PREVENTIVE EFFECT OF COMPOUNDS FROM *DENDROBIUM PACHYGLOSSUM* AND *DENDROBIUM HETEROCARPUM* ON HYDROGEN PEROXIDE-INDUCED CYTOTOXICITY OF KERATINOCYTES

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A Dissertation Submitted in Partial Fulfillment of the Requirements
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ผลของสารจากเอื้องขนหมูและเอื้องสีตาลในการป้องกันการเกิดพิษต่อเคอราติโนไซต์ที่ถูกเหนี่ยวนำโดยไฮโดรเจนเพอร์ออกไซด์

นายสกันท์ วารินหอมหวล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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Thesis Title	PREVENTIVE EFFECT OF COMPOUNDS FROM *DENDROBIUM PACHYGLOSSUM* AND *DENDROBIUM HETEROCARPUM* ON HYDROGEN PEROXIDE-INDUCED CYTOTOXICITY OF KERATINOCYTES
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สกันท์ วารินหอมหวล : ผลของสารจากเอื้องขนหมูและเอื้องสีตาลในการป้องกันการเกิดพิษต่อเคอราติโนไซต์ที่ถูกเหนี่ยวนำโดยไฮโดรเจนเพอร์ออกไซด์. (PREVENTIVE EFFECT OF COMPOUNDS FROM *DENDROBIUM PACHYGLOSSUM* AND *DENDROBIUM HETEROCARPUM* ON HYDROGEN PEROXIDE-INDUCED CYTOTOXICITY OF KERATINOCYTES) อ.ที่ปรึกษาหลัก : รศ. ภก. ดร.บุญชู ศรีตุลารักษ์, อ.ที่ปรึกษาร่วม : ศ. ภก. ดร.กิตติศักดิ์ ลิขิตวิทยาวุฒิ,อ. ภก. ดร.วิศรุต บูรณสัจจะ

การศึกษาพฤกษเคมีของสารสกัดหยาบด้วยเมทานอลของเอื้องขนหมู (*Dendrobium pachyglossum*) และเอื้องสีตาล (*Dendrobium heterocarpum*) วงศ์ Orchidaceae พบว่าสามารถแยกสารบริสุทธิ์ได้ทั้งหมด 13 ชนิด จากเอื้องขนหมูมีสารชนิดใหม่ 1 ชนิดเป็นสารกลุ่ม bisbibenzyl ได้แก่ dendropachol และพบสารที่เคยมีการรายงานอีก 6 ชนิด คือ 4,5-dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene, moscatilin, gigantol, 4,5,4' -trihydroxy-3,3'-dimethoxybibenzyl, dendrocandin T และ isovitexin ตามลำดับ ส่วนเอื้องสีตาล แยกได้สารที่เคยมีรายงานจำนวน 6 ชนิด ได้แก่ amoenylin, methyl 3-(4-hydoxyphenyl) propionate, 3,4-dihydroxy-5,4'-dimethoxybibenzyl, dendrocandin B, dendrofalconerol A และ syringaresinol ตามลำดับ สารบริสุทธิ์ที่แยกได้นั้นนำมาพิสูจน์โครงสร้างสารด้วยวิธีทางสเปกโทรสโกปี จากนั้นจึงนำสารบริสุทธิ์ไปทดสอบความเป็นพิษต่อเซลล์และฤทธิ์ป้องกันการเสื่อมของเซลล์คีราติโนไซต์ที่ถูกเหนี่ยวนำด้วยไฮโดรเจนเพอร์ออกไซด์ ผลการทดสอบความเป็นพิษต่อเซลล์พบว่า dendropachol, isovitexin, methyl 3-(4 hydoxyphenyl) propionate และ syringaresinol ไม่เป็นพิษต่อเซลล์ที่ความเข้มข้น 50 ไมโครกรัมต่อมิลลิลิตร เมื่อเปรียบเทียบกับกลุ่มควบคุม และยังพบว่า dendropachol, methyl 3-(4-hydoxyphenyl) propionate และ syringaresinol สามารถช่วยเพิ่มการอยู่รอดของเซลล์ที่ถูกเหนี่ยวนำให้เกิดภาวะเครียดด้วยไฮโดรเจนเพอร์ออกไซด์ ได้มากขึ้นตามความเข้มข้นที่ได้รับที่เพิ่มขึ้นเช่นเดียวกัน เมื่อเปรียบเทียบกับกลุ่มควบคุม

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Sakan Warinhomhoun : PREVENTIVE EFFECT OF COMPOUNDS FROM *DENDROBIUM PACHYGLOSSUM* AND *DENDROBIUM HETEROCARPUM* ON HYDROGEN PEROXIDE-INDUCED CYTOTOXICITY OF KERATINOCYTES. Advisor: Assoc. Prof. BOONCHOO SRITULARAK, Ph.D. Co-advisor: Prof. KITTISAK LIKHITWITAYAWUID, Ph.D., VISARUT BURANASUDJA, Ph.D.

Phytochemical investigation of a methanol extracts prepared from *Dendrobium pachyglossum* and *Dendrobium heterocarpum*, Orchidaceae, led to the the isolation of thirteen compounds. One new bizbibenzyl compound and 6 known compounds including 4,5-dihydroxy-2,3-dimethoxy-9,10-phenanthrene, moscatilin, gigantol, 4,5,4'-trihydroxy-3,3'-dimethoxybibenzyl, dendrocandin T, and isovitexin were separated from *D. pachyglossum.* From *D. heterocarpum,* 6 compounds were isolated including amoenylin, methyl 3-(4-hydoxyphenyl) propionate, 3,4-dihydroxy-5,4'-dimethoxybibenzyl, dendrocandin B, dendrofalconerol A, and syringaresinol, respectively. The structure of isolated compounds were determined by analysis of spectroscopic data (NMR and HR-ESI-MS). They were then investigated for cytotoxicity and cytoprotective effect against hydrogen peroxide-induced oxidative stress on HaCaT keratinocytes. The result showed that dendropachol, isovitexin, methyl 3-(4-hydoxyphenyl) propionate, and syringaresinol at concentration of 50 µg/mL showed non-toxicity as compared the untreated group. In addtion, It was found that pre-treatment with dendropachol, methyl 3-(4 hydoxyphenyl) propionate, and syringaresinol protected HaCaT keratinocyte cells by preventing hydrogen peroxide-induced oxidative stress as compared with untreated group.

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Sakan Warinhomhoun

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ABBREVIATIONS AND SYMBOLS

Acetone-d_6	=	Deuterated acetone
br s	=	Broad singlet (for NMR spectra)
°C	=	Degree celsius
CC	=	Column chromatography
$CDCl_3$	=	Deuterated chloroform
CH_2Cl_2	=	Dichloromethane
cm	=	Centimeter
^{13}C-NMR	=	Carbon-13 Nuclear Magnetic Resonance
1-D NMR	=	One-dimensional Nuclear Magnetic Resonance
2-D NMR	=	Two-dimensional Nuclear Magnetic Resonance
d	=	Doublet (for NMR spectra)
dd	=	Doublet of doublets (for NMR spectra)
δ	=	Chemical shift
DEPT	=	Distortionless Enhancement by Polarization Transfer
DMSO-d_6	=	Deuterated dimethylsulfoxide
ε	=	Molar absorptivity
ESI-MS	=	Electrospray Ionization Mass Spectrometry
EtOAc	=	Ethyl acetate
FCC	=	Flash Column Chromatography
g	=	Gram
Glc	=	Glucose
HMBC	=	^{1}H-detected Heteronuclear Multiple Bond Correlation
HR-ESI-MS	=	High Resolution Electrospray Ionization Mass Spectrometry
^{1}H-NMR	=	Proton Nuclear Magnetic Resonance
HSQC	=	^{1}H-detected Heteronuclear Single Quantum Coherence

Hz	=	Hertz
IC_{50}	=	Concentration exhibiting 50% inhibition
IR	=	Infrared
J	=	Coupling constant
Kg	=	Kilogram
L	=	Liter
λ_{max}	=	Wavelength at maximal absorption
$[M+Na]^+$	=	Sodium-adduct molecular ion
m	=	Multiplet (for NMR spectra)
MeOH	=	Methanol
mg	=	Milligram
µg	=	Microgram
min	=	Minute
ml	=	Milliliter
µl	=	Microliter
µmol/L	=	Micromolar
mm	=	Millimeter
mM	=	Millimolar
MS	=	Mass spectrum
MW	=	Molecular weight
m/z	=	Mass to charge ratio
N/A	=	Not applicable
nm	=	Nanometer
nM	=	Nanomolar
NMR	=	Nuclear Magnetic Resonance
NOESY	=	Nuclear Overhauser Effect Spectroscopy

ν_{max}	=	Wave number at maximal absorption
OEt	=	Ethoxy group
OMe	=	Methoxy group
s	=	Singlet (for NMR spectra)
t	=	Triplet (for NMR spectra)
TEAC	=	Trolox Equivalent Antioxidant Capacity
TLC	=	Thin Layer Chromatography
UV-VIS	=	Ultraviolet and Visible spectrophotometry
VLC	=	Vacuum Liquid Column Chromatography
VCEAC	=	Vitamin C Equivalent Antioxidant Capacity

CHAPTER I

INTRODUCTION

Skin aging is a process which occurs by intrinsic and extrinsic factors lead to lose of strength and physical properties. Intrinsic aging is caused by genetic and hormonal influence (Tobin, 2017). Extrinsic aging is included by environmental and chemical factors. Over 90% of skin aging is affected by ultraviolet (UV) from sunlight, which is stimulated reactive oxygen species (ROS) including superoxide anion ($O_2^{\cdot-}$), hydrogen peroxide (H_2O_2), hydroxyl radical ($OH^{\cdot}$), and singlet oxygen ($^1O_2$). ROS is producing damage of cellular components (lipids, proteins, nuclear, and mitochondrial DNA), inducing to cell death. The disrupted of the skin by ROS is developed to wrinkles, dry appearance of the skin, and an enhanced risk on skin disorders (Kammeyer & Luiten, 2015).

Keratinocytes are mainly the epidermis layer, containing with primary cellular barriers functions and resulted in prevention against exogenous damage by physical, chemical, and biochemical damages (Proksch et al., 2008). Under the severe damage status of keratinocytes caused by the extrinsic and intrinsic factors, the accumulation of H_2O_2 is response to oxidative stress in epidermal cells, causing damage to biomolecules (Pelle et al., 2005) which induce to initiate apoptosis or necrosis programs (Taylor et al., 1999).

Many kinds of phytochemicals from natural products such as anthocyanins, phenolics, diterpenoids and curcuminoids have been showed antioxidant activities against keratinocytes caused by ROS (Han et al., 2018; Hu et al., 2016; Molagoda et al., 2020; Yang et al., 2014). Several studies have been reported that the main antioxidant mechanism of natural compound depends on the number of conjugated double bonds and hydroxyl groups, which can protect biological molecule from oxidative stress lead to apoptosis cells (Bendary et al., 2013; Maoka et al., 2001).

The genus *Dendrobium* is one of the largest and most important genera in the family Orchidaceae with approximately 1,400 species. There were more than 1,100 species, mainly distributed in south-western Asia, Europe, and Australia, of

which about 150 species are widely dispersed in Thailand (Sarakulwattana et al., 2018; Xiaohua et al., 2009). This genus has been traditionally used in Chinese medicine as an analgesic, antipyretic, nourishing the stomach, and enhancing production of body fluids or nourishing Yin (Xu et al., 2003). Several chemical investigations have reported that the genus *Dendrobium* can be classified into several groups including alkaloids, bibenzyls, fluorenones, phenanthrenes, sesquiterpenoids, polysaccharides, and amino acids (Lam et al., 2015).

Numerous therapeutic effects of *Dendrobium* extracts and chemical constituents revealed that *Dendrobium* plants are newly reported to be a good source for skin anti-aging. The crude extracts from *D. sonia* earsakul a *Dendrobium* hybrid) and bioactive constituents from *D. loddigesii* have been found to inhibit matrix metalloproteinase enzymes (MMP) and stimulate to produce collagen in human dermal fibroblasts (Karayavattanakul et al., 2018; Ma et al., 2019). Studies on *D. tosaense*, *D. loddigesii*, and *D. sonia* earsakul (a *Dendrobium* hybrid) showed inhibit effects on melanogenesis (Chan et al., 2018; Kanlayavattanakul et al., 2018; Ma et al., 2019). Polysaccharides isolated from *D. denneanum*, *D. officinale* and the crude extracts from *D. sabin*, as well as *D. moniliforme* showed *in vitro* antioxidant activities (Abu et al., 2017; Luo et al., 2011; Paudel et al., 2018).

Dendrobium pachyglossum Par. & Rchb.f., known Thai name as Ueang Khon Mu (เอื้องขนหมู). It is an epiphyte orchid with clustered stems, glass-like. It is produces one to few flowered inflorescences arising from the center of the leaf cluster. This species is distributed in northeastern, eastern, and south of Thailand (Vaddhanaphuti, 2005).

Dendrobium heterocarpum Wall. ex. Lindl, known Thai name as Ueang Si Tan (เอื้องสีตาล). It is an epiphyte orchid with fusiform stems. It is produces one to few flowered inflorescences arising from the nodes. This species is distributed in north, northeastern, eastern, southeastern, and south of Thailand (Vaddhanaphuti, 2005).

However, there have been no reports of the chemical constituents and biological activity of these plants. In the present study, the EtOAc extracts of *D. pachyglossum* and *D. heterocarpum* were screened for cytoprotective effect against

H_2O_2-induced oxidative stress in HaCaT keratinocytes. The results demonstrated that the percentage of cell survival significantly increased to 86.60 ± 14.71 % and 90.50 ± 4.17% at 200 µg/mL compared to the untreated group (50.81 ± 1.12%). Therefore, the extracts of *D. pachyglossum* and *D. heterocarpum* were then investigated for their chemical constituents and cytoprotective effects against H_2O_2-induced oxidative stress in HaCaT keratinocytes. The result of this research may provide useful information on the chemical constituents of this plant family, which might be used as lead compounds for cosmeceutical agent in skin care and rejuvenation.

The major objectives of this study are as follows.

1. To isolate and purify the chemical constituents from *D. pachyglossum* and *D. heterocarpum.*
2. To characterize the chemical structures of the isolated compounds.
3. To evaluate the cytoprotective effects against of H_2O_2-induced oxidative stress in HaCaT keratinocytes of the isolated compounds.

(A) (B)

Figure 1 (A) *Dendrobium pachyglossum* (B) *Dendrobium heterocarpum*

CHAPTER II

LITERATURE REVIEWS

1. Aging of keratinocytes

Skin is the largest organ of the human body, with first barrier in protection against physical and chemical damage caused environment. It consists of three main layers: epidermis, dermis, and hypodermis. Skin aging is attributed to two pathways, which are intrinsic and extrinsic factor. Intrinsic factor is caused by an individual genetics, hormones, and metabolism whereas extrinsic factor is the result of chronic exposure to environment. All these factors led to the change in the aged skin (Kammeyer and Luiten, 2015).

The epidermis is the first layer of human skin and constantly exposed damage caused by environmental stimuli, such as harmful chemical, microorganism, and ultraviolet radiation (Proksch et al., 2008). This layer is consisting primarily of keratinocytes, Langerhans cells, melanocytes, and Merkel cells. Keratinocytes is a main of the epidermis, which are make up more than 90% of epidermis cells (Tobin, 2017). They function is to produce keratin and filaggrin, which are affected in maintaining the skin's barrier. Under severe injury conditions, for example, chronic exposure to the harmful free radicals, keratinocyte cells may react by self-healing or initiating apoptosis. Therefore, disruption of keratinocytes can lead to disfunction of the skin barrier, namely extreme skin dryness, increasing sensitivity to irritant dermatitis, and also reduced-epidermal water flux, and, eventually aged of skin (Taylor et al., 1999; Hirobe, 2014; Tobin, 2017).

2. Reactive oxygen species (ROS) and oxidative stress

ROS play an important role in age of skin. Previous study has been reported that long-term exposure environmental stress is mainly cause physical changes of the complex pathway and finally generates reactive oxygen species (ROS) including superoxide anion ($O2^{-}$), hydrogen peroxide (H_2O_2), hydroxyl radical ($OH^{\cdot}$), and singlet oxygen ($^1O_2$) (Kammeyer and Luiten, 2015). ROS are continuously produced by mitochondria oxidative metabolisms in organelles and various extrinsic stresses. In

the skin, especially keratinocytes, H_2O_2 is mainly accumulated in the epidermis layer and can diffuse freely in and out of the cells and tissues (Pelle et al., 2005). Normally, the skin cells have produced antioxidants to control ROS production and propagation. The antioxidant activities in the skin including enzymatic antioxidant (superoxide dismutase (SOD), catalase (CAT), glutathione (GSH)), and non-enzymatic antioxidant (glutathione peroxidase, GPx), which responsible for regulating ROS by converting lipid peroxidation and H_2O_2 into water and/or oxygen (Covarrubias et al., 2008; Wagener et al., 2013; Markiewicz and Idowu, 2019). However, excessive ROS generation provoked by environmental stresses may overwhelm the antioxidant defense mechanism, which triggers oxidative stress of epidermal keratinocytes. Severe oxidative stress can cause programmed cell death including apoptosis and necrosis (Poljsak and Dahmane, 2011)

3. Chemical constituents of *Dendrobium*

Dendrobium plants are commonly known as Shihu or Huangcao, which is the one of the largest genera in Orchidaceae with approximately 1,400 species. There are widely distrusted about 150 species in Thailand have been identified. The chemical constituents of the genus of *Dendrobium* can be divided into several classes including, bibenzyls and derivatives, flavonoids, terpenoids, and miscellaneous compounds (Sarakulwattana et al., 2019; Xiaohua et al., 2009)

Bibenzyl and their derivatives of stilbene compounds are found in *Dendrobium* spp., which are derived from the general phenylpropanoid pathway. The biosynthesis pathway of stilbene backbone is initially from three malonyl-CoA and one cinnamic acid-CoA units. In addition, phenanthrene derivatives are also derived by synthesis of *trans*-cinnamic acid or its derivative *p*-coumaric acid from the aromatic amino acid phenylalanine or tyrosine (Dubrovina & Kiselev, 2017).

Flavonoids biosynthesized is initially through the combination of the phenylpropanoid and polyketide pathways. The phenylpropanoid pathway affords *p*-coumaroyl-CoA. The polyketide pathway elongates C-2 chain by utilizing malonyl-CoA. The aromatic amino acids phenylalanine and tyrosine are the initiation of the phenylpropanoid pathway (Saito et al., 2013).

Terpenoids compounds are provides from biosynthesis pathway via the mevalonate and the methylerythritol phosphate pathway. Terpenoid can be divided by the number of C5 isoprene units as hemiterpenes (1 unit), monoterpenes (2 units), sesquiterpenes (3 units), diterpenes (4 units), sesterterpenes (5 units), triterpenes (6 units), tetraterpenes (8 units), and polyterpenes (more than 9 units) (Schrader & Bohlmann).

Dendrobium spp. are also reported several minor constituents including aliphatic compounds, benzoic acid derivatives, phenylpropanoids, fluorenones, coumarins, lignans, alkaloids and neolignanes, which are categorized together as miscellaneous compounds.

Table 1 Distribution of secondary metabolites in the *Dendrobium* spp.

Category and compounds	Plants	Plant parts	References
Bibenzyls and derivatives: (a) Simple bibenzyls			
Aloifol I [**1**]	*D. infundibulum*	whole plant	(Naranong, et al., 2019)
	D. longicornu	stem	(Hu et al., 2008a)
	D. williamsonii	whole plant	(Yang et al., 2017b)
	D. scabrilingue	whole plant	(Sarakulwattana et al., 2018)
Amoenylin [**2**]	*D. amoenum*	whole plant	(Majumder et al., 1999) (Yang et al., 2017b)
	D. williamsonii	whole plant	
Batatasin [**3**]	*D. longicornu*	stem	(Hu et al., 2008a)
	D. plicatile	stem	(Yamaki & Honda, 1996)
Batatasin III [**4**]	*D. cariniferum*	stem	(Chen et al., 2008c)
	D. gratiosissimum	stem	(Li et al., 2009a)
	D. chrysotoxum	whole plant	(Li et al., 2009b)
	D. loddigesii	stem	(Ito et al., 2010)
	D. draconis	stem	(Sritularak et al., 2011b)
	D. venustum	whole plant	(Sukphan et al., 2014)
	D. aphyllum	stem	(Yang et al., 2015)
	D. formosum	whole plant	(Inthongkaew et al., 2017)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Brittonin A [**5**]	*D. secundum*	stem	(Sritularak et al., 2011a)
Chrysotobibenzyl [**6**]	*D. chrysanthum*	stem	(Yang et al., 2006a)
	D. aurantiacum var. *denneanum*	stem	(Yang et al., 2006b)
	D. nobile	stem	(Zhang et al., 2007b)
	D. chrysotoxum	stem	(Hu et al., 2012)
	D. capillipes	stem	(Phechrmeekha et al., 2012)
	D. pulchellum	stem	(Chanvorachote et al., 2013)
Crepidatin [**7**]	*D. crepidatum*	whole plant	(Majumder et al., 1989)
	D. chrysanthum	stem	(Yang et al., 2006a)
	D. aurantiacum	whole plant	(Yang et al., 2006b)
	D. capillipes	stem	(Phechrmeekha et al., 2012)
Cumulatin [**8**]	*D. cumulatum*	whole plant	(Majumder et al., 1993)
Dendrobin A [**9**]	*D. nobile*	stem	(Wang et al., 1985); (Q. Ye & Zhao, 2002)
Dendromoniliside E [**10**]	*D. nobile*	stem	(Miyazawa et al., 1999)
3,3′-Dihydroxy-4,5-dimethoxybibenzyl [**11**]	*D. williamsonii*	whole plant	(Rungwichaniwat et al., 2014)
3,4′-Dihydroxy-5-methoxy bibenzyl [**12**]	*D. amoenum*	whole plant	(Majumder et al., 1999)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
3,4′-Dihydroxy-5,5′-dimethoxydihydrostilbene [**13**]	*D. nobile*	stem	(Hwang et al., 2010)
3,4′-Dihydroxy-3′,4,5,-trimethoxybibenzyl [**14**]	*D. infundibulum*	whole plant	(Na Ranong et al., 2019)
Erianin [**15**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
Gigantol [**16**]	*D. densiflorum*	stem	(Fan et al., 2001)
	D. nobile	stem	(Zhang et al., 2007b)
	D. longicornu	stem	(Hu et al., 2008a)
	D. trigonopus	stem	(Hu et al., 2008b)
	D. aphyllum	whole plant	(Chen et al., 2008a)
	D. polyanthum	stem	(Hu et al., 2009)
	D. aurantiacum var. *denneanum*	whole	(Liu et al., 2009)
	D. draconis	plant	(Sritularak et al., 2011b)
	D. devonianum	stem	(Sun et al., 2014)
	D. brymerianum	whole plant	(Klongkumnuankarn et al., 2015)
		whole plant	
	D. palpebrae	whole plant	(Kyokong et al., 2018)
	D. scabrilingue	whole plant	(Sarakulwattana et al., 2018)
	D. officinale	stem	(Zhao et al., 2018)
	D. venustum	whole plant	(Sukphan et al., 2014)
	D. wardianum	stem	(Zhang et al., 2017)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Gigantol-5-O-β-D-glucopyranoside [**17**]	*D. fimbriatum*	stem	(Xu et al., 2017)
4-Hydroxy-3,5,3′-trimethoxy bibenzyl [**18**]	*D. nobile*	stem	(Ye & Zhao, 2002)
5-Hydroxy-3,4,3′,4′,5′-penta methoxybibenzyl [**19**]	*D. secundum*	stem	(Phechrmeekha et al., 2012)
Isoamoenylin [**20**]	*D. amoenum*	whole plant	(Majumder et al., 1999)
Moscatilin [**21**]	*D. moscatum*	whole plant	(Majumder & Sen, 1987)
	D. loddigesii	whole plant	(Chen et al., 1994a)
	D. amoenum	whole plant	(Majumder et al., 1999)
	D. nobile	stem	(Miyazawa et al., 1999); (Yang et al., 2007)
	D. densiflorum	stem	(Fan et al., 2001b)
	D. chrysanthum	stem	(Yang et al., 2006a)
	D. aurantiacum var. denneanum	stem	(Yang et al., 2006b)
	D. gratiosissimum	stem	(Zhang et al., 2008a)
	D. longicornu	stem	(Hu, et al., 2008a)
	D. polyanthum	stem	(Hu et al., 2009)
	D. secundum	stem	(Sritularak et al., 2011a)
	D. pulchellum	stem	(Chanvorachote et al., 2013)
	D. formosum	whole plant	(Inthongkaew et al., 2017)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Moscatilin [**21**] (continued)	*D. brymerianum*	whole plant	(Klongkumnuankarn et al., 2015)
	D. ellipsophyllum	whole plant	(Tanagornmeatar et al., 2014)
	D. wardianum	stem	(Zhang et al., 2017)
	D. williamsonii	stem	(Yang et al., 2017b)
	D. parishii	whole plant	(Kongkatitham et al., 2018)
	D. palpebrae	whole plant	(Kyokong et al., 2018)
	D. infundibulum	whole plant	(Na Ranong et al., 2019)
Moscatilin diacetate [**22**]	*D. loddigesii*	stem	(Chen et al., 1994)
3,3′,4-Trihydroxy bibenzyl [**23**]	*D. longicornu*	stem	(Hu et al., 2008b)
3,3′,5-Trihydroxy bibenzyl [**24**]	*D. cariniferum*	whole plant	(Chen et al.,2008c)
3,5,4′-Trihydroxy bibenzyl [**25**]	*D. gratiosissimum*	stem	(Zhang et al., 2008a)
4,5,4′-Trihydroxy-3,3′-dimethoxy bibenzyl [**26**]	*D. ellipsophyllum*	whole plant	(Tanagornmeatar et al., 2014)
	D. palpebrae	whole plant	(Kyokong et al., 2018)
	D. parishii	whole plant	(Kongkatitham et al., 2018)
	D. secundum	stem	(Sritularak et al.,2011a)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
4,3′,4′-Trihydroxy-3,5-dimethoxybibenzyl [**27**]	*D. parishii*	whole plant	(Kongkatitham et al., 2018)
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 et al., 2008a)
	D. longicornu	stem	(Hu et al., 2008a)
	D. officinale	stem	(Zhao et al., 2018)
	D. trigonopus	Stem	(Hu et al., 2008b)
Dendrophenol [**29**]	*D. candidum*	stem	(Li et al., 2008)
Dendrocandin E [**30**]	*D. candidum*	stem	(Li et al., 2009c)
	D. parishii	whole plant	(Kongkatitham et al., 2018)
Dendrosinen B [**31**]	*D. sinense*	whole plant	(Chen et al., 2014)
	D. infundibulum	whole plant	(Na Ranong et al., 2019)
3,4-Dihydroxy-5,4′-dimethoxybibenzyl [**32**]	*D. candidum*	stem	(Li et al., 2008)
	D. signatum	whole plant	(Mittraphab et al., 2016) (Limpanit et al., 2016)
	D. tortile	whole plant	(Zhang et al., 2017)
	D. wardianum	stem	(Yang et al., 2017b)
	D. williamsonii	whole plant	
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 et al., 2017b)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
3-*O*-Methylgigantol [**34**]	*D. candidum*	stem	(Li et al., 2008)
	D. plicatile	stem	(Yamaki & Honda, 1996)
Bibenzyls and derivatives: (b) Bibenzyls with substitution at ethylene bridge			
4-[2-(3-hydroxyphenol)-1 methoxyethyl]-2,6-dimethoxyphenol [**35**]	*D. longicornu*	stem	(Hu et al., 2008)
Dendrocandin A [**36**]	*D. candidum*	stem	(Li et al., 2008)
	D. wardianum	stem	(Zhang et al., 2017)
Dendrocandin C [**37**]	*D. sinense*	whole plant	(Li et al., 2009c)
Dendrocandin D [**38**]	*D. candidum*	whole plant	(Li et al., 2009c)
Dendrosinen A [**39**]	*D. sinense*	whole plant	(Chen et al., 2014)
4-[2-(3-Hydroxyphenol)-1-methoxyethyl]-2,6-dimethoxyphenol [**40**]	*D. longicornu*	stem	(Hu et al., 2008a)
Loddigesiinol C [**41**]	*D. loddigesii*	whole plant	(Ito et al., 2010)
Nobilin A [**42**]	*D. nobile*	stem	(Zhang et al., 2006)
Nobilin B [**43**]	*D. nobile*	stem	(Zhang et al., 2006)
Nobilin C [**44**]	*D. nobile*	stem	(Zhang et al., 2006)
Nobilin D [**45**]	*D. nobile*	stem	(Zhang et al., 2006)
4,4′,5-Trihydroxy-3,3′,α-trimethoxybibenzyl [**46**]	*D. lindleyi*	stem	(Shang, Li, & Xiao, 2020)
4,5-Dihydroxy-3, α,3′,4′-tetramethoxybibenzyl [**47**]	*D. lindleyi*	stem	(Shang et al., 2020)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Bibenzyls and derivatives: (c) Bibenzyls with other substitutions			
Dendrosinen C [**48**]	*D. sinense*	whole plant	(Chen et al., 2014)
Loddigesiinol D [**49**]	*D. loddigesii*	whole plant	(Ito et al., 2010)
Densiflorol A [**50**]	*D. densiflorum*	stem	(Fan et al., 2001)
Crepidatuol A [**51**]	*D. crepidatum*	stem	(Li et al., 2013)
Crepidatuol B [**52**]	*D. crepidatum*	stem	(Li et al., 2013)
Trigonopol B [**53**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
Longicornuol A [**54**]	*D. longicornu*	stem	(Hu et al., 2008a)
Trigonopol A [**55**]	*D. trigonopus*	stem	(Hu et al., 2008b)
Dendrocandin B [**56**]	*D. candidum*	stem	(Li et al., 2008)
	D. signatum	whole plant	(Mittraphab et al., 2016)
			(Yang et al., 2015)
	D. officinale	stem	
Dendrocandin T [**57**]	*D. officinale*	stem	(Yang et al., 2015)
Dendrocandin U [**58**]	*D. officinale*	stem	(Yang et al., 2015)
	D. wardianum	stem	(Zhang et al., 2017)
Dendrocandin V [**59**]	*D. wardianum*	stem	(Zhang et al., 2017)
Dendrowillol A [**60**]	*D. williamsonii*	whole plant	(Yang et al., 2017b)
Denofficin [**61**]	*D. officinale*	stem	(Ren et al., 2020)
Bibenzyls and derivatives: (d) Dihydrophenanthrenes			
Amoenumin [**62**]	*D. amoenum*	whole plant	(Veerraju et al., 1989)
1,5-Dihydroxy-3,4,7-trimethoxy-9,10-dihydro-phenanthrene [**63**]	*D. moniliforme*	whole plant	(Zhao et al., 2016)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Coelonin [**64**]	*D. aphyllum*	whole plant	(Chen et al., 2008a)
	D. formosum	whole plant	(Inthongkaew et al., 2017)
	D. nobile	stem	(Yang et al., 2007)
	D. scabrilingue	whole plant	(Sarakulwattana et al., 2018)
Dendroinfundin A [**65**]	*D. infundibulum*	whole plant	(Na Ranong et al., 2019)
Dendroinfundin B [**66**]	*D. infundibulum*	whole plant	(Na Ranong et al., 2019)
4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [**67**]	*D.ellipsophyllum*	whole plant	(Tanagornmeatar et al., 2014)
	D. sinense	whole plant	(Chen et al., 2013)
4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydro-phenanthrene [**68**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydrophenanthrene [**69**]	*D. nobile*	stem	(Ye & Zhao, 2002)
4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene (Orchinol) [**70**]	*D. nobile*	stem	(Zhang et al., 2007a)
9,10-Dihydromoscatin [**71**]	*D. polyanthum*	stem	(Hu et al., 2009)
9,10-Dihydrophenan threne-2,4,7-triol [**72**]	*D. officinale*	stem	(Zhao, et al., 2018)
	D. polyanthum	stem	(Hu et al., 2009)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydrophenanthrene [**73**]	*D. densiflorum*	stem	(Fan et al., 2001)
2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydro phenanthrene [**74**]	*D. nobile*	stem	(Yang et al., 2007)
4,7-Dihydroxy-2,3,6-tri-methoxy-9,10-dihydro phenanthrene [**75**]	*D. rotundatum*	whole plant	(Majumder & Pal, 1992)
3,4-Dimethoxy-1-(methoxymethyl)-9,10-dihydrophenanthrene-2,7-diol [**76**]	*D. hainanense*	aerial part	(Zhang et al., 2018)
Ephemeranthol A [**77**]	*D. infundibulum*	whole plant	(Na Ranong et al., 2019)
	D. nobile	stem	(Yang et al., 2007); (Hwang et al., 2010)
	D. officinale	stem	(Zhao et al., 2018)
Ephemeranthol C [**78**]	*D. nobile*	stem	(Yang et al., 2007); (Hwang et al., 2010)
Erianthridin [**79**]	*D. nobile*	stem	(Hwang et al., 2010)
	D. formosum	whole plant	(Inthongkaew et al., 2017)
	D. plicatile	stem	(Yamaki & Honda, 1996)
Flavanthridin [**80**]	*D. nobile*	stem	(Hwang et al., 2010)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Hircinol [**81**]	*D. aphyllum*	stem	(Yang et al., 2015)
	D. draconis	stem	(Sritularak et al., 2011b)
	D. formosum	whole plant	(Inthongkaew et al., 2017)
3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene [**82**]	*D. nobile*	stem	(Yang et al., 2007)
7-Hydroxy-2,3,4-trimethoxy-9,10-Dihydro-phenanthrene [**83**]	*D. hainanense*	aerial part	(Zhang et al., 2018)
	D. brymerianum	whole plant	(Klongkumnuankarn et al., 2015)
	D. formosum	whole plant	(Inthongkaew et al., 2017)
	D. palpebrae	whole plant	(Kyokong et al., 2018)
Lusianthridin [**84**]	*D. plicatile*	stem	(Yamaki & Honda, 1996)
	D. venustum	whole plant	(Sukphan et al., 2014)
	D. scabrilingue	whole plant	(Sarakulwattana et al., 2018)
2-Hydroxy-4,7-dimethoxy-9,10-dihydrophenan-threne [**85**]	*D. nobile*	stem	(Yang et al., 2007)
7-Methoxy-9,10-dihydro phenanthrene-2,4,5-triol [**86**]	*D. draconis*	stem	(Sritularak et al., 2011b)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
2,5,7-Trimethoxy-4-methoxy-9,10-dihydro-phenanthrene [**87**]	*D. formosum*	whole plant	(Inthongkaew et al., 2017)
Plicatol C [**88**]	*D. plicatile*	stem	(Honda & Yamaki, 2000)
Rotundatin [**89**]	*D. rotundatum*	whole plant	(Majumder et al., 1992)
(*S*)-2,4,5,9-Tetrahydroxy-9,10-dihydrophenanthrene [**90**]	*D. fimbriatum*	stem	(Xu et al., 2014)
Bibenzyls and derivatives: (e) phenanthrenes			
2,5-Dihydroxy-3,4-dimeth-oxyphenanthrene [**91**]	*D. nobile*	stem	(Yang et al., 2007)
2,5-Dihydroxy-4,9-dimeth-oxyphenanthrene [**92**]	*D. nobile*	stem	(Zhang et al., 2008b)
	D. palpebrae	whole plant	(Kyokong et al., 2018)
2,8-Dihydroxy-3,4,7-trimet-hoxyphenanthrene [**93**]	*D. nobile*	stem	(Yang et al., 2007)
Epheranthol B [**94**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
	D. plicatile	stem	(Yamaki & Honda, 1996)
Fimbriol B [**95**]	*D. nobile*	stem	(Yang et al., 2007); (Hwang et al., 2010)
Loddigesiinol B [**96**]	*D. loddigesii*	whole plant	(Ito et al., 2010)
	D. polyanthum	stem	(Hu et al., 2009)
Chrysotoxol A [**97**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
Chrysotoxol B [**98**]	*D. chrysotoxum*	stem	(Hu et al., 2012)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Flavanthrinin [**99**]	*D. brymerianum*	whole plant	(Klongkumnuankarn et al., 2015)
	D. venustum	whole plant	(Sukphan et al., 2014)
	D. nobile	stem	(Zhang et al., 2008b)
	D. parishii	whole plant	(Kongkatitham et al., 2018)
Dendrodevonin A [**100**]	*D.devonianum*	stem	(Wu et al., 2019)
Dendrodevonin B [**101**]	*D.devonianum*	stem	(Wu et al., 2019)
Moscatin [**102**]	*D. aphyllum*	whole plant	(Hu et al., 2008a)
	D. chrysanthum	stem	(Yang et al., 2006a)
	D. chrysotoxum	whole plant	(Li et al., 2009a)
	D. densiflorum	stem	(Fan et al., 2001)
	D. polyanthum	stem	(Hu et al., 2009)
Loddigesiinol A [**103**]	*D. loddigesii*	whole plant	(Ito et al., 2010)
	D. wardianum	stem	(Zhang et al., 2017)
Dendroscabrol A [**104**]	*D. scabrilingue*	whole plant	(Sarakulwattana et al., 2018)
Nudol [**105**]	*D. formosum*	whole plant	(Inthongkaew et al., 2017)
	D. nobile	stem	(Yang et al., 2007)
	D. rotundatum	whole plant	(Majumder & Pal, 1992)
Plicatol A [**106**]	*D. nobile*	stem	(Yang et al., 2007)
	D. plicatile	stem	(Honda & Yamaki, 2000)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Plicatol B [**107**]	*D. plicatile*	stem	(Honda & Yamaki, 2000)
2,3,5-Trihydroxy-4,9-dimethoxyphenanthrene [**108**]	*D. nobile*	stem	(Yang et al., 2007)
3,4,8-Trimethoxyphenan-threne-2,5-diol [**109**]	*D. nobile*	stem	(Hwang et al., 2010)
Bulbophyllanthrin [**110**]	*D. nobile*	stem	(Yang et al., 2007)
Denthyrsinin [**111**]	*D. thyrsiforum*	stem	(Zhang et al., 2005)
5-Hydroxy-2,4-dimethoxy phenanthrene [**112**]	*D. loddigesii*	whole plant	(Ito et al., 2010)
3-Hydroxy-2,4,7-trime-thoxyphenanthrene [**113**]	*D. nobile*	stem	(Yang et al., 2007)
Confusarin [**114**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
	D. formosum	whole plant	(Inthongkaew et al., 2017)
	D. nobile	stem	(Zhang et al., 2008c)
	D. officinale	stem	(Zhao et al., 2018)
2,6-Dihydroxy-1,5,7-trimethoxyphenanthrene [**115**]	*D. densiflorum*	stem	(Fan et al., 2001)
	D. palpebrae	whole plant	(Kyokong et al., 2018)
1,5,7-Trimethoxy-phenanthren-2-ol [**116**]	*D. nobile*	stem	(Kim et al., 2015)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Bibenzyls and derivatives: (f) Phenanthrene-1,4-dione			
Cypripedin [**117**]	*D. densiflorum*	stem	(Fan et al., 2001)
Densiflorol B [**118**]	*D. densiflorum*	stem	(Fan et al., 2001)
	D. venustum	whole plant	(Sukphan et al., 2014)
Denbinobin [**119**]	*D. moniliforme*	stem	(Lin et al., 2001)
	D. nobile	stem	(Yang et al., 2007)
	D. wardianum	stem	(Zhang et al., 2017)
Bibenzyls and derivatives: (g) 9,10-Dihydrophenanthrene -1,4-dione			
Dendronone [**120**]	*D. chrysanthum*	stem	(Yang et al., 2006a)
	D. longicornu	stem	(Hu et al., 2008a)
Ephemeranthoquinone [**121**]	*D. plicatile*	stem	(Yamaki & Honda, 1996)
5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenan-threnequinone [**122**]	*D. draconis*	stem	(Sritularak et al., 2011b)
	D. formosum	whole plant	(Inthongkaew et al., 2017)
Bibenzyls and derivatives: (h) Phenanthropyran derivatives			
Fimbriatone [**123**]	*D. nobile*	stem	(Zhang et al., 2008b)
	D. pulchellum	stem	(Chanvorachote et al., 2013)
Crystalltone [**124**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
Bibenzyls and derivatives: (i) 9,10-dihydrophenanthrodioxine			
Dendrocandin P2 [**125**]	*D. officinale*	stem	(Zhao et al., 2018)
Bibenzyls and derivatives: (j) Phenanthrodioxine			
Dendrocandin P1 [**126**]	*D. officinale*	stem	(Zhao et al., 2018)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Bibenzyls and derivatives: (k) Others			
Dendrochrysanene [**127**]	*D. chrysanthum*	stem	(Yang et al., 2006a)
Aphyllone [**128**]	*D. nobile*	stem	(Hwang et al., 2010)
9,10-Dihydro-aphyllone A-5-*O*-β-D-glucopyranoside [**129**]	*D. fimbriatum*	stem	(Xu et al., 2017)
2,4,5,9*S*-Tetrahydroxy-9,10-dihydrophenanthrene -4-*O*-β-D-glucopyranoside [**130**]	*D. primulinum*	whole plant	(Ye et al., 2016)
Bibenzyls and derivatives: (l) Dimeric bibenzyls			
Dendrocandin I [**131**]	*D. candidum*	stem	(Wang et al., 2009)
	D. signatum	whole plant	(Mittraphab et al., 2016)
Dendrocandin F [**132**]	*D. candidum*	stem	(Li et al., 2009c)
Dendrocandin G [**133**]	*D. candidum*	stem	(Li et al., 2009c)
Dendrosinen D [**134**]	*D. sinense*	whole plant	(Chen et al., 2014)
Dendrofalconerol B [**135**]	*D. falconeri*	stem	(Boonchoo Sritularak & Likhitwitayawuid, 2009)
Nobilin E [**136**]	*D. nobile*	stem	(Zhang et al., 2007b)
Dendroscabrol B [**137**]	*D. scabrilingue*	whole plant	(Sarakulwattana et al., 2018).
Dengraol A [**138**]	*D. gratiosissimum*	stem	(Zhang et al., 2008a)
Dengraol B [**139**]	*D. gratiosissimum*	stem	(Zhang et al., 2008a)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Bibenzyls and derivatives: (m) Bibenzyl-phenanthrene and derivatives			
Dendrosignatol [**140**]	*D. signatum*	whole plant	(Mittraphab et al., 2016)
Dendroparishiol [**141**]	*D. parishii*	whole plant	(Kongkatitham et al., 2018)
Dendrocandin H [**142**]	*D. candidum*	stem	(Li et al., 2009c)
Loddigesiinol G [**143**]	*D. loddigesii*	stem	(Lu et al., 2014)
Loddigesiinol H [**144**]	*D. loddigesii*	stem	(Lu et al., 2014)
Loddigesiinol I [**145**]	*D. loddigesii*	stem	(Lu et al., 2014)
Loddigesiinol J [**146**]	*D. loddigesii*	stem	(Lu et al., 2014)
Bibenzyls and derivatives: (n) Biphenanthrene and derivatives			
2,2′-Dihydroxy-3,3′,4,4′, 7,7′-hexamethoxy-9,9′, 10,10′-tetrahydro-1,1′-biphenanthrene [**147**]	*D. nobile*	stem	(Yang et al., 2007)
2,2′-Dimethoxy-4,4′,7,7′-tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene [**148**]	*D. plicatile*	stem	(Yamaki & Honda, 1996)
Flavanthrin [**149**]	*D. aphyllum*	whole plant	(Chen et al., 2008c)
Phoyunnanin C [**150**]	*D. venustum*	whole plant	(Sukphan et al., 2014)

