrum of **compound 2** in acetone-d_6

1.3 Identification of compound 3 (2-Methoxy-9,10-dihydro-4,5-phenanthrenediol)

The positive HR-ESI-MS showed a hydrogen-adduct molecular ion $[M+H]^+$ at *m/z* 243.1026 (calcd. for $C_{15}H_{15}O_3$, 243.1021) (**Figure 34**), suggesting the molecular formula $C_{15}H_{14}O_3$.

The ^{1}H NMR spectrum (**Figure 35**) exhibited two aromatic protons as doublet at δ_H 6.47 (*J* = 2.5 Hz, H-3) and 6.50 (*J* = 2.5 Hz, H-1) ppm, three doublet of doublets at δ_H 6.85 (*J* = 7.0, 2.0 Hz, H-6), 6.90 (*J* = 7.0, 2.0 Hz, H-8) and 7.08 (*J* = 7.5, 8.3 Hz, H-7) ppm, and two methylene protons as singlet at δ_H 2.65 ppm (H-9, H-10). Considering with chemical shift of aromatic carbon at δ_C 102.3-160.6 ppm and and two

methylene carbons at δ_C 31.5 and 32.0 ppm presented in ^{13}C NMR spectrum (**Figure 36**), this structure contained a dihydrophenanthrene ring. A methoxy proton and two hydroxy protons substituted in the dihydrophenanthrene ring were assigned regarding δ_C 160.6, 152.8 and 155.2 ppm, respectively. According to ^{1}H-NMR spectrum, two doublets confirmed no adjacent proton in an aromatic ring. Three doublets of doublets showed that there were three adjacent protons. After considering ^{13}C NMR spectrum together with ^{1}H NMR spectrum, a methoxy group and two hydroxy group were assigned at C-2, C-4 and C5, respectively.

By comparison to the above evidence and the previously reported spectral data (Matsuda et al. 2004), **compound 3** was identified as 2-methoxy-9,10-dihydro-4,5-phenanthrenediol (**Figure 33**).

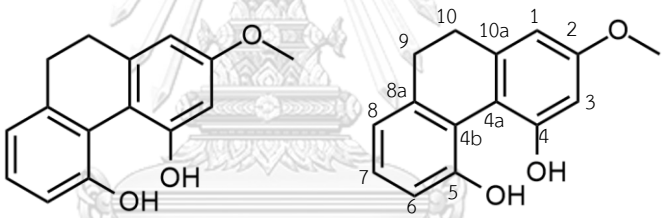

Figure 33 Structure of **compound 3**

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Table 12 Comparison of ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) in acetone-d_6 of **compound 3** in this study with ^{1}H NMR (270 MHz) and ^{13}C NMR (68 MHz) in CD_3OD of 2-methoxy-9,10-dihydro-4,5-phenanthrenediol reported in previous study

Position	Compound 3		2-Methoxy-9,10-dihydro-4,5-phenanthrenediol[a]	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
1	6.50 (*d*, 2.5)	107.3	6.47 (*d*, 2.6)	107.3
2	-	160.6	-	160.8

Position	Compound 3		2-Methoxy-9,10-dihydro-4,5-phenanthrenediol[a]	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
3	6.47 (*d*, 2.5)	102.3	6.43 (*d*, 2.6)	102.1
4	-	152.8	-	152.8
4a	-	114.7	-	115.0
4b	-	121.8	-	122.1
5	-	155.2	-	154.9
6	6.85 (*dd*, 7.0, 2.0)	116.9	6.82 (*dd*, 8.2, 1.8)	116.8
7	7.08 (*dd*, 7.5, 8.3)	128.0	7.05 (*dd*, 8.2, 8.2)	128.0
8	6.90 (*dd*, 7.0, 2.0)	120.8	6.83 (*dd*, 8.2, 1.8)	120.9
8a	-	141.7	-	141.9
9	2.65 (*s*)	32.0	2.63 (*s*)	32.4
10	2.65 (*s*)	31.5	2.63 (*s*)	31.9
10a	-	143.4	-	143.7
MeO-2	3.78 (*s*)	55.4	3.77 (*s*)	55.5

[a](Matsuda et al. 2004)

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Mass Spectrum List Report

Analysis Info

Analysis Name	17122020_CU_DV3.d	Acquisition Date	12/17/2020 11:02:33 AM
Method	Tune_low_40_POS_2019_NATTHAPAT.m	Operator	Administrator
Sample Name	DV3 17122020	Instrument	micrOTOF 72

Acquisition Parameter

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Scan Begin	50 m/z	Hexapole RF	150.0 V	Set Pulsar Push	337 V
Scan End	3000 m/z	Skimmer 1	45.0 V	Set Reflector	1300 V
		Hexapole 1	24.3 V	Set Flight Tube	9000 V
				Set Detector TOF	2295 V

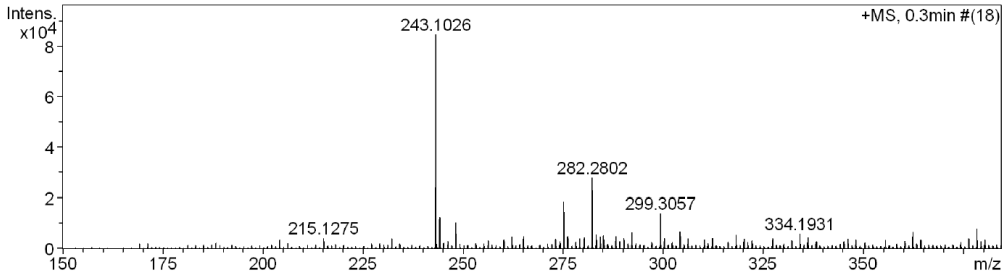

Figure 34 HR-ESI-MS spectrum of **compound 3**

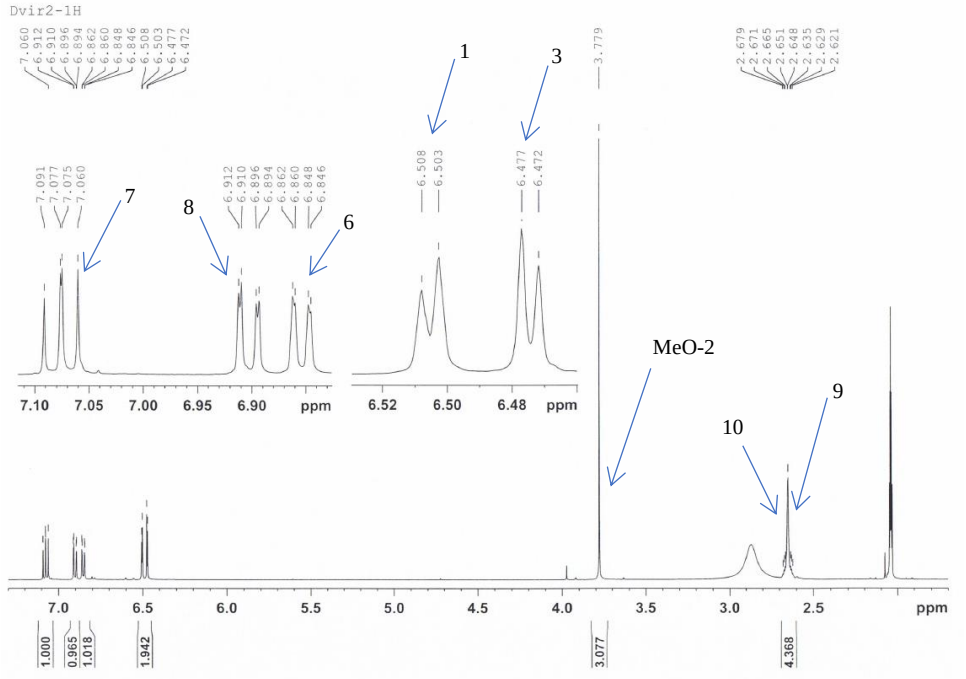

Figure 35 ^{1}H NMR spectrum of **compound 3** (500 MHz) in acetone-d_6

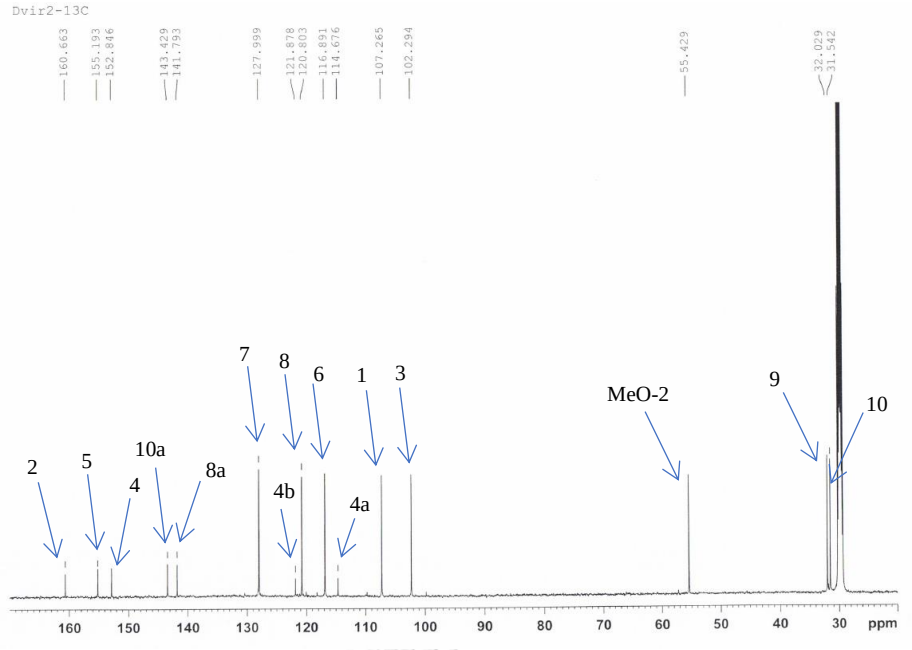

Figure 36 ^{13}C NMR spectrum of **compound 3** (125 MHz) in acetone-d_6

1.4 Identification of compound 4 (Gigantol)

The positive HR-ESI-MS showed a hydrogen-adduct molecular ion $[M+H]^+$ at m/z 275.1286 (calcd. for $C_{16}H_{19}O_4$, 275.1283) (**Figure 38**), suggesting the molecular formula $C_{16}H_{18}O_4$.