Table 1 (continued)

Category and compounds	Plants	Plant parts	references
Phoyunnanin E [**151**]	*D. venustum*	whole plant	(Sukphan et al., 2014)
Dendropalpebrone [**152**]	*D. palpebrae*	whole plant	(Kyokong et al., 2018)
Bibenzyls and derivatives: (o) Bisbibenzyl			
Dendrofalconerol A [**153**]	*D. falconeri*	stem	(Boonchoo Sritularak & Likhitwitayawuid, 2009)
	D. signatum	whole plant	(Mittraphab et al., 2016)
	D. tortile	whole plant	(Limpanit et al., 2016)
Flavonoids : (a) Flavones			
Apigenin [**154**]	*D. crystallinum*	stem	(Wang et al., 2009)
	D. williamsonii	whole plant	(Rungwichaniwat et al., 2014)
Isovitexin [**155**]	*D. catenatum*	stem	(Ren et al., 2020)
	D. officinale		
apigenin 6-*C*-glucosyl-(1→2)-α-*L*- arabinoside [**156**]	*D. officinale*	leaves	(Zhang et al., 2017)
6-*C*-(α-Arabinopyrano-syl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-galactopyranosyl] apigenin [**157**]	*D. huoshanense*	aerial part	(Chang et al., 2010)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
6-*C*-(β-Xylopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyra-nosyl)-β-glucopyranosyl] apigenin [**158**]	*D. huoshanense*	aerial part	(Chang et al., 2010)
5,6-Dihydroxy-4′-methoxyflavone [**159**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
6‴-Glucosyl-vitexin [**160**]	*D. crystallinum*	stem	(Wang et al., 2009)
5-Hydroxy-3-methoxy-flavone-7-*O*-[β-D-apiosyl-(1⟶6)]-β-D-glucoside [**161**]	*D. devonianum*	whole plant	(Sun *et al.,* 2014)
Isoschaftoside [**162**]	*D. huoshanense*	aerial part	(Chang et al., 2010)
Isoviolanthin [**163**]	*D. crystallinum*	stem	(Wang et al., 2009)
Kaempferol [**164**]	*D. aurantiacum* var. *denneanum*	stem	(Yang et al., 2006b)
Kaempferol-3-*O*-α-L-rhamnopyranoside [**165**]	*D. secundum*	stem	(Phechrmeekha et al., 2012)
Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside [**166**]	*D. secundum*	stem	(Phechrmeekha et al., 2012)
Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)- β-D-glucopyranoside [**167**]	*D. capillipes*	stem	(Phechrmeekha et al., 2012)
Kaempferol-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside [**168**]	*D. capillipes*	stem	(Phechrmeekha et al., 2012)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Luteolin [**169**]	*D. aurantiacum* var. *denneanum*	whole plant	(Liu et al., 2009)
	D. ellipsophyllum	whole plant	(Tanagornmeatar et al., 2014)
	D. longicornu	stem	(Hu et al., 2008a)
Vicenin-2 [**170**]	*D. aurantiacum* var. *denneanum*	stem	(Xiong et al., 2013)
Quercetin-3-*O*-L-rhamnopyranoside [**171**]	*D. secundum*	stem	(Phechrmeekha et al., 2012)
Quercetin-3-*O*-α-L-rhamnopyranosyl-(1⟶2)-β-D-xylopyranoside [**172**]	*D. capillipes*	stem	(Phechrmeekha et al., 2012)
Flavonoids : (b) Flavanones			
(2*S*)-Homoeriodictyol [**173**]	*D. densiflorum*	stem	(Fan et al., 2001)
	D. ellipsophyllum	whole plant	(Tanagornmeatar et al., 2014)
Naringenin [**174**]	*D. aurantiacum* var. *denneanum*	stem	(Yang et al., 2006b)
	D. densiflorum	stem	(Fan et al., 2001)
	D. longicornu	stem	(Hu et al., 2008a)
(2*S*)-Eriodictyol [**175**]	*D. ellipsophyllum*	whole plant	(Tanagornmeatar et al., 2014)
	D. trigonopus	stem	(Hu et al., 2008b)
	D. tortile	whole plant	(Limpanit et al., 2016)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Terpenoids			
Amoenin [**176**]	*D. amoenum*	whole plant	(Dahmen & Leander, 1978)
	D. williamsonii	whole plant	(Yang et al., 2017a)
Asiatic acid [**177**]	*D. parishii*	whole plant	(Kongkatitham et al., 2018)
Corchoionoside C [**178**]	*D. wardianum*	stem	(Fan et al., 2013)
Dendrobane A [**179**]	*D. moniliforme*	stem	(Wang et al., 2004)
Dendromoniliside A [**180**]	*D. nobile*	stem	(Zhnag et al., 2007a)
Dendromoniliside B [**181**]	*D. moniliforme*	stem	(Zhao et al., 2003)
Dendromoniliside C [**182**]	*D. moniliforme*	stem	(Zhao et al., 2003)
Dendromoniliside D [**183**]	*D. moniliforme*	stem	(Zhao et al., 2003)
Dendronobiloside A [**184**]	*D. moniliforme*	stem	(Zhao et al., 2003);
	D. nobile	stem	(Zhao et al., 2001); (Ye & Zhao, 2002)
Dendronobiloside B [**185**]	*D. nobile*	stem	(Zhao et al., 2001); (Ye & Zhao, 2002)
Dendronobiloside C [**186**]	*D. nobile*	stem	(Zhao et al., 2001); (Ye & Zhao, 2002)
Dendronobiloside D [**187**]	*D. nobile*	stem	(Zhao et al., 2001); (Ye & Zhao, 2002)
Dendronobiloside E [**188**]	*D. nobile*	stem	(Zhao et al., 2001); (Ye & Zhao, 2002)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Dendronobilin A [**189**]	*D. wardianum*	stem	(Zhang et al., 2007a)
Dendronobilin B [**190**]	*D. wardianum*	stem	(Zhang et al., 2007a);
	D. nobile	stem	(Meng et al., 2017;
			Wang et al., 2009)
Dendronobilin C [**191**]	*D. crystallium*	stem	(Wang et al., 2009)
Dendronobilin D [**192**]	*D. nobile*	stem	(Zhang et al., 2007a)
Dendronobilin E [**193**]	*D. nobile*	stem	(Zhang et al., 2007a)
Dendronobilin F [**194**]	*D. nobile*	stem	(Zhang et al., 2007a)
Dendronobilin G [**195**]	*D. nobile*	stem	(Zhang et al., 2007a)
Dendronobilin H [**196**]	*D. nobile*	stem	(Zhang et al., 2007a)
Dendronobilin I [**197**]	*D. nobile*	stem	(Zhang et al., 2007a)
Dendronobilin J [**198**]	*D. nobile*	stem	(Zhang et al., 2007a)
Dendronobilin K [**199**]	*D. wardianum*	stem	(Fan et al., 2013)
Dendronobilin L [**200**]	*D. nobile*	stem	(Zhang et al., 2007a)
Dendronobilin M [**201**]	*D. nobile*	stem	(Zhang et al., 2008b);
			(Meng et al., 2017)
Dendronobilin N [**202**]	*D. nobile*	stem	(Zhang et al., 2008b)
Dendroside A [**203**]	*D. moniliforme*	stem	(Zhao et al., 2003)
	D. nobile	stem	(Zhao et al., 2001);
			(Ye & Zhao, 2002)
Dendroside B [**204**]	*D. nobile*	stem	(Ye & Zhao, 2002)
	D. williamsonii	whole plant	(Yang et al., 2017a)
Dendroside C [**205**]	*D. moniliforme*	stem	(Zhao et al., 2003)
	D. nobile	stem	(Ye & Zhao, 2002)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Dendroside D [**206**]	*D. nobile*	stem	(Ye & Zhao, 2002)
Dendroside E [**207**]	*D. nobile*	stem	(Ye et al., 2003)
Dendroside F [**208**]	*D. moniliforme*	stem	(Zhao et al., 2003)
Dendroside G [**209**]	*D. nobile*	stem	(Ye et al., 2002)
Dendrowardol A [**210**]	*D. wardianum*	stem	(Fan et al., 2013)
Dendrowardol B [**211**]	*D. wardianum*	stem	(Fan et al., 2013)
Dendrowardol C [**212**]	*D. wardianum*	stem	(Fan et al., 2013)
Amotin [**213**]	*D. amoenum*	whole plant	(Majumder et al., 1999)
Dendrowillin A [**214**]	*D. williamsonii*	whole plant	(Yang et al., 2017a)
Dendrowillin B [**215**]	*D. williamsonii*	whole plant	(Yang et al., 2017a)
α-Dihydropicrotoxinin [**216**]	*D. amoenum*	whole plant	(Majumder et al., 1999)
Picrotin [**217**]	*D. williamsonii*	whole plant	(Yang et al., 2017a)
Findlayanin [**218**]	*D. nobile*	stem	(Meng et al., 2017)
	D. polyanthum	stem	(Hu et al., 2009)
Alkaloids			
3-Hydroxy-2-oxodendrobine [**219**]	*D. findlayanum*	whole plant	(Qin et al., 2011)
Wardianumine A [**220**]	*D. wardianum*	stem	(Zhang et al., 2017)
Crepidtumines A [**221**]	*D. crepidatum*	stem	(Xu et al., 2020)
Crepidtumines B [**222**]	*D. crepidatum*	stem	(Xu et al., 2020)
(-)-(*1R*,*2S*,*3R*,*4S*,*5R*,*6S*,*9S*, *11R*)-11-Carboxymethyl dendrobine [**223**]	*D. wardianum*	stem	(Fan et al., 2013)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Dendrobine [**224**]	*D. nobile*	stem	(Wang et al., 1985) (Meng et al., 2017)
Crystalline [**225**]	*D. wardianum*	stem	(Fan et al., 2013)
Aliphatic acid derivatives			
Aliphalic acids [**226**]	*D. clavatum* var. *aurantiacum*	stem	(Chang et al., 2001)
Aliphatic alcohols [**227**]	*D. clavatum* var. *aurantiacum*	stem	(Chang et al., 2001)
Decumbic acid [**228**]	*D. nobile*	stem	(Zhou et al., 2016)
Dimethyl malate [**229**]	*D. huoshanense*	aerial part	(Chang et al., 2010)
Malic acid [**230**]	*D. huoshanense*	aerial part	(Chang et al., 2001)
Isopentyl butyrate [**231**]	*D. huoshanense*	aerial part	(Chang et al., 2010)
(-)-Shikimic acid [**232**]	*D. fuscescens*	whole plant	(Talapatra et al., 1989)
	D. huoshanense	aerial part	(Chang et al., 2010)
	D. longicornu	stem	(Hu et al., 2008a)
	D. pulchellum	stem	(Chanvorachote et al., 2013)
Benzoic acid derivatives and phenolic compounds			
Antiarol [**233**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
Ethylhaematommate [**234**]	*D. longicornu*	whole plant	(Li et al., 2009d)
Gallic acid [**235**]	*D. longicornu*	whole plant	(Li et al., 2009d)
p-Hydroxybenzaldehyde [**236**]	*D. tortile*	whole plant	(Limpanit et al., 2016)
p-Hydroxybenzoic acid [**237**]	*D. williamsonii*	whole plant	(Yang et al., 2017b)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid [**238**]	*D. crystallinum*	stem	(Wang et al., 2009)
Methyl 4-hydroxy-benzoate [**239**]	*D. williamsonii*	whole plant	(Yang et al., 2017b)
Methyl β-orsellinate [**240**]	*D. longicornu*	stem	(Li et al., 2009d)
	D. williamsonii	whole plant	(Rungwichaniwat et al., 2014)
Protocatechuic acid [**241**]	*D. nobile*	stem	(Ye & Zhao, 2002)
Salicylic acid [**242**]	*D. huoshanense*	aerial part	(Chang et al., 2010)
	D. williamsonii	whole plant	(Yang et al., 2017b)
Syringic acid [**243**]	*D. crystallinum*	stem	(Wang et al., 2009)
Tachioside [**244**]	*D. denneanum*	stem	(Pan et al.,2012)
Vanillic acid [**245**]	*D. crystallinum*	stem	(Wang et al., 2009)
	D. williamsonii	whole plant	(Rungwichaniwat et al., 2014)
Vanillin [**246**]	*D. williamsonii*	whole plant	(Yang et al., 2018)
Vanilloside [**247**]	*D. denneanum*	stem	(Pan et al., 2012)
Phenylpropanoids			
Alkyl 4′-hydroxy-*trans*-cinnamates [**248**]	*D. clavatum* var. *aurantiacum*	stem	(Chang et al., 2001)
Alkyl *trans*-ferulates [**249**]	*D. clavatum* var. *aurantiacum*	stem	(Chang et al., 2001)
Defuscin [**250**]	*D. aurantiacum* var. *denneanum*	Stem	(Yang et al., 2006b)
	D. moniliforme	stem	(Bi et al., 2004)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
n-Octacosyl ferulate [**251**]	*D. aurantiacum var. denneanum*	stem	(Yang et al., 2006b)
	D. moniliforme	stem	(Bi et al., 2004)
n-Triacontyl *p*-hydroxy-*cis*-cinnamate [**252**]	*D. moniliforme*	stem	(Bi et al., 2004)
Tetratriacontanyl-*trans*-*p*-coumarate [**253**]	*D. williamsonii*	whole plant	(Rungwichaniwat et al., 2014)
n-Docosyl *trans*-ferulate [**254**]	*D. longicornu*	whole plant	(Li et al., 2009d)
trans-tetracosyl ferulate [**255**]	*D. tortile*	whole plant	(Limpanit et al., 2016)
	D. scabrilingue	whole plant	(Sarakulwattana et al., 2018)
Ferulaldehyde [**256**]	*D. longicornu*	whole plant	(Li et al., 2009d)
Ferulic acid [**257**]	*D. secundum*	stem	(Sritularak et al., 2011a)
2-(*p*-Hydroxyphenyl) ethyl *p*-coumarate [**258**]	*D. falconeri*	stem	(Boonchoo Sritularak & Likhitwitayawuid, 2009)
Coniferyl alcohol [**259**]	*D. trigonopus*	stem	(Hu et al., 2008b)
Dendroside [**260**]	*D. nobile*	stem	(Zhou et al., 2017)
cis-Hexacosanoyl ferulate [**261**]	*D. tortile*	whole plant	(Limpanit et al., 2016)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
cis-Tetracosanoyl ferulate [**262**]	*D. scabrilingue*	whole plant	(Sarakulwattana et al., 2018)
Tetracosyl (*Z*)-*p*-coumarate [**263**]	*D. falconeri*	whole plant	(Sritularak & Likhitwitayawuid, 2009)
Dihydroconiferyl dihydro-*p*-coumarate [**264**]	*D. formosum*	whole plant	(Inthongkaew et al., 2017)
	D. nobile	stem	(Zhang et al., 2006)
	D. williamsonii	whole plant	(Yang et al., 2017b)
1-[4-(β-D-Glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone [**265**]	*D. aurantiacum* var. *denneanum*	stem	(Xiong et al., 2013)
p-Hydroxyphenyl propionic methyl ester [**266**]	*D. aphyllum*	whole plant	(Chen et al., 2008a)
Phloretic acid [**267**]	*D. ellipsophyllum*	whole plant	(Tanagornmeatar et al., 2014)
Dihydroconiferyl alcohol [**268**]	*D. longicornu*	stem	(Hu et al., 2008a)
Salidrosol [**269**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
Shashenoside I [**270**]	*D. aurantiacum* var. *denneanum*	stem	(Xiong et al., 2013)
Syringin [**271**]	*D. aurantiacum* var. *denneanum*	stem	(Xiong et al., 2013)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Coumarins			
Ayapin [**272**]	*D. densiflorum*	stem	(Fan et al., 2001)
Coumarin [**273**]	*D. aurantiacum* var. *denneanum*	stem	(Yang et al., 2006b)
	D. clavatum var. *aurantiacum*	stem	Chang et al., 2001
Denthyrsin [**274**]	*D. thyrsiflorum*	stem	(Zhang et al., 2005)
Scoparone [**275**]	*D. densiflorum*	stem	(Fan et al., 2001)
	D. palpebrae	whole plant	(Kyokong et al., 2018)
	D. thyrsiflorum	stem	(Zhang et al., 2005)
	D. williamsonii	whole plant	(Yang et al., 2017b)
Scopoletin [**276**]	*D. densiflorum*	Stem	(Fan et al., 2001)
Lignans and neolignans			
Acanthoside B [**277**]	*D. chrysanthum*	stem	(Ye et al., 2004)
Liriodendrin [**278**]	*D. aurantiacum* var. *denneanum*	stem	(Xiong et al., 2013)
	D. pulchellum	stem	(Chanvorachote et al., 2013)
Syringaresinol [**279**]	*D. secundum*	stem	(Sritularak et al., 2011a)
	D. williamsonii	whole plant	(Yang et al., 2017b)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Syringaresinol-4-*O*-D-monoglucopyranoside [**280**]	*D. aurantiacum* var. *denneanum*	stem	(Xiong et al., 2013)
Episyringaresinol [**281**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
	D. longicornu	stem	(Hu et al., 2008a)
	D. nobile	stem	(Zhang et al., 2008b)
Episyringaresinol 4′′-*O*- β-D-glucopyranoside [**282**]	*D. moniliforme*	stem	(Zhao et al., 2003)
(-)-(7*S*,8*R*,7′ *E*) -4-Hydroxy-3,3',5,5'-tetramethoxy-8,4′-oxyneolign-7′-ene-7,9,9′-triol-7,9′-bis-*O*-β-D-glucopyranoside [**283**]	*D. aurantiacum* var. *denneanum*	stem	(Xiong et al., 2013)
Lyoniresinol [**284**]	*D. chrysanthum*	stem	(Ye et al., 2004)
(-)-Medioresinol [**285**]	*D. loddigesii*	whole plant	(Ito et al., 2010)
(-)-Pinoresinol [**286**]	*D. loddigesii*	whole plant	(Ito et al., 2010)

Table 1 (continued)

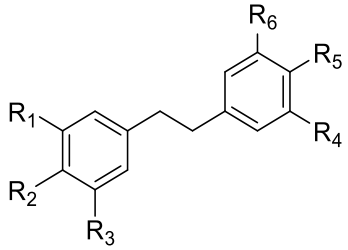
Category and compounds	Plants	Plant parts	References
Erythro-1-(4-*O*-β-D-glucopyranosyl-3-methoxyphenyl)-2-[4-(3-hydroxypropyl)-2,6-dimethoxyphenoxy]-1,3-propanediol [**287**]	*D. longicornu*	stem	(Hu et al., 2008a)
(-)-(8*R*,7′*E*)-4-Hydroxy-3,3′,5,5′-tetra-methoxy-8,4′-oxyneolign-7′-ene-9,9′-diol-4,9-bis-*O*-β-D-glucopyranoside [**288**]	*D. auranticum*	stem	(Li et al., 2014)
(-)-(8*S*,7′*E*)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-*O*-β-D-glucopyranoside [**289**]	*D. auranticum*	stem	(Li et al., 2014)
(-)-(8*R*,7′*E*)-4-hydroxy-3,3′,5,5′,9′-penta-methoxy-8,4′-oxyneolign-7′-ene-9-ol-4,9-bis-*O*-β-D-glucopyranoside [**290**]	*D. auranticum*	stem	(Li et al., 2014)
Fluorenones			
Denchrysan A [**291**]	*D. chrysotoxum*	whole plant	(Li et al., 2009a)

Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Dendroflorin [**292**]	*D. aurantiacum* var. *denneanum*	stem	(Yang et al., 2006b)
	D. brymerianum	whole plant	(Klongkumnuankarn et al., 2015)
	D. palpebrae	whole plant	(Kyokong et al., 2018)
Dengibsin [**293**]	*D. aurantiacum* var. *denneanum*	stem	(Yang et al., 2006b)
	D. chrysanthum	stem	(Yang et al., 2006a)
	D. chrysotoxum	whole plant	(Li et al., 2009a)
Nobilone [**294**]	*D. brymerianum*	whole plant	(Klongkumnuankarn et al., 2015)
	D. nobile	stem	(Zhang et al., 2007b)
	D. palpebrae	whole plant	(Kyokong et al., 2018)
1,4,5-Trihydroxy-7-methoxy-9H-fluoren-9-one [**295**]	*D. chrysotoxum*	whole plant	(Chen et al., 2008b)
2,4,7-Trihydroxy-5-methoxy-9-fluorenone [**296**]	*D. chrysotoxum*	stem	(Ye et al., 2004)
2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone [**297**]	*D. chrysotoxum*	stem	(Ye et al., 2004)

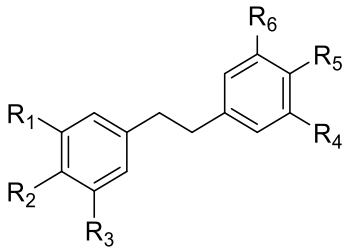
Table 1 (continued)

Category and compounds	Plants	Plant parts	References
Denchrysan B [**298**]	*D. brymerianum*	whole plant	(Klongkumnuankarn et al., 2015)
	D. chrysanthemum	whole plant	(Ye et al., 2003)
Dendrogibsol [**299**]	*D. gibsonii*	whole plant	(Thant et al., 2020)
Dihydrodengibsinin [**300**]	*D. gibsonii*	whole plant	(Thant et al., 2020)
Others			
3,6,9-Trihydroxy-3,4-dihydro anthracen-1-(2*H*)-one [**301**]	*D. chrysotoxum*	stem	(Hu et al., 2012)
Palmarumycin JC2 [**302**]	*D. crystallinum*	stem	(Wang et al., 2009)
Dehydrovomifoliol [**303**]	*D. loddigesii*	whole plant	(Ito et al., 2010)
Moniliformin [**304**]	*D. moniliforme*	stem	(Lin et al., 2001)
4-(2-Hydroxypropyl)-2(*5H*)-furanone [**305**]	*D. tortile*	whole plant	(Limpanit et al., 2016)
5,7-Dihydroxychromen-4-one [**306**]	*D. ellipsophyllum*	whole plant	(Tanagornmeatar et al., 2014)
RF-3192C [**307**]	*D. scabrilingue*	whole plant	(Sarakulwattana et al., 2018)
Dendrolactone [**308**]	*D. nobile*	stem	(Zhou et al., 2016)



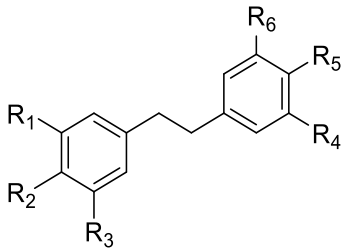
	R_1	R_2	R_3	R_4	R_5	R_6
[**1**] Aloifol I	OMe	OH	OMe	OH	H	H
[**2**] Amoenylin	OMe	OH	OMe	H	OMe	H
[**3**] Batatasin	OMe	H	H	OH	H	OH
[**4**] Batatasin III	OH	H	OMe	H	H	OH
[**5**] Brittonin A	OMe	OMe	OMe	OMe	OMe	OMe
[**6**] Chrysotobibenzyl	OMe	OMe	OMe	OMe	OMe	H
[**7**] Crepidatin	OMe	OMe	OMe	OMe	OH	H
[**8**] Cumulatin	OMe	OMe	OH	OH	OMe	OMe
[**9**] Dendrobin A	OH	OH	OMe	H	H	OMe
[**10**] Dendromoniliside E	OGlc	OGlc	OMe	H	OMe	H
[**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′-dimethoxydihydro stilbene	OH	H	OMe	OMe	OH	H
[**14**] 3,4′-Dihydroxy-3′,4,5-tri methoxybibenzyl	OMe	OMe	OH	H	OH	OMe

Figure 2 Structures of compounds from *Dendrobium* spp.

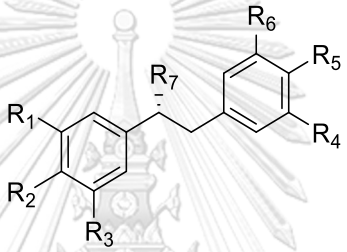


	R_1	R_2	R_3	R_4	R_5	R_6
[**15**] Erianin	OMe	OMe	H	OMe	OH	OMe
[**16**] Gigantol	OMe	H	H	H	OH	OMe
[**17**] Gigantol-5-*O*-β-D-glucopyranoside	OMe	H	OGlc	H	OH	OMe
[**18**] 4-Hydroxy-3,5,3′-trimethoxy bibenzyl	OMe	OH	OMe	H	H	OMe
[**19**] 5-Hydroxy-3,4,3′,4′,5′-pentamethoxybibenzyl	OMe	OMe	OH	OMe	OMe	OMe
[**20**] Isoamoenylin	OMe	OMe	OMe	H	H	OH
[**21**] Moscatilin	OMe	OH	OMe	H	OH	OMe
[**22**] Moscatilin diacetate	OMe	OAc	OMe	H	OAc	OMe
[**23**] 3,3′,4 -Trihydroxy bibenzyl	OH	OH	H	H	H	OH
[**24**] 3,3′,5-Trihydroxy bibenzyl	OH	H	OH	H	H	OH
[**25**] 3,5,4′-Trihydroxy bibenzyl	OH	H	OH	H	OH	H
[**26**] 4,5,4′-Trihydroxy-3,3′ dimethoxybibenzyl	OMe	OH	OH	H	OH	OMe

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)

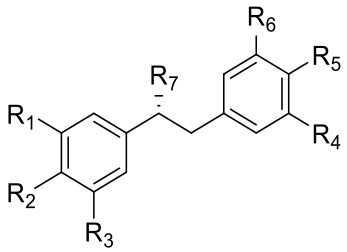


	R_1	R_2	R_3	R_4	R_5	R_6
[**27**] 4,3′,4′-Trihydroxy-3,5-dimethoxy bibenzyl	OMe	OH	OMe	H	OH	OH
[**28**] Tristin	OH	H	OH	H	OH	OMe

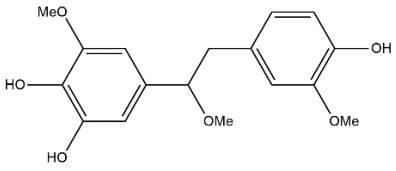


	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**29**] Dendrophenol	OMe	OH	OMe	OH	H	OH	H
[**30**] Dendrocandin E	OMe	OH	OH	OH	OH	H	H
[**31**] Dendrosinen B	OMe	OMe	OH	H	OH	H	H
[**32**] 3,4-Dihydroxy-5,4′-dimethoxy bibenzyl	OH	OH	OMe	H	OMe	H	H
[**33**] 4,4′-Dihydroxy-3,5-dimethoxy bibenzyl	OMe	OH	OMe	H	OH	H	H
[**34**] 3-*O*-Methylgigantol	OMe	H	OH	OMe	OMe	H	H
[**35**] 4-[2-(3-hydroxyphenol)-1-methoxyl]-2,6-dimethoxyphenol	OMe	OH	OMe	H	H	OH	OMe
[**36**] Dendrocandin A	OMe	OH	OH	H	OMe	H	OMe

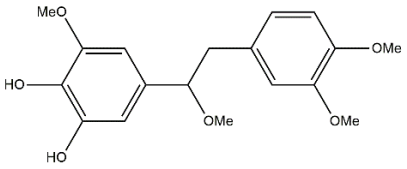
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**37**] Dendrocandin C	OMe	OH	OH	H	OH	H	OMe
[**38**] Dendrocandin D	OMe	OH	OH	H	OH	H	OEt
[**39**] Dendrosinen A	OMe	OMe	OH	H	OH	H	OH
[**40**] 4-[2-(3-Hydroxyphenol)-1-methoxyl]-2,6-dimethoxyphenol	OMe	OH	OMe	H	H	OH	OMe
[**41**] Loddigesiinol C	OMe	OH	OMe	H	OH	OMe	OMe
[**42**] Nobilin A	OMe	OH	OH	H	H	OMe	OMe
[**43**] Nobilin B	OMe	OH	OMe	H	OH	OMe	OMe
[**44**] Nobilin C	OMe	OH	OMe	H	OMe	OMe	OMe
[**45**] Nobilin D	OMe	OH	H	OMe	OH	OMe	OH

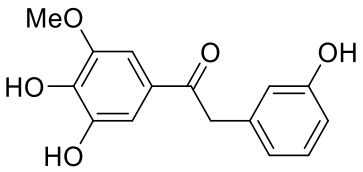


[**46**] 4,4′,5-Trihydroxy-3,3′, α-trimethoxybibenzyl

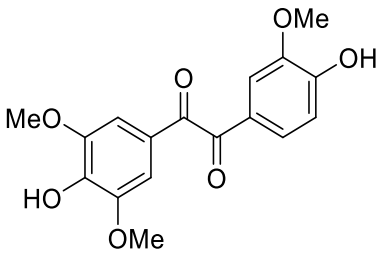


[**47**] 4,5-Dihydroxy-3, α, 3′, 4′-tetramethoxybibenzyl

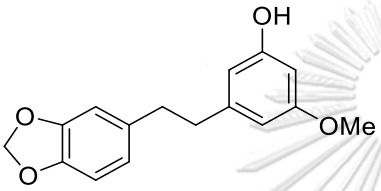
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



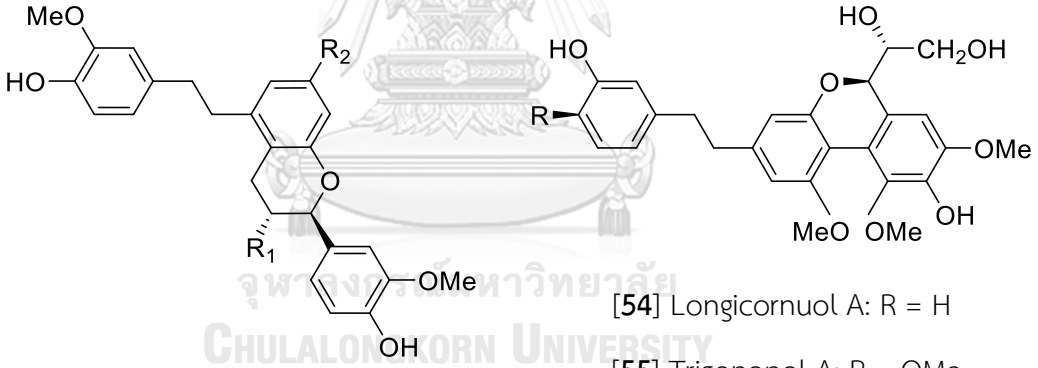
[**48**] Dendrosinen C



[**49**] Loddigesiinol D



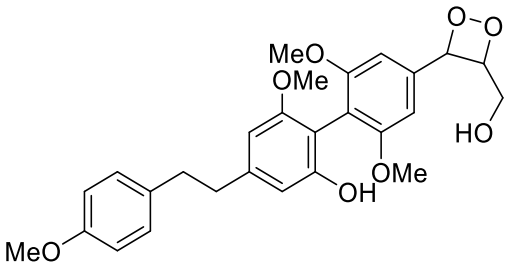
[**50**] Densiflorol A



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

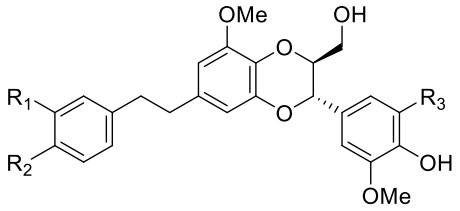
[**55**] Trigonopol A: R = OMe

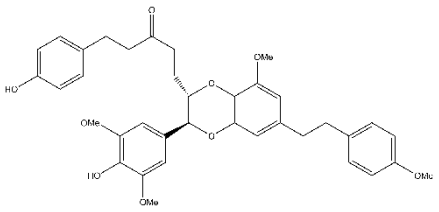
	R_1	R_2
[**51**] Crepidatuol A	H	OMe
[**52**] Crepidatuol B	OH	OMe
[**53**] Trigonopol B	OH	OH



[**60**] Dendrowillol A

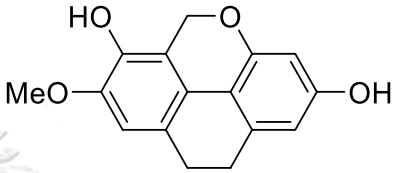
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



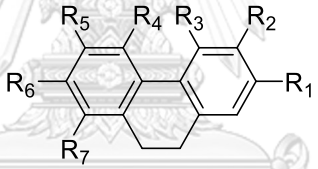


[**61**] Denofficin

	R_1	R_2	R_3
[**56**] Dendrocandin B	H	OMe	OMe
[**57**] Dendrocandin T	OMe	OH	OMe
[**58**] Dendrocandin U	H	OH	OMe
[**59**] Dendrocandin V	H	OMe	H

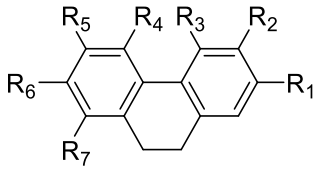


[**62**] Amoenumin



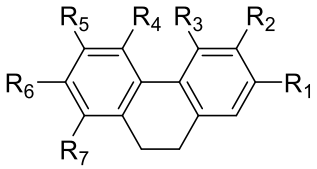
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**63**] 1,5-Dihydroxy-3,4,7-tri-methoxy-9,10-dihydro phenanthrene	H	OMe	OMe	OH	H	OMe	H
[**64**] Coelonin	OH	H	OMe	H	H	OH	H
[**65**] Dendroinfundin A	OMe	OMe	OH	H	H	OMe	H
[**66**] Dendroinfundin B	OMe	OMe	OH	OH	H	H	OMe

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



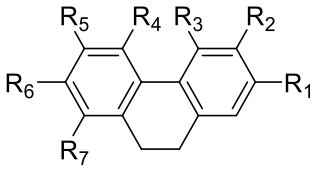
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**67**] 4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydro phenanthrene	OMe	OMe	OH	OH	H	H	H
[**68**] 4,5-Dihydroxy-2,6-dimethoxy-9,10-dihydro phenanthrene	OMe	H	OH	OH	OMe	H	H
[**69**] 4,5-Dihydroxy-3,7-dimethoxy-9,10-dihydro phenanthrene	H	OMe	OH	OH	H	OMe	H
[**70**] 4,5-Dihydroxy-2-methoxy-9,10-dihydrophenanthrene (Orchinol)	OMe	H	OH	OH	H	H	H
[**71**] 9,10-Dihydromoscatin	H	H	OH	OMe	H	OH	H
[**72**] 9,10-Dihydrophenan threne -2,4,7-triol	OH	H	OH	H	H	OH	H
[**73**] 2,7-Dihydroxy-3,4,6-trimethoxy-9,10-dihydro phenanthrene	OH	OMe	OMe	H	OMe	OH	H

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)