The structure of **compound 4** was elucidated as bibenzyl regarding two methylene protons presented as multiplet in ^{1}H NMR spectrum (**Figure 39**) at δ_H 2.77 and 2.78 ppm, twelve aromatic carbons in ^{13}C NMR spectrum (**Figure 40**) at δ_C 99.7-161.7 ppm, and two methylene carbons at δ_C 37.9 and 38.9 ppm. Additionally, according to ^{1}H-NMR spectrum, three triplet and one doublet signals at δ_H 6.26 (J = 2.0 Hz, H-4), 6.30 (J = 2.0 Hz, H-2), 6.33 (J = 2.0 Hz, H-6) and 6.79 (J = 1.5 Hz, H-2′) ppm, respectively, indicated absence of adjacent protons. Doublet and doublet of doublets at δ_H 6.74 (J = 8.0 Hz, H-5′), 6.65 (J = 8.0, 1.5 Hz, H-6′) ppm, respectively, indicated adjacent protons. Therefore, there were four substitutions in aromatic rings of bibenzyl. Two methoxy groups assigned at C-3 and C-3′ were confirmed by ^{1}H NMR spectrum as singlet at δ_H 3.69 and 3.77 ppm, and ^{13}C NMR spectrum at δ_C 148.0 and 159.1 ppm. The remaining substitutions at C-5 and C-4′ were hydroxy group.

According to the above spectral data and previous study (Klongkumnuankarn et al. 2015), compound 4 was characterized as gigantol (**Figure 37**).

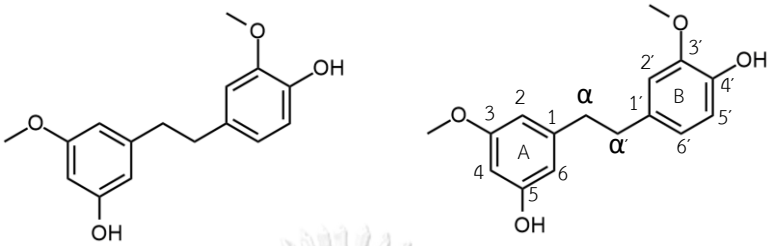

Figure 37 Structure of **compound 4**

Table 13 Comparison of ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) in acetone-d_6 of **compound 4** in this study with ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) in acetone-d_6 of gigantol reported in previous study

Position	Compound 4		Gigantol[a]	
	δ_H in ppm (mult., *J* in Hz)	**δ_C in ppm**	**δ_H in ppm (mult., *J* in Hz)**	**δ_C in ppm**
1	-	145.4	-	145.4
2	6.30 (*t*, 2.0)	108.9	6.22 (*t*, 2.0)	108.8
3	-	159.1	-	159.1
4	6.26 (*t*, 2.0)	99.7	6.28 (*t*, 2.0)	99.6
5	-	161.7	-	161.7
6	6.33 (*t*, 2.0)	106.3	6.30 (*t*, 2.0)	106.2
α	2.78 (*m*)	38.9	2.78 (*m*)	39.0
α′	2.77 (*m*)	37.9	2.78 (*m*)	37.9
1′	-	134.1	-	134.0
2′	6.79 (*d*, 1.5)	115.5	6.79 (*d*, 1.5)	115.4
3′	-	148.0	-	147.9
4′	-	145.4	-	145.1
5′	6.74 (*d*, 8.0)	112.8	6.69 (*d*, 8.0)	112.8

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Position	Compound 4		Gigantol[a]	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
6′	6.65 (*dd*, 8.0 ,1.5)	121.4	6.64 (*dd*, 8.0, 1.5)	121.5
MeO-3	3.69 (*s*)	55.2	3.69 (*s*)	55.2
MeO-3′	3.77 (*s*)	56.1	3.78 (*s*)	56.0

[a](Klongkumnuankarn et al. 2015)

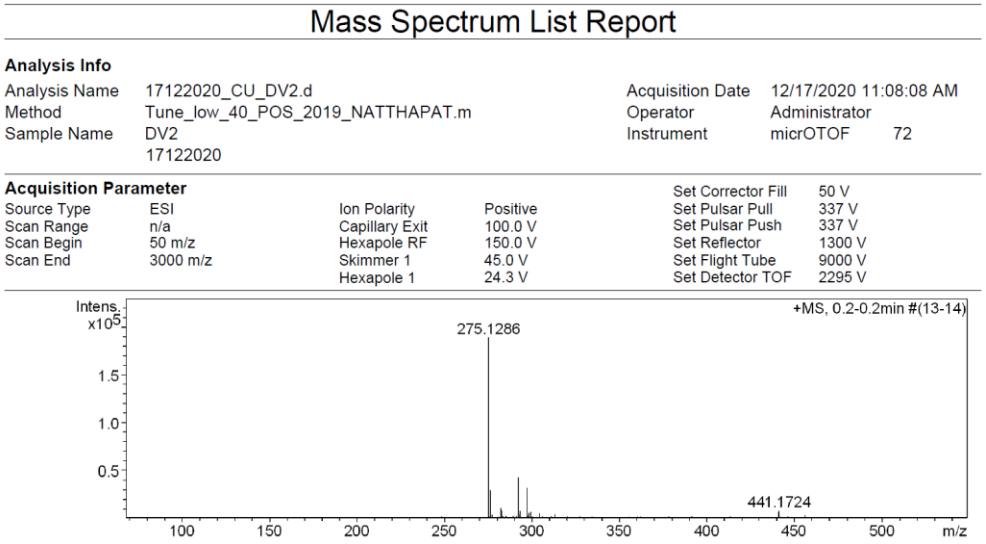

Figure 38 HR-ESI-MS spectrum of **compound 4**

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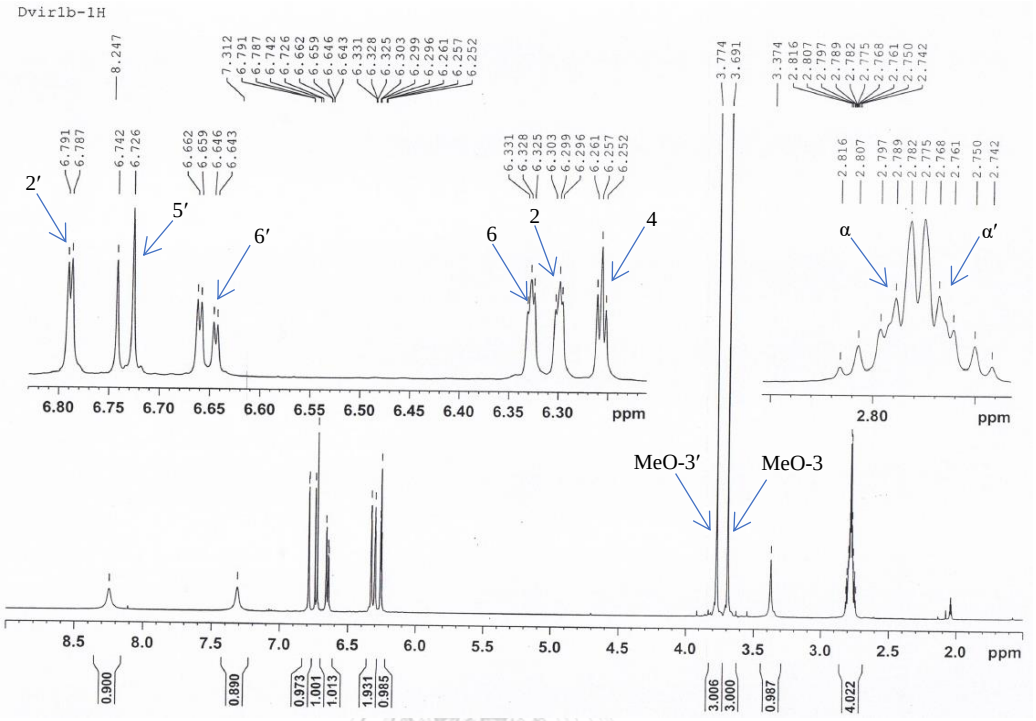