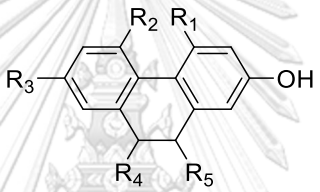


	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**74**] 2,8-Dihydroxy-3,4,7-trimethoxy-9,10-dihydro phenanthrene	OH	OMe	OMe	H	H	OMe	OH
[**75**] 4,7-Dihydroxy-2,3,6-trimethoxy-9,10-dihydro phenanthrene	OMe	OMe	OH	H	OMe	OH	H
[**76**] 3,4-Dimethoxy-1-(methoxymethyl)-9,10-dihydrophenanthrene-2,7-diol	OH	H	H	OMe	OMe	OH	CH_2O Me
[**77**] Ephemeranthol A	OH	H	H	OH	OMe	OMe	H
[**78**] Ephemeranthol C	OH	OH	OMe	OH	H	H	H
[**79**] Erianthridin	OH	OMe	OMe	H	H	OH	H
[**80**] Flavanthridin	OH	H	H	OMe	OH	OMe	H
[**81**] Hircinol	OH	H	OMe	OH	H	H	H
[**82**] 3-Hydroxy-2,4,7-trimethoxy-9,10-dihydrophenanthrene	OMe	OH	OMe	H	H	OMe	H

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)

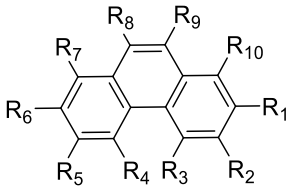


	R_1	R_2	R_3	R_4	R_5	R_6	R_7
[**83**] 7-Hydroxy-2,3,4-trimethoxy-9,10-dihydrophenanthrene	OMe	OMe	OMe	H	H	OH	H
[**84**] Lusianthridin	OMe	H	OH	H	H	OH	H

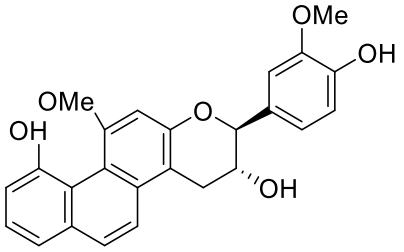


	R_1	R_2	R_3	R_4	R_5
[**85**] 2-Hydroxy-4,7-dimethoxy-9,10-dihydro phenanthrene	OMe	H	OMe	H	H
[**86**] 7-Methoxy-9,10-dihydrophenanthrene-2,4,5-triol	OH	OH	OMe	H	H
[**87**] 2,5,7-Trihydroxy-4-methoxy-9,10-dihydrophenanthrene	OMe	OH	OH	H	H
[**88**] Plicatol C	OMe	OH	H	OMe	OMe
[**89**] Rotundatin	OMe	OH	H	OH	OH
[**90**] (*S*)-2,4,5,9-Tetrahydroxy-9,10dihydrophenanthrene	OH	OH	H	OH	H

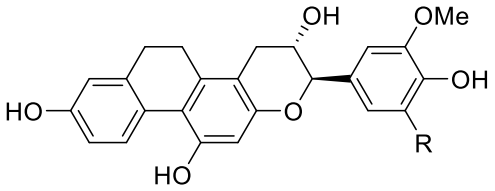
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
[**91**] 2,5-Dihydroxy-3,4-dimethoxy phenanthrene	OH	OMe	OMe	OH	H	H	H	H	H	H
[**92**] 2,5-Dihydroxy-4,9-dimethoxyphenanthrene	OH	H	OMe	OH	H	H	H	OMe	H	H
[**93**] 2,8-Dihydroxy-3,4,7- trimethoxy phenanthrene	OH	OMe	OMe	H	H	OMe	OH	H	H	H
[**94**] Epheranthol B	H	H	OMe	OH	H	OMe	H	H	H	H
[**95**] Fimbriol B	OH	OMe	OH	H	H	H	H	H	H	H



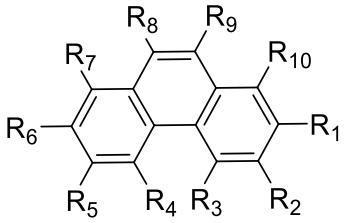
[**96**] Loddigesiinol B



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

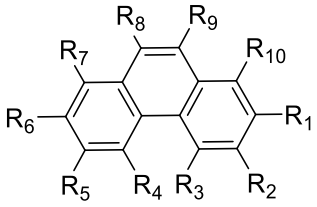
[**98**] Chrysotoxol B: R = OMe

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



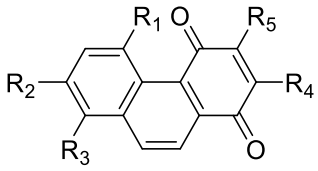
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
[**99**] Flavanthrinin	H	H	OMe	H	H	OH	H	H	H	H
[**100**] Dendrodevonin A	OH	H	H	O	OH	H	OMe	H	H	H
[**101**] Dendrovonin B	OH	H	H	O	OH	H	OMe	H	H	H
[**102**] Moscatin	H	H	OH	OMe	H	OH	H	H	H	H
[**103**] Loddigesiinol A	OH	H	OMe	OMe	H	H	H	OH	H	H
[**104**] Dendroscabrol A	OH	OMe	OMe	H	H	OMe	H	H	H	H
[**105**] Nudol	OH	OMe	OMe	H	H	OH	H	H	H	H
[**106**] Plicatol A	OH	H	OMe	OH	H	H	H	OMe	OMe	OH
[**107**] Plicatol B	OH	H	OMe	OH	H	H	H	H	H	H
[**108**] 2,3,5-Trihydroxy-4,9-dimethoxy phenanthrene	OH	OH	OMe	OH	H	H	H	OMe	H	H
[**109**] 3,4,8-Trimethoxyphenanthrene-2,5-diol	OH	OMe	OMe	OH	H	H	OMe	H	H	H
[**110**] Bulbophyllanthrin	OMe	OH	OMe	OH	H	H	H	H	H	H

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)

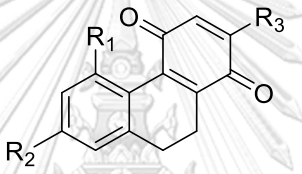


	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
[**111**] Denthyrsinin	OMe	OH	OMe	H	H	OH	OMe	H	H	H
[**112**] 5-Hydroxy-2,4-dimethoxy phenanthrene	OMe	H	OMe	OH	H	H	H	H	H	H
[**113**] 3-Hydroxy-2,4,7-trimethoxyphenanthrene	OMe	OH	OMe	H	OMe	H	H	H	H	H
[**114**] Confusarin	OH	H	H	OMe	OMe	OH	H	H	H	OMe
[**115**] 2,6-Dihydroxy-1,5,7-trimethoxy phenanthrene	OH	H	H	OMe	OH	OMe	H	H	H	OMe
[**116**] 1,5,7-Trimethoxyphenanthre-2-ol	OH	H	H	OMe	H	OMe	H	H	H	OMe

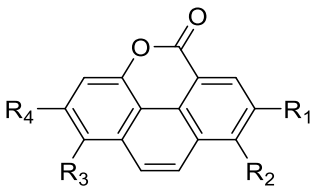
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



	R_1	R_2	R_3	R_4	R_5
[**117**] Cypripedin	H	OH	OMe	OMe	H
[**118**] Densiflorol B	H	OH	H	OMe	H
[**119**] Denbinobin	OH	OMe	H	H	OMe

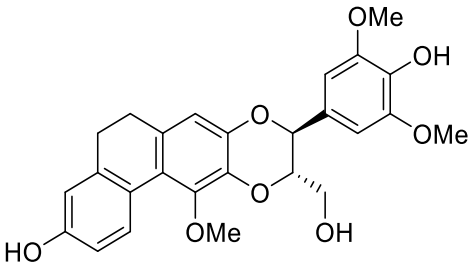


	R_1	R_2	R_3
[**120**] Dendronone	OH	OMe	H
[**121**] Ephemeranthoquinone	H	OH	OMe
[**122**] 5-Methoxy-7-hydroxy-9,10-dihydro-1,4-phenanthrenequinone	OMe	OH	H

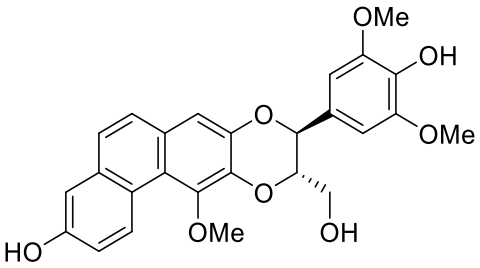


	R_1	R_2	R_3	R_4
[**123**] Fimbriatone	OH	OMe	H	OH
[**124**] Crystalltone	OMe	H	OH	EtO

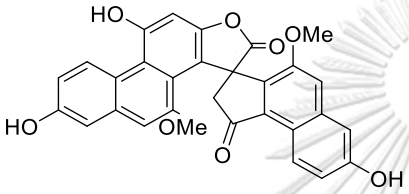
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



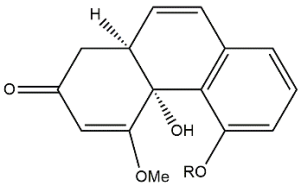
[**125**] Dendrocandin P2



[**126**] Dendrocandin P1

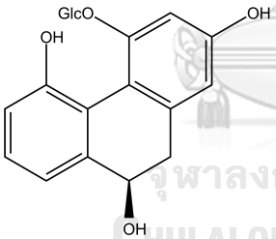


[**127**] Dendrochrysanene

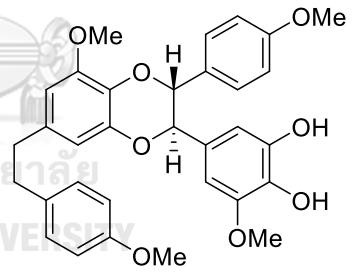


[**128**] Aphyllone: R = H

[**129**] 9,10-Dihydro-aphyllone A-5-*O*-β-D-glucopyranoside: R = Glc

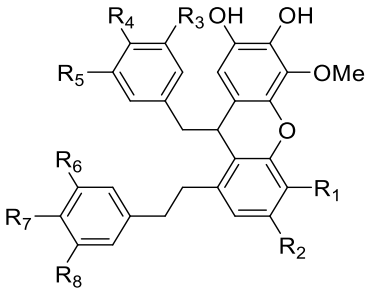


[**130**] 2,4,5,9*S*-Tetrahydroxy-9,10-dihydro-phenanthrene-4-*O*-β-D-glucopyranoside

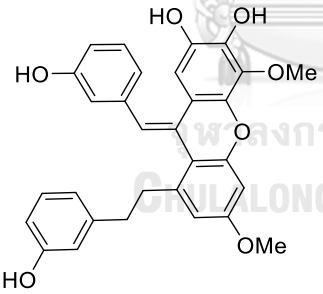


[**131**] Dendrocandin I

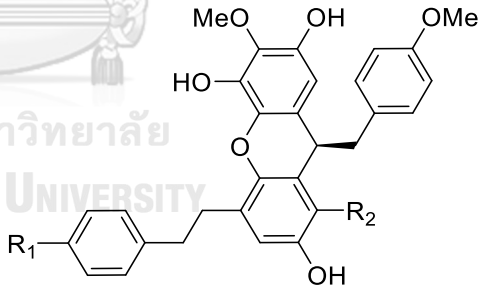
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
[**132**] Dendrocandin F	H	OMe	H	OMe	H	H	OMe	H
[**133**] Dendrocandin G	OH	OMe	H	OH	H	H	OMe	H
[**134**] Dendrosinen D	OH	OMe	OH	H	H	OH	H	H
[**135**] Dendrofalconerol B	H	OH	H	OMe	H	H	OH	H
[**136**] Nobilin E	OH	OMe	H	H	OMe	H	H	OMe



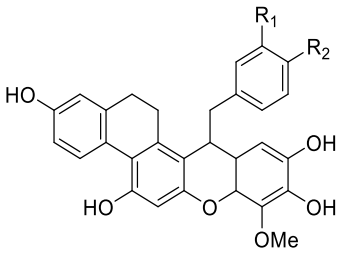
[**138**] Dengraol A: R_1 = OH, R_2 = H



[**137**] Dendroscabrol B

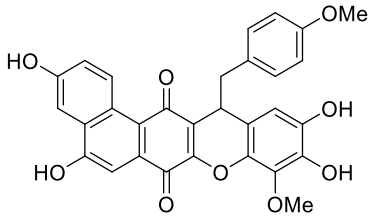
[**139**] Dengraol B: R_1 = R_2 = OMe

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)

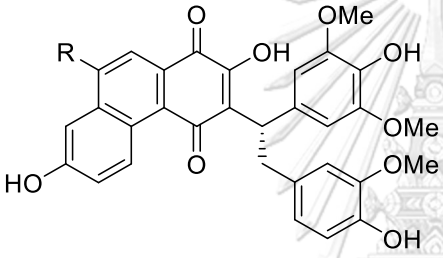


[**140**] Dendrosignatol: R_1 = H, R_2 =OMe

[**141**] Dendroparishiol: R_1=OMe, R_2=OH

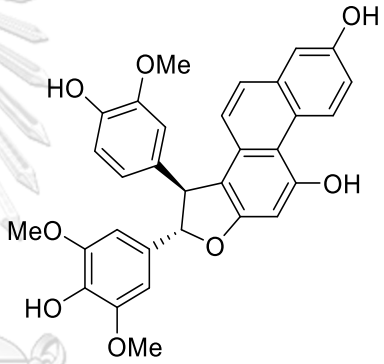


[**142**] Dendrocandin H

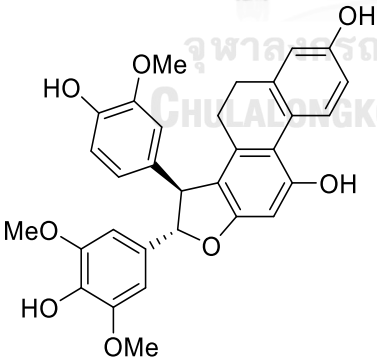


[**143**] Loddigesiinol G: R = H

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

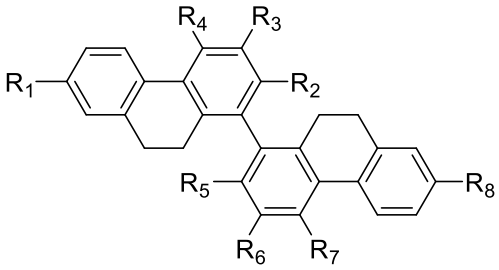


[**145**] Loddigesiinol I

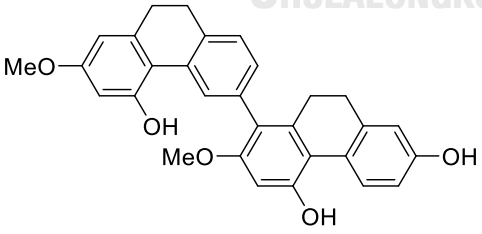


[**146**] Loddigesiinol J

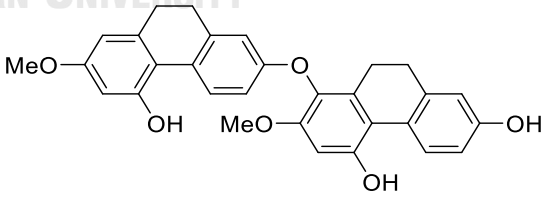
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
[**147**] 2,2′-Dihydroxy-3,3′,4,4′, 7,7′-hexam-ethoxy-9,9′, 10, 10′-tetrahydro-1,1′-biphenan- threne	OMe	OH	OMe	OMe	OH	OMe	OMe	OMe
[**148**] 2,2′-Dimethoxy-4,4′,7,7′- tetrahydroxy-9,9′,10,10′-tetrahydro-1,1′-biphenanthrene	OH	OMe	H	OH	OMe	H	OH	OH
[**149**] Flavanthrin	OH	OH	H	OMe	OH	H	OMe	OH

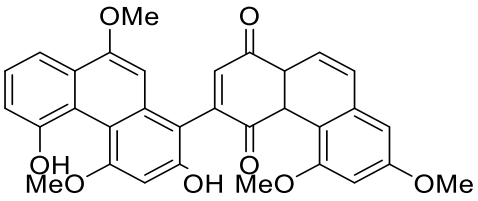


[**150**] Phoyunnanin C

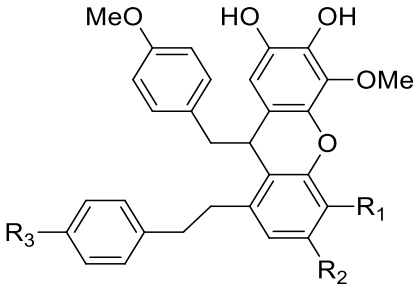


[**151**] Phoyunnanin E

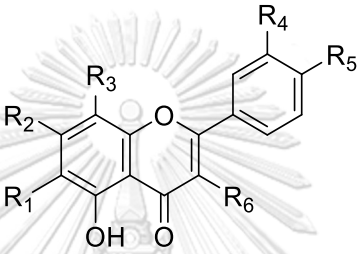
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



[**152**] Dendropalpebrone

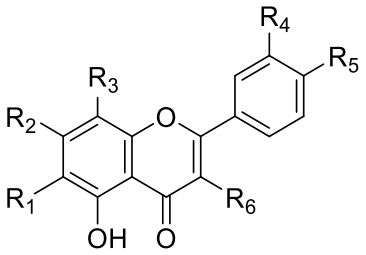


[**153**] Dendrofalconerol A



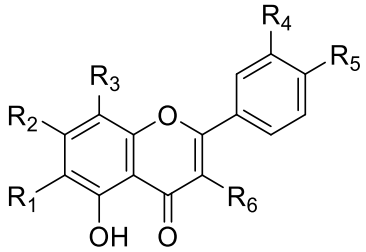
	R_1	R_2	R_3	R_4	R_5	R_6
[**154**] Apigenin	H	OH	H	H	OH	H
[**155**] Isovitexin	-Glc	OH	H	H	OH	H
[**156**] Apigenin-6-*C*-glucosyl-(1→2)-α-L-arabinoside	[Ara-]$_2$	OH	H	H	OH	H
[**157**] 6-*C*-(α-Arabinopyranosyl)-8-*C*-[(2-*O*-α-rhamnopyranosyl)-β-glucopyranosyl]apigenin	-Ara	OH	-Glc-Rha	H	OH	H
[**158**] 6-*C*-(β-Xylopyrano-syl)-8-*C*-[(2-*O*-α-rhamno-pyranosyl)-β-glucopyranosyl]apigenin	-Xyl	OH	-Glc-Rha	H	OH	H
[**159**] 5,6-Dihydroxy-4′ methoxyflavone	OH	H	H	H	OMe	H

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



	R_1	R_2	R_3	R_4	R_5	R_6
[**160**] 6‴-Glucosyl-vitexin	H	OH	-$(Glc)_2$	H	OH	H
[**161**] 5-Hydroxy-3-methoxy-flavone-7-*O*-[[β-D-apiosyl-(1⟶6)]-β-D-glucoside	H	-Glc-Api	H	H	H	OMe
[**162**] Isoschaftoside	-Ara	OH	-Glc	H	OH	H
[**163**] Isoviolanthin	-Rha	OH	-Glc	H	OH	H
[**164**] Kaempferol	H	OH	H	H	OH	OH
[**165**] Kaempferol-3-*O*-α-L-rhamnopyranoside	H	OH	H	H	OH	O-Rha
[**166**] Kaempferol-3,7-*O*-di-α-L-rhamnopyranoside	H	O-Rha	H	H	OH	O-Rha
[**167**] Kaempferol-3-*O*-α-L-rhamnopyranosyl (1⟶2)-β-D-glucopyranoside	H	OH	H	H	OH	O-Glc-Rha
[**168**] Kaempferol-3-*O*-α-L-rhamnopyranosyl(1⟶2)-β-D-xylopyranoside	H	OH	H	H	OH	O-Xyl-Rha

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



	R_1	R_2	R_3	R_4	R_5	R_6
[**169**] Luteolin	H	OH	H	OH	OH	H
[**170**] Vicenin-2	-Glc	OH	-Glc	H	OH	H
[**171**] Quercetin-3-*O*-α-L-Rhamnopyranoside	H	OH	H	OH	OH	-O-Rha
[**172**] Quercetin-3-*O*-α-L-rhamnopyranosyl-(1→2)-β-D-xylopyranoside	H	OH	H	OH	OH	-O-Xyl-Rha

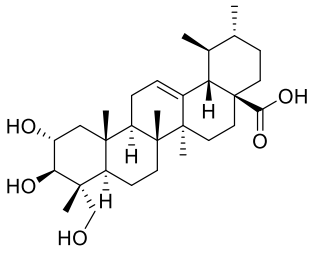
[**173**] (2*S*)-Homoeriodictyol: R = OMe

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

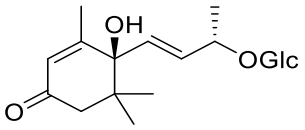
[**175**] (2*S*)-Eriodictyol: R = OH

[**176**] Amoenin

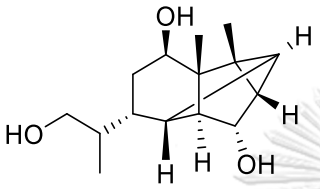
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



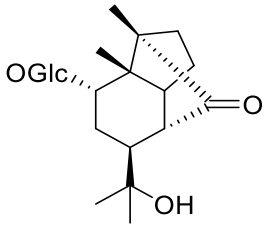
[**177**] Asiatic acid



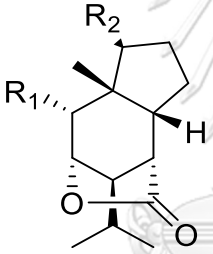
[**178**] Corchoionoside C



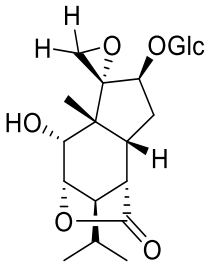
[**179**] Dendrobane A



[**180**] Dendromoniliside A



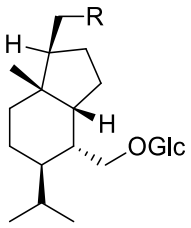
[**181**] Dendromoniliside B,R_1 = OGlc,R_2 = COOH



[**182**] Dendromoniliside C

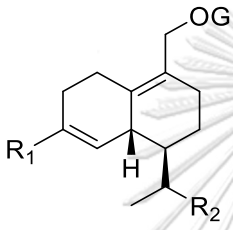
[**183**] Dendromoniliside D, R_1 = OH, R_2 = OGlc

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



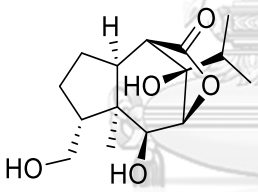
[**184**] Dendronobiloside A: R = OGlc

[**185**] Dendronobiloside B: R = OH

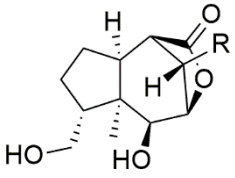


[**186**] Dendronobiloside C, R_1= -CH_2OGlc, R_2=H

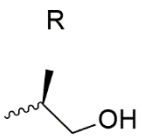
[**187**] Dendronobiloside D, R_1=H, R_2= OGlc



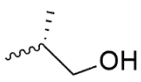
[**190**] Dendronobilin B

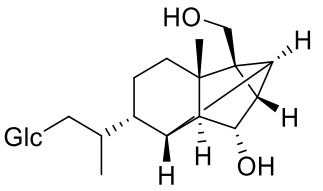


[**192**] Dendronobilin D

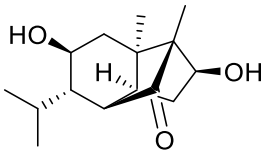


[**193**] Dendronobilin E

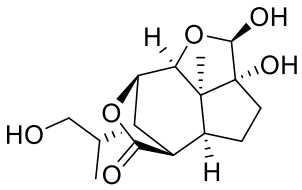




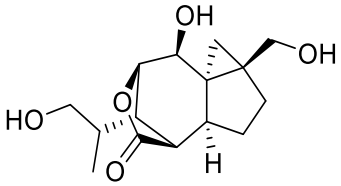
[**188**] Dendronobiloside E



[**189**] Dendronobilin A

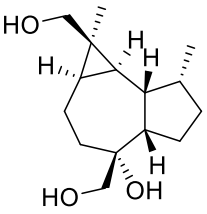


[**191**] Dendronobilin C

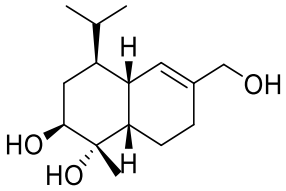


[**194**] Dendronobilin F

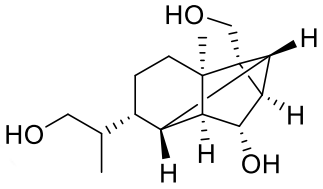
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



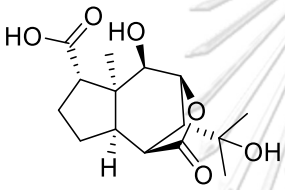
[**196**] Dendronobilin H



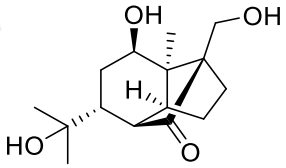
[**195**] Dendronobilin G



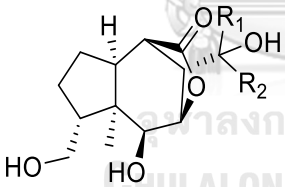
[**197**] Dendronobilin I



[**198**] Dendronobilin J



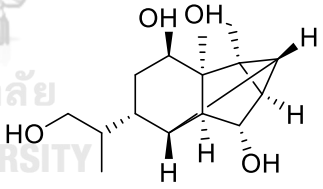
[**199**] Dendronobilin K



[**200**] Dendronobilin L, R_1=CH_3, R_2=CH_3

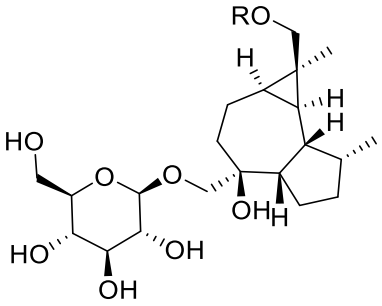
[**201**] Dendronobilin M, R_1=CH_2OH,

R_2=OH



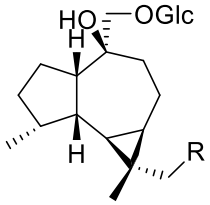
[**202**] Dendronobilin N

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



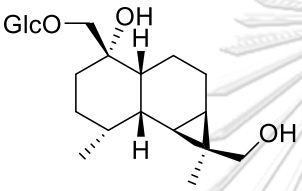
[**203**] Dendroside A : R = H

[**204**] Dendroside B : R = Glc

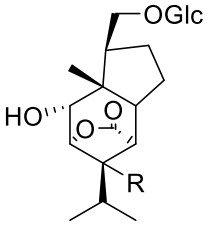


[**205**] Dendroside C; R = OH

[**206**] Dendroside D; R= OGlc



[**207**] Dendroside E

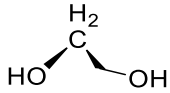


[**208**] Dendroside F; R = H

[**209**] Dendroside G; R = OH

[**212**] Dendrowardol C

R

[**210**] Dendrowardol A 

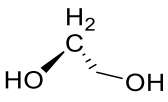
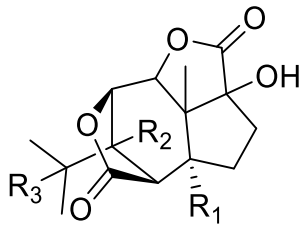
[**211**] Dendrowardol B 

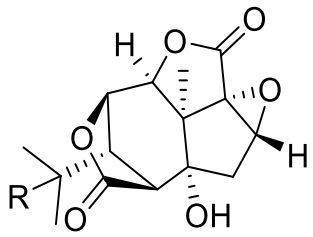
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



[**213**] Amotin: R_1 = R_3 = H, R_2 = OH

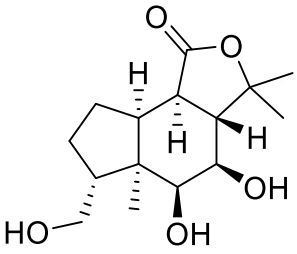
[**214**] Dendrowillin A: R_1 = R_3 = OH, R_2 = H

[**215**] Dendrowillin B: R_1 = R_2 = H, R_3 = OH

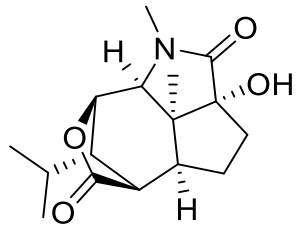


[**216**] α-Dihydropicrotoxinin: R = H

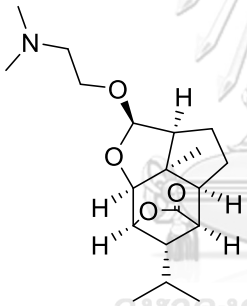
[**217**] Picrotin: R = OH



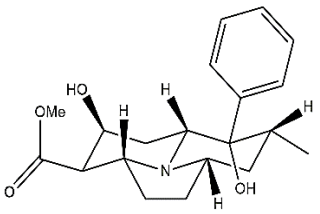
[**218**] Findlayanin



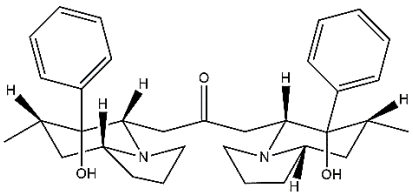
[**219**] 3-Hydroxy-2-oxodendrobine



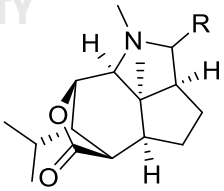
[**220**] Wardianumine A



[**221**] Crepidtumines A



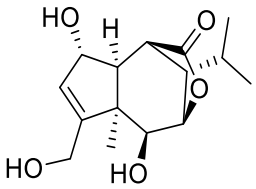
[**222**] Crepidtumines B



[**223**] (-)-(1*R*,2*S*,3*R*,4*S*,5*R*,6*S*,9*S*,11*R*)-11 Carboxymethyldendrobine: R = CH_2COOH

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

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)

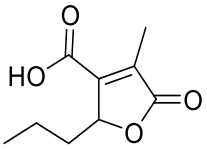


[**225**] Crystalline

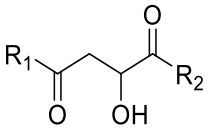
CH3-(CH2)n-CH2-R

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

[**227**] Aliphatic alcohols: R = OH, n = 22-32

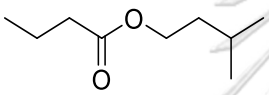


[**228**] Decumbic acid

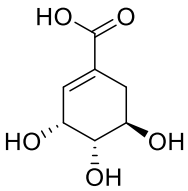


[**229**] Dimethyl malate: R_1 = R_2 = OMe

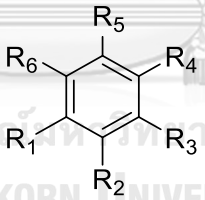
[**230**] Malic acid: R_1 = R_2 = OH



[**231**] Isopentyl butyrate

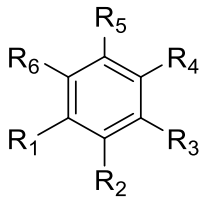


[**232**] (-)-Shikimic acid

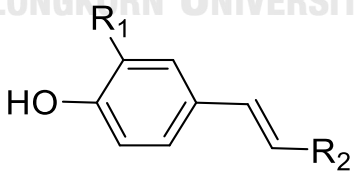


	R_1	R_2	R_3	R_4	R_5	R_6
[**233**] Antiarol	OMe	OMe	H	OH	H	OMe
[**234**] Ethylhaematommate	H	CH_3	$COOC_2H_5$	OH	CHO	OH
[**235**] Gallic acid	OH	OH	OH	H	COOH	H
[**236**] *p*-Hydroxy-benzaldehyde	OH	H	H	CHO	H	H
[**237**] *p*-Hydroxybenzoic acid	H	OH	H	H	H	COOH

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)

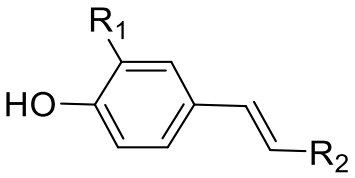


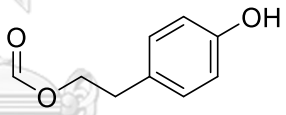
	R_1	R_2	R_3	R_4	R_5	R_6
[**238**] 3-Hydroxy-2-methoxy-5,6-dimethylbenzoic acid	COOH	CH_3	CH_3	H	OH	OMe
[**239**] Methyl-4 hydroxybenzoate	H	H	COOMe	H	H	OH
[**240**] Methyl β-orsellinate	H	OH	COOMe	CH_3	H	OH
[**241**] Protocatechuic acid	H	OH	OH	H	COOH	H
[**242**] Salicylic acid	H	H	H	COOH	OH	H
[**243**] Syringic acid	OMe	OH	OMe	H	COOH	H
[**244**] Tachioside	H	H	OH	OMe	H	-OGlc
[**245**] Vanillic acid	H	OH	OMe	H	COOH	H
[**246**] Vanillin	OH	H	H	CHO	H	OMe
[**247**] Vanilloside	-OGlc	H	H	CHO	H	OMe

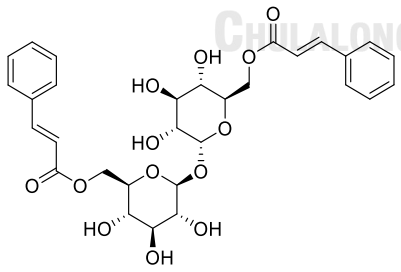


	R_1	R_2	
[**248**] Alkyl 4′-hydroxy-*trans*-cinnamates	H	COO-C_nH_{2n+1}	n =22-32
[**249**] Alkyl *trans*-ferulates	OMe	COO-C_nH_{2n+1}	n=18-28,30
[**250**] Defuscin	H	COO-$(CH_2)_{29}CH_3$	

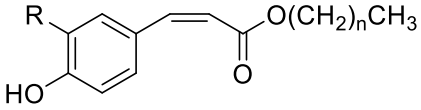
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



	R_1	R_2
[**251**] *n*-Octacosyl ferulate	OMe	COO- $(CH_2)_{27}CH_3$
[**252**] *n*-Triacontyl *p*-hydroxy-*cis*-cinnamate	H	COO-$C_{30}H_{61}$
[**253**] Tetratriacontanyl-*trans*-*p*-coumarate	H	COO-$(CH_2)_{33}CH_3$
[**254**] *n*-Docosyl *trans*-ferulate	OMe	COO-$(CH_2)_{21}CH_3$
[**255**] *trans*-Tetracosyl ferulate	OMe	COO-$(CH_2)_{23}CH_3$
[**256**] Ferulaldehyde	OMe	CHO
[**257**] Ferulic acid	OMe	COOH
[**258**] 2-(*p*-Hydroxyphenyl)-ethyl-*p*-coumarate	OMe	
[**259**] Coniferyl alcohol	OMe	CHO



[**260**] Dendroside

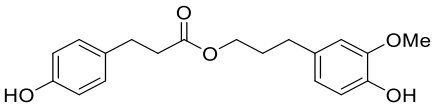


[**261**] *cis*-Hexacosanoyl ferulate:R= OMe, n=25

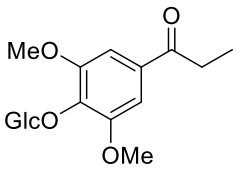
[**262**] *cis*-Tetracosanoyl ferulate :R= OMe, n=22

[**263**] Tetracosyl (*Z*)-*p*-coumarate:R= H, n=23

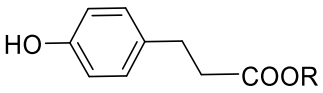
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



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

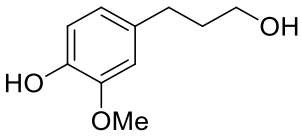


[**265**] 1-[4-(β-D-glucopyranosyloxy)-3,5-dimethoxyphenyl]-1-propanone

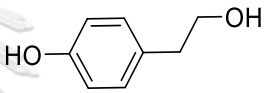


[**266**] *p*-Hydroxyphenyl propionic methyl ester: R = CH_3

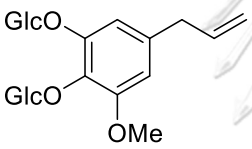
[**267**] Phloretic acid: R =H



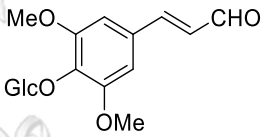
[**268**] Dihydroconiferyl alcohol



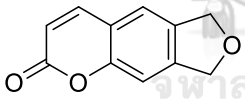
[**269**] Salidrosol



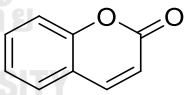
[**270**] Shashenoside I



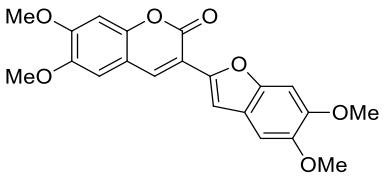
[**271**] Syringin



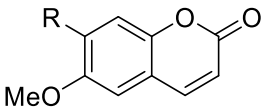
[**272**] Ayapin



[**273**] Coumarin



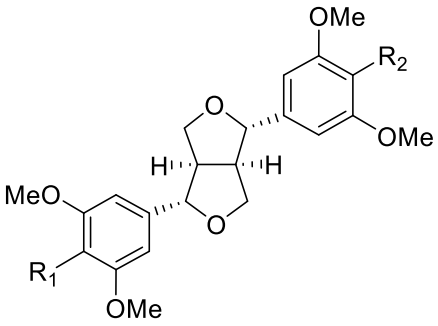
[**274**] Denthyrsin



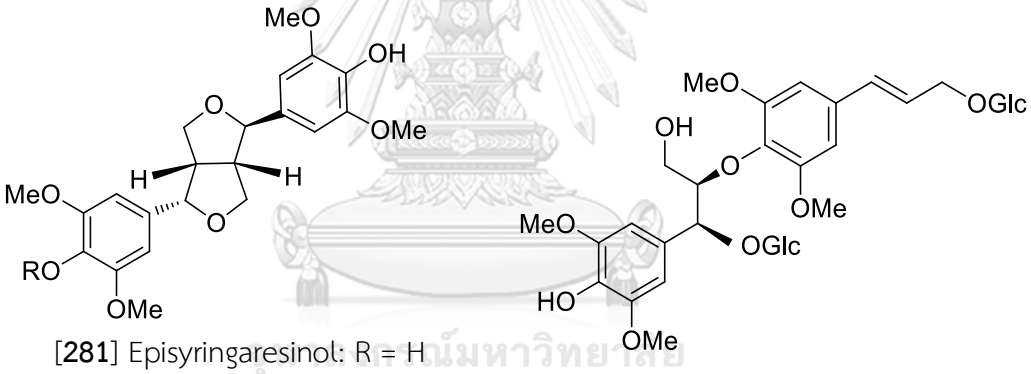
[**275**] Scoparone: R = OMe

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

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



	R_1	R_2
[**277**] Acanthoside B	OGlc	OH
[**278**] Liriodendrin	OGlc	OGlc
[**279**] Syringaresinol	OH	OH
[**280**] Syringaresinol-4-*O*-D-monoglucopyranoside	OGlc	H

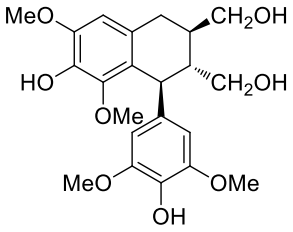


[**281**] Episyringaresinol: R = H

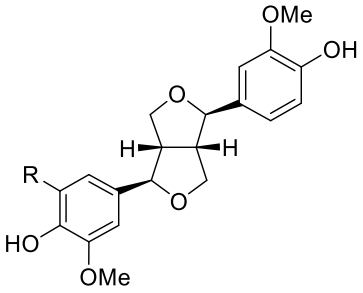
[**282**] Episyringaresinol 4′′-*O*-β-D-glucopyranoside: R = Glc

[**283**] (-)-(7*S*,8*R*,7′*E*)-4-Hydroxy-3,3′,5,5-tetramethoxy-8,4′-oxyneolign-7′-ene 7,9,9′-triol-7,9′-bis-*O*-β-D-gluco-pyranoside

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)

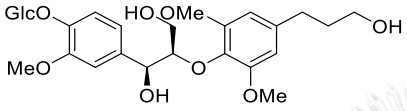


[**284**] Lyoniresinol

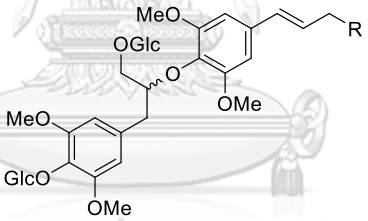


[**285**] (-)-Medioresinol: R = OMe

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



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

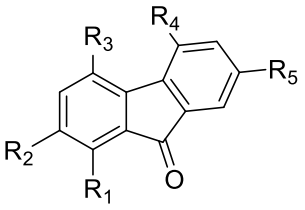


[**288**] (-)-(8*R*,7′*E*)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-*O*-β-D-glucopyranoside: R = OH; 8*R*

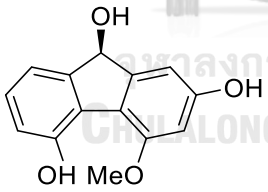
[**289**] (-)-(8*S*,7′*E*)-4-Hydroxy-3,3′,5,5′-tetramethoxy-8,4′-oxyneolign-7′-ene-9,9′-diol 4,9-bis-*O*-β-D-glucopyranoside: R = OH; 8*S*

[**290**] (-)-(8*R*,7′*E*)-4-Hydroxy-3,3′,5,5′,9′-pentamethoxy-8,4′-oxyneolign-7′-ene-9-ol 4,9-bis-*O*-β-D-glucopyranoside: R = OMe; 8*R*

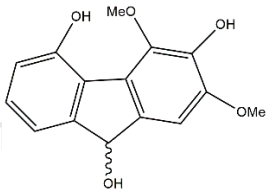
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



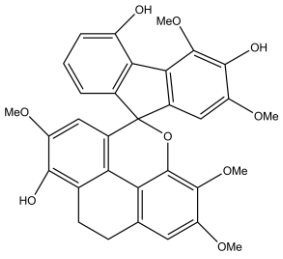
	R_1	R_2	R_3	R_4	R_5
[**291**] Denchrysan A	H	OH	OH	OMe	OH
[**292**] Dendroflorin	OH	H	OH	OMe	OH
[**293**] Dengibsin	H	OH	OMe	OH	H
[**294**] Nobilone	H	OH	H	OMe	OH
[**295**] 1,4,5-Trihydroxy-7-methoxy-9*H*-fluoren-9-one	OH	H	OH	OH	OMe
[**296**] 2,4,7-Trihydroxy-5-methoxy-9-fluorenone	OMe	OH	OH	H	OH
[**297**] 2,4,7-Trihydroxy-1,5-dimethoxy-9-fluorenone	OMe	OH	OH	OMe	OH



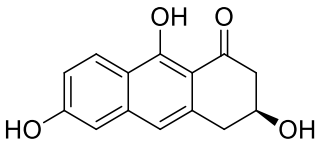
[**298**] Denchrysan B



[**299**] Dendrogibsol

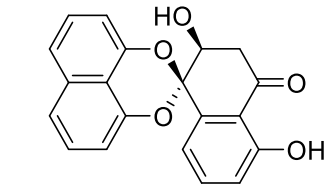


[**300**] Dihydrodengibsinin

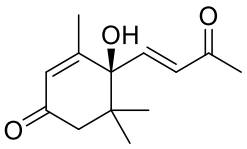


[**301**] 3,6,9-Trihydroxy-3,4-dihydroanthracen-1-(2*H*)-one

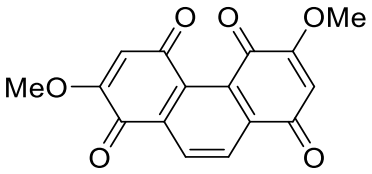
Figure 2 Structures of compounds from *Dendrobium* spp. (continued)



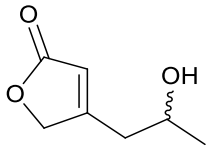
[**302**] Palmarumycin JC2



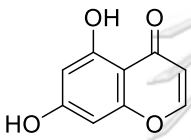
[**303**] Dehydrovomifoliol



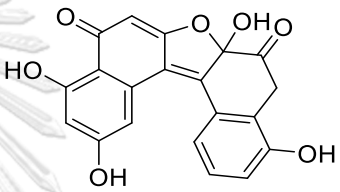
[**304**] Moniliformin



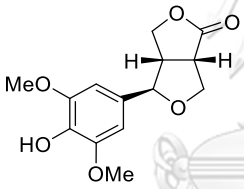
[**305**] 4-(2-Hydroxypropyl)-2(5*H*)-furanone



[**306**] 5,7-Dihydroxy-chromen-4-one



[**307**] RF-3192C



[**308**] Dendrolactone

Figure 2 Structures of compounds from *Dendrobium* spp. (continued)

4. Biological activities of *Dendrobium* spp.

Crude extract and isolated compounds from *Dendrobium* spp. have been found to have various skin anti-aging activities such as antioxidant, anti-melanogenesis, and matrix metalloproteinase (MMP) inhibition.