Figure 39 ^{1}H NMR spectrum of **compound 4** (500 MHz) in acetone-d_6

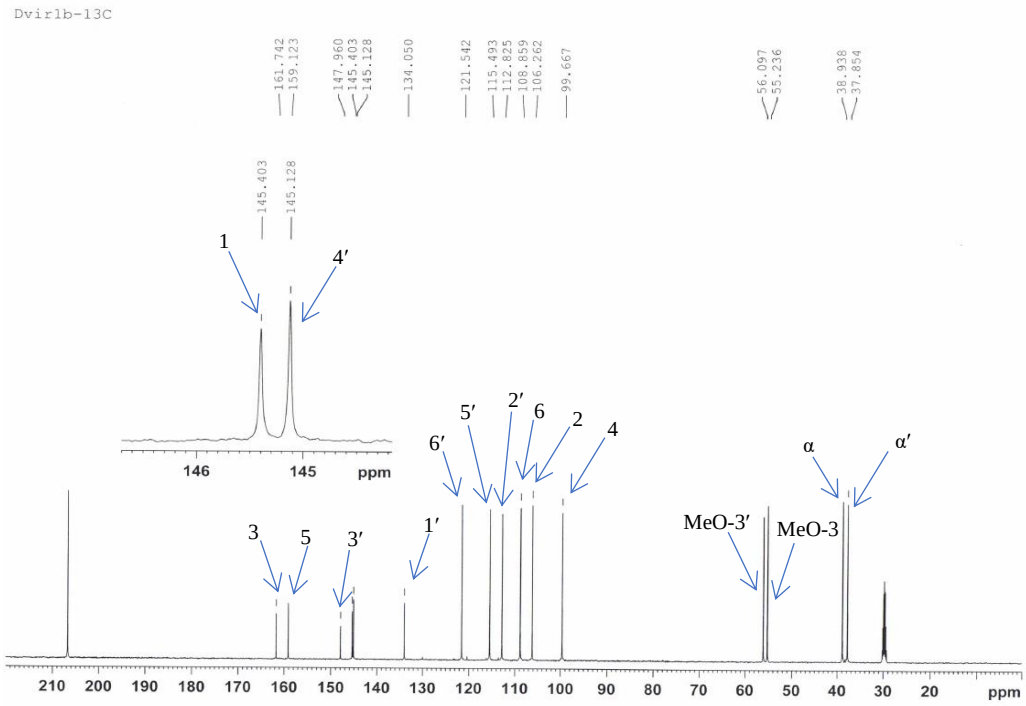

Figure 40 ^{13}C NMR spectrum of **compound 4** (125 MHz) in acetone-d_6

1.5 Identification of compound 5 (5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone)

The negative HR-ESI-MS showed a deprotonated molecular ion $[M-H]^-$ at m/z 255.0659 (calcd. for $C_{15}H_{11}O_4$, 255.0657) (**Figure 42**), suggesting the molecular formula $C_{15}H_{12}O_4$.

Two multiplet shown in ^{1}H NMR spectrum (**Figure 43**) at δ_H 2.48 and 2.60 ppm, twelve aromatic carbon shown in ^{13}C NMR spectrum (**Figure 44**) at δ_C 99.3-186.0 ppm, two methylene carbon at δ_C 20.7 and 29.1 ppm, and two ketone carbons at δ_C 185.6 and 186.0 ppm determined 9,10-dihydro-1,4-phenanthrenequinone. An absence of nearby proton was confirmed by two doublets at δ_H 6.42 (*J* = 2.0 Hz, H-8) and 6.44 (*J* = 2.5 Hz, H-6) ppm. Adjacent protons were assinged regarding two doublets at δ_H 6.71 (*J* = 10.0 Hz, H-2) and 6.81 (*J* = 10.0 Hz, H-3) ppm. ^{1}H NMR spectrum shown as singlet at δ_H 3.70 ppm, and ^{13}C NMR spectrum shown at δ_C 56.0 and 160.1 ppm indicated a methoxy group substituted at C-5.

By comparison to the above evidence and the previously reported spectral data (Sritularak, Anuwat and Likhitwitayawuid 2011), **compound 5** was identified as 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone (**Figure 41**).

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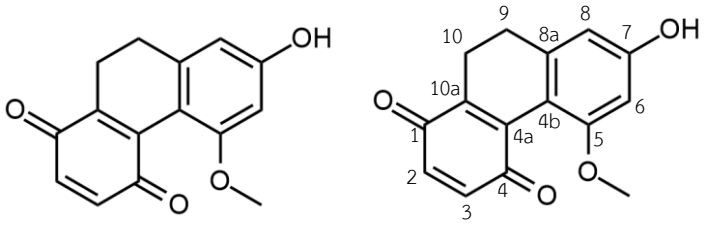

Figure 41 Structure of **compound 5**

Table 14 Comparison of ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) in acetone-d_6 of **compound 5** in this study with ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) in $CDCl_3$ of 5-methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone reported in previous study

Position	Compound 5		5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone[a]	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
1	-	185.6	-	185.4
2	6.71 (*d*, 10.0)	135.9	6.68 (*d*, 10.0)	135.1
3	6.81 (*d*, 10.0)	138.0	6.78 (*d*, 10.0)	137.2
4	-	186.0	-	185.7
4a	-	141.7	-	140.9
4b	-	112.4	-	112.3
5	-	160.1	-	158.9
6	6.44 (*d*, 2.5)	99.3	6.33 (*d*, 2.0)	98.6
7	-	161.5	-	158.8
8	6.42 (*d*, 2.0)	108.2	6.31 (*d*, 2.0)	107.4
8a	-	143.7	-	143.1
9	2.60 (*m*)	29.1	2.60 (*m*)	28.5
10	2.48 (*m*)	20.7	2.55 (*m*)	20.1
10a	-	139.7	-	139.8
MeO-5	3.70 (*s*)	56.0	3.73 (*s*)	55.8

[a](Sritularak, Anuwat and Likhitwitayawuid 2011)

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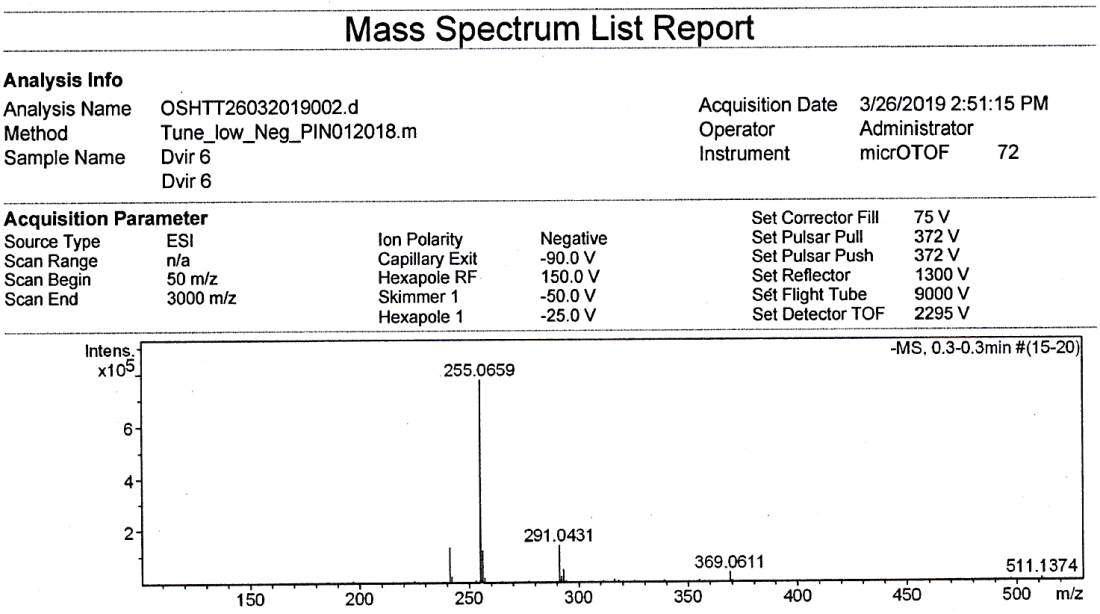

Figure 42 HR-ESI-MS spectrum of **compound 5**

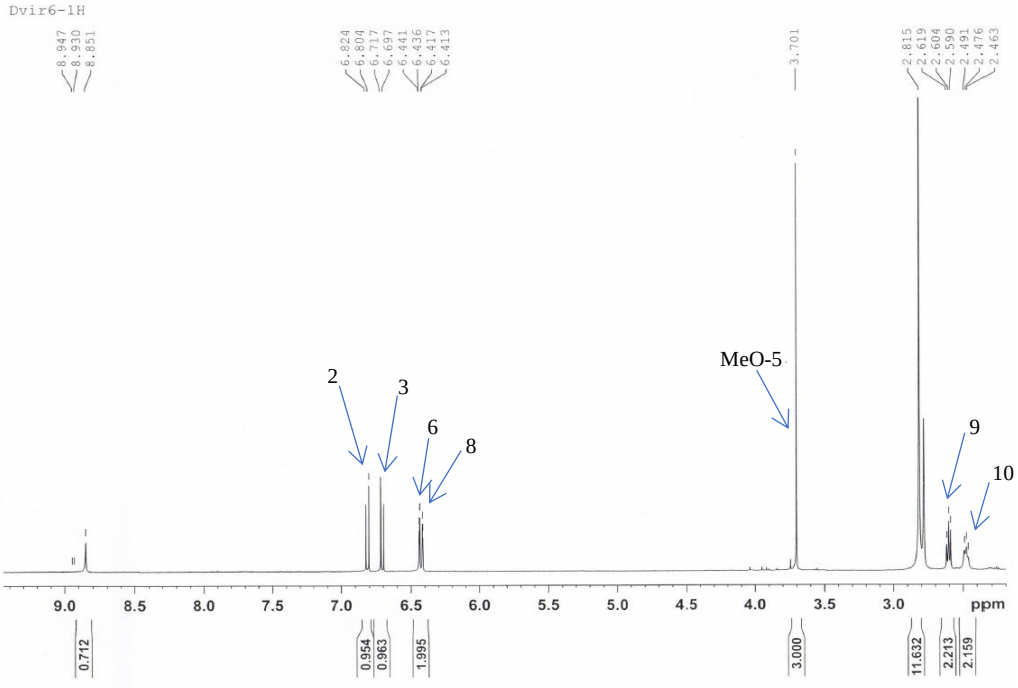

Figure 43 ^{1}H NMR spectrum of **compound 5** (500 MHz) in acetone-d_6

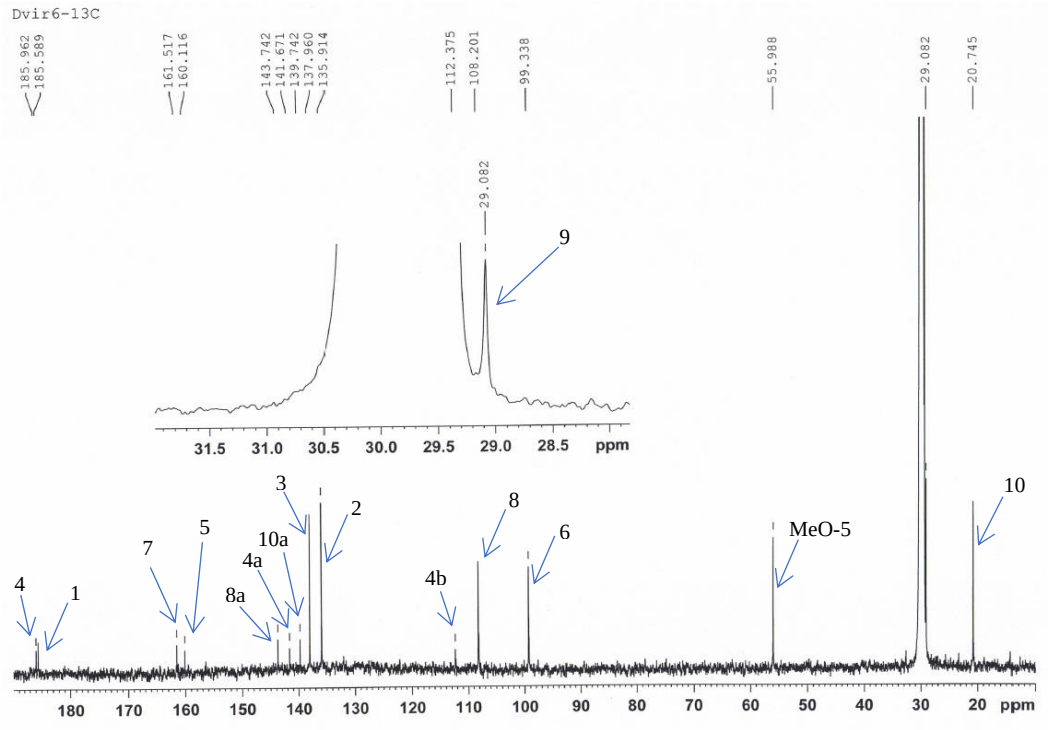

Figure 44 ^{13}C NMR spectrum of **compound 5** (125 MHz) in acetone-d_6

1.6 Identification of compound 6 (*p*-Coumaric acid)

The positive HR-ESI-MS showed a hydrogen-adduct molecular ion $[M+H]^+$ at *m/z* 165.0554 (calcd. for $C_9H_9O_3$, 165.0552) (**Figure 46**), suggesting the molecular formula $C_9H_8O_3$.

Six aromatic carbons in ^{13}C NMR spectrum (**Figure 48**) at δ_C 114.87-167.23 ppm indicated β-methylstyrene in the structure. Every carbon in this structure has adjacent protons given that all signal in ^{1}H NMR spectrum (**Figure 47**) showed as doublet at δ_H 6.32 (*J* = 16.0 Hz, H-8), 6.89 (*J* = 8.5 Hz, H-3, H-5), 7.54 (*J* = 8.5 Hz, H-2, H-6) and 7.60 (*J* = 16.0 Hz, H-7) ppm. Carboxylic group assigned at C-9 and hydroxy group assigned at C-4 was confirmed by ^{13}C NMR at δ_C 167.23 and 159.59 ppm, respectively.

Regarding the above evidence and the previously reported spectral data (Rho and Yoon 2017), **compound 6** was identified as *p*-coumaric acid (**Figure 45**).

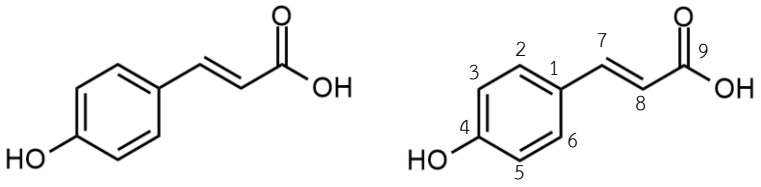

Figure 45 Structure of **compound 6**

Table 15 Comparison of ^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) in acetone-d_6 of **compound 6** in this study with ^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) in CD_3OD of *p*-coumaric acid reported in previous study

Position	Compound 6		*p*-Coumaric acid[a]	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
1	-	126.16	-	127.26
2	7.54 (*d*, 8.5)	129.96	7.44 (*d*, 8.6)	131.06
3	6.89 (*d*, 8.5)	115.76	6.79 (*d*, 8.6)	116.79
4	-	159.59	-	161.16
5	6.89 (*d*, 8.5)	115.76	6.79 (*d*, 8.6)	116.79
6	7.54 (*d*, 8.5)	129.96	7.44 (*d*, 8.6)	131.06
7	7.60 (*d*, 16.0)	144.61	7.58 (*d*, 15.9)	146.49
8	6.32 (*d*, 16.0)	114.87	6.28 (*d*, 15.9)	115.82
9	-	167.23	-	171.20

[a](Rho and Yoon 2017)

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Mass Spectrum List Report

Analysis Info

Analysis Name	17122020_CU_DV7.d	Acquisition Date	12/17/2020 11:17:39 AM
Method	Tune_low_40_POS_2019_NATTHAPAT.m	Operator	Administrator
Sample Name	DV7 17122020	Instrument	micrOTOF 72

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Corrector Fill	50 V
Scan Range	n/a	Capillary Exit	120.0 V	Set Pulsar Pull	337 V
Scan Begin	50 m/z	Hexapole RF	150.0 V	Set Pulsar Push	337 V
Scan End	3000 m/z	Skimmer 1	45.0 V	Set Reflector	1300 V
		Hexapole 1	24.3 V	Set Flight Tube	9000 V
				Set Detector TOF	2295 V