4.1 Antioxidant activities

There are several studies that crude extracts and chemical compounds of *Dendrobium* spp. showed potential antioxidant activities. The polysaccharide fraction DDP2-1 which was separated from *D. denneanum*, exhibited potent DPPH scavenging

activity, but its scavenging ABTS radicals was not effective (Fan et al., 2009). A water crude polysaccharide (DFHP) obtained from *D. fimhriatum* had percentage of inhibition nearly ascorbic acid on hydroxyl radical, and ABTS scavenging activities, but the inhibitory effect on DPPH scavenging was weak (Luo et al., 2011). The crude of *D. officinale* polysaccharides (DOP) showed DPPH, and ABTS scavenging action as well as chelating activity, but it was less potent than ascorbic acid and EDTA respectively (Lui et al., 2016). The *D. tosaense* (DT) extract had strong ABTS scavenging with TEAC of 66.0 ± 3.0 trolox/mg DT extract and the reducing power VCEAC of 12.00 ± 0.50 L-ascorbic acid/mg DT extract. However, 50% ethanol extract at room temperature (RT+50E) has the lowest activities ABTS free radical scavenging of 1.30 ± 0.00 mg (Chan et al., 2018). Fan et al. (2018) found that IC_{50} values of five fractions of DOPs obtained from *D. officinale* (42.39-58.77 μg/mL) were similar to the ascorbic acid (38.21 μg/mL). (-)-Dendroparishiol isolated from *D. parashii* had the highest antioxidant activities of oxygen radical absorbance capacity (ORAC), DPPH, and deoxyribose (Kongkatitham et al., 2018). In addition, Ma et al. (2019) found that eight compounds (dihydro-*p*-coumarate, tristin, crepidatin, moscatilin, 4′,5-dihydroxy-3-3′-dimethoxybibenzyl, 4,5,4′-trihydroxy-3-3′-dimethoxybibenzyl, dihydroconiferyl, thero-7-*O*-ethyl-9-*O*-4-hydroxyphenyl propyonyl-guaiacylglycerol, and *p*-hydroxyphenethyl *trans*-ferulate)had effects on inhibition of DPPH free radical at concentration of 100 μg/mL up to 90%. The *D. officinale* supernatant (DOP-S) and *D. officinale* fermentation (DOP-F) of the crude extracts exhibited DPPH and ABTS scavenging activity with IC_{50} values of 4.9, 1.0, 1.4, and 0.3 mg/mL (Li et al., 2020).

4.2 Tyrosinase inhibitory activities

The effect of crude extracts and compounds of *Dendrobium* spp. on tyrosinase inhibitory activities have been reported. The *D. moniliforme* partitioned using CH_2Cl_2 (DMC) showed inhibition activities of both melanogenesis (tyrosinase-related protein-1 and -2, TRP-1 and TRP-2) and murine melanoma cells (B16F10) depending on its concentration (12.5, 25, and 50 μg/mL) (Ko et al., 2015). Kanlayavattanakul et al. (2018) reported the extract of *D. sonia* earsakul flowers with 70% EtOH at 1.0 mg/mL inhibited melanogenesis (17.76 ± 2.95%) lower than kojic

acid at the same concentration (39.44 ± 9.61%). However, 70% EtOH extract at 0.1 mg/mL was able to inhibit the anti-tyrosinase mechanism (34.51 ± 7.16%) and anti-TRP-2 activity (89.20 ± 13.88%), which are better than kojic acid (31.74 ± 4.42% and 53.90 ± 0.71% at 0.1 mg/mL, respectively). The similar results were examined by Athipornchai and Jullapo (2018) reporting that *D. sonia* flower extract had a potential tyrosinase inhibition activity using a substrate L-tyrosine and L-DOPA with an IC_{50} values of 57.38 ± 9.26% and 816.81 ± 49.17%, respectively. Moreover, Chan et al. (2018) also reported that 50% ethanol extract at room temperature (RT+50E)of DT had strongest anti-mushroom tyrosinase activity at IC_{50} 6.40 ± 0.30 mg/mL. In addition, the DT extract using temperature at 50°C (50T) with water (50T+W), and RT+50E exhibited a strong anti-melanin production on B16/F10 cells by 35.0 ± 3.0%, 33.0 ± 7.0% and 36.0 ± 3.0%, respectively. Furthermore, 3,5,3′-hydroxybibenzyl and aphyllals C isolated from *D. loddigesii* showed tyrosinase inhibition with an IC_{50} values of 37.90 and 152.56 µg/mL, respectively (Ma et al., 2019).

4.3 Collagen production and enzymatic inhibition

Recently, Kanlayavattanakul et al. (2018) reported the extract of *D. sonia* earsakul flowers with 70% EtOH at 0.1 and 1.0 mg/mL had a strong anti-matrix metalloproteinase-2 (MMP-2), while the water extract at 0.1 mg/mL showed moderate anti-MMP-2 by 43.10 ± 1.02%. However, antipro-MMP-2 of both extracts were lower. Moreover, Batatasin III, isolated from *D. loddigesii* at 10 µg/mL increased collagen production (78.92%) in human dermal fibroblast (HDF) but 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl and 4′,5-dihydroxy-3,3′-dimethoxybibenzyl at 10 µg/mL showed lower collagen production by 33.06% and 29.15%, respectively (Ma et al.,2019).

CHAPTER III

EXPERIMENTAL

1. Source of plant materials

1.1 *Dendrobium pachyglossum* Par. & Rchb.f.

The whole plants of *Dendrobium pachyglossum* were purchased from Chatuchak market, Bangkok, in July 2015. Plants identification was performed by Assoc. Prof. Boonchoo Sritularak, Ph.D. and comparison with database of the Botanical Garden Organization. A voucher specimen (BS-DPachy-072558) has been deposited at the herbarium of the Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University.

1.2 *Dendrobium heterocarpum* Lindl.

The whole plants of *Dendrobium heterocarpum* were purchased from Chatuchak market, Bangkok, in June 2019. Plants identification was performed by Mr. Yanyong Punpreuk, department of Agriculture and comparison with database of the Botanical Garden Organization. A voucher specimen (BS-Dhet-012562) has been deposited at the herbarium of the Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University.

2. Experimental techniques

2.1 Analytical thin-layer chromatography (TLC)

2.1.1 Normal-phase thin-layer chromatography

Technique	:	One-dimension ascending
Absorbent	:	Silica gel 60 F254 precoated plate (E. Merck)
Layer thickness	:	0.2 mm
Distance	:	5.0 cm
Temperature	:	Laboratory temperature (30-35 ºC)
Detection	:	Ultraviolet light at wavelengths of 254 and 365 nm

2.1.2 Reverse-phase thin-layer chromatography

Technique	:	One-dimension ascending
Absorbent	:	RP C-18 precoated on aluminum sheet (Anal Tech)
Layer thickness	:	0.2 mm
Distance	:	5.0 cm
Temperature	:	Laboratory temperature (30-35 ºC)
Detection	:	Ultraviolet light at wavelengths of 254 and 365 nm.

2.2 Column chromatography (CC)

2.2.1 Vacuum liquid chromatography (VLC)

Adsorbent	:	Silica gel 60 (No. 107734), size 0.063-0.200 mm (E.Merck)
Packing method:		Dry packing
Sample loading:		The sample was dissolved in a small volume of organic solvent, triturated with a small amount of the adsorbent, dried and then gradually placed on top of the column.
Detection	:	Each fraction was examined by TLC under UV light at the wavelengths of 254 and 365 nm.

2.2.2 Flash column chromatography (FCC), normal phase

Adsorbent	:	Silica gel 60 (No. 109385), size 0.040-0.063 mm (E. Merck)
Packing method:		Wet packing
Sample loading:		The sample was dissolved in a small volume of organic solvent, triturated with a small amount of the adsorbent, dried and then gradually placed on top of the column.
Detection	:	Fractions were examined as described in section 2.2.1

2.2.3 Flash column chromatography (FCC), reverse phase

Adsorbent	:	C-18 (No. 113900), size 40-63 μm (E. Merck)
Packing method:		Wet packing
Sample loading:		The sample was dissolved in a small volume of organic solvent, and then gradually loaded on top of the column.

Detection : Fractions were examined as described in section 2.2.1

2.2.4 Gel filtration chromatography

Gel filter : Sephadex LH-20, particle size 25-100 μm (GE Healthcare)

Packing method: The gel filter was suspended in an appropriate solvent, left standing about 24 hours and then poured into the column and left to set tightly.

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

Detection : Fractions were examined in a similar manner as described in section 2.2.1.

2.2.5 Semi-preparative high-pressure liquid chromatography (HPLC)

Column : COSMOSIL 5C18-AR-II (4.6ID x 250 mm)

Flow rate : 2 ml/min

Mobile phase : Isocratic 50%-80% methanol in water

Sample preparation: The sample was dissolved in a small volume of the mobile phase and centrifuged for remove particle before injection.

Injection volume: 0.1-1 ml

Pump : LC-8A (Shimadzu)

Detector : SPD-10A UV-Vis Detector (Shimadzu)

Recorder : C-R6A Chromatopac (Shimadzu)

Temperature : Room temperature

2.3 Spectroscopy

2.3.1 Mass spectra

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

2.3.2 Ultraviolet (UV) spectra

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

2.3.3 Infrared (IR) spectra

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

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

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

^{1}H NMR (500 MHz) and ^{13}C NMR (125 MHz) spectra were recorded on a Bruker Avance III HD 500 NMR spectrometer (Scientific and Technology Research Equipment Center, Chulalongkorn University).

^{1}H NMR (600 MHz) and ^{13}C NMR (125 MHz) spectra were recorded on a Bruker Avance III HD 600 NMR spectrometer (Graduate School of Pharmaceutical Sciences, Kyushu University).

Solvents for NMR spectra were deuterated acetone (Acetone-d_6), deuterated dimethyl sulfoxide (DMSO-d_6) or deuterated chloroform ($CDCl_3$). Chemical shifts were reported in *ppm* scale using the chemical shift of the solvent as the reference signal.

2.3.5 Optical rotations

Optical rotations were measured on a Perkin-Elmer 341 polarimeter (Pharmaceutical Research Instrument Center, Faculty of Pharmaceutical Sciences, Chulalongkorn University).

2.4 Solvents

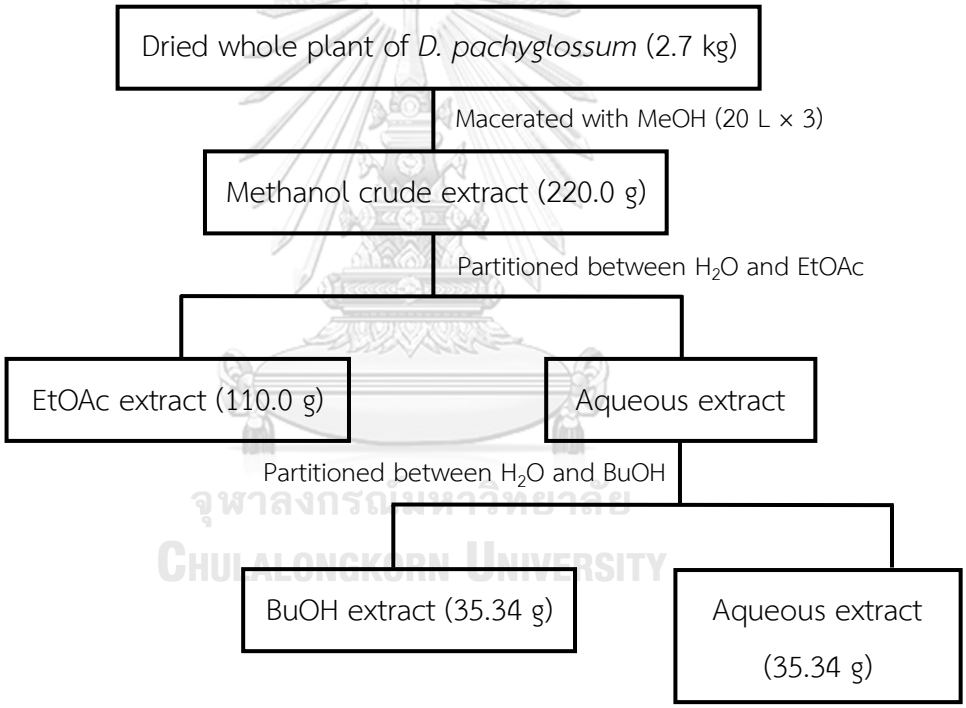
All organic solvents employed throughout this work were of commercial grade and were redistilled prior to use.

3. Extraction and isolation

3.1. Extraction of *Dendrobium pachyglossum*

3.1.1 Extraction

The dried whole plant of *Dendrobium pachyglossum* (2.7 kg) were ground and then macerated with MeOH (20 L × 3) for 72 hours, three times. The organic solvent was evaporated under reduced pressure to give 220.0 g of crude MeOH extract. This material was dispersed in water and partitioned with EtOAc and then *n*-butanol to give an EtOAc extract (110.0 g), a *n*-butanol extract (35.34 g), and an aqueous extract (55.1 g) (**Scheme 1**).



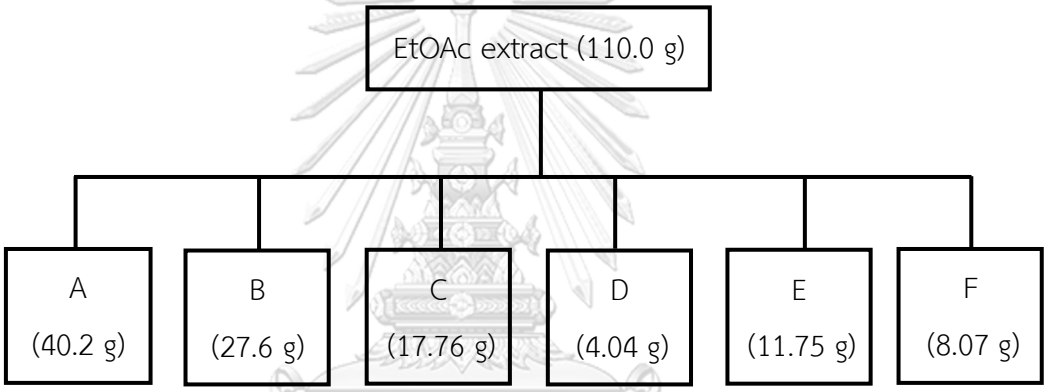
Scheme 1 Extraction of *Dendrobium pachyglossum*

All three extracts were screened for cytotoxicity on HaCaT keratinocyte cells at concentration 200 µg/mL. The results showed that all of extracts showed non-toxicity (percentage of cell viability more than 80%) compared to the control groups. Then, the extracts were tested for antioxidant activity using by the DPPH free radical scavenging assay. The EtOAc and *n*-butanol extracts

represented the highest percentage of inhibition with 85.19% and 80.92% at concentration of 100 µg/mL. Therefore, the EtOAc and *n*-butanol extract were selected for further studies.

3.1.2 Separation of EtOAc extract

The EtOAc extract (110.0 g) was initially fractionated by vacuum-liquid chromatography (VLC) on silica gel (Hexane-EtOAc, gradient). The eluents were collected about 400 mL per fraction and examined by TLC (Silica gel, hexane-EtOAc, 7:3). Then, fractions with similar TLC patterns were combined to give six fractions (A-F) as shown in **Scheme 2.**

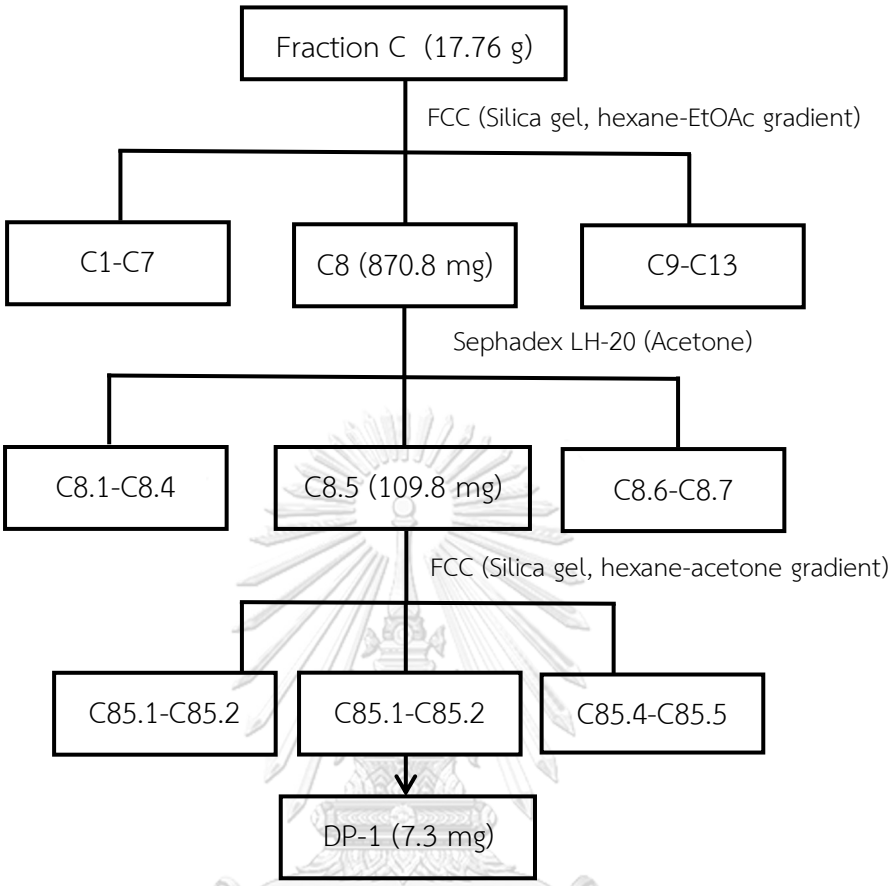


Scheme 2 Separation of the EtOAc extract from *D. pachyglossum*

3.1.3 Isolation of EtOAc extract of *D. pachyglossum*

3.1.3.1 Isolation of compound DP-1 (4,5-dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene)

Fraction C (17.76 g) was separated by flash column chromatography (silica gel, gradient mixture of hexane-EtOAc) to give thirteen fractions (C1-C13) (**Scheme 3**). Fraction C8 (870.8 mg) was further separated on a Sephadex LH-20 column eluted with acetone to afford seven fractions (C8.1-C8.7). Then, fraction C8.5 (109.8 mg) was purified by using FCC (Silica gel, gradient mixture of hexane-acetone) to obtain five fractions (C85.1-C85.5). Fraction C85.3, after drying gave compound DP-1 (7.3 mg), which was identified as 4,5-dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene.

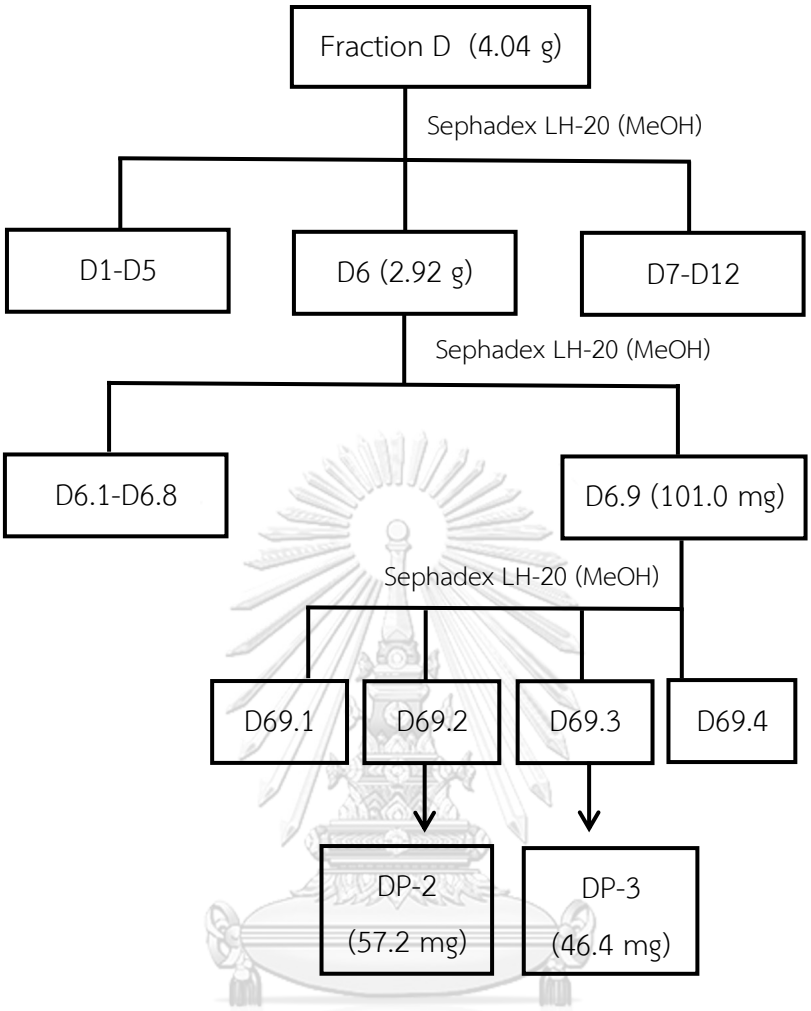


Scheme 3 Separation of fraction C of *D. pachyglossum*

3.1.3.2 Isolation of compound DP-2 (Moscatilin) and DP-3 (Gigantol)

Fraction D (4.04 g) was separated on Sephadex LH-20 column eluted with methanol to give twelve fractions (D1-D12). Fraction D6 (2.62 g) was further separated by using Sephadex LH-20 column eluted with methanol to obtain nine fractions (D6.1-D6.9) (**Scheme 4**).

Fraction D6.9 (101.0 mg) was purified on a Sephadex LH-20 column eluted with methanol to give four fractions (D69.1-D69.4). Fraction D69.2 and D69.3, after drying gave compound DP2 (57.2 mg) and compound DP3 (46.4 mg) and identified as Moscatilin and Gigantol, respectively.



Scheme 4 Separation of fraction D of *D. pachyglossum*

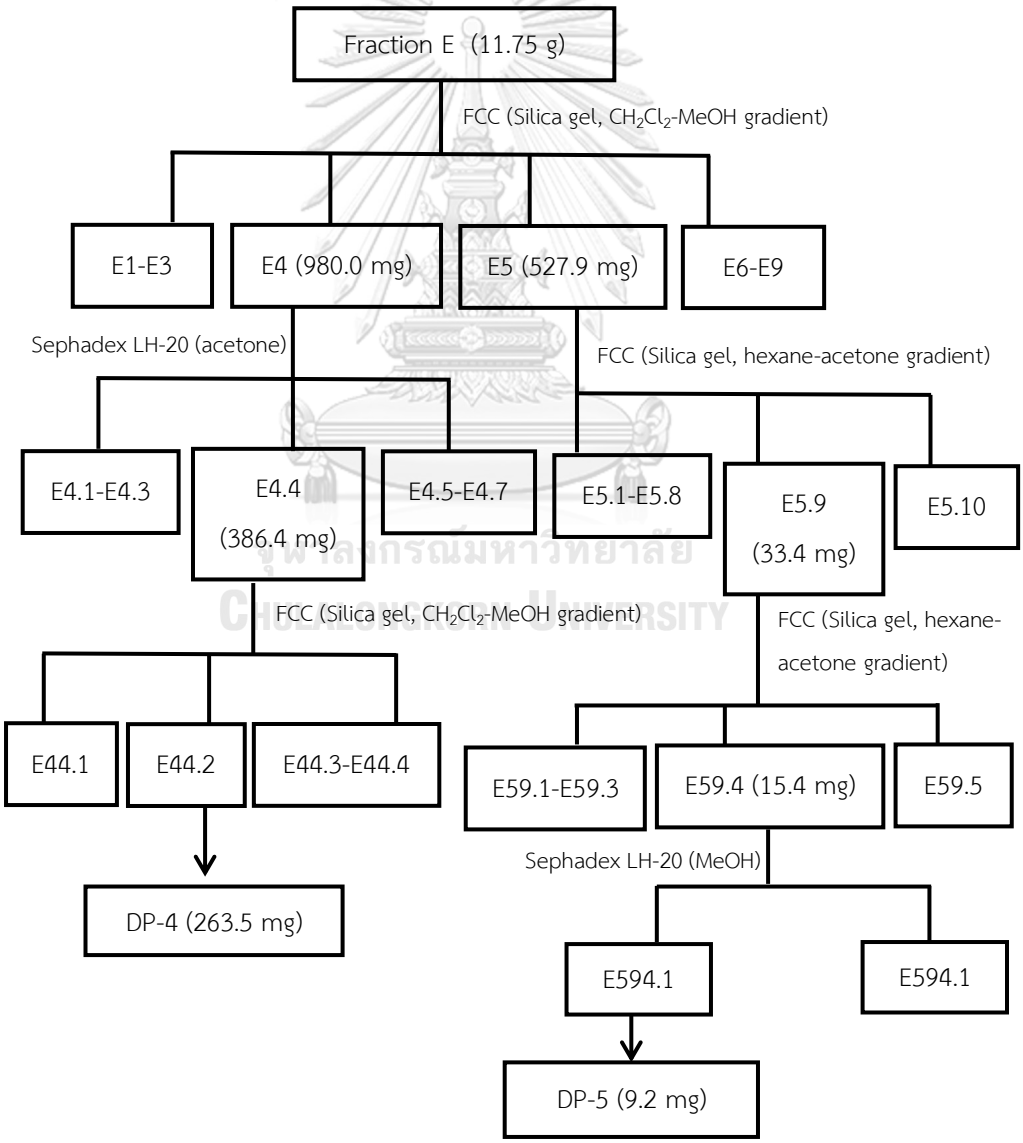
3.1.3.3 Isolation of compound DP-4 (4-5-4′-trihydroxy-3-3′-dimethoxy bibenzyl) and DP-5 (New compound)

Fraction E (11.75 g) was further separated by flash column chromatography (silica gel, gradient mixture of CH_2Cl_2-MeOH) to give nine fractions (E1-E 9) (**Scheme 5**).

Fraction E4 (980.0 mg) was separated on a Sephadex LH-20 column eluted with acetone to afford seven fractions (E4.1-E4.7). Then, fraction E4.4 (386.4 mg) was purified by using FCC (Silica gel, gradient mixture of CH_2Cl_2-MeOH) to obtain four fractions (E44.1-E44.4). Fraction E44.2, after drying gave

compound DP-4 (263.5 mg), which was identified as 4-5-4′-trihydroxy-3-3′-dimethoxy bibenzyl.

Fraction E5 (527.9 mg) was separated by using FCC (Silica gel, gradient mixture of hexane-acetone) to obtain ten fractions (E5.1-E5.10). Fraction E5.9 (33.4 mg) was separated on flash column chromatography (silica gel, gradient mixture of hexane-acetone) to give five fractions (E59.1-E59.5). Then, fraction E59.4 (15.4 mg) was purified on a Sephadex LH-20 column eluted with MeOH to afford 2 fractions (E594.1-E594.2). Fraction E594.2, after drying gave compound DP-5 (9.2 mg), which was identified as new compound.



Scheme 5 Separation of fraction E of *D. pachyglossum*

3.1.3.4 Isolation of compound DP-6 (Dendrocantin T)

Fraction F (8.07 g) was further separated by flash column chromatography (silica gel, gradient mixture of hexane-EtOAc) to give six fractions (F1-F6). Then, fraction F5 (3.32 g) was separated by using flash column chromatography (silica gel, gradient mixture of hexane-acetone) to obtain thirteen fractions (F5.1-F5.13) (**Scheme 6**). Fraction F5.12 (2.94 g) was fractionated on flash column chromatography (silica gel, gradient mixture of hexane-acetone) to give ten fractions (F512.1-512.10). Then, fraction F512.9 (1.30 g) was separated on Sephadex LH20 column eluted with methanol to give eleven fractions (F5129.1-F5129.11). Fraction F5129.7 (118.0 mg) was separated by using Sephadex LH20 column eluted with methanol to obtain ten fractions (F51297.1-F52197.10). Separation of fraction F51297.4 (16.8 mg) on reverse-phase CC (C18, MeOH-H_2O, gradient) to obtain DP-6 (1.0 mg) and identified as Dendrocantin T.

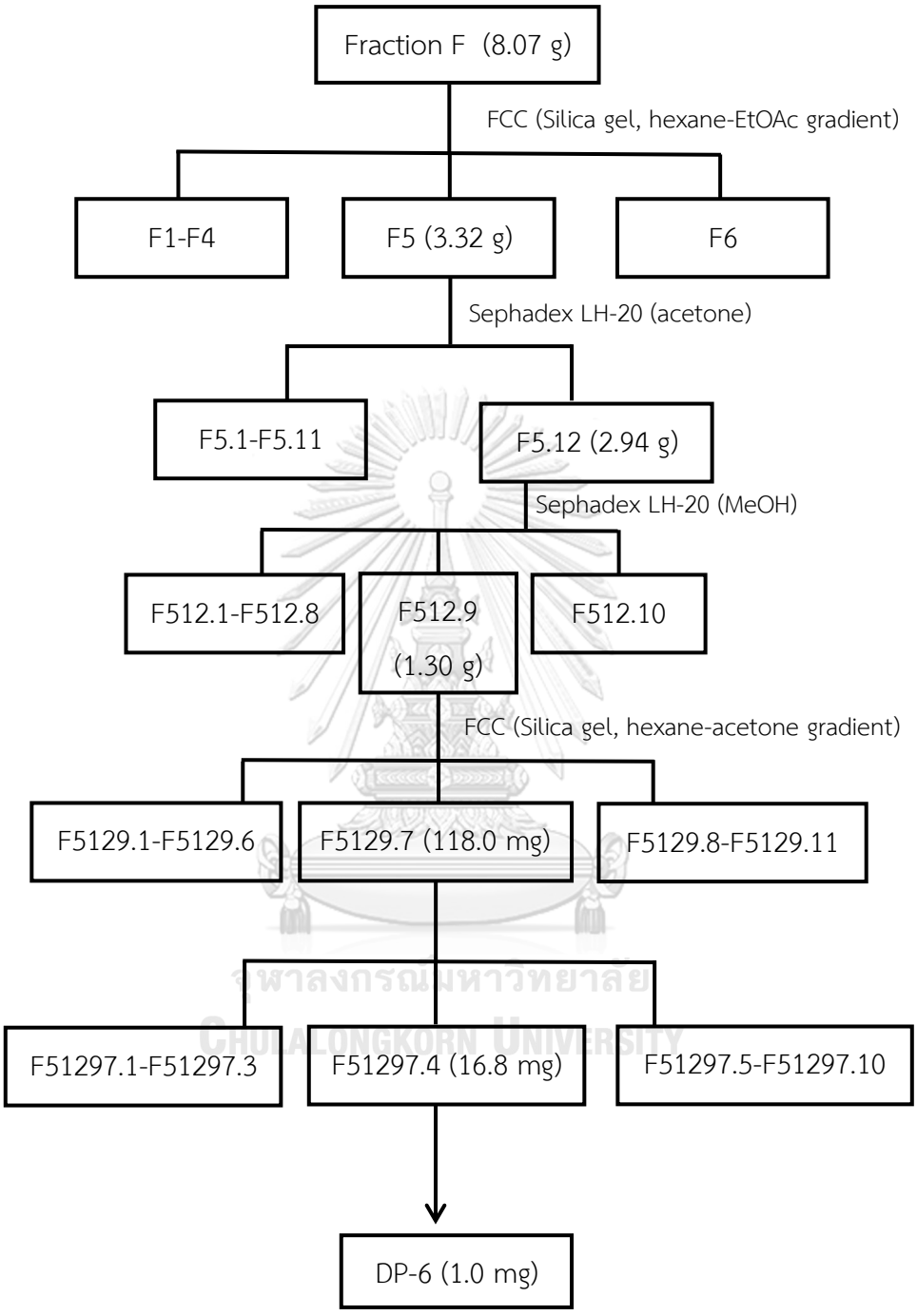
3.1.4 Separation of n-butanol extract of *D. pachyglossum*

The BuOH extract (35.4 g) was initially fractionated by flash column chromatography (Dianion HP20, gradient mixture of MeOH-H_2O). The eluents were collected about 500 mL per fraction and examined by TLC (Silica gel, EtOAc-MeOH, 8.5:1.5). Then, fractions with similar TLC patterns were combined to give three fractions (A-C) (**Scheme 7**).