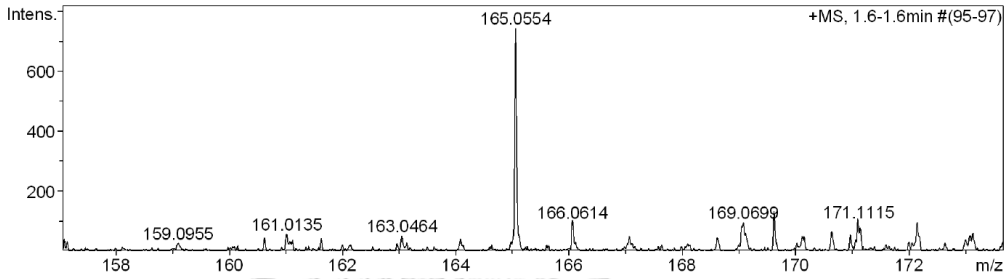

Figure 46 HR-ESI-MS spectrum of **compound 6**

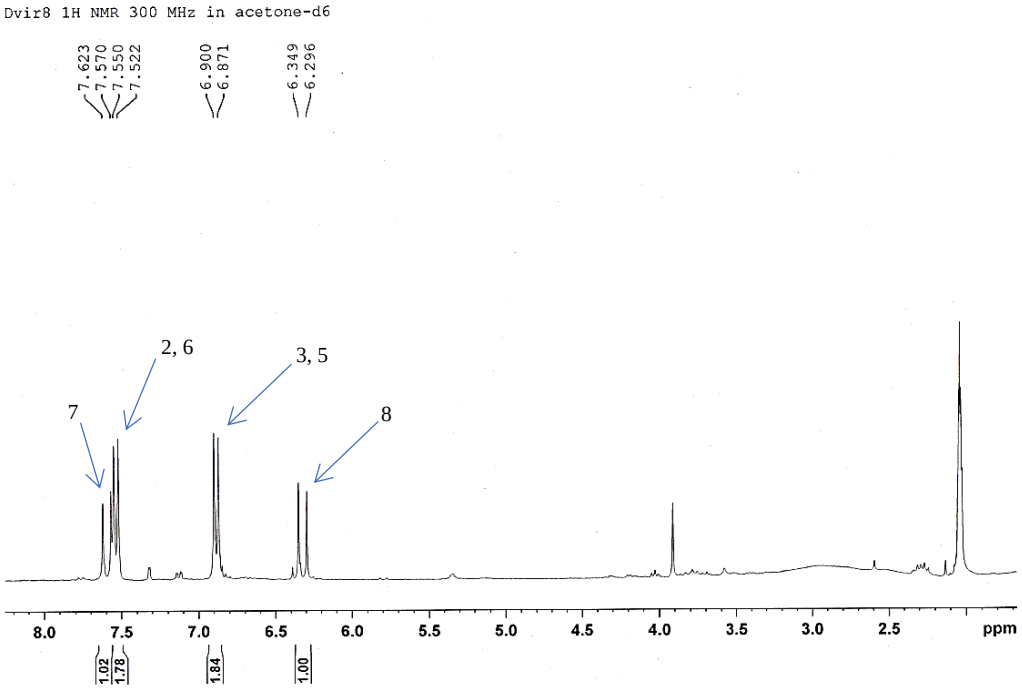

Figure 47 ^{1}H NMR spectrum of **compound 6** (300 MHz) in acetone-d_6

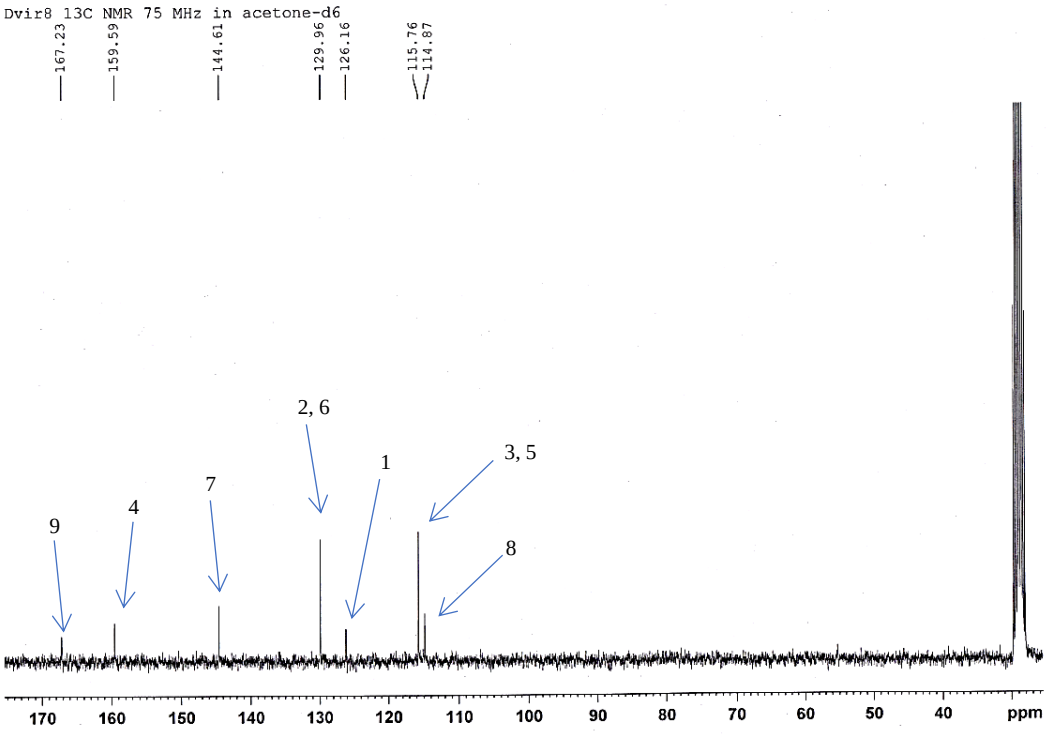

Figure 48 ^{13}C NMR spectrum of **compound 6** (75 MHz) in acetone-d_6

1.7 Identification of compound 7 (Tristin)

The positive HR-ESI-MS showed a hydrogen-adduct molecular ion $[M+H]^+$ at *m/z* 261.1150 (calcd. for $C_{15}H_{17}O_4$, 261.1127) (**Figure 50**), suggesting the molecular formula $C_{15}H_{16}O_4$.

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compound 7 was assigned as bibenzyl given two methylene protons as multiplet in ^{1}H NMR spectrum (**Figure 51**) at δ_H 2.76 ppm, twelve aromatic carbons in ^{13}C NMR spectrum (**Figure 52**) at δ_C 100.2-158.4 ppm, and two methylene carbons at δ_C 37.1 and 38.1 ppm. The signal shown in ^{1}H NMR as two doublet signals at δ_H 6.23 (2H, *J* = 1.8 Hz, H-2, H-6) ppm, a doublet signal at δ_H 7.02 (*J* = 2.5 Hz, H-2′) ppm, and a triplet signal at δ_H 6.19 (*J* = 5, H-4) ppm indicated absence of adjacent protons. Doublet and doublet of doublets at δ_H 6.75 (*J* = 7.0 Hz, H-5′), 6.65 (*J* = 2.0, 10.0 Hz, H-6′) ppm, respectively, indicated adjacent protons. Thus, the aromatic rings of bibenzyl had four substitutions at C-3, C-5, C-4′ and C-5′. A methoxy groups assigned at C-5′ was

confirmed by ^{1}H NMR spectrum as singlet at δ_H 3.77 ppm, and ^{13}C NMR spectrum at δ_C 147.3 ppm. The remaining substitutions were hydroxy group.

By comparison to the above evidence and the previously reported spectral data (Leong, Harrison and Powell 1999), **compound 7** was identified as tristin (**Figure 49**).

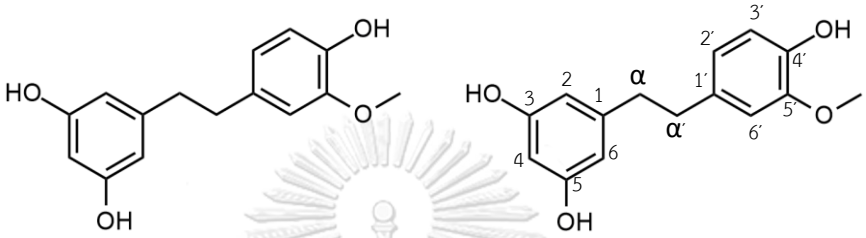

Figure 49 Structure of **compound 7**

Table 16 Comparison of ^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) in acetone-d_6 of **compound 7** in this study with ^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) in acetone-d_6 of tristin reported in previous study

Position	Compound 7		Tristin[a]	
	δ_H in ppm (mult., *J* in Hz)	**δ_C in ppm**	**δ_H in ppm (mult., *J* in Hz)**	**δ_C in ppm**
1	-	147.3	-	148.1
2	6.23 (*d*, 1.8)	106.9	6.22 (*m*)	107.8
3	-	158.4	-	159.3
4	6.19 (*t*, 1.8)	100.2	6.18 (*t*, 2.1)	101.1
5	-	158.4	-	159.3
6	6.23 (*d*, 1.8)	106.9	6.22 (*m*)	107.8
α	2.76 (*m*)	37.1	2.74 (*m*)	37.9
α′	2.76 (*m*)	38.1	2.74 (*m*)	39.0
1′	-	133.4	-	134.2

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Position	Compound 7		Tristin[a]	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
2′	6.65 (*dd*, 2.0, 10.0)	112.0	6.65 (*dd*, 1.7, 8.0)	112.9
3′	6.75 (*d*, 8.0)	144.7	6.72 (*d*, 8.0)	145.5
4′	-	144.4	-	145.1
5′	-	114.7	-	115.5
6′	6.73 (*d*, 2.0)	120.7	6.80 (*d*, 1.7)	121.5
OH-3	8.12 (*s*)	-	8.07 (*s*)	-
OH-5	8.12 (*s*)	-	8.07 (*s*)	-
OH-4′	7.33 (*s*)	-	7.30 (*s*)	-
MeO-5′	3.77 (*s*)	55.3	3.80 (*s*)	56.2

[a](Leong, Harrison and Powell 1999)

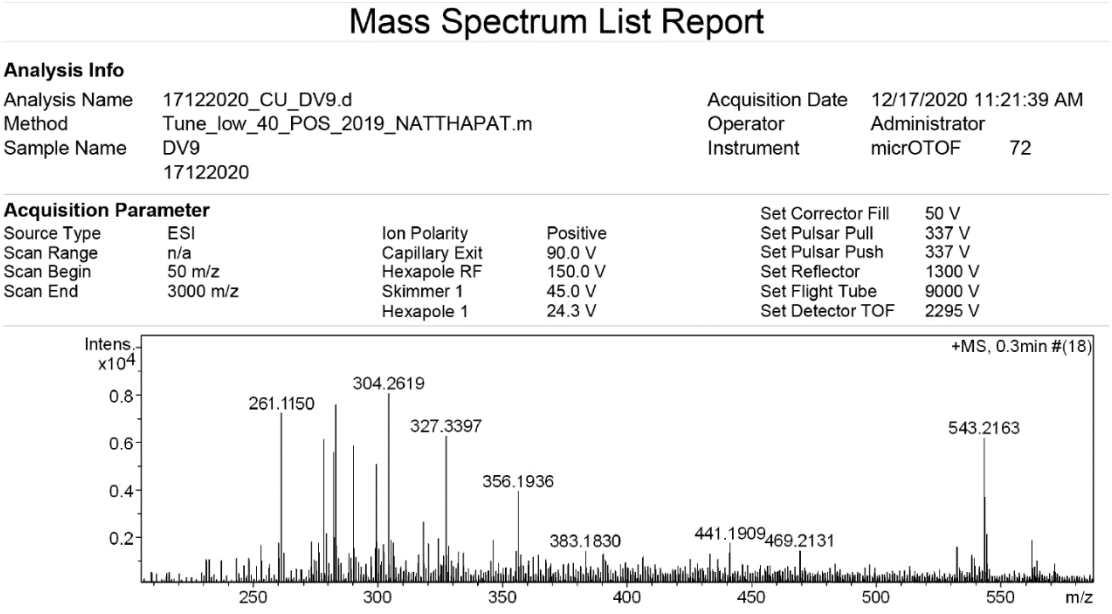

Figure 50 HR-ESI-MS spectrum of **compound 7**

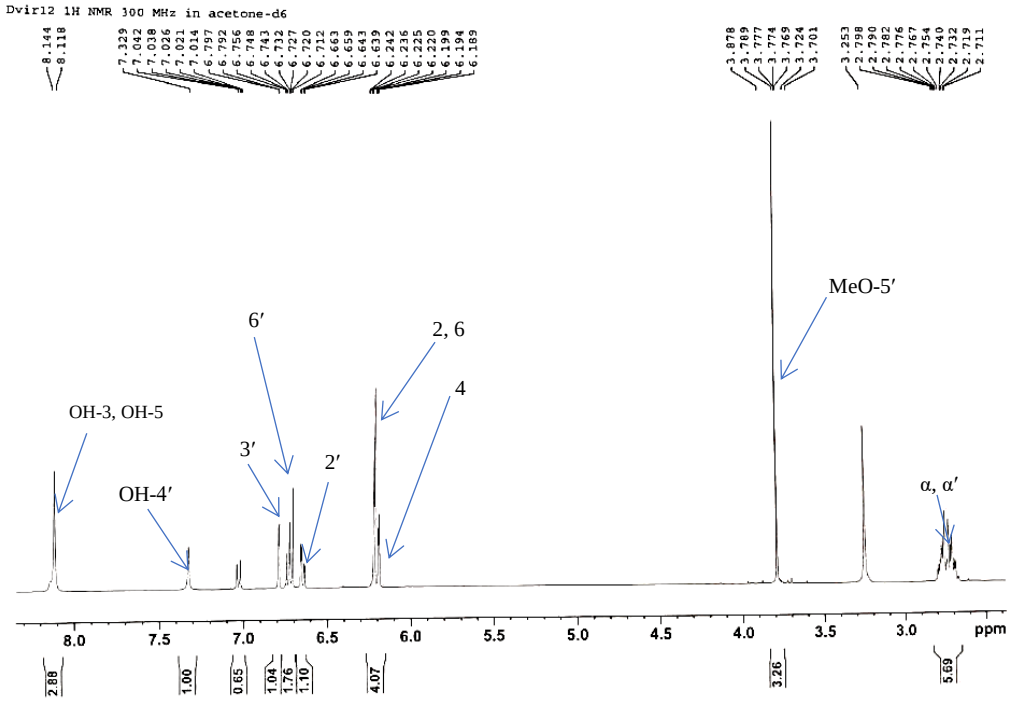

Figure 51 ^{1}H NMR spectrum of **compound 7** (300 MHz) in acetone-d_6

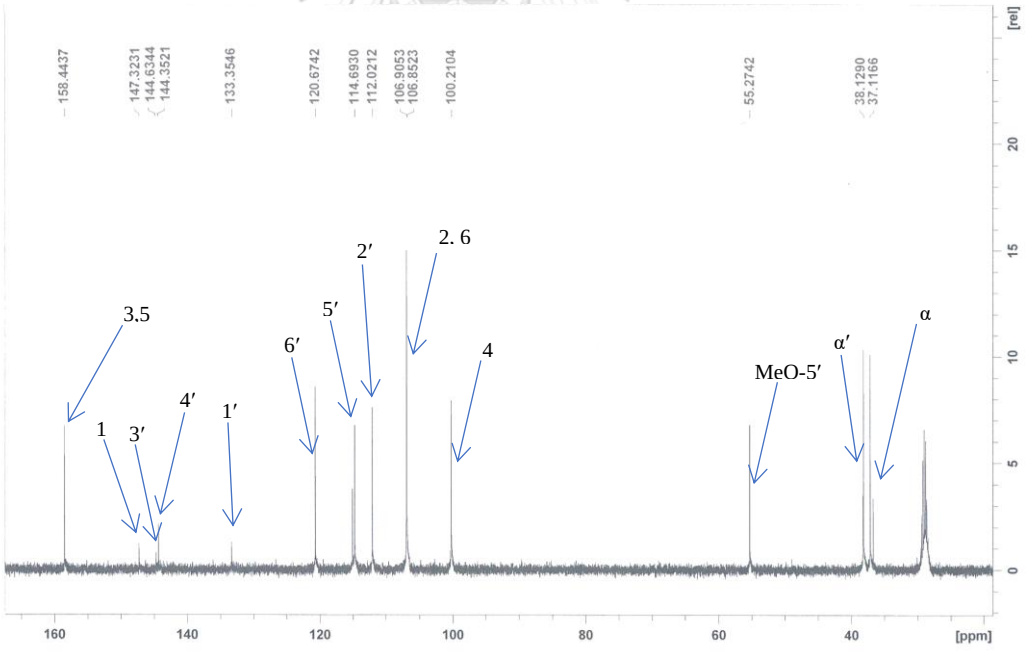

Figure 52 ^{13}C NMR spectrum of **compound 7** (75 MHz) in acetone-d_6

1.8 Identification of compound 8 (2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene)

The positive HR-ESI-MS showed a hydrogen-adduct molecular ion $[M+H]^+$ at *m/z* 259.0969 (calcd. for $C_{15}H_{15}O_4$, 259.0970) (**Figure 54**), suggesting the molecular formula $C_{15}H_{14}O_4$.

The ^1H NMR spectrum (**Figure 55**) exhibited four aromatic protons as broad singlet at δ_H 6.35 (H-3), 6.37 (H-1), 6.54 (H-6), and 6.57 (H-8) ppm, and two methylene protons as multiplet at δ_H 2.55 ppm (H-9, H-10). By consideration with chemical shift of twelve aromatic carbon at δ_C 99.9-157.9 ppm and two methylene carbons at δ_C 31.9 and 32.5 ppm presented in ^{13}C NMR spectrum (**Figure 56**), this structure contained a dihydrophenanthrene ring. Four doublets indicated absence of adjacent protons in an aromatic ring. δ_C 155.4, 155.8, 157.8 and 157.9 ppm showed the substitution of phenanthrene ring at C-4, C-5, C-2 and C-7, respectively. Methoxy substitution at C-4 was assigned according to ^{13}C-NMR spectrum at δ_C 57.2 ppm together with ^{13}C-NMR spectrum at lowest chemical shift, δ_C 155.4 ppm.

By comparison to the above evidence and the previously reported spectral data (Hu et al. 2008a), **compound 8** was identified as 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene (**Figure 53**).

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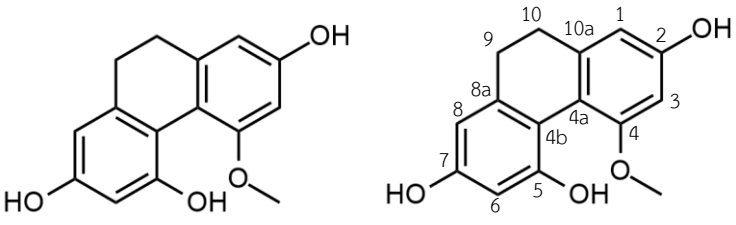

Figure 53 Strucure of **compound 8**

Table 17 Comparison of ^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) in acetone-d_6 of **compound 8** in this study with ^{1}H NMR (500 MHz) and ^{13}C NMR (100 MHz) in acetone-d_6 of 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene reported in previous study

Position	Compound 8		2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene[a]	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
1	6.37 (*brs*)	109.7	6.35 (*d*, 2.5)	109.9
2	-	157.8	-	157.6
3	6.35 (*brs*)	99.9	6.31 (*d*, 2.5)	100.0
4	-	155.4	-	155.5
4a	-	115.0	-	115.1
4b	-	113.5	-	113.6
5	-	155.8	-	155.9
6	6.54 (*brs*)	104.6	6.52 (*d*, 2.3)	104.6
7	-	157.9	-	157.9
8	6.57 (*brs*)	108.0	6.57 (*d*, 2.3)	108.1
8a	-	142.3	-	142.4
9	2.55 (*m*)	31.9	2.56 (*m*)	31.9
10	2.55 (*m*)	32.5	2.56 (*m*)	32.0
10a	-	143.2	-	143.3
MeO-4	3.92 (*s*)	57.2	3.94 (*s*)	57.3

[a](Hu et al. 2008a)

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Mass Spectrum List Report

Analysis Info

Analysis Name	17122020_CU_DV6.d	Acquisition Date	12/17/2020 11:15:03 AM
Method	Tune_low_40_POS_2019_NATTHAPAT.m	Operator	Administrator
Sample Name	DV6	Instrument	micrOTOF 72
	17122020		

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Corrector Fill	50 V
Scan Range	n/a	Capillary Exit	120.0 V	Set Pulsar Pull	337 V
Scan Begin	50 m/z	Hexapole RF	150.0 V	Set Pulsar Push	337 V
Scan End	3000 m/z	Skimmer 1	45.0 V	Set Reflector	1300 V
		Hexapole 1	24.3 V	Set Flight Tube	9000 V
				Set Detector TOF	2295 V