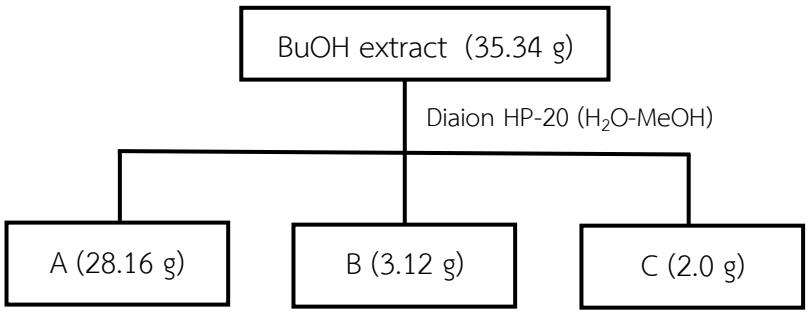
3.1.5 Isolation of BuOH fractions of *D. pachyglossum*

3.1.5.1 Isolation of compound DP-7 (Isovitexin)

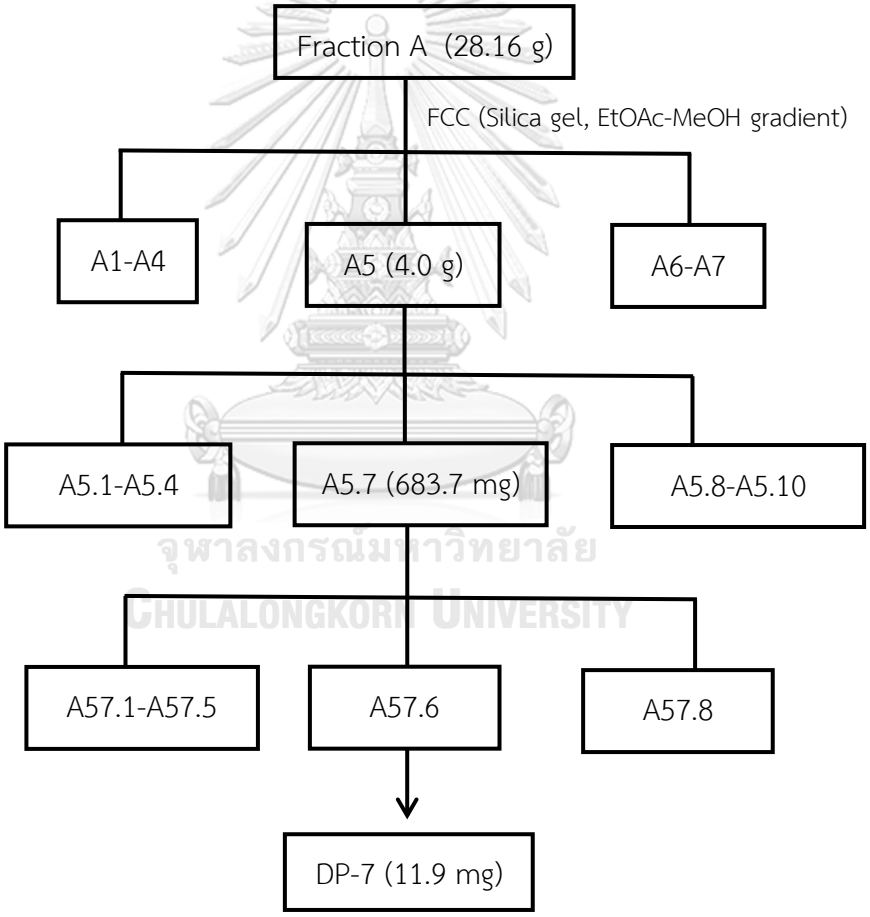
Fraction A (28.16 g) was separated on flash column chromatography (Silica gel, gradient mixture of EtOAc-MeOH) to give seven fractions (A1-A7). Fraction A5 (4.0 g) was fractioned by using FCC (Silica gel, gradient mixture of EtOAc-MeOH) to obtain ten fractions (A5.1-A5.7) (**Scheme 8**).Then, fraction A5.7 (683.7 mg) was separated on FCC (C_{18}, isocratic mixture of MeOH-H_2O) give eight fractions (A57.1-A57.8). Fraction A57.6, after drying gave compound DP-7 (11.9 mg), which was identified as Isovitexin.



Scheme 6 Separation of fraction F of *D.pachyglossum*



Scheme 7 Separation of n-BuOH extract of *D. pachyglossum*

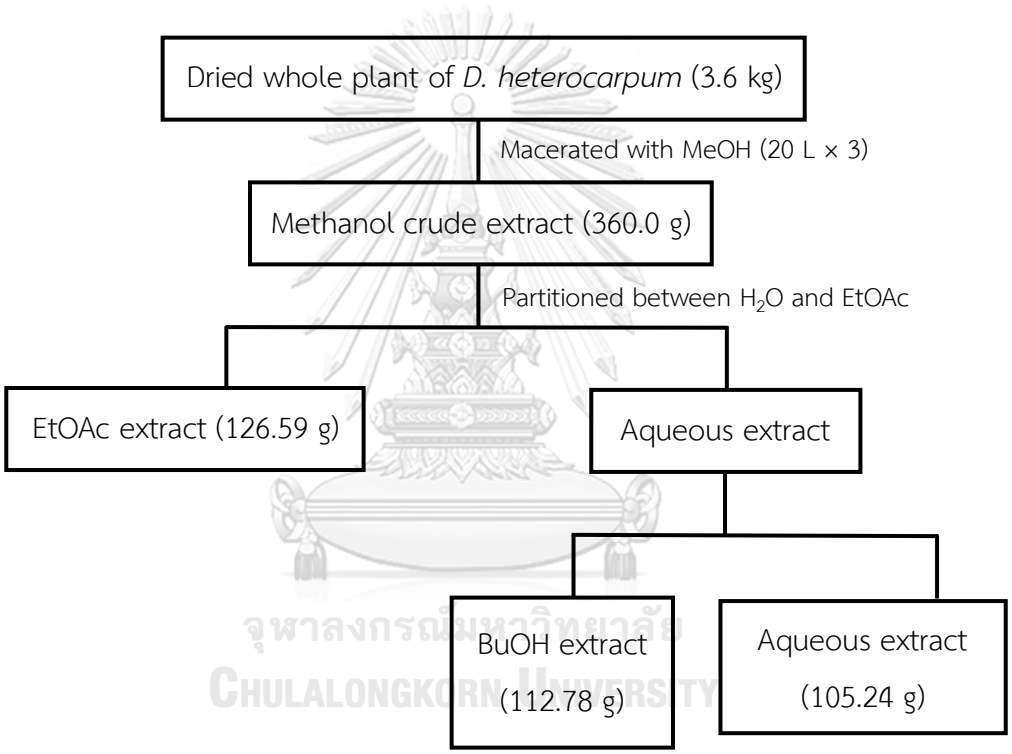


Scheme 8 Separation of fraction A (*n*-BuOH extract) of *D. pachyglossum*

3.2 Extraction of *Dendrobium heterocarpum*

3.2.1 Extraction

The dried whole plant of *Dendrobium heterocarpum* (3.6 kg) were chopped and extracted with MeOH (20L × 3) for 72 hours, three times. to give a MeOH extract after removal of the solvent (**Scheme 9**). The MeOH extract (360.0 g) was dispersed in water and partitioned with EtOAc and then *n*-butanol to give EtOAc extract (126.59 g), a *n*-butanol extract (112.78 g), and aqueous extract (105.24 g).



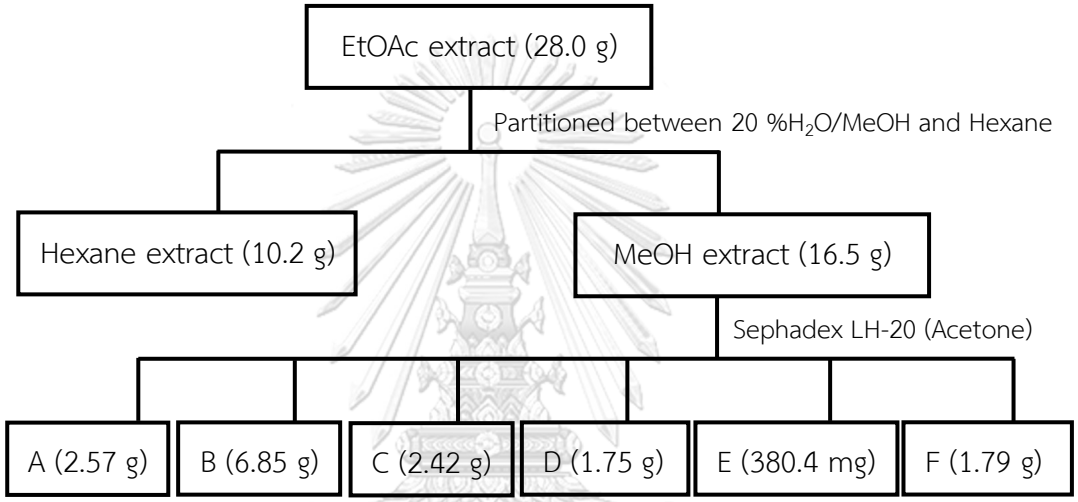
Scheme 9 Extraction of *D. heterocarpum*

All three extracts were screened for cytotoxicity on HaCaT keratinocyte cells at concentration 200 µg/mL. The results showed that all of extracts showed non-toxicity (percentage of cell viability more than 80%) compared to the control groups. Then, the extracts were tested for antioxidant activity using by the DPPH free radical scavenging assay. The EtOAc extract exhibited the highest percentage of inhibition

with 80.25% concentration at 100 µg/mL. Therefore, the EtOAc extract was selected for further studies.

3.2.2 Separation of EtOAc extract of *D. heterocarpum*

As shown in **Scheme 10**, EtOAc extract (28.0 g) was partitioned with hexane-20% H_2O/MeOH to obtain hexane extract (11.0 g) and MeOH extract (16.5 g). Then, the MeOH extract (16.5 g) was separated Sephadex LH-20 column eluted with acetone to give six fractions (A-F).

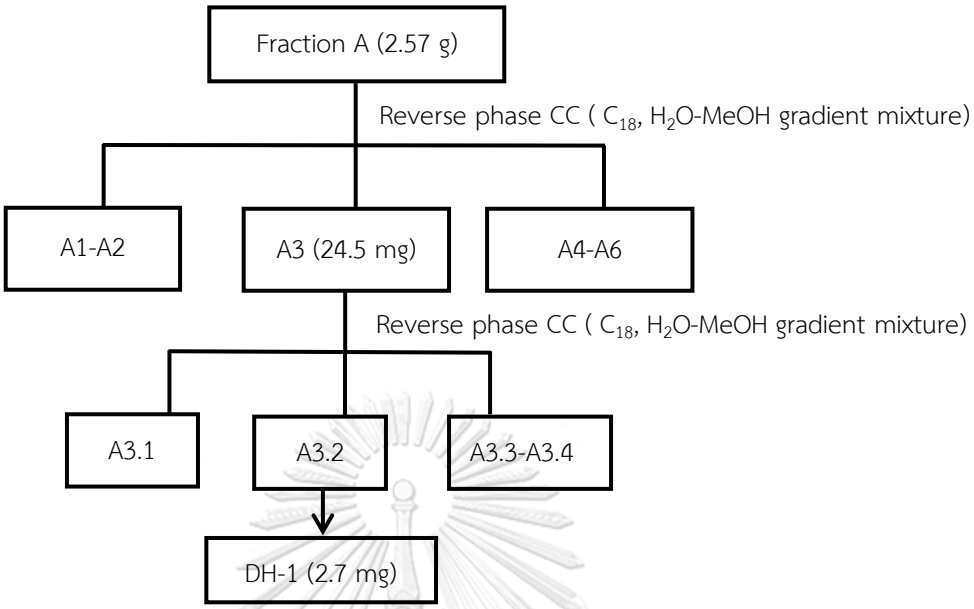


Scheme 10 Extraction of *D. heterocarpum*

3.2.3 Isolation of EtOAc extract of *D. heterocarpum*

3.2.3.1 Isolation of compound DH-1 (amoenylin)

Fraction A (2.57 g) was separated by reverse phase column chromatography (C_{18}, gradient mixture of MeOH-H_2O) to give six fractions (A1-A6) (**Scheme 11**). Fraction A3 (24.5 mg) was further separated on a reverse phase column chromatography (C_{18}, gradient mixture of MeOH-H_2O) to give four fractions (A3.1- A3.6). Fraction A3.2, after drying gave compound DH-1 (2.7 mg), which was amonyelin.



Scheme 11 Separation of fraction A of *D. heterocarpum*

3.2.3.1 Isolation of compound DH-2 to DH-6 (methyl-3-(4-hydroxyphenyl) propionate, 3,4-dihydroxy-5,4′-dimethoxybibenzyl, dendrocandin B, dendrofalconerol A, and syringaresinol)

Fraction B (6.85 g) was fractioned by Sephadex LH-20 column eluted with MeOH to give eight fractions (B1-B8) (**Scheme 12**).

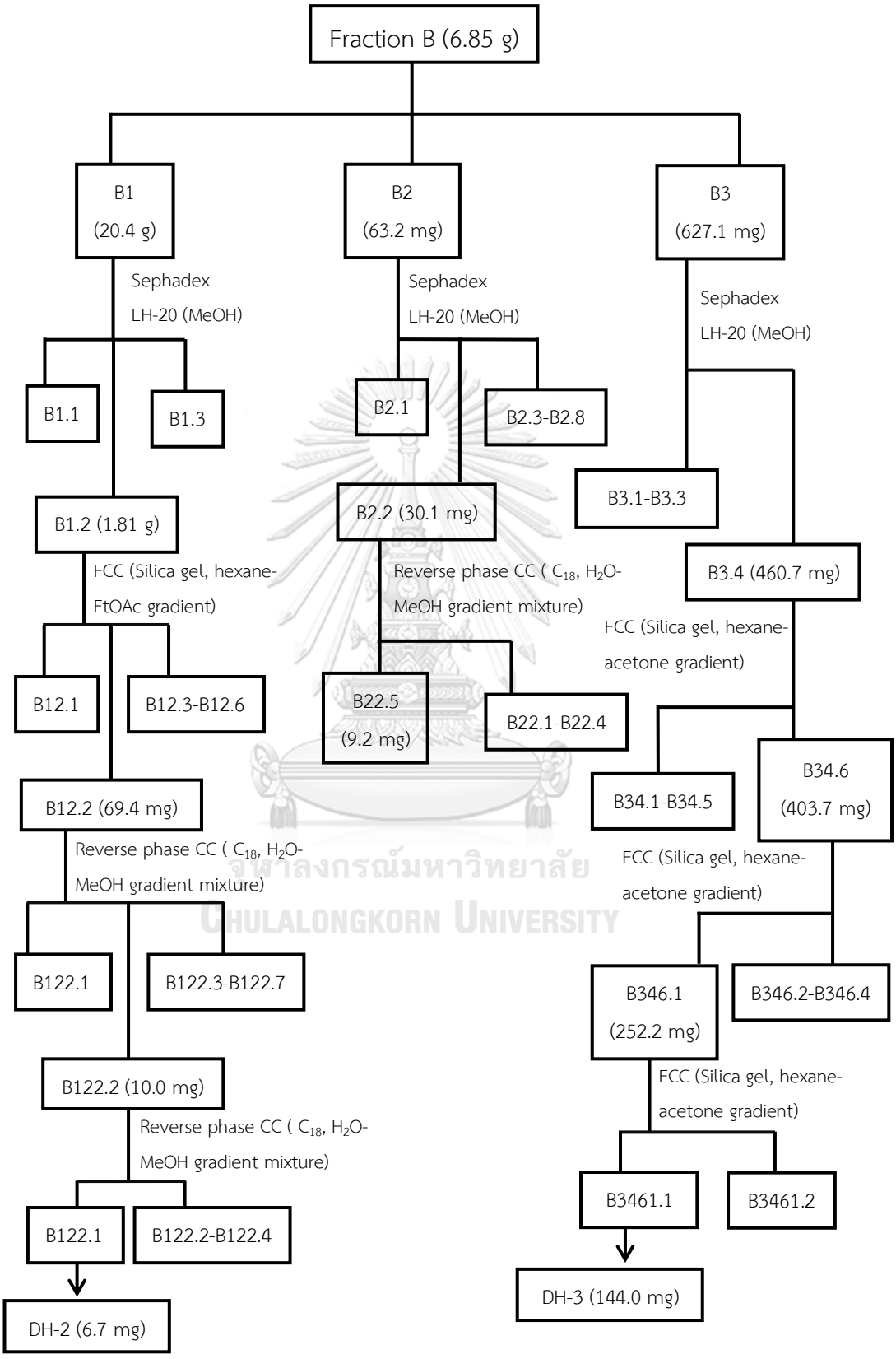
Fraction B1 (2.04 g) was separated by Sephadex LH-20 column eluted with MeOH to obtain three fractions (B1.1-B1.3) (**Scheme 12**). Fraction B1.2 (1.81 g) was separated on FCC (Silica gel, gradient mixture of hexane-EtOAc) to obtain six fractions (B12.1-B12.6). Fraction B12.2 (69.4 mg) was subjected to reverse phase column chromatography (C_{18}, gradient mixture of MeOH-H_2O) to obtain seven fractions (B122.1-B122.7). Fraction B122.2 (10.0 mg) was purified by semi-preparative HPLC column chromatography (C_{18}, gradient mixture of MeOH-H_2O) to obtain four fractions (B1222.1-B1222.4). Fraction B1222.1, after drying to give compound DH-2 (6.7 mg) which was methyl-3-(4-hydroxyphenyl) propionate.

Fraction B3 (627.1 mg) was separated on Sephadex LH-20 column eluted with methanol to give four fractions (B3.1-B3.4)(**Scheme 12**). Fraction B3.4 (460.7 mg) was fractioned on FCC (Silica gel, gradient mixture of hexane-acetone) to obtain six fractions (B32.1-B32.6). Fraction B32.5 (403.7 mg) was fractioned by using FCC (Silica gel, gradient mixture of hexane-acetone) to obtain four fractions (B325.1-B325.4). Fraction B325.1 (252.2 mg) was separated on FCC (Silica gel, gradient mixture of hexane-acetone) to obtain two fractions (B3251.1-B3251.2). Fraction B325.1, after drying to give compound DH-3 (144.0 mg) which was 3,4-dihydroxy-5,4′-dimethoxybibenzyl.

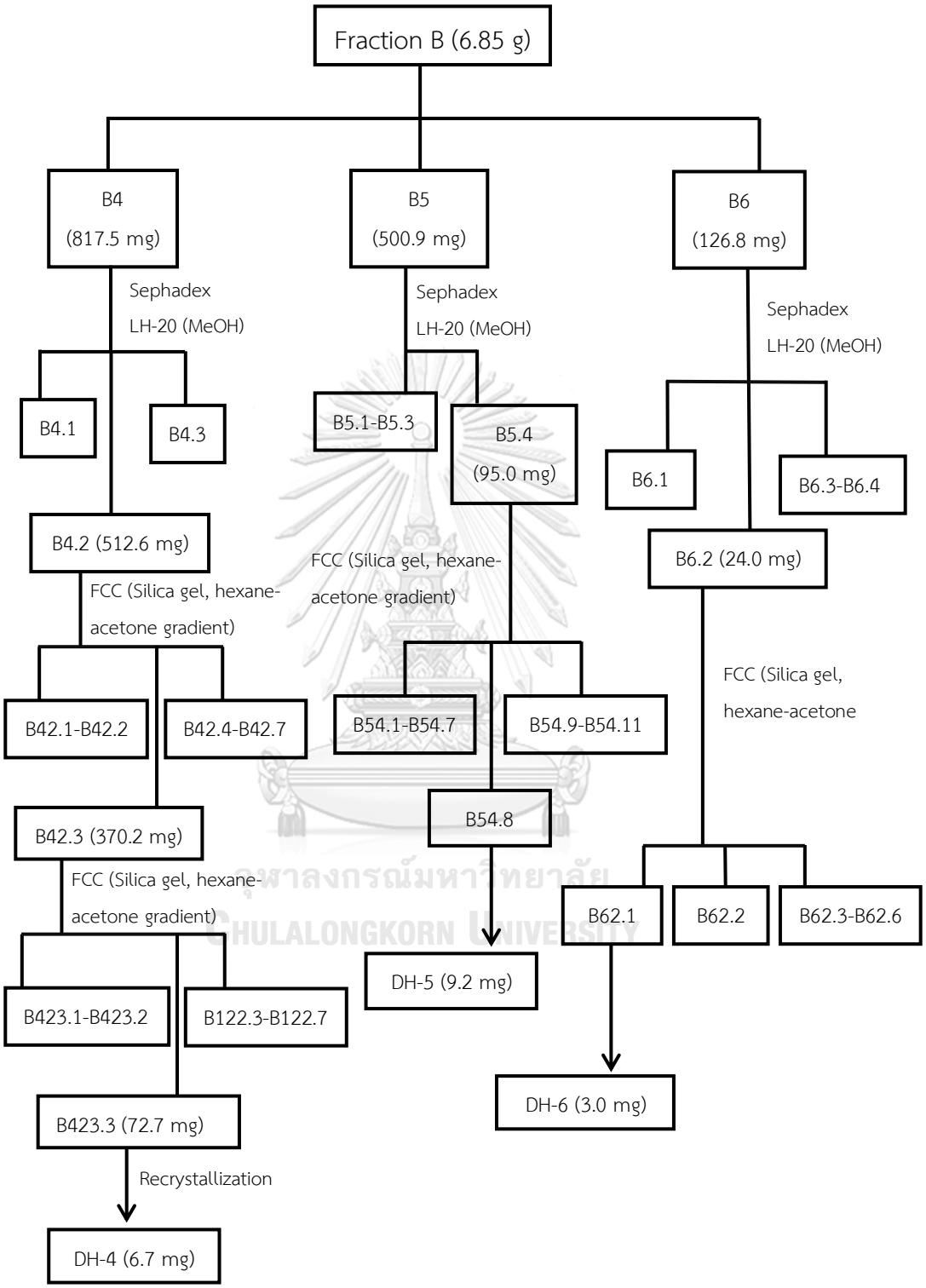
Fraction B4 (817.5 mg) was separated on Sephadex LH-20 column eluted with methanol to give three fractions (B4.1-B4.4) (**Scheme 13**). Fraction B4.2 (512.6 mg) was fractioned on FCC (Silica gel, gradient mixture of hexane-acetone) to obtain seven fractions (B42.1-B42.7). Fraction B42.3 (370.2 mg) was fractioned by using FCC (Silica gel, gradient mixture of hexane-acetone) to obtain seven fractions (B423.1-B423.7). Fraction B423.3 (72.7 mg) gave a white precipitate (dissolve with MeOH) after left standing at room temperature overnight. The MeOH part were dried to give DH-4 (6.7 mg) which was dendrocandin B.

Fraction B5 (500.9 mg) was separated on Sephadex LH-20 column eluted with methanol to give four fractions (B5.1-B5.4) (**Scheme 13**). Fraction B5.4 (95.0 mg) was fractioned on FCC (Silica gel, gradient mixture of hexane-acetone) to obtain eleven fractions (B54.1-B54.11). Fraction B54.8, after drying to give compound DH-5 (9.2 mg) which was dendrofalconerol A.

Fraction B6 (126.7 mg) was separated on Sephadex LH-20 column eluted with methanol to give four fractions (B6.1-B6.4) (**Scheme 13**). Fraction B6.2 (24.0 mg) was fractioned on FCC (Silica gel, gradient mixture of hexane-acetone) to obtain six fractions (B62.1-B62.6). Fraction B62.2, after drying to give compound DH-6 (3.0 mg) which was syringaresinol.



Scheme 12 Separation of fraction B of *D. heterocarpum*



Scheme 13 Separation of fraction B of *D. heterocarpum* (continued)

4. Physical and spectral data of isolated compounds

4.1 Isolated compounds from *D. pachyglossum*

4.1.1 Compound DP-1 (4,5-Dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene)

Compound DP-1 was obtained as 7.3 mg (7.3 mg, 0.003% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 295.09521 ($C_{16}H_{14}O_6Na$); **Figure 3**

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

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

4.1.2 Compound DP-2 (Moscatilin)

Compound DP-2 was obtained as 46.4 mg (46.4 mg, 0.020% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 327.12204 ($C_{17}H_{20}O_5Na$) ; **Figure 10**

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

4.1.3 Compound DP-3 (Gigantol)

Compound DP-3 was obtained as 57.2 mg (57.2 mg, 0.024% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 297.10824 ($C_{16}H_{18}O_4Na$) ; **Figure 12**

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

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

4.1.4 Compound DP-4 (4,5,4′-Trihydroxy-3,3′-dimethoxybibenzyl)

Compound DP-4 was obtained as 263.5 mg (263.5 mg, 0.114% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 313.1056 ($C_{16}H_{18}O_5Na$) ; **Figure 16**

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

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

4.1.5 Compound DP-5 (New compound)

Compound DP-5 was obtained as 9.2 mg (9.2 mg, 0.003% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 575.1906 ($C_{32}H_{31}O_{10}Na$) ; **Figure 19**

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

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

4.1.6 Compound DP-6 (Dendrocantin T)

Compound DP-6 was obtained as 1.0 mg (1.0 mg, 0.0004% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 521.17980 ($C_{27}H_{30}O_9Na$) ; **Figure 27**

^{1}H NMR : δ ppm, 500 MHz, in acetone-d_6; **Table 7**

^{13}C NMR : δ ppm, 125 MHz, in acetone-d_6; **Table 7**

4.1.7 Compound DP-7 (Isovitexin)

Compound DP-7 was obtained as 11.9 mg (11.9 mg, 0.005% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 455.0954 ($C_{21}H_{20}O_{10}Na$) ; **Figure 33**

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

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

4.2 Isolated compounds from *D. heterocarpum*

4.2.1 Compound DH-1 (Amonyelin)

Compound DH-1 was obtained as 2.7 mg (2.7 mg, 0.00075% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 311.12604 ($C_{16}H_{14}O_6Na$); **Figure 38**

^{1}H NMR : δ ppm, 600 MHz, in acetone-d_6; **Table 9**

^{13}C NMR : δ ppm, 150 MHz, in acetone-d_6; **Table 9**

4.2.2 Compound DH-2 (Methyl-3-(4-hydroxyphenyl) propionate)

Compound DH-2 was obtained as 6.7 mg (6.7 mg, 0.00186% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 203.066 ($C_{10}H_{12}O_3Na$) ; **Figure 44**

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

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

4.2.3 Compound DH-3 (3,4-Dihydroxy-5,4′-dimethoxybibenzyl)

Compound DH-3 was obtained as 144.0 mg (144.0 mg, 0.04% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 297.1127 ($C_{16}H_{18}O_4Na$) ; **Figure 49**

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

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

4.2.4 Compound DH-4 (Dendrocandin B)

Compound DH-4 was obtained as 6.7 mg (6.7 mg, 0.00186% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 505.1850 ($C_{24}H_{30}O_8Na$) ; **Figure 55**

^{1}H NMR : δ ppm, 300 MHz, in $CDCl_3$; **Table 12**

^{13}C NMR : δ ppm, 75 MHz, in $CDCl_3$; **Table 12**

4.2.5 Compound DH-5 (Dendrofalconerol A)

Compound DH-5 was obtained as 9.2 mg (9.2 mg, 0.0025% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 567.2003 ($C_{32}H_{32}O_8Na$) ; **Figure 61**

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

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

4.2.6 Compound DH-6 (Syringaresinol)

Compound DH-6 was obtained as 3.0 mg (3.0 mg, 0.00083% based on dried weight of whole plant). It was soluble in acetone.

HR-ESI-MS : $[M+Na]^+$ ion at *m/z* 441.1529 ($C_{22}H_{26}O_8Na$) ; **Figure 65**

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

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

5. Biological activities of isolated compounds from *D. pachyglossum* and *D. heterocarpum*

5.1 cell cultures

The immortalized human epidermal keratinocyte (HaCaT) cell line was obtained from Thermo Fisher Scientific (Waltham, MA). The HaCaT cells were cultured in complete media, which comprised of Dulbecco's modified Eagle's medium (DMEM) supplemented with 10% (v/v) heat-inactivated fetal bovine serum and 1% (v/v) penicillin streptomycin at 37 °C in a humidified atmosphere of 5% CO_2/95% air. All reagents were purchased from Invitrogen (Grand Island, NY, USA).

5.2 Determination of cytotoxicity

The cytotoxic effect of the isolated compounds from *D. pachyglossum* and *D. heterocarpumon* on cell viability of HaCaT cells were evaluated using the 3-(4,5-dimethlthiazol-2-yl)-2,5-diphenyl tetrazolium bromide tetrazolium (MTT) assay. The HaCaT cells were seeded in 96-well plates at a density of 3.0×10^4 cells/well and incubated at 37 °C in a humidified atmosphere of 5% CO_2 for 24 h. After seeding for 24 h, the media was removed, and the cells were washed with serum free media. Subsequently, the cells were incubated with isolated compounds at the concentrations of 50 and 100 µg/mL in serum-free media for 24 h. The 0.5% DMSO was used as a control. After incubation, the cells were washed and incubated in serum-free media containing 0.5 mg/mL of an MTT solution at 37 °C in a humidified atmosphere of 5% CO_2 /95% air for 4 h. Subsequently, the media was removed, and 200 µL of DMSO was added to each well to dissolve the formazan crystals.

The absorbance of formazan was measured at 540 nm using a microplate reader (CLARIOstar, BMG Labtech, Ortenberg, Germany). Four replicates of each experiment were performed. The results were expressed as percentage of cell viability. The cell survival was calculated as follows.

$$\text{Cell viability} = \frac{A_{540} \text{ of treated well} \times 100}{A_{540} \text{ of medium containing 0.5 \% DMSO}}$$

5.3 Determination of cytoprotective effect against H_2O_2 on HaCaT cells

To determine the concentration of H_2O_2 required to reduce the cell viability of HaCaT cells by 50%, the cells were treated with different concentrations of H_2O_2 (100, 200, 300, 400, and 500 µmol/L) in serum-free media at 37 °C for 1 h. The serum-free medium without H_2O_2 was used as a control. After incubation, the cells were washed twice with an excess of PBS, and the cell viability was measured using the MTT assay.

5.4 Determination of cytoprotective effect on HaCaT cells under oxidative stress

The HaCaT cells were seeded in 96-well plates at a cell density of 3.0×10^4 cells/well. The cells were treated with serum-free media containing MeOH extract (500 µg/mL) and isolated compounds (12.5, 25 and 50 µg/mL) for 24 h and then washed with PBS. Subsequently, the cells were added with H_2O_2 at the concentration of 500 µmol/L in serum-free media prior to incubation at 37 °C for 1 h. The cell viability was determined using the MTT assay measured at 540 nm. DMSO (0.5% v/v) was used as a control.

5.5 Statistical analysis

All of the data were performed at least in three replicates. Comparisons between groups were performed using the GraphPad Prism software Version 8.00 for Mac (GraphPad Software, Inc., San Diego, CA, USA). Values were presented as mean ± standard deviation (SD). Means were compared by one-way analysis of variance (ANOVA) with Dunnett's test, and differences were considered significant at $p<0.05$.

CHAPTER IV

RESULT AND DISCUSSION

In the present study, the methanol extract of the whole plants of *D. pachyglossum* (2.7 kg) and *D. heterocarpum* (3.6 kg) were dissolved in water and partitioned with ethyl acetate (EtOAc) and *n*-butanol, respectively. All of extract presented non-toxicity on HaCaT cells at concentration of 200 µg/mL. In addition, the EtOAc and *n*-BuOH extracts of *D. pachyglossum* and EtOAc extract from *D. heterocarpum* had strong DPPH radical scavenging activity with more than 80% inhibition at a concentration of 100 µg/mL. From above the results, the extracts were further separated using several chromatographic techniques to afford thirteen compounds. The structures of these compounds were characterized using several spectroscopic techniques, including MS and NMR, as follows.

4.1 Structure determination of compound DP-1 (4,5-dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene)

Compound DP-1 was isolated as a yellow amorphous solid. The HR-ESI-MS spectrum (**Figure 3**) showed a sodium-adduct molecular ion $[M+Na]^+$ *m/z* at 295.0957 (calcd. for $C_{16}H_{16}O_4Na$; 295.0946). Its molecular formula was determined as $C_{16}H_{16}O_4$.

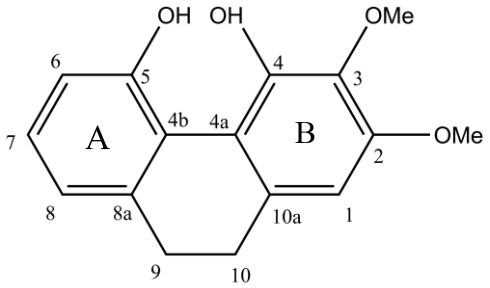
The ^{1}H-NMR spectrum of compound DP-1 (**Figure 4** and **Table 2**) presented two methylene protons at δ_H 2.65 (2H, *m*, H_2-9) and 2.65 (2H, *m*, H_2-10), and two methoxy groups at δ_H 3.83 (3H, s, 3-OMe), 3.90 (3H, s, 2-OMe).

The ^{13}C-NMR (**Figure 5** and **Table 2**) spectra presented signals of 4 aromatic methines at δ_C 104.7 (C-1), 117.2 (C-8), 119.5 (C-6) and 127.4 (C-7), 8 aromatic quaternary carbons at δ_C 113.9 (C-4a), 120.9 (C-4b), 135.5 (C-3), 136.0 (C-10a), 140.4 (C-8a), 145.4 (C-4), 151.6 (C-2) and 153.3 (C-5), two methoxyl at δ_C 55.3 and 60.0, respectively. Eight proton signals were assigned of eight carbon atoms by the HSQC spectrum (**Figure 6**). It also indicated eight quaternary carbon. In addition, the HSQC correlations to carbon atoms at δ_C 30.7 (C-9) and 30.8 (C-10), which suggested a dihydrophenanthrene skeleton (Fisch et al., 1973).

The assignments of ^{1}H and ^{13}C NMR signals were based on the HMBC spectrum (**Figure 7).** The ^{1}H-NMR spectrum of ring A, the signal of H-8 at δ_H 6.84 (1H, *d*, *J* =8.1 Hz, H-8) was correlated to C-6 (δ_C 119.5) and C-9 (δ_C 30.7). The signal of H-6 at δ_H 6.87 (1H, *d*, *J* =8.1 Hz, H-6) was assigned by the correlation of C-4b (δ_C 120.9). The proton of H-7 signal at δ_H 7.10 (1H, *d*, *J* =8.1 Hz, H-7) exhibited correlation to C-5 (δ_C 153.3). On ring B, the signal at δ_H 6.67 (1H, *s*, H-1) observed correlation to δ_C C-10 (30.8), C-4a (113.9) and C-3 (135.5), respectively. Moreover, the ^{1}H-NMR spectrum also showed methoxyl group at δ_H 3.8 (3H, *s*, 3-OMe) and 3.9 (3H, *s*, 2-OMe), respectively.

To confirm the position of aromatic protons and methoxy groups were determined by NOESY spectrum (**Figure 8-9**). The assignment of H-1 according to the cross peak with H-10. The first methoxyl was related at C-2 based on its correlation with H-1. The H-8 was located at C-8 based on its NOESY cross peak with H-9. The HMBC correlations of C-3 with 3-OMe and H-1 suggested the substitution of the second methoxy at C-3.

By comparing the data mentioned above with this compound with previously reported (Tanagornmetar et al., 2014) , compound DP-1 was identified as 4,5-dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [**67**]. This compound has been isolated from *Empertrum nigrum* (Wollenweber et al., 1992), *D. sinense* (Chen et al., 2013), and *D. ellipsophyllum* (Tanagornmetar et al., 2014).