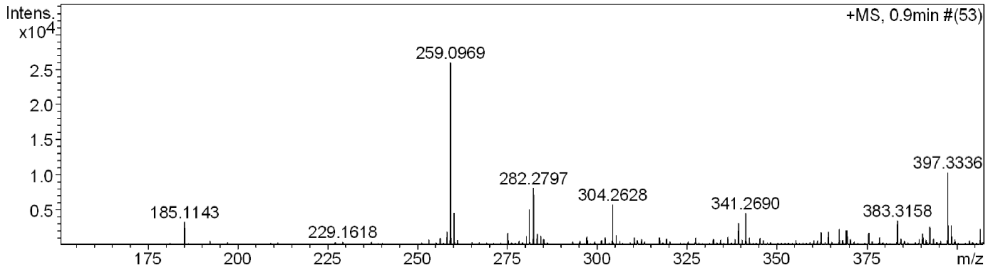

Figure 54 HR-ESI-MS spectrum of **compound 8**

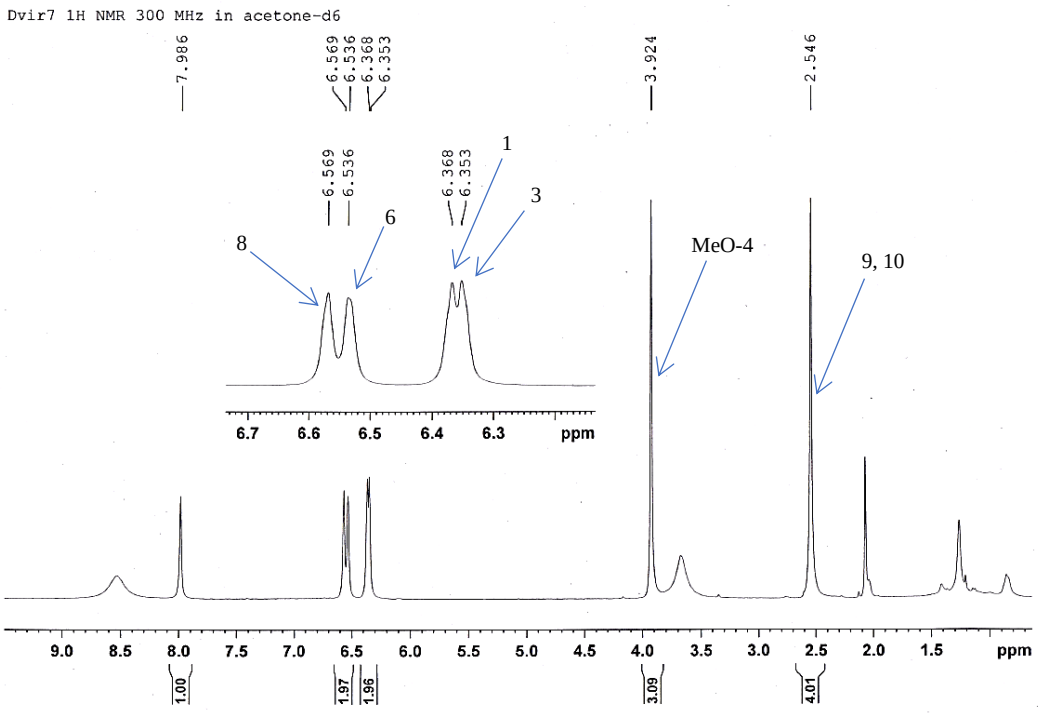

Figure 55 ^{1}H NMR spectrum of **compound 8** (300 MHz) in acetone-d_6

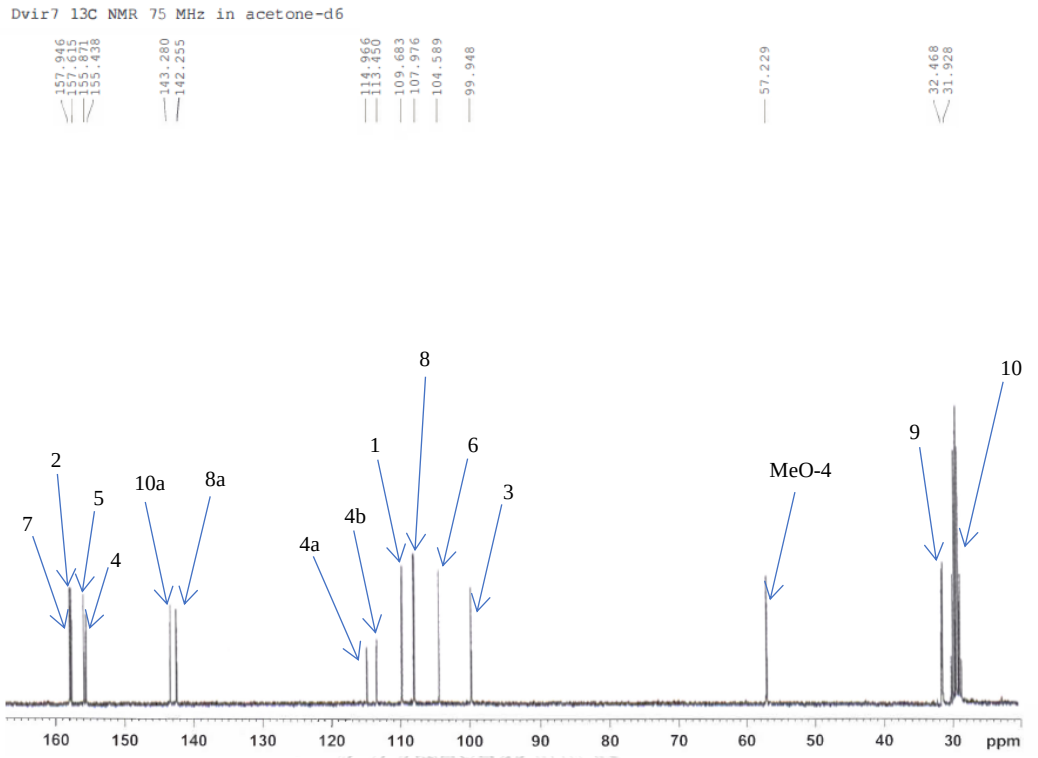

Figure 56 ^{13}C NMR spectrum of **compound 8** (75 MHz) in acetone-d_6

1.9 Identification of compound 9 (9,10-Dihydro-2,4,7-phenanthrenetriol)

The positive HR-ESI-MS showed a hydrogen-adduct molecular ion $[M+H]^+$ at *m/z* 229.0888 (calcd. for $C_{14}H_{13}O_3$, 229.0865) (**Figure 58**), suggesting the molecular formula $C_{14}H_{12}O_3$.

A Dihydrophenanthrene nucleus was confirmed by two methylene protons expressed as broad singlet in ^{1}H-NMR (**Figure 59**) at δ_H 2.62 ppm, twelve aromatic carbons at δ_C 102.8-156.9 ppm in ^{13}C-NMR spectrum (**Figure 60**), and two methylene carbons at δ_C 30.8 and 31.3. Three substitution of dihydrophenanthrene was confirmed by five aromatic protons expressed as three board singlets spectrum at δ_H 6.27 (H-3), 6.37 (H-1) and 6.67 (H-8), a multiplet at δ_H 6.64 (H-6) and a doublet at δ_H 8.14 (J = 9.3 Hz, H-5). The assignment of hydroxyl group at C-2, C-4 and C-7 were confirmed by ^{13}C-NMR spectrum at δ_C 156.9, 156.0 and 155.8 ppm, respectively.

By comparison to the above evidence and the previously reported spectral data (Pham et al. 2022), **compound 9** was identified as 9,10-dihydro-2,4,7-phenanthrenetriol (**Figure 57**).

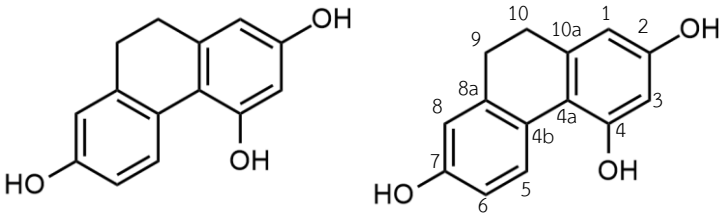

Figure 57 Structure of **compound 9**

Table 18 Comparison of ^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) in acetone-d_6 of **compound 9** in this study with ^{1}H NMR (400 MHz) in CD_3OD and ^{13}C NMR (100 MHz) in CD_3OD of 9,10-dihydro-2,4,7-phenanthrenetriol reported in previous study

Position	Compound 9		9,10-Dihydro-2,4,7-phenanthrenetriol[a]	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
1	6.37 (*brs*)	107.7	6.27 (*d*, 2.3)	107.6
2	-	156.9	-	156.4
3	6.27 (*brs*)	102.8	6.22 (*d*, 2.3)	102.8
4	-	156.0	-	156.9
4a	-	116.8	-	115.3
4b	-	126.1	-	126.7
5	8.14 (*d*, 9.3)	129.7	8.13 (*d*, 9.3)	129.9
6	6.64 (*m*)	113.4	6.64 (*m*)	113.6
7	-	155.8	-	155.8
8	6.67 (*brs*)	114.9	6.64 (*m*)	115.0
8a	-	139.6	-	141.8
9	2.62 (*brs*)	31.3	2.64 (*s*)	31.3
10	2.62 (*brs*)	30.8	2.64 (*s*)	31.8

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Position	Compound 9		9,10-Dihydro-2,4,7-phenanthrenetriol[a]	
	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm	δ_H in ppm (mult., *J* in Hz)	δ_C in ppm
10a	-	141.3	-	140.2

[a](Pham et al. 2022)

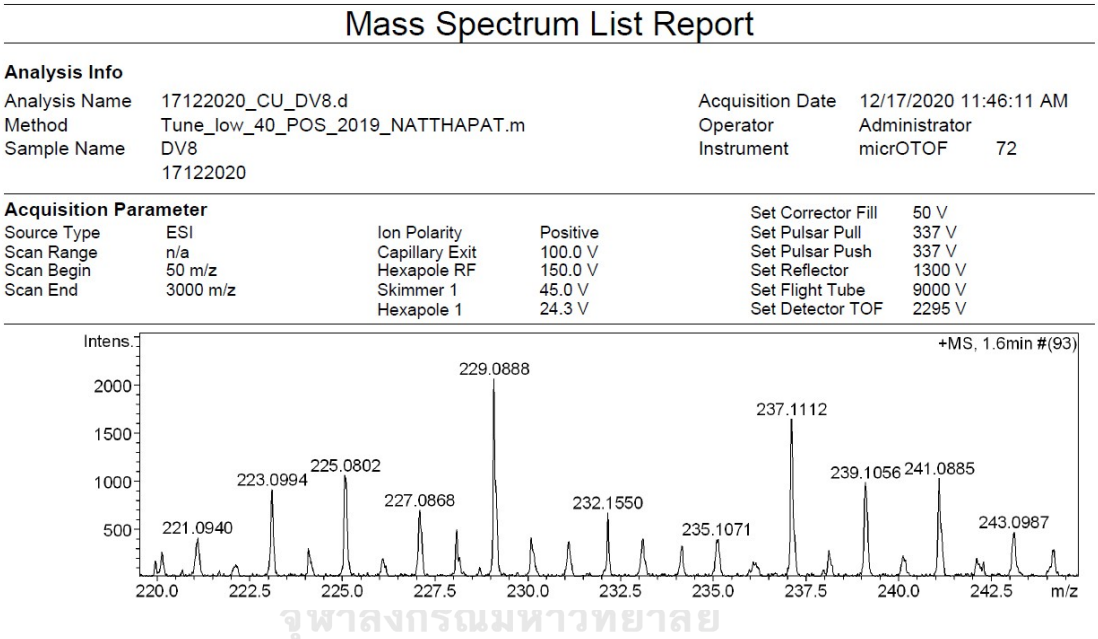

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Figure 58 HR-ESI-MS spectrum of **compound 9**