4,5-dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene [**67**]

Table 2 NMR spectral data of compound DP-1 (in Acetone-d_6) and 4,5-dihydroxy-2,3 dimethoxy-9,10-dihydrophenanthrene (in Acetone-d_6)

Positions	Compound DP-1 (acetone-d_6)		4,5-dihydroxy-2,3 dimethoxy-9,10-dihydrophenanthrene (acetone-d_6) *	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	6.67	104.7	6.56	105.0
2	-	151.6	-	150.4
3	-	135.5	-	134.0
4	-	145.4	-	143.7
4a	-	113.9	-	113.1
4b	-	120.9	-	120.4
5	-	153.3	-	153.2
6	6.87 (*d*, 8.1)	119.5	6.98 (*d*, 8.0)	120.0
7	7.10 (*t*, 8.1)	127.4	7.16 (*t*, 8.0)	128.0
8	6.84 (*d*, 8.1)	117.2	6.87 (*d*, 8.0)	118.0
8a	-	140.7	-	140.2
9	2.65 (*m*)	30.7	2.72 (*m*)	30.9
10	2.65 (*m*)	30.8	2.72 (*m*)	30.9
10a	-	136.5	-	136.7
2-OMe	3.90 (*s*)	55.3	3.93 (*s*)	55.9
3-OMe	3.83 (*s*)	60.0	3.99 (*s*)	61.2

*(Tanagornmetar et al., 2014)

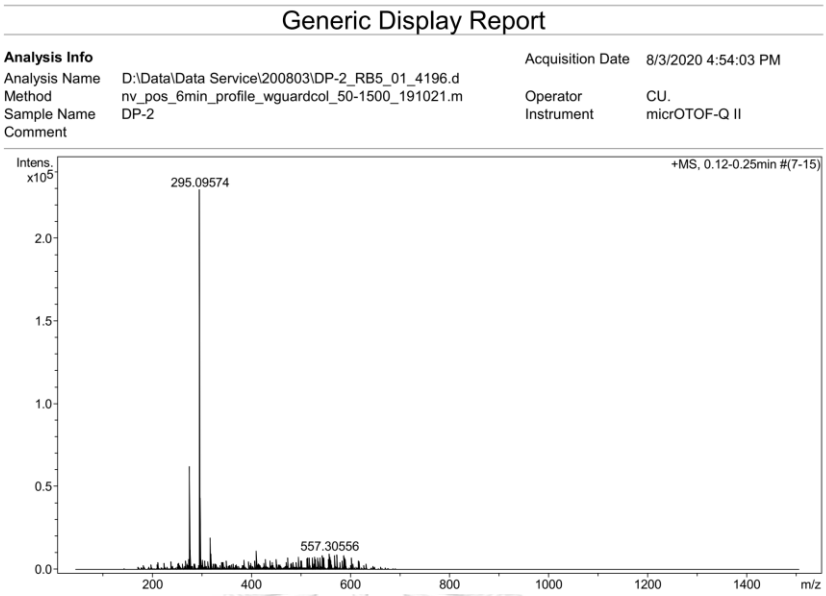


Figure 3 Mass spectrum of compound DP-1

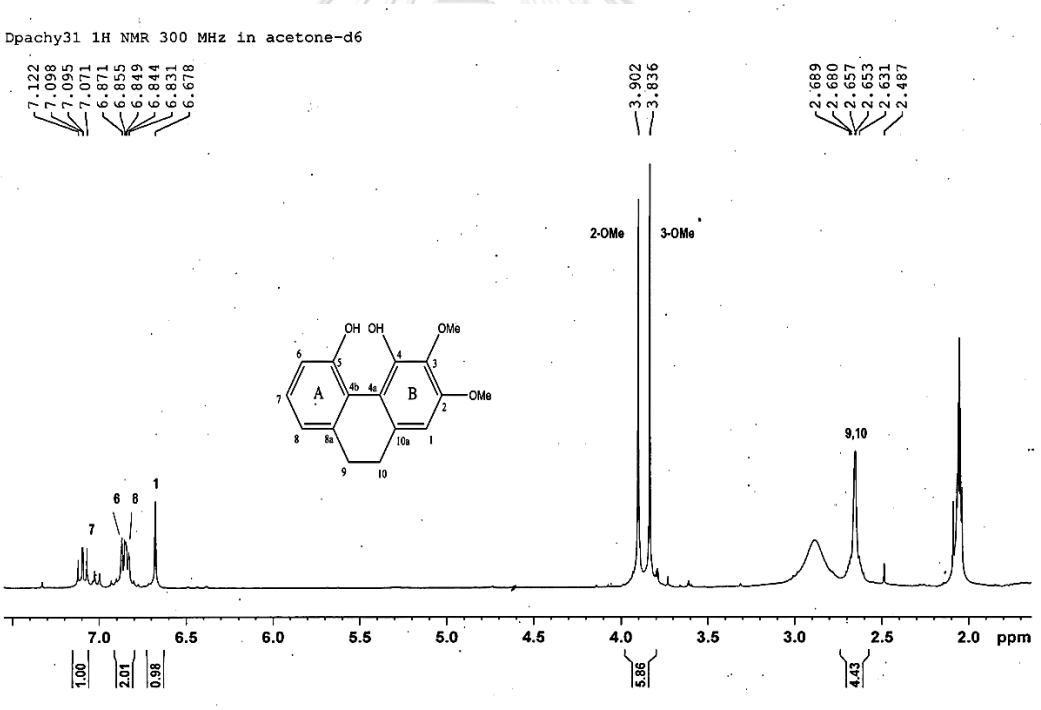


Figure 4 ^{1}H-NMR (300 MHz) spectrum of compound DP-1 (in Acetone-d_6)

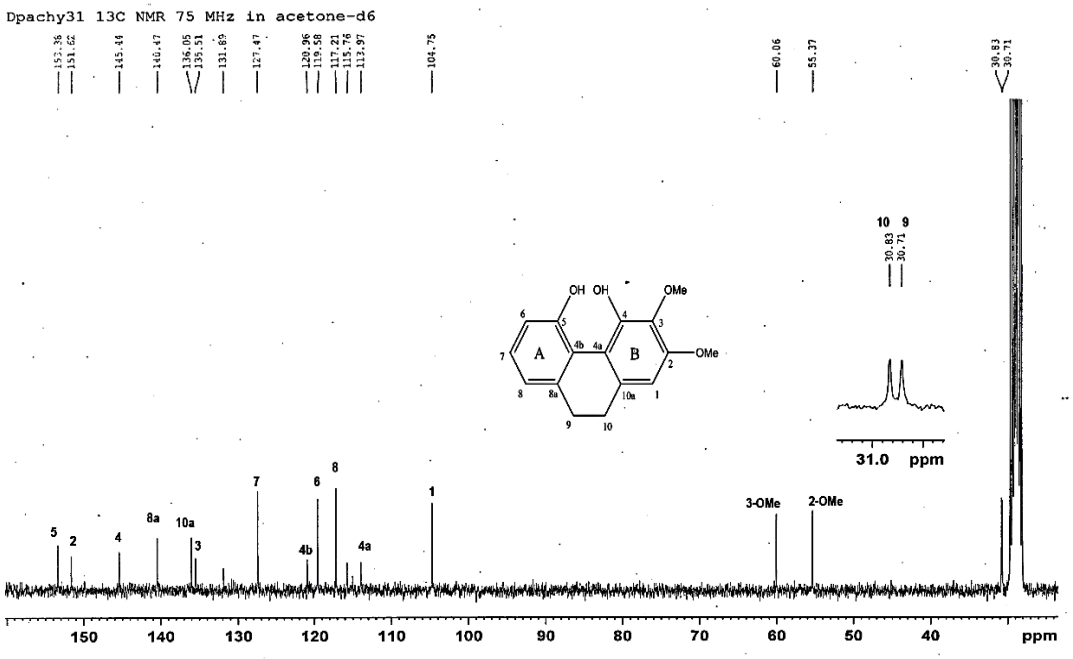


Figure 5 ^{13}C-NMR (75 MHz) spectrum of compound DP-1 (in Acetone-d_6)

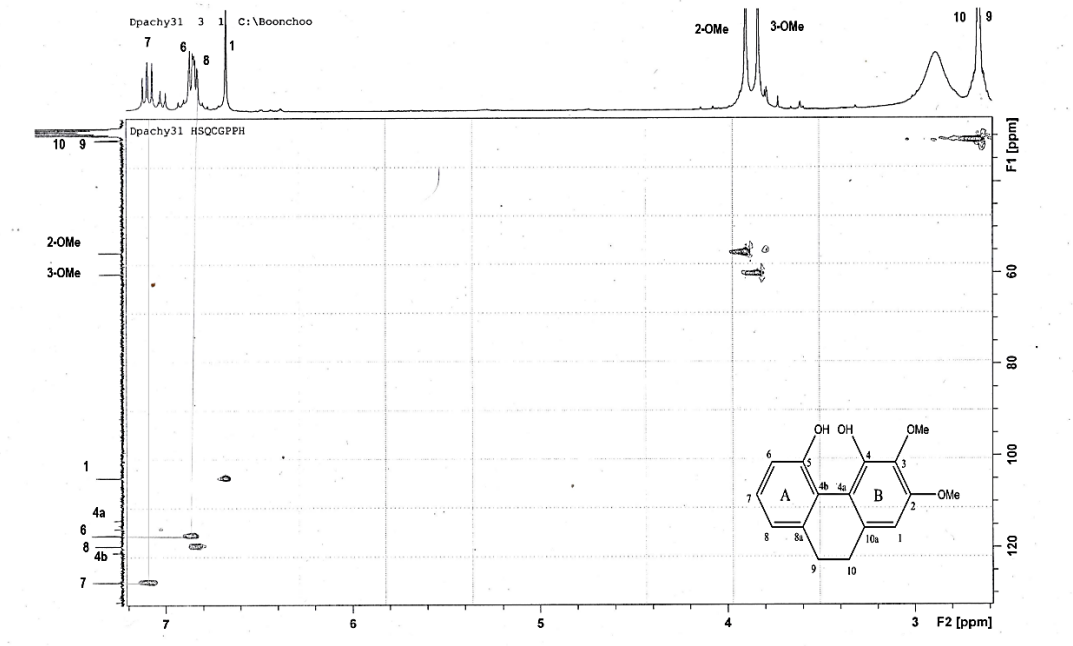


Figure 6 HSQC spectrum of compound DP-1 (in Acetone-d_6)

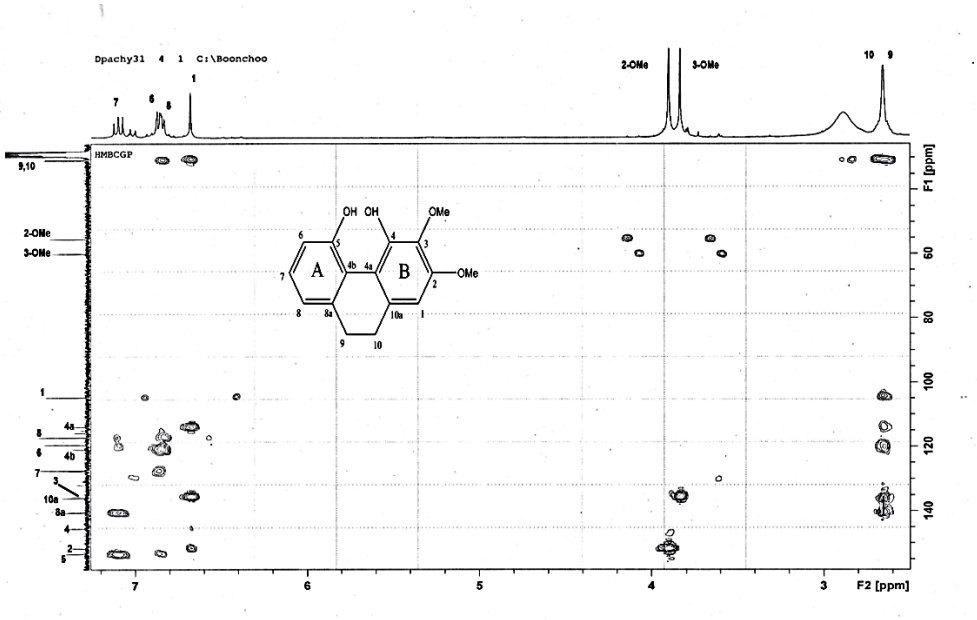


Figure 7 HMBC spectrum of compound DP-1 (in Acetone-d_6)

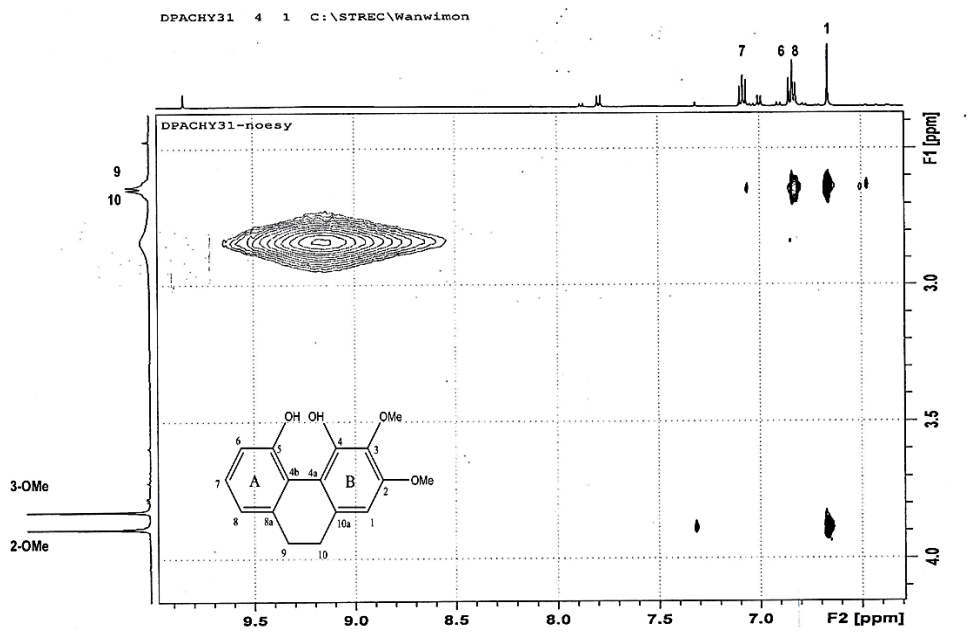


Figure 8 NOESY spectrum of compound DP-1 (in Acetone-d_6)

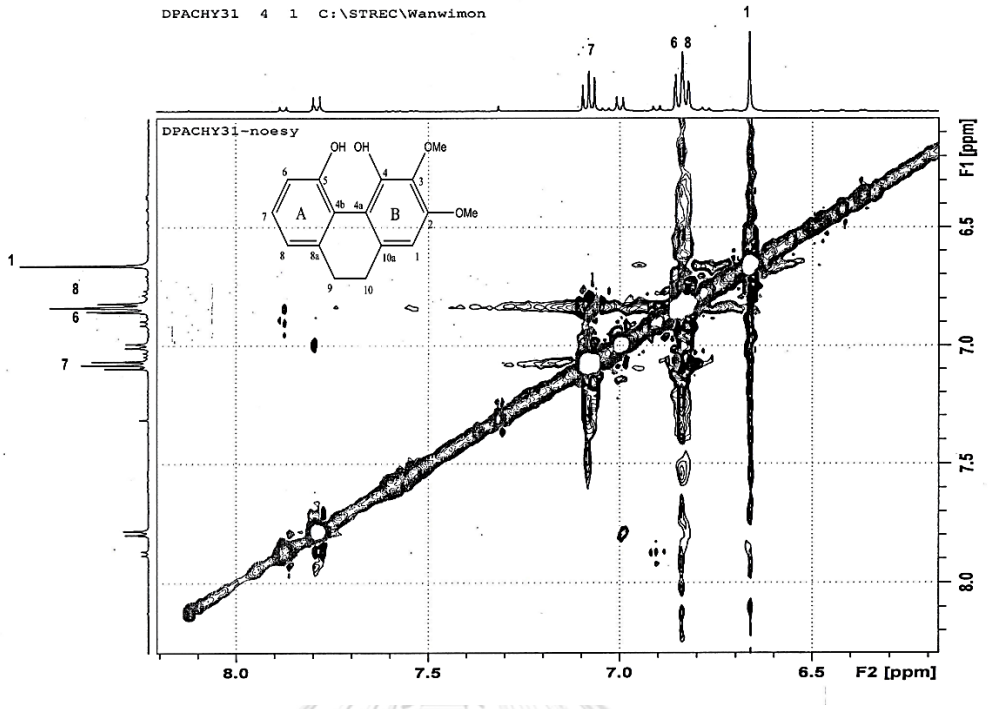


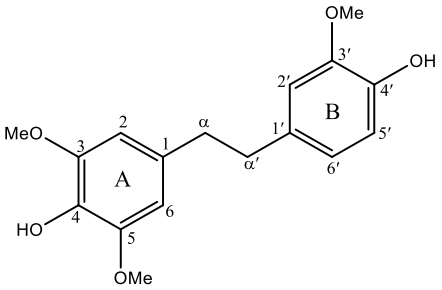
Figure 9 NOESY spectrum of compound DP-1 (in Acetone-d_6)

4.2 Structure determination of compound DP-2 (Moscatilin)

Compound DP-2 was obtained as a brown amorphous solid. The HR-ESI mass spectrum of this compound (**Figure 10**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 327.1216 (calculated for $C_{17}H_{20}O_5Na$; 327.1208), suggesting the molecular formula $C_{17}H_{20}O_5$.

The ^{1}H-NMR spectrum of DP-2 (**Figure 11** and **Table 3**) showed characteristic of a bibenzyl skeleton, indicated methylene proton signals at δ_H 2.81 (4H, *m*, H_2-α, H_2-α'). The ^{1}H NMR data also exhibited signals of three methoxy groups δ_H at 3.79 (6H, *s*, 3-OMe, 5-OMe), 3.81 (3H, *s*, 3′-OMe), and five aromatic proton signals at δ_H 6.50 (2H, s, H-2, H-6), 6.81 (1H, *d*, *J* =2.0 Hz, H-2′), 6.74 (2H, *d*, *J* = 8.1 Hz, H-5′), 6.67 (1H, *dd*, *J* = 8.1, 2.0 Hz, H-6′) (**Figure 11**).

On the basis of these ^{1}H NMR and MS data compound DP-2 was identified as moscatilin [**21**]. This compound has been reported from several *Dendrobium* spp. including *D. amoenum* (Majumder et al., 1999), *D. aurantiacum* var. *denneanum* (Yang et al., 2006b), *D. brymerianum* (Klongkumnuanken et al., 2015), *D. chrysanthum* (Yang et al., 2006a), *D. densiflorum* (Fan et al., 2001b), *D. ellipsophyllum* (Tanagornmeatar et al., 2014), *D. formosum* (Inthongkaew et al., 2017), *D. gratiosissimum* (Zhang et al., 2008a), *D. infundibulum* (Na Ranong et al., 2019), *D. loddigesii* (Chen et al., 1994; Ito et al., 2010), *D. longicornu* (Hu et al., 2008a), *D. moscatum* (Majumder and Sen, 1987), *D. nobile* (Miyazawa et al., 1999; Yang et al., 2007), *D. palpebrae* (Kyokong et al., 2018), *D. parishii* (Kongkatitham et al., 2018), *D. polyanthum* (Hu et al., 2009), *D. pulchellum* (Chanvorachote et al., 2013) and *D. secundum* (Sritularak et al., 2011b).



Moscatilin [**21**]

Table 3 ^{1}H NMR 300 MHz and ^{13}C NMR 75 MHz spectral data of compound DP-2 (in Acetone-d_6) and moscatilin (in Acetone-d_6)

Position	Compound DP-2	Moscatilin*	
	δ_H (mult., *J* in Hz)	δ_H (mult., *J* in Hz)	δ_C
1	-	-	132.8
2	6.50 (*s*)	6.36 (*s*)	105.2
3	-	-	146.8
4	-	-	133.5
5	-	-	146.8
6	6.50 (*s*)	6.36 (*s*)	105.2
α	2.81 (*s*)	2.89 (*s*)	38.3
α′	2.81 (*s*)	2.89 (*s*)	37.7
1′	-	-	132.8
2′	6.81 (*d*, 2.0)	6.65 (*d*, 2.0)	111.2
3′	-	-	146.1
4′	-	-	143.7
5′	6.74 (*d*, 8.1)	6.94 (*d*, 8.0)	114.1
6′	6.67 (*dd*, 8.1, 2.0)	6.75 (*dd*, 8.0, 2.0)	121.0
3′-OMe	3.81 (*s*)	3.81 (*s*)	55.8
3-OMe	3.79 (*s*)	3.81 (*s*)	56.1
5-OMe	3.79 (*s*)	3.81 (*s*)	56.1

*(Majumder et al., 1987)

Mass Spectrum List Report

Analysis Info

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Sample Name	DP-4	Instrument / Ser#	micrOTOF-Q II 10335
Comment			

Acquisition Parameter

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Scan End	1500 m/z	Set Collision Cell RF	250.0 Vpp	Set Divert Valve	Waste

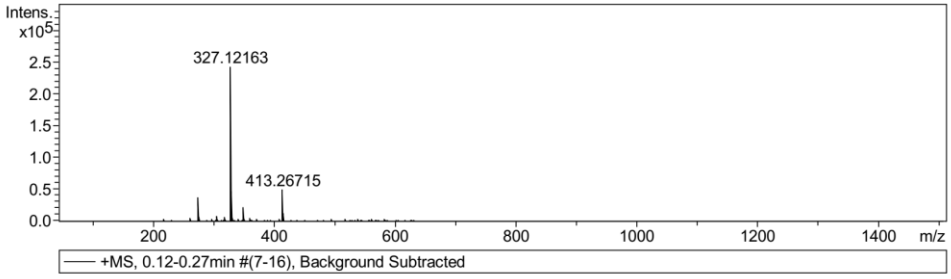


Figure 10 Mass spectrum of compound DP-2

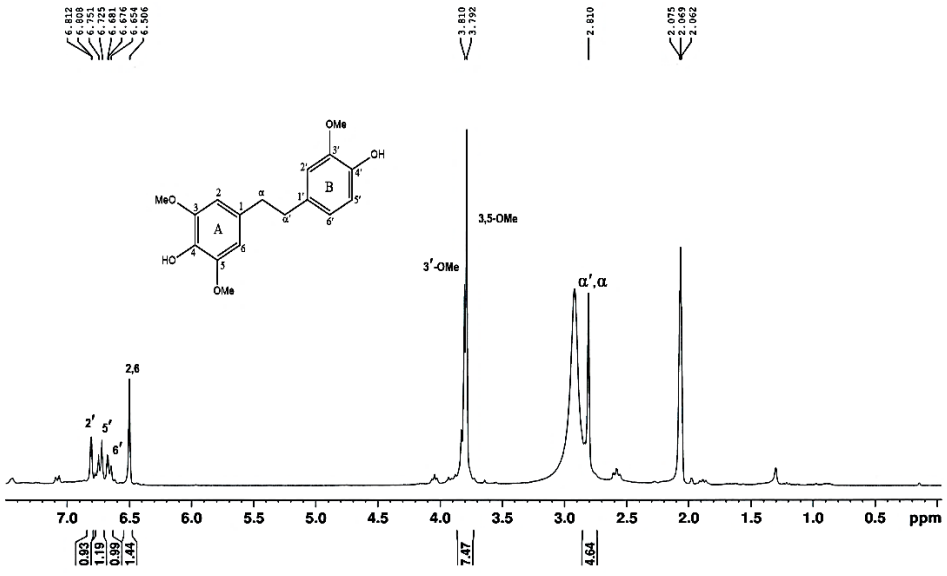


Figure 11 ^{1}H-NMR (300 MHz) spectrum of compound DP-2 (in Acetone-d_6)

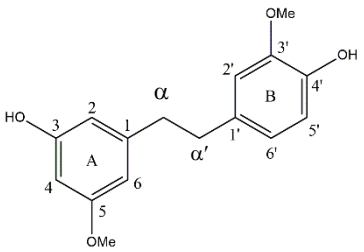
4.3 Structure determination of compound DP-3 (Gigantol)

Compound DP-3 was obtained as a brown amorphous solid. The HR-ESI mass spectrum (**Figure 12**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 297.10824 (calculated for $C_{16}H_{18}O_4Na$; 297.1103), suggesting the molecular formula $C_{16}H_{18}O_4$.

The ^1H NMR spectrum of compound DP-3 (**Figure 13** and **Table 4**) presented characteristic signals for a bibenzyl skeleton of four methylene proton signals at δ_H 2.80 (4H, *m*, H_2-α, H_2-α'). The ^1H NMR data also displayed 1,3,5-trisubstitution of ring A was indicated from the broad singlet signal at δ_H 6.25 (1H, *br*, H-2), and the broad singlet-like overlapping signals of two protons at 6.27 (1H, *br,* H-4), 6.30 (1H, *br*, H-6). The 1,3,4-trisubstitution of ring B was determined from three doublet proton signals at δ_H 6.67 (1H, brd, *J* = 8.1 Hz, H-6′), 6.72 (1H, *d*, *J* = 8.1 Hz, H-5′), and 6.81 (1H, *d*, *J* = 1.8 Hz, H-2′). Two methoxy groups showed at δ_H 3.71 (3H, *s*, 5-OMe) and 3.80 (3H, *s*, 3′-OMe).

The ^{13}C NMR data (**Figure 14** and **Table 4**) demonstrated twelve aromatic, two methoxy carbons at δ_C 55.3 (C-5-OMe) and 54.4 (C-3′-OMe), two methylene carbons at δ_C 38.2 (C-α) and 37.1 (C-α'), six methine carbons at δ_C 98.8 (C-4), 105.4 (C-6), 108.0 (C-2), 112.1 (C-5′), 114.7 (C-2′) and 120.8 (C-6′), and six quaternary carbons at δ_C 133.3 (C-1′), 144.3 (C-4′), 144.7 (C-1), 147.2 (C-3′), 158.4 (C-3) and 160.9 (C-5) (**Table 4**). Eight proton signals were assigned of eight carbon atoms by the HSQC spectrum (**Figure 15**). It also indicated eight quaternary carbon.

Previous studies have been reported that gigantol [**16**] is commonly found in the *Dendrobium* spp. Examples are *D. brymerianum* (Klongkumnuankarn et al., 2015), *D. devonianum* (Sun et al., 2014), *D. draconis* (Sritularak et al., 2011b), *D. formosum* (Inthongkaew et al., 2017), *D. officinale* (Zhao et al., 2018), *D. palpebrae* (Kyokong et al., 2018), *D. venustum* (Sukphan et al., 2014) and *D. scabrilingue* (Sarakulwattana et al., 2018).



Gigantol [**16**]

Table 4 ^{1}H NMR 300 MHz and ^{13}C NMR 75 MHz spectral data of compound DP-3 (in Acetone-d_6) and gigantol (in $CDCl_3$)

Position	Compound DP-3 (acetone-d_6)		Gigantol ($CDCl_3$)*	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	144.7	-	144.5
2	6.25 (*s*)	98.8	6.30 (*dd,* 2.0, 2.0)	98.7
3	-	158.4	-	158.2
4	6.27 (*s*)	108.0	6.26 (*dd,* 2.0, 2.0)	107.9
5	-	160.9	-	160.8
6	6.30 (*s*)	105.4	6.33 (*dd,* 2.0, 2.0)	105.3
α	2.80 (s)	38.2	2.79 (s)	37.9
α′	2.80 (s)	37.1	2.78 (s)	36.9
1′	-	133.3	-	133.1
2′	6.81 (*d,* 1.8)	114.7	6.80 (*d,* 2.0)	114.6
3′	-	147.2	-	147.0
4′	-	144.3	-	144.2
5′	6.72 (*d,* 8.1)	112.1	6.74 (*d,* 8.0)	111.9
6′	6.67 (*brd,* 8.1)	120.8	6.66 (*dd,* 8.0, 2.0)	120.6
3′-OMe	3.80 (s)	54.4	3.78 (s)	54.3
5-OMe	3.71 (s)	55.3	3.69 (s)	55.2

* (Chen et al., 2008d)

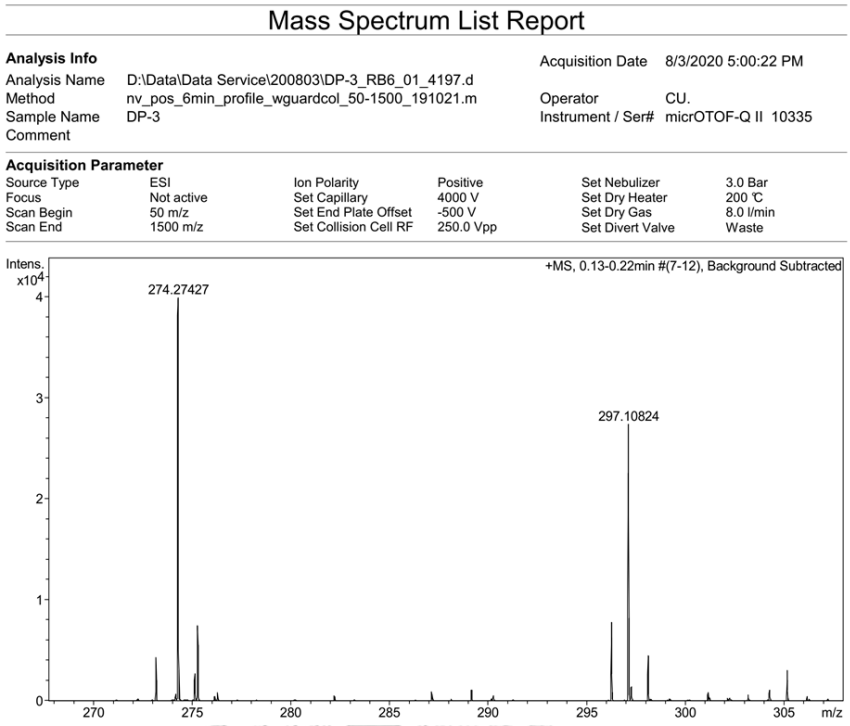


Figure 12 Mass spectrum of compound DP-3

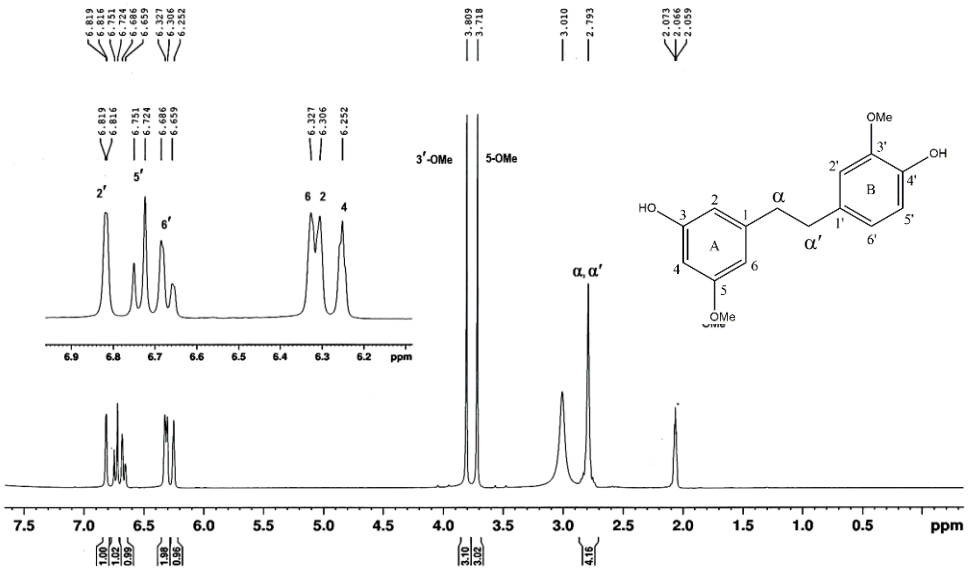


Figure 13 ^{1}H-NMR (300 MHz) spectrum of compound DP-3 (in Acetone-d_6)

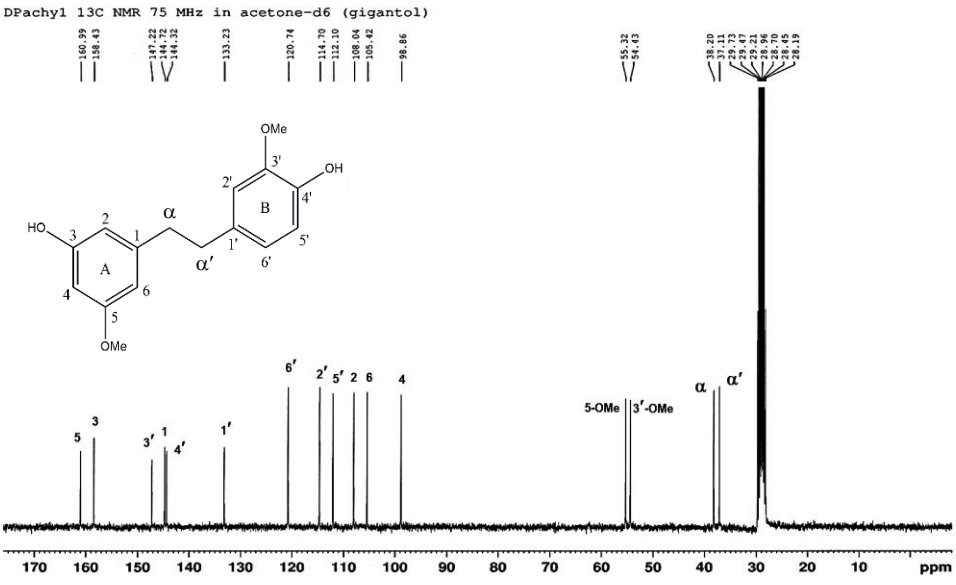


Figure 14 ^{13}C-NMR (75 MHz) spectrum of compound DP-3 (in Acetone-d_6)

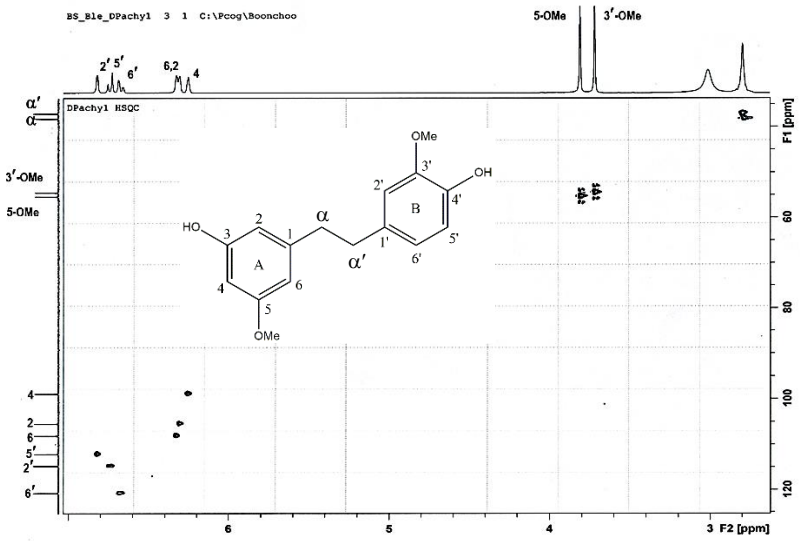


Figure 15 HSQC spectrum of compound DP-3 (in Acetone-d_6)

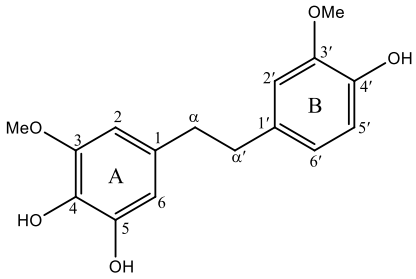
4.4 Structure determination of compound DP-4 (4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl)

Compound DP-4 was obtained as a brown amorphous solid. The HR-ESI-MS of this compound (**Figure 16**) showed an $[M+Na]^+$ peak at *m/z* 313.1049 (calcd. for $C_{16}H_{18}O_5Na$; 313.1051), suggesting the molecular formula $C_{16}H_{18}O_5$.

Comparing with the ^{1}H-NMR spectrum of DP-4 with DP-2 and DP-3, it was observed that ring B of DP-4 exhibited signals similar to DP-1 and DP-2. The ^{1}H-NMR spectrum of compound DP-4 (**Figure 17** and **Table 5**) presented signals of four methylene protons at δ_H 2.71 (4H, *m*, H_2-α, H_2-α'), two methoxyl groups at δ_H 3.78 (3H, *s*, 3-OMe) and 3.75 (3H, *s*, 3′-OMe) and five aromatic protons at δ_H 6.34 (1H, *d*, *J*=2.0 Hz, H-2), 6.36 (1H, *d*, *J*=2.0 Hz, H-6), 6.63 (1H, *dd*, *J*=8.1, 2.0 Hz H-6′), 6.71 (1H, *d*, *J*=2.0 Hz, H-2′) and 6.78 (1H, *d*, *J*=8.1 Hz, H-5′).

The ^{13}C-NMR spectra (**Figures 18** and **Table 5**) presented sixteen carbon signals, including two methoxyls at δ_C 56.2 (C-3′) and 56.3 (C-3-OMe), two aliphatic methylenes at 38.4 (C-α') and 38.8 (C-α). Other aromatic carbon signals could be separated into those of five methine carbons at δ_C 104.6 (C-2), 109.7 (C-6), 112.9 (C-2′), 115.5 (C-5′), 121.6 (C-6′), and seven quaternary carbons at δ_C 132.7 (C-1), 133.8 (C-4), 134.2 (C-1′), 145.2 (C-4′), 146.0 (C-5), 148.0 (C-3′), and 148.7 (C-3).

By comparing ^{1}H, ^{13}C-NMR and MS data of this compound with previously data, DP-4 was identified as 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**26**]. Previous studies have been reported that 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl is commonly found in the *Dendrobium* spp. including *D. ellipsophyllum* (Tanagornmeatar et al., 2014), *D. palpebrae* (Kyokong et al., 2018), *D. parishii* (Kongkatitham et al., 2018), and *D. secundum* (Sritularak et al., 2011a).



4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl [**26**]

Table 5 ^{1}H NMR 300 MHz and ^{13}C NMR 75 MHz spectral data of compound DP-4 (in acetone-d_6) and 4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl (in $CDCl_3$).

Position	Compound DP-4		4,5,4′-trihydroxy-3,3′-dimethoxybibenzyl*	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	132.7	-	130.4
2	6.34 (*d*, 2.0)	104.6	6.21 (*d*, 2.0)	103.5
3	-	148.7	-	146.6
4	-	133.8	-	133.7
5	-	146.0	-	143.7
6	6.36 (*d*, 2.0)	109.7	6.42 (*d*, 2.0)	108.6
α	2.71 (*m*)	38.8	2.75 (*m*)	38.2
α′	2.77 (*m*)	38.4	2.78 (*m*	37.7
1′	-	134.2	-	133.8
2′	6.71 (*d*, 2.0)	112.9	6.60 (*d*, 2.0)	111.2
3′	-	148.0	-	146.2
4′	-	145.2	-	143.7
5′	6.78 (*d*, 8.1)	115.5	6.80 (*d*, 8.0)	114.1
6′	6.63 (*dd*, 8.1, 2.0)	121.6	6.65 (*dd*, 8.0, 2.0)	121.0
3′-OMe	3.78 (*s*)	56.2	3.83 (*s*)	55.9
3-OMe	3.75 (*s*)	56.3	3.80 (*s*)	56.1

*(Sritularak et al., 2011a)

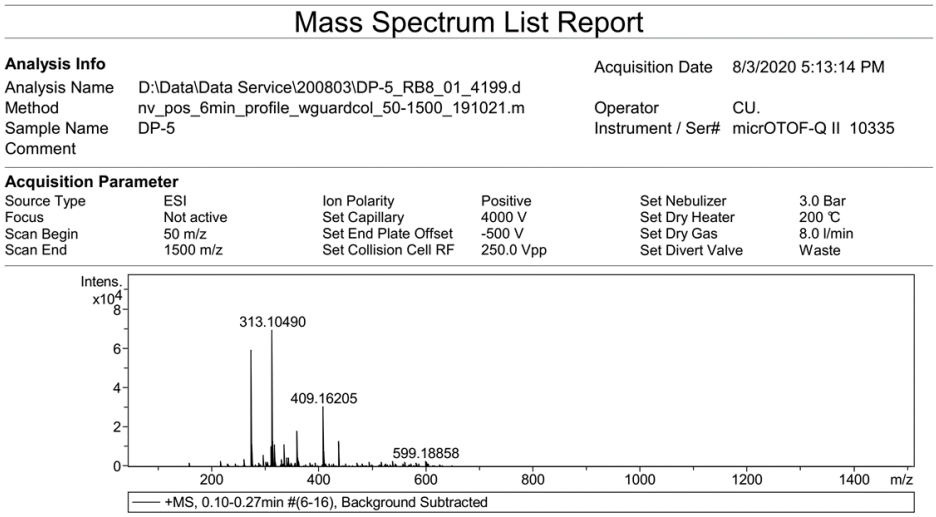


Figure 16 Mass spectrum of compound DP-4

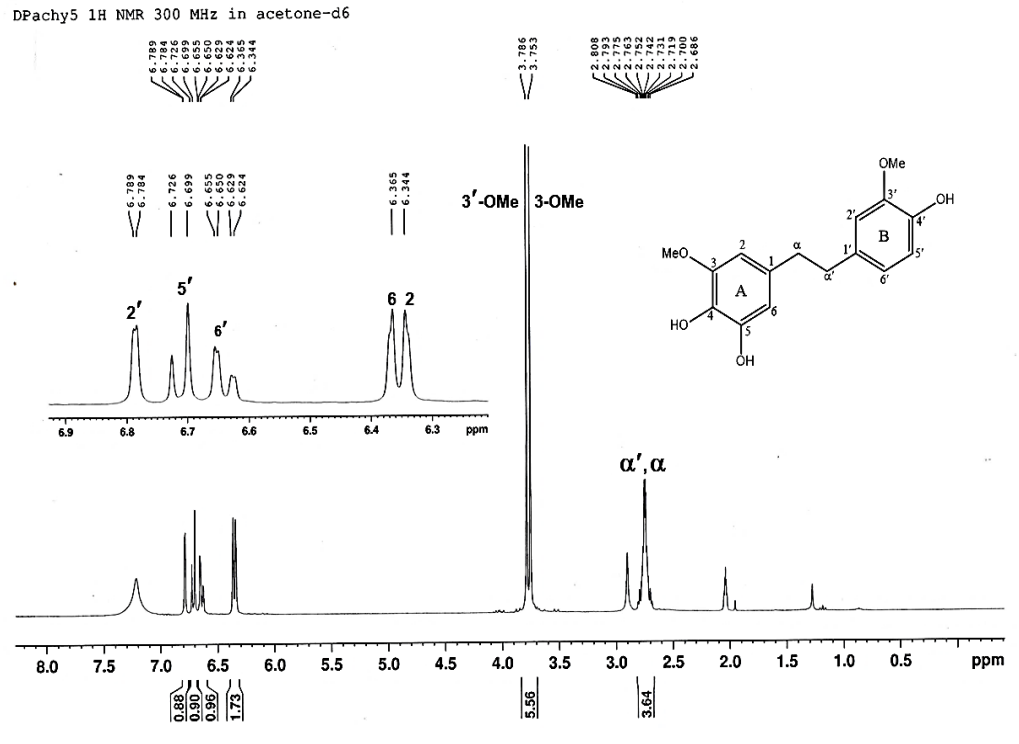


Figure 17 ^{1}H-NMR (300 MHz) spectrum of compound DP-4 (in Acetone-d_6)

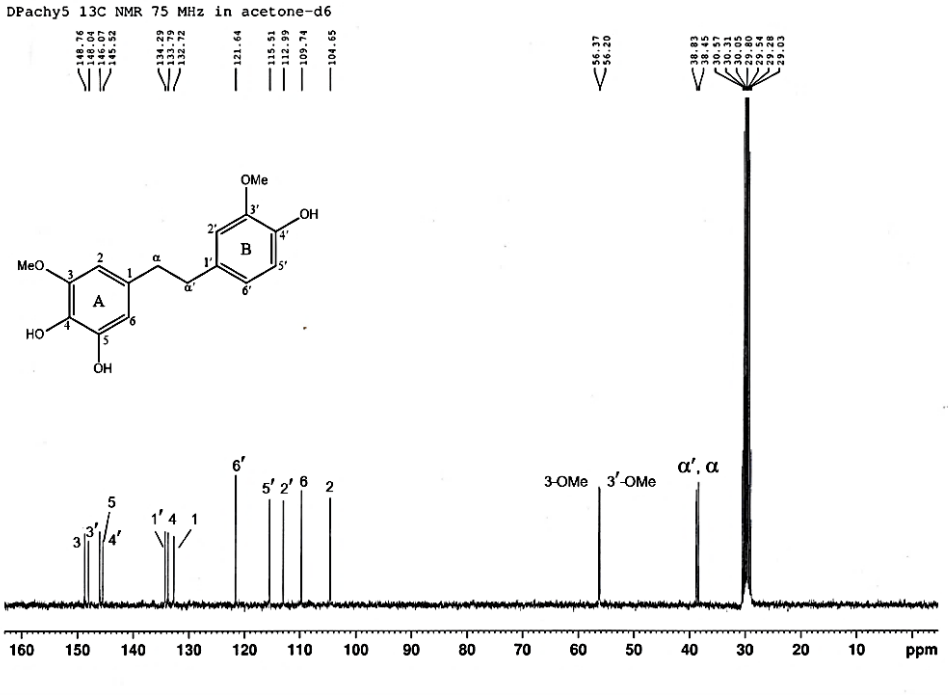


Figure 18 ^{13}C-NMR (75 MHz) spectrum of compound DP-4 (in Acetone-d_6)

4.5 Structure determination of compound DP-5 (New compound)

Compound DP-5 was obtained as a brown amorphous solid. The negative HR-ESI-MS of compound (**Figure 19**) showed an $[M-H]^-$ at *m/z* 575.1906 (calculated for $C_{32}H_{31}O_{10}$, 575.1917). The IR spectrum exhibited absorption bands for hydroxyl (3355 cm^{-1}), aromatic ring (2923, 1606 cm^{-1}), methylene (1450 cm^{-1}) and ether (1268 cm^{-1}) functionalities (**Figure 20**). The UV absorptions at 204 and 281 nm suggested a bisbibenzyl nucleus of the compound (Zhang et al., 2007b) (**Figure 21**).