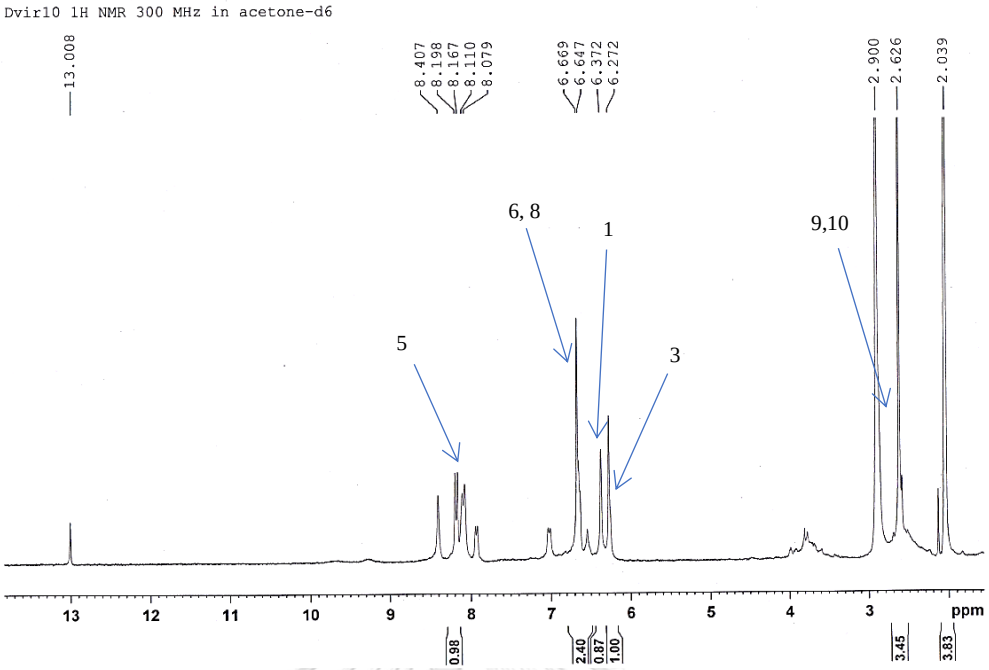

Figure 59 ^{1}H NMR spectrum of **compound 9** (300 MHz) in acetone-d_6

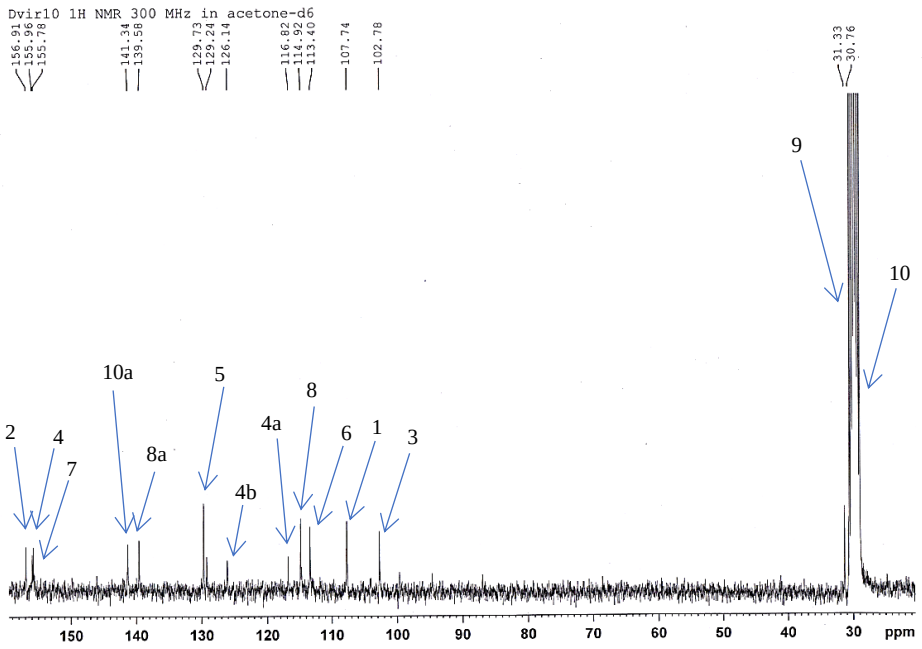

Figure 60 ^{13}C NMR spectrum of **compound 9** (75 MHz) in acetone-d_6

2. Free radical scavenging activities

Among the extracts tested, only the ethyl acetate extract of *Dendrobium virgineum* Rchb.f exhibited a colour change from purple to yellow accordingly for the antioxidation activity when subjected to the DPPH spraying method. As a result, nine pure compounds isolated from the ethyl acetate extract were further evaluated for their antioxidant activity using three different methods: DPPH assay, superoxide radical scavenging activity assay, and ORAC assay. Trolox® was employed as the positive control. The results of these assays are presented in **Table 19** below. However, the quantities of **compound 1, compound 3, compound 5, compound 6, and compound 9** were insufficient to perform the superoxide radical scavenging activity assay and ORAC assay.

Table 19 The results of ORAC value, DPPH and NBT of 9 isolated compounds

Compounds	ORAC value (μmol TE/g)	DPPH IC_{50} (μM)	NBT IC_{50} (mM)
Trolox®		5.17 ± 0.16	5.33 ± 0.11
Compound 1	ND	6.60 ± 0.08	ND
Compound 2	254.10 ± 86.97	> 10 μg/mL	3.46 ± 0.12
Compound 3	ND	ND	ND
Compound 4	244.61 ± 57.42	5.91 ± 0.11	3.14 ± 0.13
Compound 5	ND	> 10 μg/mL	ND
Compound 6	ND	> 10 μg/mL	ND
Compound 7	200.43 ± 39.81	9.43 ± 0.36	5.28 ± 0.30
Compound 8	261.22 ± 78.31	4.38 ± 0.09	2.85 ± 0.03
Compound 9	ND	< 10 μg/mL	ND

Remarks: ND, Not determined

The results of three different methods for assessing free radical scavenging activities indicated that **compound 8**, which has a phenanthrene ring structure, exhibited the strongest antioxidant activity. It showed an ORAC value of 261.22 ± 78.31 μmol/g, a DPPH IC_{50} of 4.38 ± 0.09 μM, and an NBT IC_{50} of 2.85 ± 0.03 mM. These

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values were higher than those of Trolox®, with DPPH IC_{50} and NBT IC_{50} values of 5.17 ± 0.16 μM and 5.33 ± 0.11 mM, respectively. Moreover, the results of the ORAC, DPPH, and NBT assays also demonstrated that **compound 2**, which contains a phenanthrene ring, exhibited stronger antioxidant activity compared to **compound 7**, which has a bibenzyl structure. This finding is consistent with a previous study by Li, Wang, and Chen in 2016, which also reported that compounds containing a phenanthrene ring displayed higher antioxidant activity than bibenzyl.

The ORAC results indicated that **compound 8**, which contained three hydroxyl group in its structure, exhibited stronger antioxidant activity compared to **compound 2**, which had only one hydroxyl group. This finding aligns with previous study by Boudjada et al. in 2019, which suggested the number of hydroxyl groups substituted in the phenanthrene structure appeared to be related to antioxidant activity.

DPPH screening results indicated that free radical scavenging activity of **compound 8** and **compound 9** at 10 μg/mL was 88% and 84%, respectively, which was comparable to each other. Furthermore, **compound 9** contained phenanthrene ring with 3 hydroxyl groups, same as **compound 8**. Therefore, **compound 9** was highly possible for strong antioxidant activity, and it was a promising candidate for further antioxidant activity study.

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In vitro antioxidant activity tested in this study provided adequate information for further study in vivo to confirm the antioxidant activity of **compound 8** to find its potential to be developed as preventive agent for free radical-related disease.

CHAPTER V

CONCLUSION

In conclusion, the natural constituents and antioxidant activities of *D. virgineum* were studied. Nine pure compounds were successfully isolated from ethyl acetate extract, including 2 new compounds which were 2-methoxy-9,10-dihydro-4,5-phenanthrenediol (**compound 1**) and 2,8-dimethoxy-9,10-dihydro-4,5-phenanthrenediol (**compound 2**). All 9 isolated compound underwent three different tests for antioxidant activity which are DPPH, NBT and ORAC assay. All three assays revealed that 2,5,7-trihydroxy-4-methoxy-9,10-dihydrophenanthrene (**compound 8**) had the strongest antioxidant activity. These findings would be benefit for further phytochemical and antioxidant study in *Dendrobium* species.

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