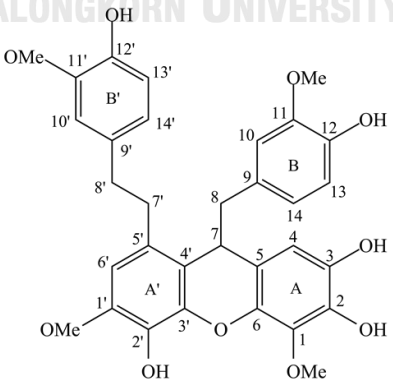
The ^1H NMR (**Figure 22** and **Table 5**) exhibited the presence of signals of aliphatic protons at δ_H 2.67, 2.74 (2H, m, H-8), 2.76, 2.84 (2H, m, H-7′), 2.80 (2H, m, H-8′) and 4.12 (1H, dd, *J* = 7.0, 5.5 Hz, H-7), eight aromatic proton signals at δ_H 6.13–6.77 and resonances for four methoxyl groups at δ_H 3.56 (3H, s, MeO-11), 3.76 (3H, s, MeO-11′), 3.81 (3H, s, MeO-1′) and 3.89 (3H, s, MeO-1).

The ^{13}C NMR spectrum (**Figure 23** and **Table 5**) presented thirty-two carbon signals including three methylene carbons at δ_C 45.9 (C-8), 38.0 (C-8′), 34.5 (C-7′) and a methine carbon at 38.8 (C-7), which were paired with aliphatic protons by HSQC correlations (**Figure 24**). The other carbon signals could be classified as those of two methoxy carbons at δ_C 56.7 (1′-OMe), 61.1 (1-OMe) and twenty four aromatic carbons at δ_C 134.0 (C-2′), 109.7 (C-4), 108.5 (C-6′), 145.8 (C-12), 145.6 (C-12′), 112.9 (C-10′), 119.0 (C-4′), 114.2 (C-10), 117.9 (C-5), 121.6 (C-14′), 122.9 (C-14), 115.1 (C-13), 115.6 (C-13′), 137.4 (C-1), 136.9 (C-2), 140.0 (C-6), 141.7 (C-3), 130.9 (C-9), 129.8 (C-5′), 134.2 (C-9′), 142.4 (C-3′), 147.5 (C-11), 148.1 (C-11′) and 147.2 (C-1′).

Comparing with the ^1H and ^{13}C NMR spectra of dendrofalconerol A, a bisbibenzyl derivative isolated from *D. falconeri* (Sritularak & Likhitwitayawuid, 2009), revealed the structural similarity with DP-5, particularly in rings A and A′ based on the substitution patterns and the points of connection. Compound DP-5 had rings A connect to ring A′ through a methane bridge and an ether linkage, as shown by the HMBC (**Figure 25**) correlations from H-7 to C-4 (δ_C 109.7), C-6 (δ_C 140.0), C-9 (δ_C 130.9), C-3′ (δ_C 142.4) and C-5′ (δ_C 129.8) (**Table 6**). On the ring A of compound DP-5, H-4 (1H, δ_H 6.21, s) exhibited a NOESY correlation (**Figure 26**) with H-7, and HMBC

correlations with C-2 (δ_C 136.9), C-6 (δ_C 140.0) and C-7 (δ_C 39.7). The NMR signal of MeO-1 protons appeared at δ_H 3.89 (3H, s). For the ring A′, the ^{1}H NMR signal at δ_H 6.66 (1H, s) was assigned to H-6′ based on its 3-bond couplings to C-2′ (δ_C 134.0), C-4′ (δ_C 119.0) and C-7′ (δ_C 34.5). The presence of a methoxyl at C-1′ (δ_C 3.89) was confirmed by its NOESY cross-peak with H-6′. For the ring B, ^{1}H NMR showed signals for two doublets at δ_H 6.13 (1H, *J* = 2.0 Hz, H-10) and δ_H 6.56 (1H, *J* = 8.0 Hz, H-13), a double doublet at δ_H 6.22 (1H, *J* = 8.0, 2.0 Hz, H-14) and a methoxy protons at δ_H 3.56 (3H, s, MeO-11). The HMBC correlations of H-10 and H-14 with C-8 indicated that the ring B was di-oxygenated with a hydroxyl group or a methoxyl group at C-11 and C-12. A NOESY cross-peak of the methoxyl group to H-10, suggesting the methoxyl group at C-11. The ^{1}H NMR ABM spin system also appeared for the ring B′ at δ_H 6.69 (1H, dd, *J* = 8.5, 2.0 Hz, H-14′), 6.71 (1H, d, *J* = 8.5 Hz, H-13′) and 6.77 (1H, d, *J* = 2.0 Hz, H-10′). The HMBC correlations of C-8′ (δ_C 38.0) with H-10′ and H-14′ confirmed that the ring B′ was di-oxygenated substitution similar to ring the B. The fourth methoxyl group was located on the ring B′ at C-11′ based on its NOESY correlation with H-10′.

Based on the above spectral evidence, the structure of DP-5 was characterized as a new bisbibenzyl derivatives. It was named dendropachol.



Dendropachol

Table 6 ^{1}H NMR 500 MHz and ^{13}C NMR 125 MHz spectral data of compound DP-5 (in Acetone-d_6)

Position	δ_H (mult., *J* in Hz)	δ_C	HMBC (correlation with ^{1}H)
1	-	137.4	1-OMe
2	-	136.9	4
3	-	141.7	4*
4	6.21 (*s*)	109.7	7
5	-	117.9	7*, 8
6	-	140.0	4, 7
7	4.12 (*dd*, 7.0, 5.5 Hz)	39.7	4, 8*
8	2.67 (*m*), 2.74 (*m*)	45.9	7*, 10, 14
9	-	130.9	7, 8*, 13
10	6.13 (*d*, 2.0)	114.2	8, 14
11	-	147.5	13, 11-OMe
12	-	145.8	10, 14
13	6.56 (*d*, 8.0)	115.1	-
14	6.22 (*dd*, 8.0, 2.0)	122.9	8, 10
1′	-	147.2	6′*, 1′-OMe
2′	-	134.0	6′
3′	-	142.4	7

Table 6 1H NMR 500 MHz and ^{13}C NMR 125 MHz spectral data of compound DP-5 (in Acetone-d_6)

Position	δ_H (mult., *J* in Hz)	^{13}C	HMBC (correlation with ^{1}H)
4′	-	119.0	7*, 8, 6′, 7′
5′	-	129.5	7, 8′
6′	6.66 (*s*)	108.5	7′
7′	2.76 (*m*), 2.84 (*m*)	34.5	6′, 8′*
8′	2.80 (*m*)	38.0	7′ *, 10′, 14′
9′	-	134.2	8′ *, 13′
10′	6.77 (*d*, 2.0)	112.9	8′, 14′
11′	-	148.1	13′, 11′-OMe
12′	-	145.6	10′, 14′
13′	6.71 (*d*, 8.5)	115.6	-
14′	6.69 (*dd*, 8.5, 2.0)	121.6	8′, 10′
MeO-1	3.89 (*s*)	61.1	-
MeO-1′	3.81 (*s*)	56.7	-
MeO-11	3.56 (*s*)	55.9	-
MeO-11′	3.76 (*s*)	56.2	-

Mass Spectrum List Report

Analysis Info

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Acquisition Parameter

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		Hexapole 1	-25.0 V	Set Flight Tube	9000 V
				Set Detector TOF	2295 V

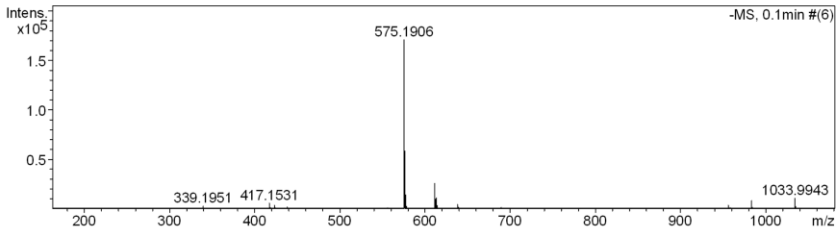


Figure 19 Mass spectrum of compound DP-5

Scientific and Technological Research Equipment Centre
Chulalongkorn University

Fourier Transform Infrared Spectrometer, PerkinElmer (Spectrum One)

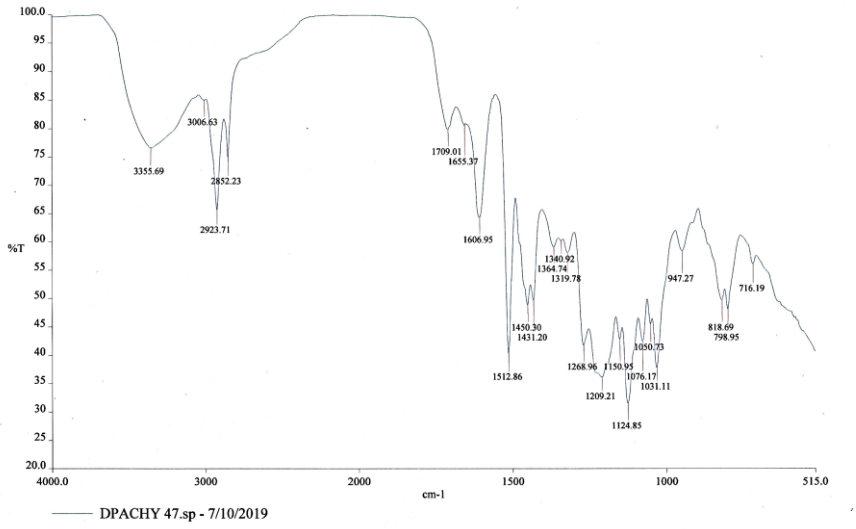


Figure 20 IR spectrum of compound DP-5

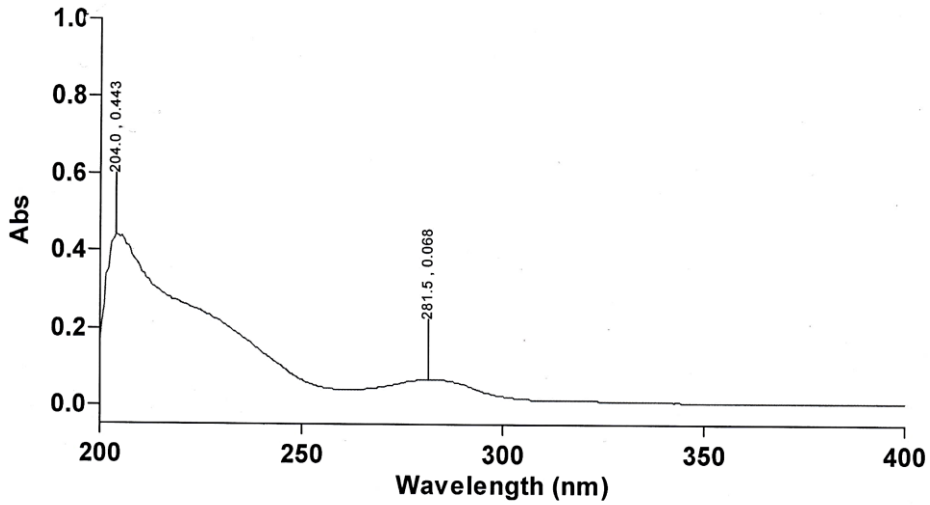


Figure 21 UV spectrum of compound DP-5

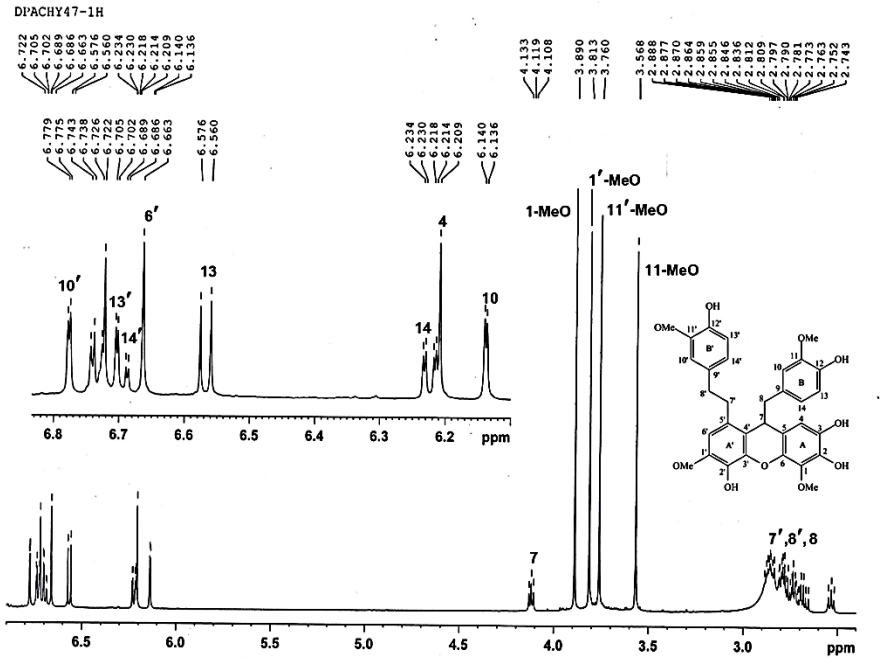


Figure 22 ^{1}H-NMR (500 MHz) spectrum of compound DP-5 (in Acetone-d_6)

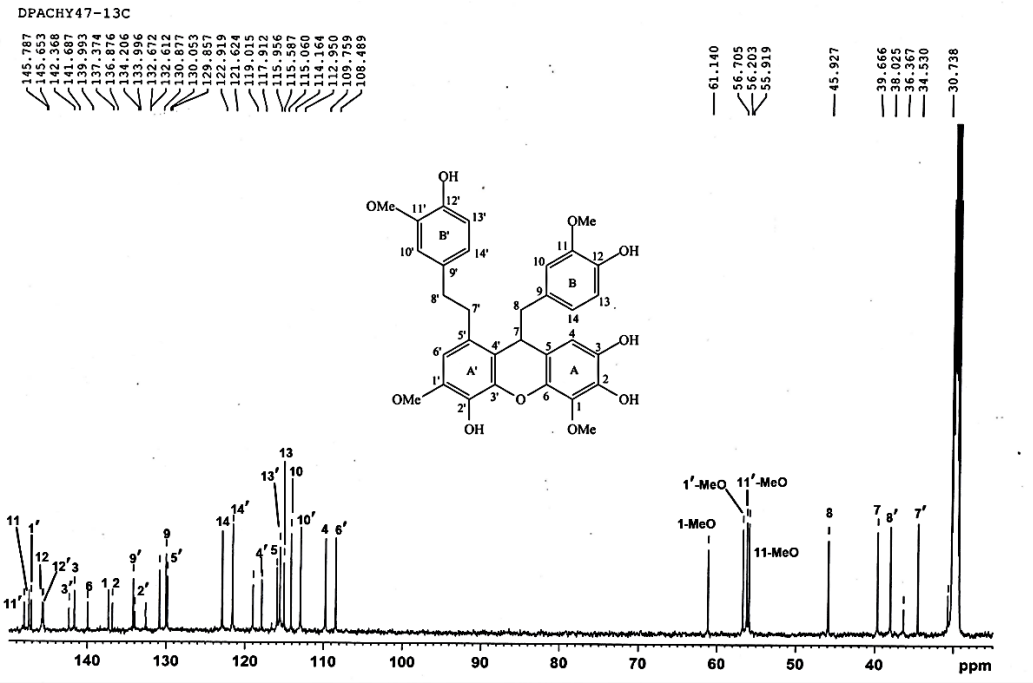


Figure 23 ^{13}C-NMR (125 MHz) spectrum of compound DP-5 (in Acetone-d_6)

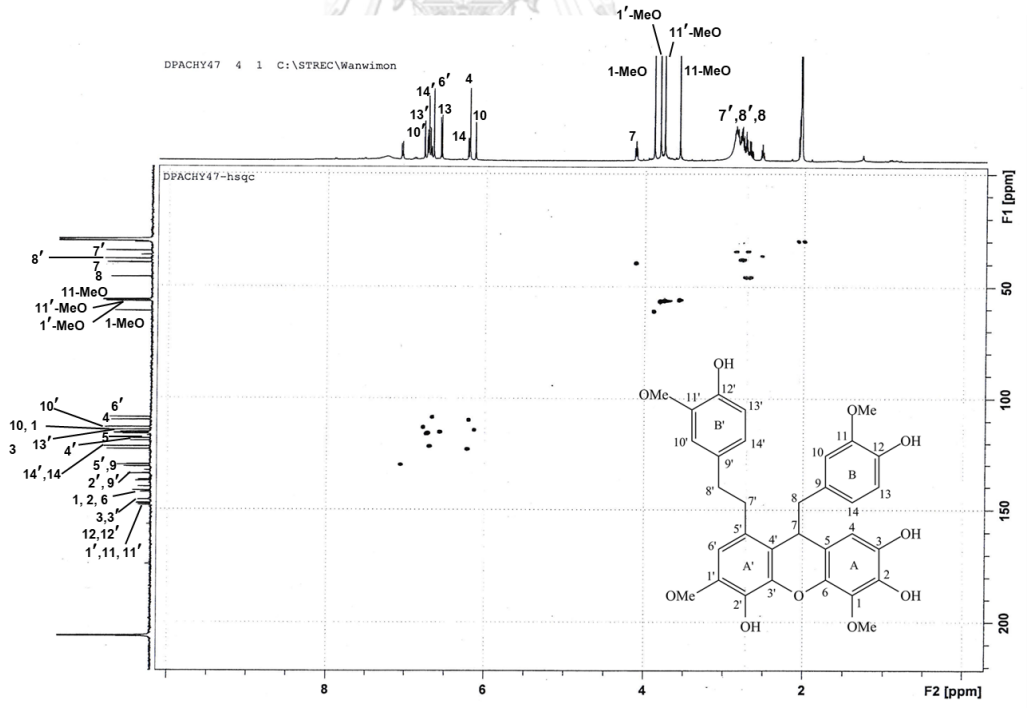


Figure 24 HSQC spectrum of compound DP-5 (in Acetone-d_6)

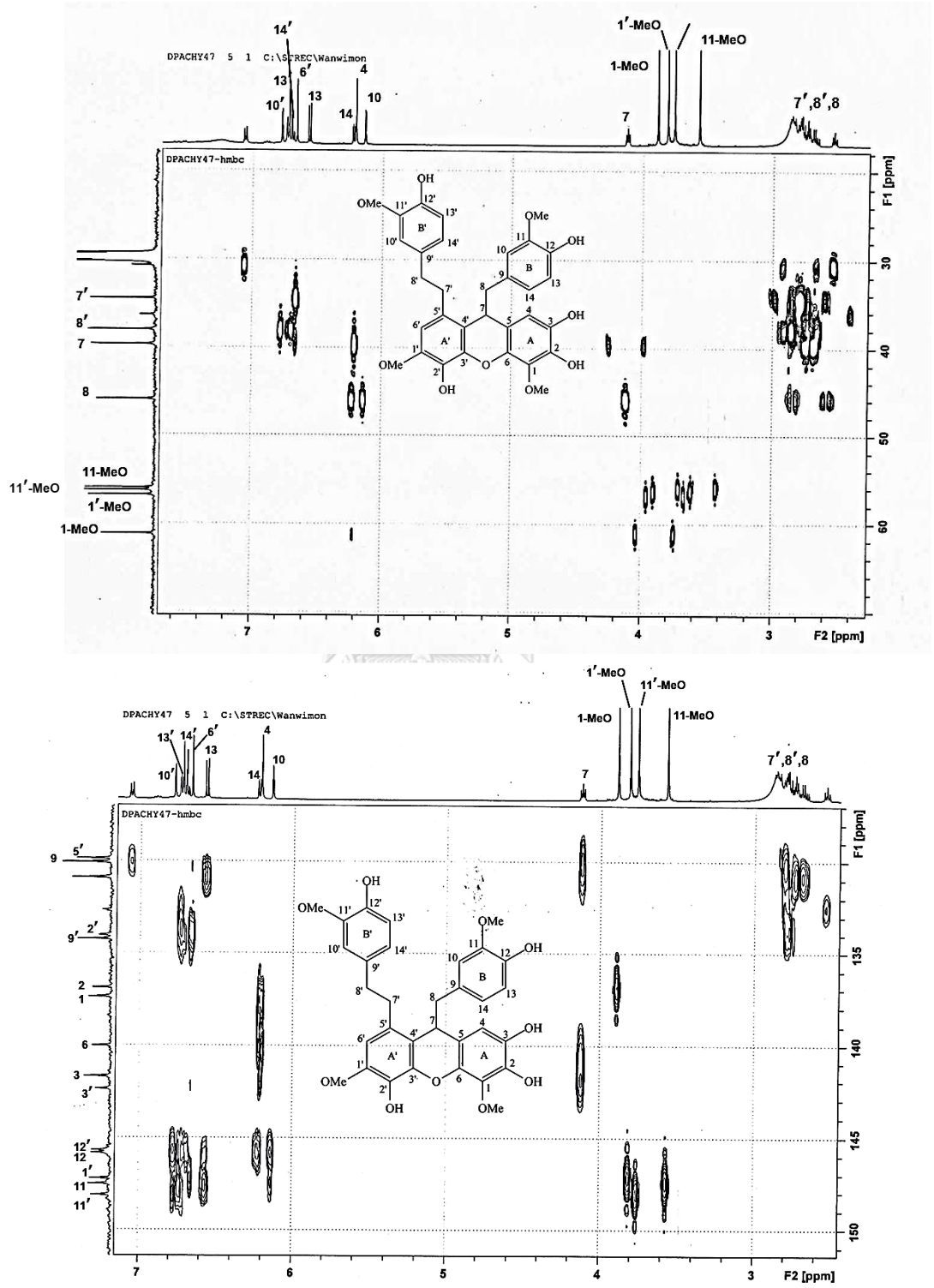


Figure 25 HMBC spectrum of compound DP-5 (in Acetone-d_6)

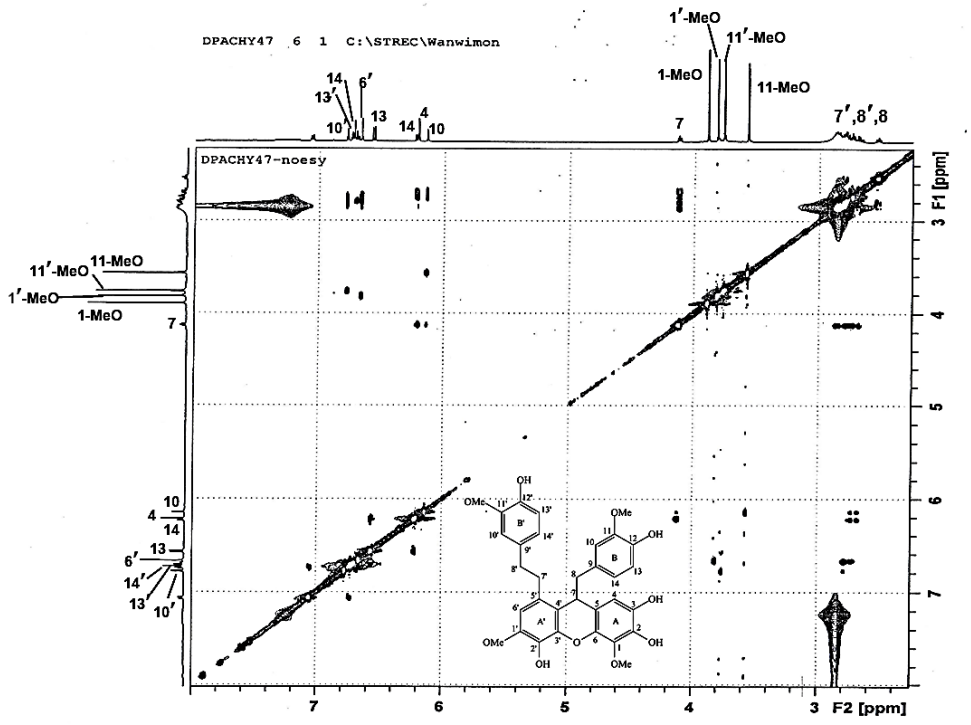


Figure 26 NOESY spectrum of compound DP-5 (in Acetone-d_6)

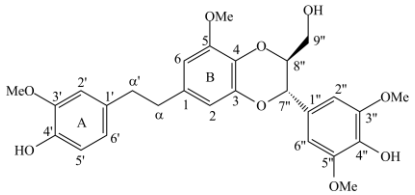
4.6 Structure determination of compound DP-6 (Dendrocandin T)

Compound DP-6 was obtained as a white powder. Its specific rotation $[\alpha]_D^{20}$ was found to be -0.786° (*c* = 0.05, MeOH). The HR-ESI mass spectrum (**Figure 27**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 521.1798, suggesting the molecular formula $C_{27}H_{30}O_9$ (calculated for $C_{27}H_{30}O_9Na$, 521.1787).

The ^{1}H-NMR data (**Figure 28** and **Table 7**) of DP-6 revealed the presence of four methoxy groups at δ_H 3.80 (3H, s, 3′-OMe), 3.79 (3H, s, 5-OMe) and 3.83 (6H, s,3′′, 5′′-OMe). The ^{1}H-NMR also showed signals for three methylene groups at δ_H 2.82 (4H, m, H-α, α'), 3.49 (1H, m, H-9′′), and 3.78-3.79 (1H, m, H-9′′) and two oxygenated methine groups at δ_H 3.96-4.00 (1H, m, H-8′′), and 4.92 (1H, *d*, *J* = 8.0, H-7′′). The ^{13}C NMR spectrum (**Figure 29** and **Table 7**) of DP-6 indicated the presence of four methoxy carbons at δ_C 56.2 (5-OMe), 56.2 (3′-OMe), and 56.7 (3′′, 5′′-OMe) and three methylene carbons at δ_C 38.2 (C-α'), 38.7 (C-α), and 61.8 (C-9′′), respectively. The ^{13}C NMR also exhibited oxygenated methine groups at δ_C 77.2 (C-7′′) and 79.2 C-8′′).

The HSQC spectrums were used to assign the correlations between protons and carbons with a single bond (**Figure 30**). The HMBC (**Figure 31**) correlation peaks between H-7′′ and C-1′′, C-2′′, and C-8′′ deducted presences of a phenylpropanoid unit, which was linked to the ring B of the bibenzyl through a dioxane rings. The NOESY correlation peaks between H-6/5-OMe, H-2′/3′-OMe, H-2′′/3′′-OMe, and H-6′′/5′′-OMe were observed (**Figure 31**).

From the basis of the above spectroscopic properties, compound DP-6 was suggested as dendrocandin T [**57**], which was first isolated from *Dendrobium officinale* (Yang et al., 2008).



Dendrocandin T [**57**]

Table 7 NMR spectral data of compound DP-6 (in Acetone-d_6) and dendrocandin T (in $CDCl_3$)

Position	Compound DP-6		Dendrocandin T*	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	134.8	-	134.4
2	6.34 (*d*, 2.0)	110.2	6.50 (*d*, 1.6)	109.5
3	-	145.1	-	144.0
4	-	132.5	-	130.8
5	-	150.8	-	148.4
6	6.41 (*d*, 2.0)	106.0	6.33 (*d*, 1.6)	104.6
1′	-	134.1	-	133.5
2′	6.81 (*br*, s)	112.9	6.67 (*br*, *s*)	110.9
3′	-	148.0	-	146.2
4′	-	145.6	-	143.6
5′	6.72 (*d*, 7.2)	115.5	6.82 (*d*, 8.2)	114.1
6′	6.76 (*dd*, 7.2, 1.5)	121.6	6.69 (*dd*, 7.8, 1.6)	120.9
α	2.82 (*m*)	38.7	2.80 (*m*)	38.0
α′	2.82 (*m*)	38.2	2.80 (*m*)	37.5
1″	-	124.4	-	127.2
2″	6.81 (*br*, *s*)	106.0	6.66 (*br*, *s*)	103.9
3″	-	149.7	-	147.2
4″	-	137.2	-	135.1
5″	-	149.7	-	147.2
6″	6.81 (*br*, *s*)	106.0	6.67 (*br*, *s*)	103.9
7″	4.92 (*d*, 8.0)	77.2	4.94 (*d*, 8.2)	76.4
8″	3.96-4.00 (*m*)	79.2	3.97-3.99 (*m*)	78.2
9″	3.49 (*dd*, 11.4, 2.4)	61.8	3.53 (*dd*, 12.0, 3.0)	61.5
	3.78-3.79 (*m*)	-	3.90-3.91 (*m*)	-
5-OMe	3.79 (*s*)	56.2	3.86 (*s*)	55.8
3′-OMe	3.79 (*s*)	56.3	3.86 (*s*)	56.0
3″-OMe	3.83 (*s*)	56.7	3.91 (*s*)	56.3
5″-OMe	3.83 (*s*)	56.7	3.91 (*s*)	56.3

*(Yang et al., 2008)

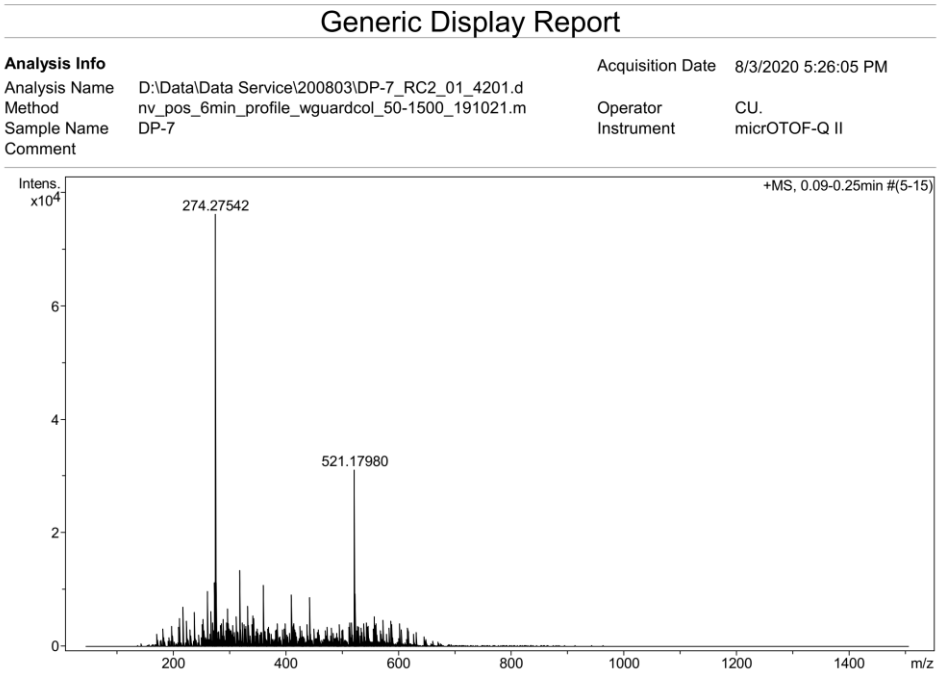


Figure 27 Mass spectrum of compound DP-6

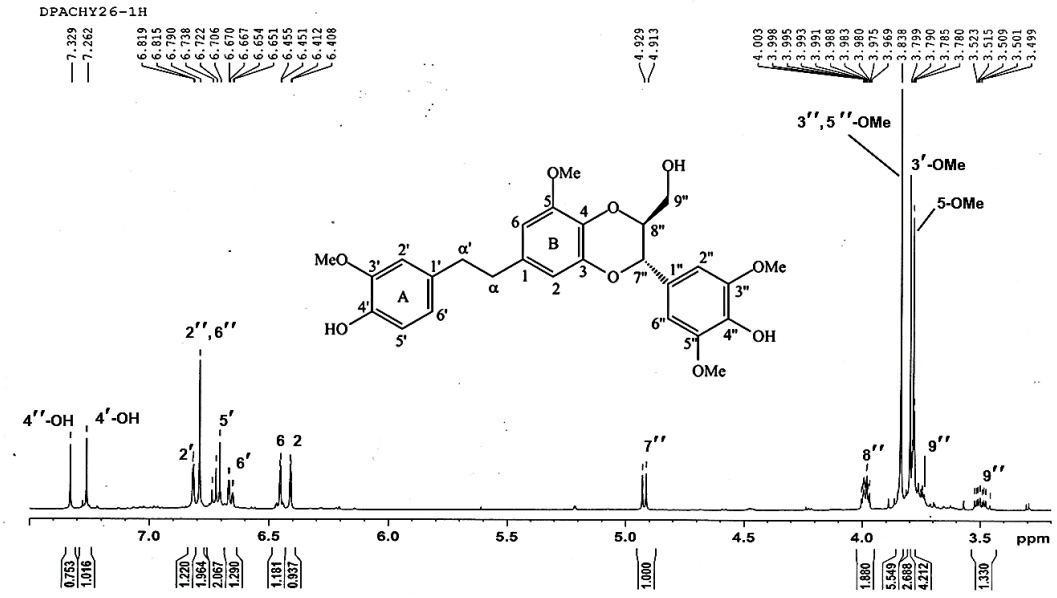


Figure 28 ^{1}H-NMR (500 MHz) spectrum of compound DP-6 (in Acetone-d_6)

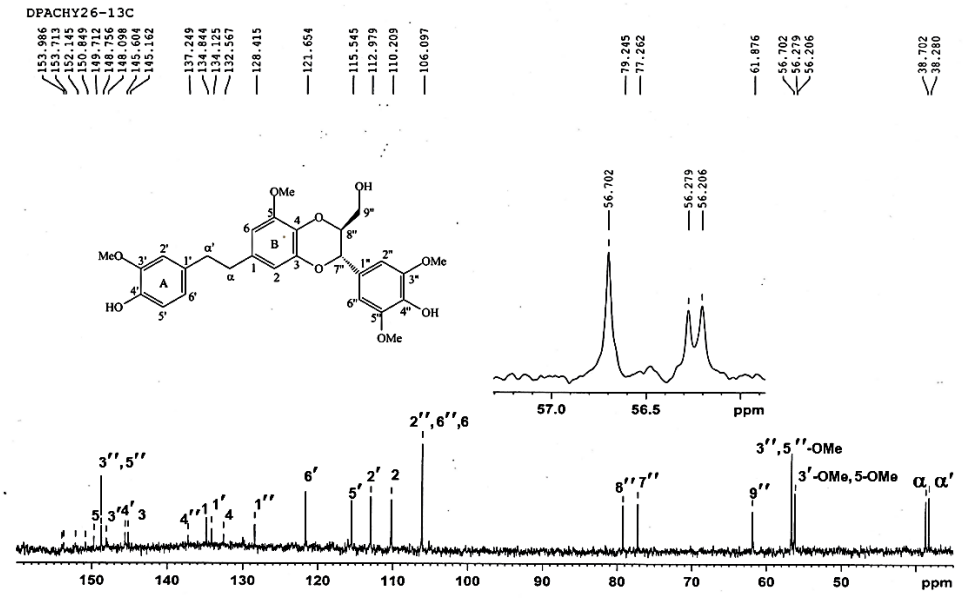


Figure 29 ^{13}C-NMR (125 MHz) spectrum of compound DP-6 (in Acetone-d_6)

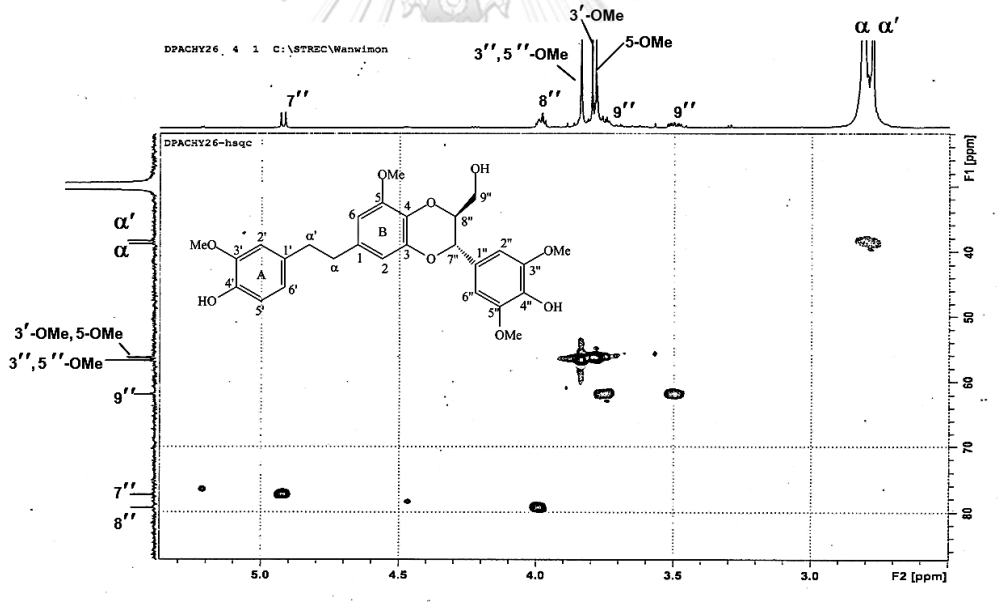


Figure 30 HSQC spectrum of compound DP-6 (in Acetone-d_6)

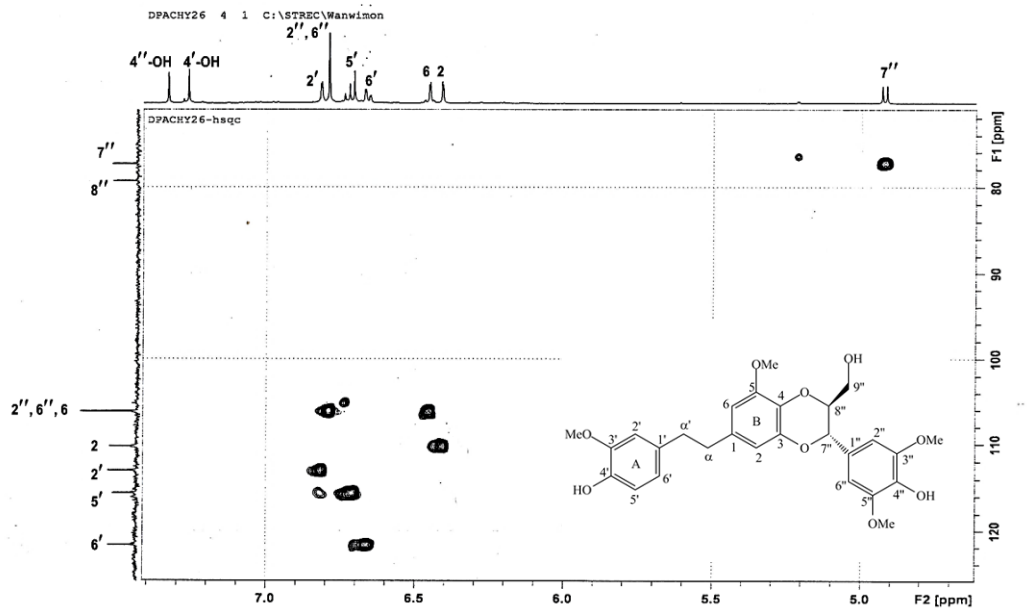


Figure 30 HSQC spectrum of compound DP-6 (in Acetone-d_6)

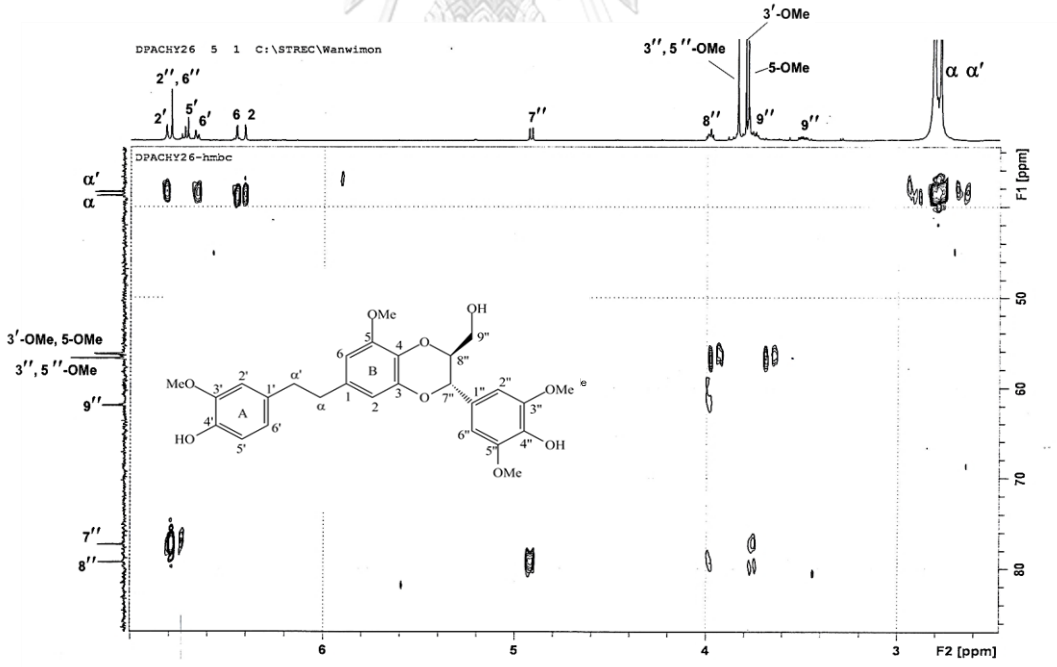


Figure 31 HMBC spectrum of compound DP-6 (in Acetone-d_6)

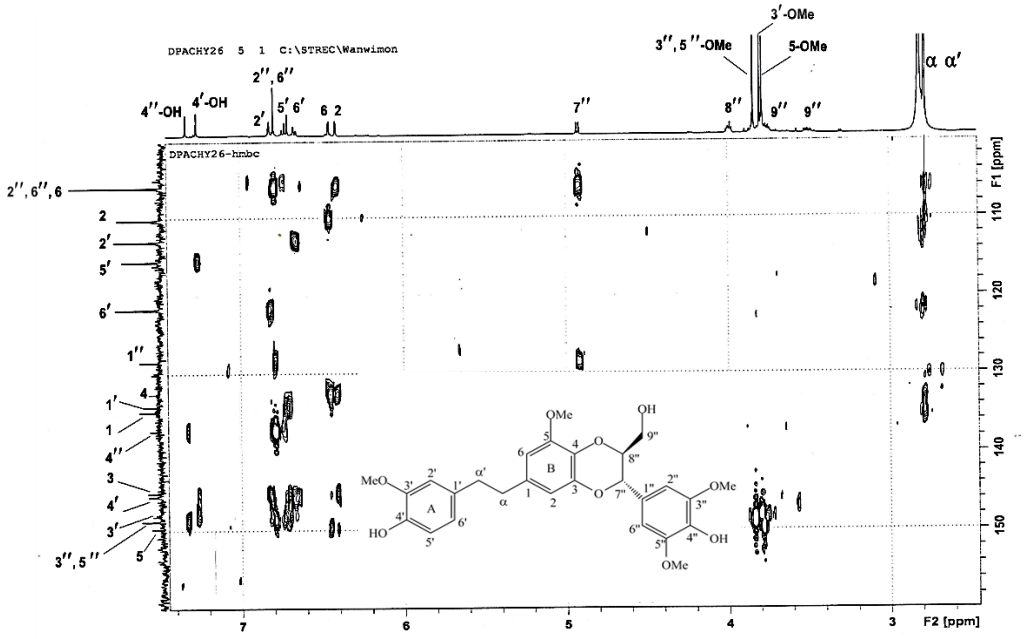


Figure 31 HMBC spectrum of compound DP-6 (in Acetone-d_6)

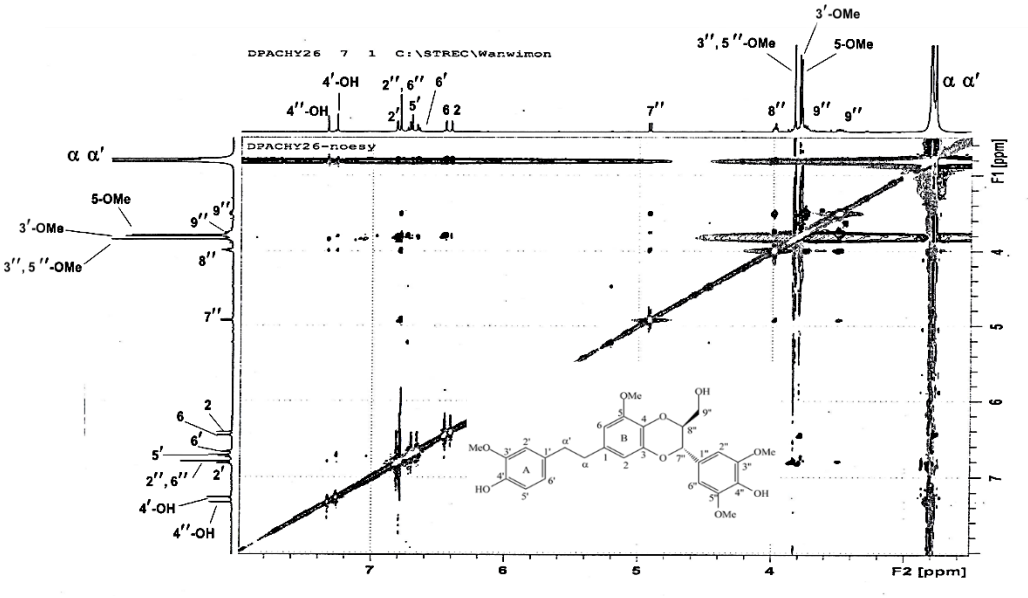


Figure 32 NOESY spectrum of compound DP-6 (in Acetone-d_6)

4.7 Structure determination of compound DP-7 (isovitexin)

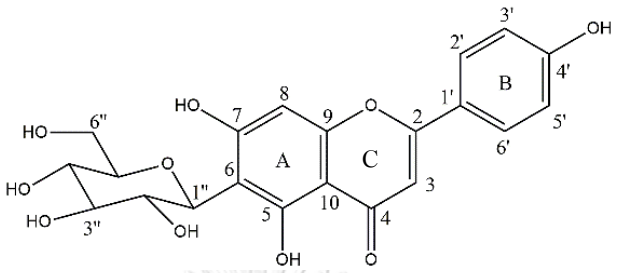
Compound DP-7 was obtained as a yellow amorphous powder. The HR-ESI mass spectrum (**Figure 33**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 455.0954, suggesting the molecular formula $C_{21}H_{20}O_{10}$ (calculated for $C_{21}H_{20}O_{10}Na$, 455.0957).

The ^{1}H-NMR data (**Figure 34** and **Table 8**) of DP-7 presented that the aromatic protons of the A and C ring appeared at δ_H 6.67 (1H, s, H-3) and 6.50 (1H, s, H-8), while those of ring B showed at δ_H 6.92 (2H, *d*, *J* = 8.4 Hz, H-3′, H-6′), and 7.92 (2H, *d*, *J* = 8.4 Hz, H-2′, H-5′), respectively, supportive of the *para*-substituted B-ring.

The ^{13}C NMR spectrum (**Figure 35** and **Table 8**) of DP-7 gave the signal for 21 carbon atoms. A singlet proton resonance at δ_H 6.77 (1H, s, H-3), which correlated to the carbon resonance at δ_C 103.2 in the HSQC spectrum (**Figure 36**), was suggestive of flavone skeleton (Cuc et al., 2015).

In the HMBC spectra of DP-7 (**Figure 37**), observed of correlation between H-3/C-2/C-10/C-1′supported this assumption. The sugar of DP-7 is attached with C-glycosidic bond to the aglycone only in one position is observed by the signals of proton H-8, which would not appear if the glycosidic bond existed (Zielinska-Pisklak, M. A. et al., 2015). The glycosyl proton at δ_H 4.59 (2H, *d*, *J* = 8.4 Hz, H-1′′), while the remaining glucosyl protons exhibited in range of δ_H 3.33-4.01 (H-2′′-6′′) (Ramarathnam et al., 1989). Moreover, the chemical shift of glucose anomeric proton of glucose unit at δ_H 4.59 (2H, *d*, *J* = 8.4 Hz, H-1′′) and the long-range correlation of corresponding carbon at C-6 (δ_C 109.3) in HMBC spectrum indicated that glucose is attached directly to aglycone with C-glycosidic bond (Ganbaatar et al., 2015). The alpha or beta (β or α) glycosidic bonds is determined by the vicinal coupling constant value of the anomeric proton doublet in the range of 7-12 Hz for beta and 3-4 Hz for alpha, respectively (Zielinska-Pisklak, M. A. et al., 2015). The coupling constant of DP-7 were equal to 8.4 Hz and 9.0 Hz, which are indicated that DP-7 represent β anomeric form.

From the basis of the above spectroscopic properties, compound DP-7 was suggested as Isovitexin [**155**], which was reported from *Dendrobium catenatum* (Ren et al., 2020).



Isovitexin [**155**]

Table 8 NMR spectral data of compound DP-7 *(*in DMSO-d_6*)* and isovitexin (in CD_3OD)

Position	Compound DP-7		Isovitexin*	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
Aglycone				
2	-	163.9	-	164.3
3	6.77 (*s*)	103.2	6.52 (*s*)	103.9
4	-	182.3	-	182.9
5	-	156.7	-	157.5
6	-	109.3	-	110.1
7	-	163.9	-	165.0
8	6.50 (*s*)	94.1	6.42 (*s*)	94.7
9	-	161.3	-	162.1
10	-	103.7	-	104.8
1′	-	121.56	-	122.2
2′	7.92 (*d*, 7.8)	128.9	7.79 (*d*, 8.0)	128.9
3′	6.92 (*d*, 8.4)	116.4	6.68 (*d,* 8.0)	116.8
4′	-	161.6	-	162.7
5′	6.92 (*d*, 8.4)	116.4	6.68 (*d,* 8.0)	116.8
6′	7.92 (*d*, 7.8)	128.9	7.79 (*d*, 8.0)	128.9
6-C-Glc				
1″	4.59 (*d*, 8.4)	73.5	4.87 (*d*, 10.0)	75.6
2″	4.03 (*dd*, 8.7, 9.0)	71.0	4.19 (*dd*, 9.0, 10.0)	72.9
3″	3.33 (*m*)	79.4	3.46 (*m*)	80.6
4″	3.33 (*m*)	70.6	3.46 (*m*)	71.9
5″	4.01 (*m*)	82.0	3.90 (*m*)	83.0
6″	3.88 (*m*)	61.9	3.72 (*dd*, 5.5, 11.0) 3.86 (*br*, *d*, 11.0)	62.7

*(Cuc et al., 2015)

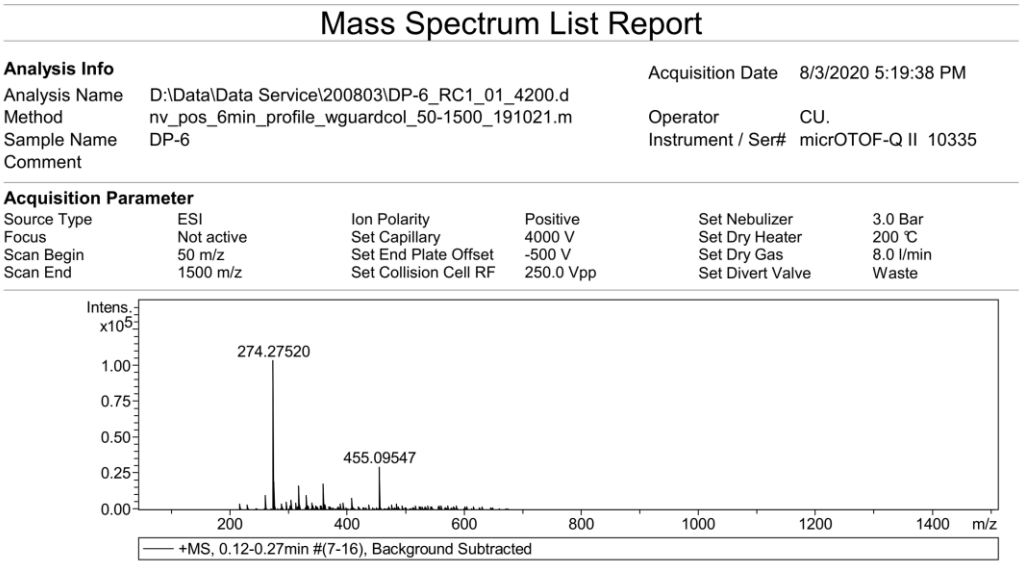


Figure 33 Mass spectrum of compound DP-7

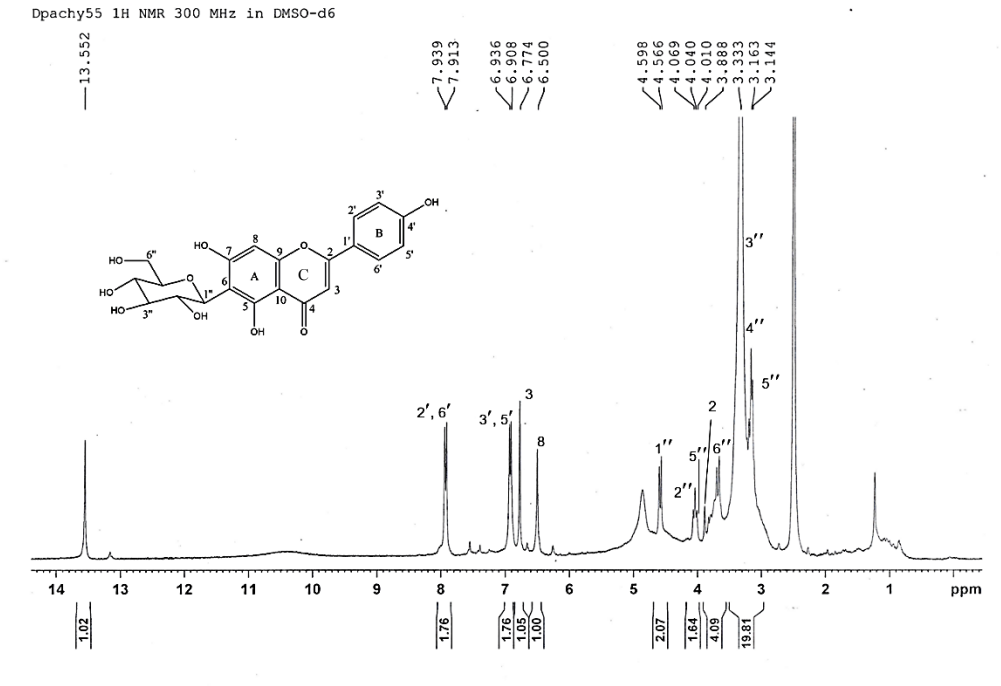


Figure 34 ^{1}H-NMR (300 MHz) spectrum of compound DP-7 (in DMSO-d_6)

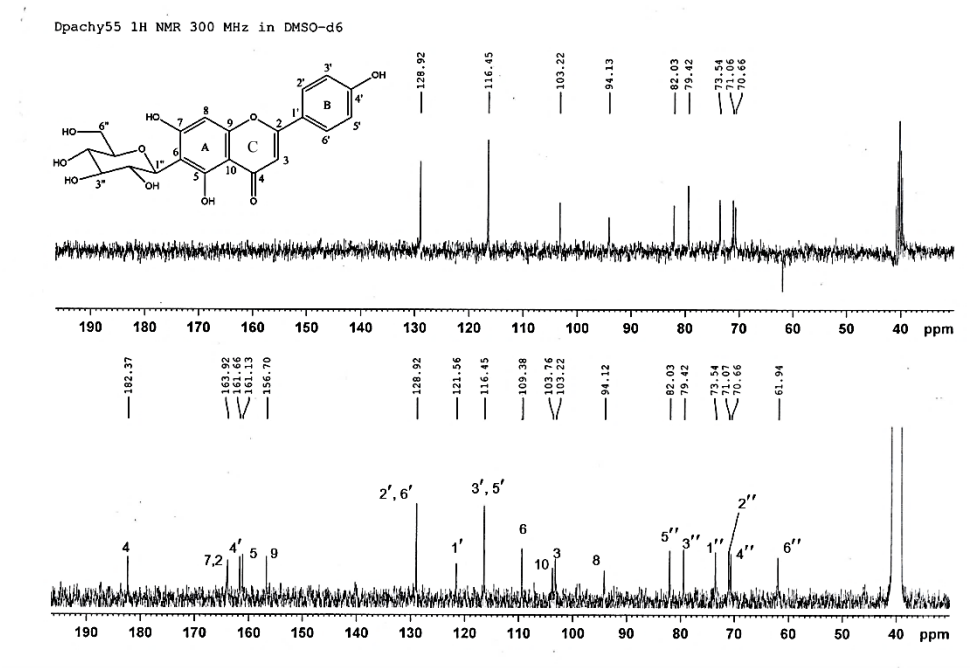


Figure 35 ^{13}C-NMR (75 MHz) spectrum of compound DP-7 (in DMSO-d_6)

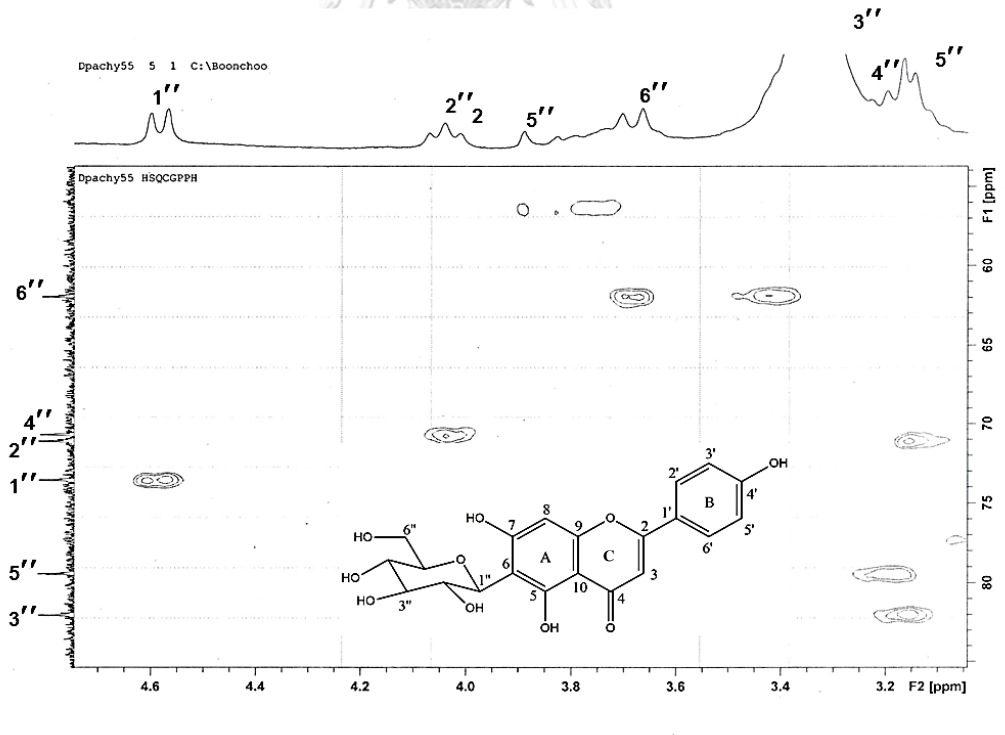


Figure 36 HSQC spectrum of compound DP-7 (in DMSO-d_6)

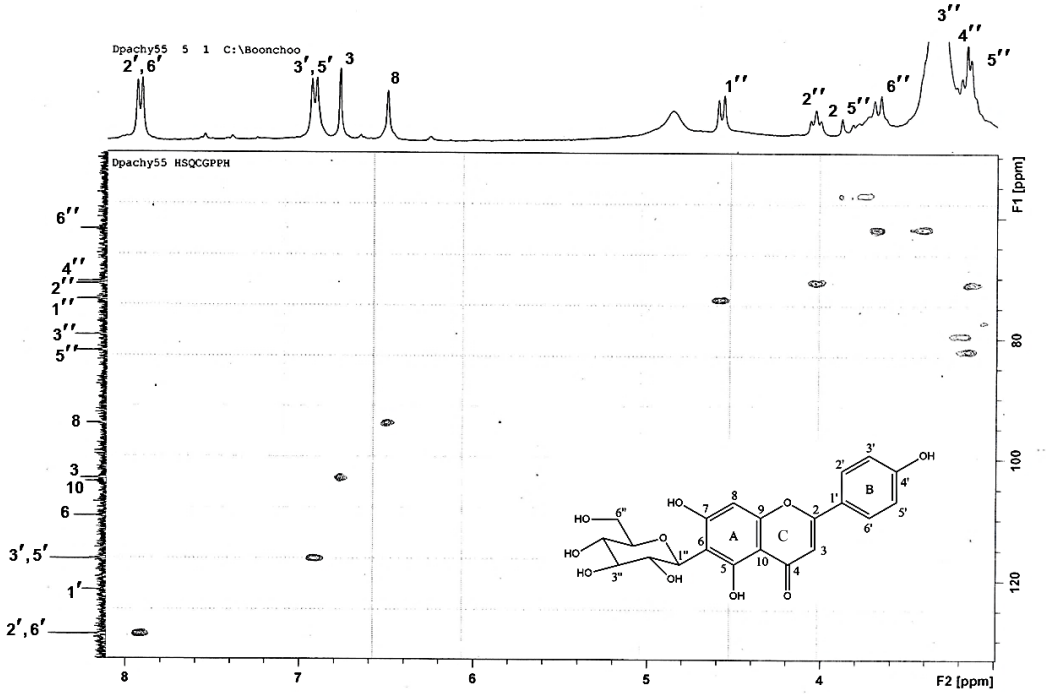


Figure 36 HSQC spectrum of compound DP-7 (in DMSO-d_6)

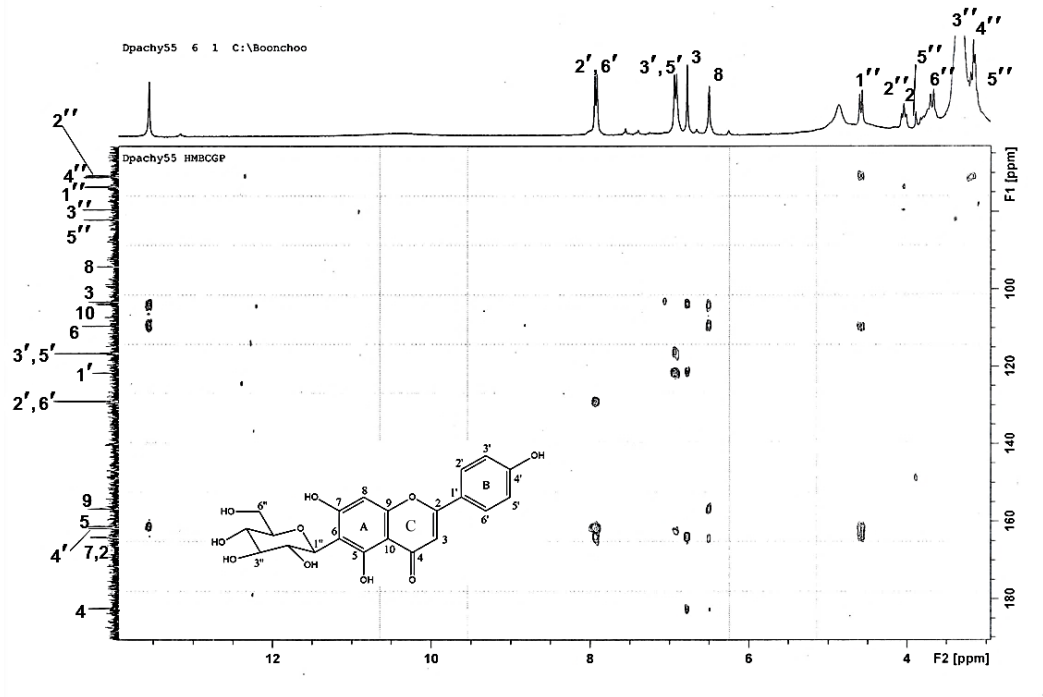


Figure 37 HMBC spectrum of compound DP-7 (in DMSO-d_6)

4.8 Structure determination of compound DH-1 (Amoenylin)

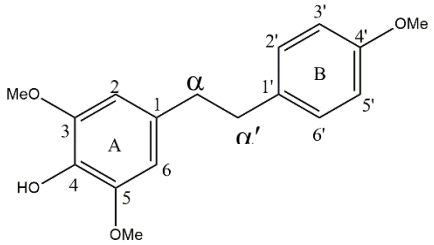
Compound DH-1 was obtained as a yellow brown amorphous solid. The HR-ESI-MS (**Figure 38**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 311.1260, suggesting the molecular formula $C_{17}H_{20}O_4$ (calculated for $C_{17}H_{20}O_4Na$, 311.1259).

The ^{1}H-NMR spectrum (**Figure 39** and **Table 9**) showed the presence of three methoxy groups at δ_H 3.79 (3H, s, 4′-OMe) and 3.84 (6H, s, 3-OMe, 5-OMe), six aromatic protons at δ_H 6.35 (2H, s, H-2,6), 6.82 (2H, *d*, *J*=8.4 Hz, H-3′,5′), 7.07 (2H, *d*, *J*=8.4 Hz, H-2′,6′), and two pairs of methylene groups at δ_H 2.83 (4H, *m*, H-α, α'), which are indicated to the bibenzyl structures.

The ^{13}C-NMR (**Figure 40** and **Table 9**) showed twelve carbons signals, including seven quaternary carbons at δ_C 133.0 (C-1), 132.9 (C-1′), 146.9 (C-3,5), 113.9 (C-3′), 133.9 (C-4), 158.0 (C-4′), five methine carbons at δ_C 105.3 (C-2), 129.6 (C-2′), 105.2 (C-6), 113.8 (C-5′), 129.5 (C-6′), two pairs of methylene carbon at δ_C 37.4 (C-α'), 38.5 (C-α), and three methoxy carbons at δ_C 55.4 (4′-OMe) and 56.4 (3,5-OMe), respectively.

The HSQC spectrum were used to assign the correlations between protons and carbons with a single bond (**Figure 41**). The positions of aromatic protons and methoxy groups were assigned by the correlation in HMBC spectra (**Figure 42**). On ring A, the position of H-2 and H-6 were assigned from the correlations to C-α, C-3, and C-5. Regarding a symmetry of ring B, the position of H-2′ and H-6′ were assigned from the correlations to C-α', C-1′, C-3′, and C-5′. The H-3′and H-5′ were assigned based on the correlation to C-1′, and C-4′. The COSY spectrum was used to confirm the position of ortho-coupled aromatic protons and methoxy groups (**Figure 43**).

Based on the above spectral data, compound DH-1 could be identified as amoenylin [**2**]. This compound has been found in *D. amornum* (Majumder et al., 1999).



Amoenylin [**2**]

Table 9 NMR spectral data of compound DH-1 (in Acetone-d_6) and amoenylin (in $CDCl_3$)

Positions	Compound DH-1		Amoenylin*	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	133.0	-	133.4
2	6.35 (*s*)	105.3	6.28 (*s*)	105.0
3	-	146.9	-	147.0
4	-	133.9	-	132.4
5	-	146.9	-	147.0
6	6.35 (*s*)	105.2	6.28 (*s*)	105.0
1′	-	132.9	-	132.6
2′	7.07 (*d*, 8.4)	129.6	7.00 (*d*, 9)	129.3
3′	6.82 (*d*, 8.4)	113.9	6.75 (*d*, 9)	113.6
4′	-	158.0	-	157.9
5′	6.82 (*d*, 8.4)	113.8	6.75 (*d*, 9)	113.6
6′	7.07 (*d*, 8.4)	129.5	7.00 (*d*, 9)	129.3
α	2.83 (*s*)	38.5	2.75 (*s*)	38.3
α′	2.80 (*s*)	37.4	2.75 (*s*)	37.2
4′-OMe	3.79 (*s*)	55.4	3.71 (*s*)	55.2
3,5-OMe	3.84 (*s*)	56.4	3.76 (*s*)	56.2

*(Majumder et al., 1999)

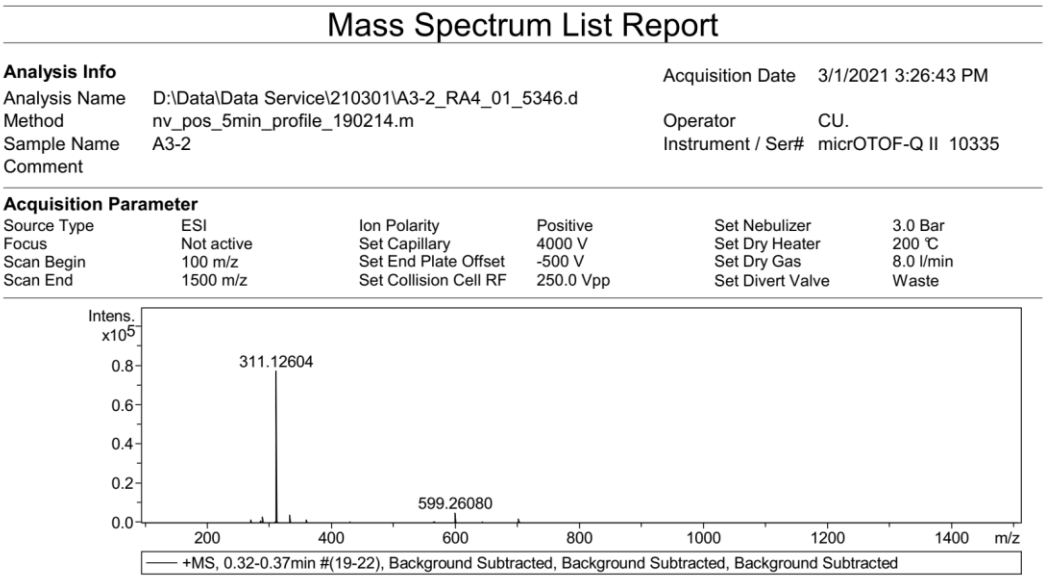


Figure 38 Mass spectrum of compound DH-1

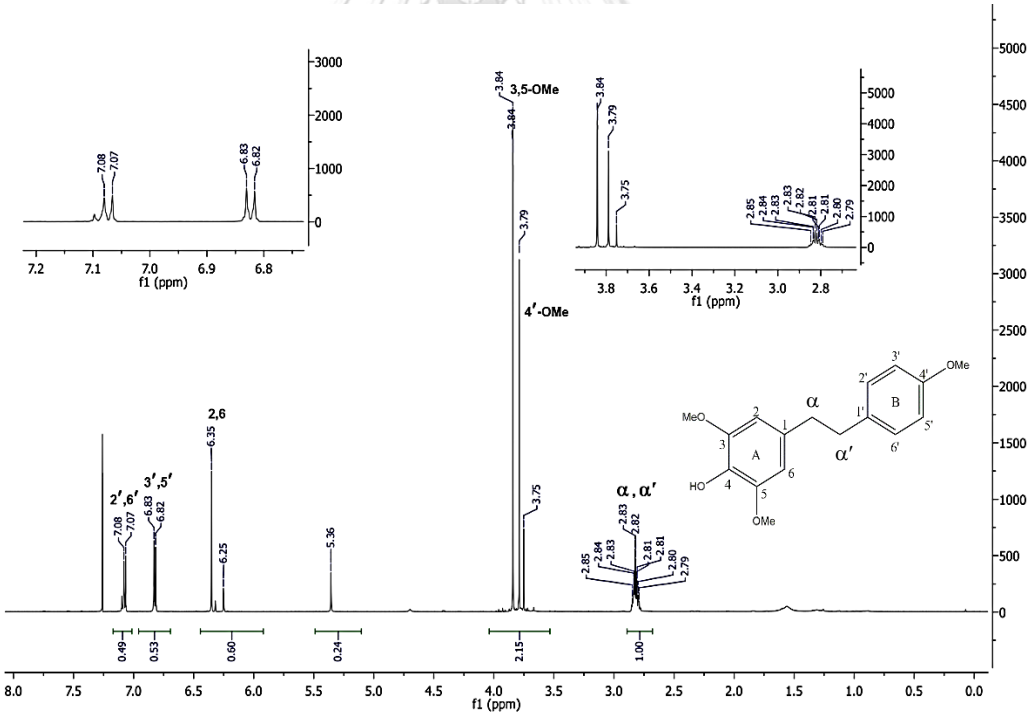


Figure 39 ^{1}H-NMR (600 MHz) spectrum of compound DH-1 (in $CDCl_3$)

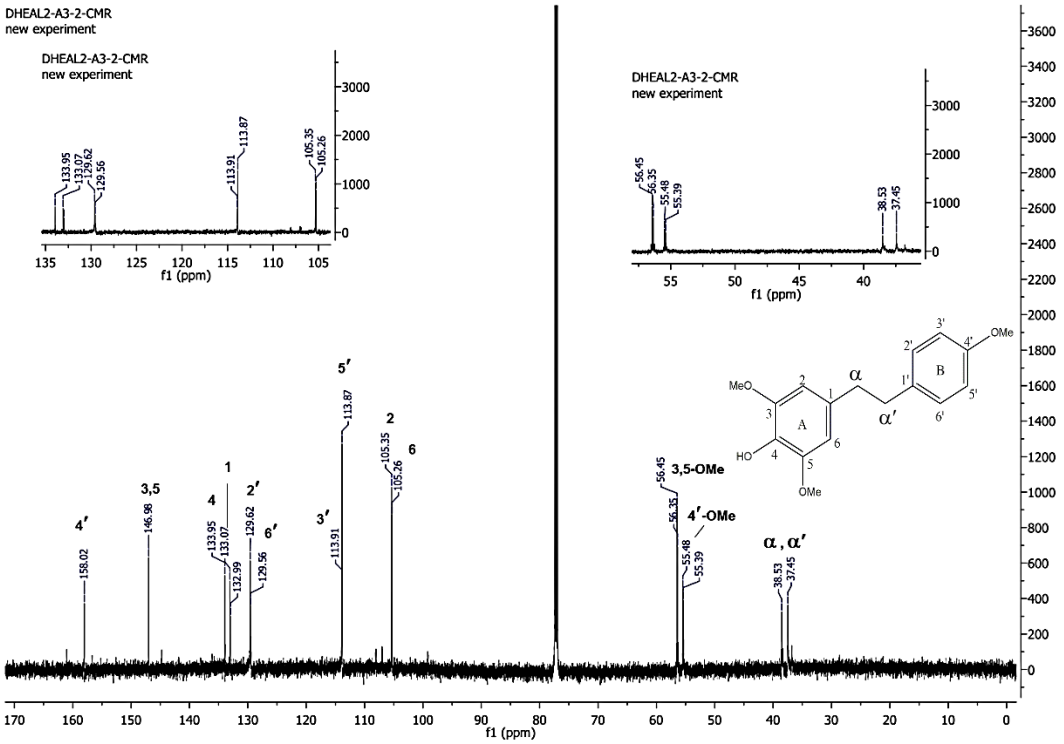


Figure 40 ^{13}C-NMR (150 MHz) spectrum of compound DH-1 (in $CDCl_3$)

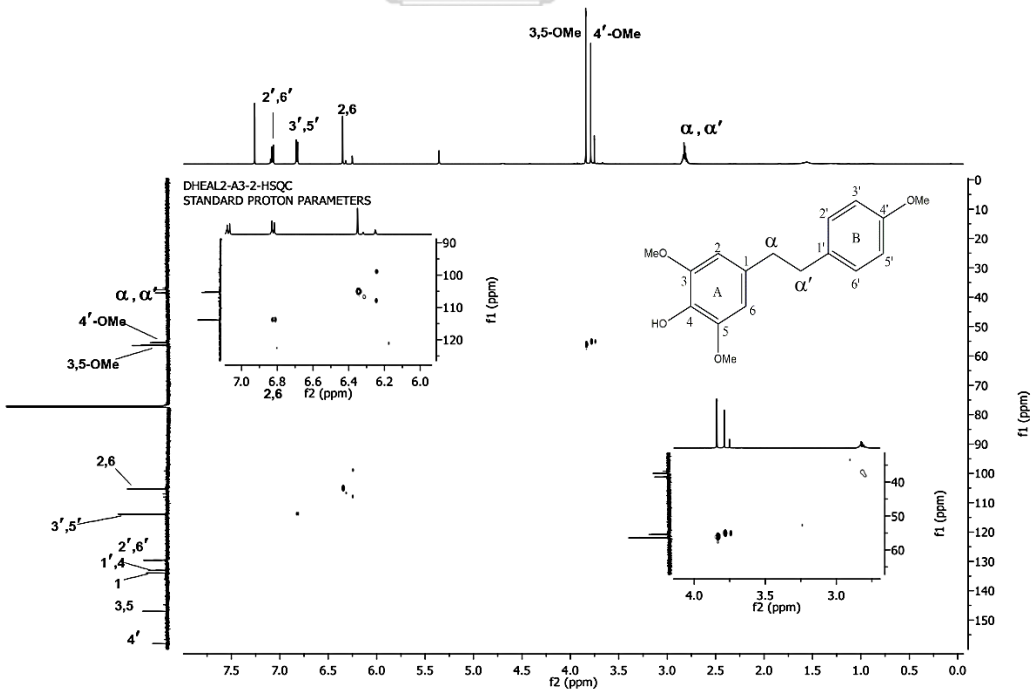


Figure 41 HSQC spectrum of compound DH-1 (in $CDCl_3$)

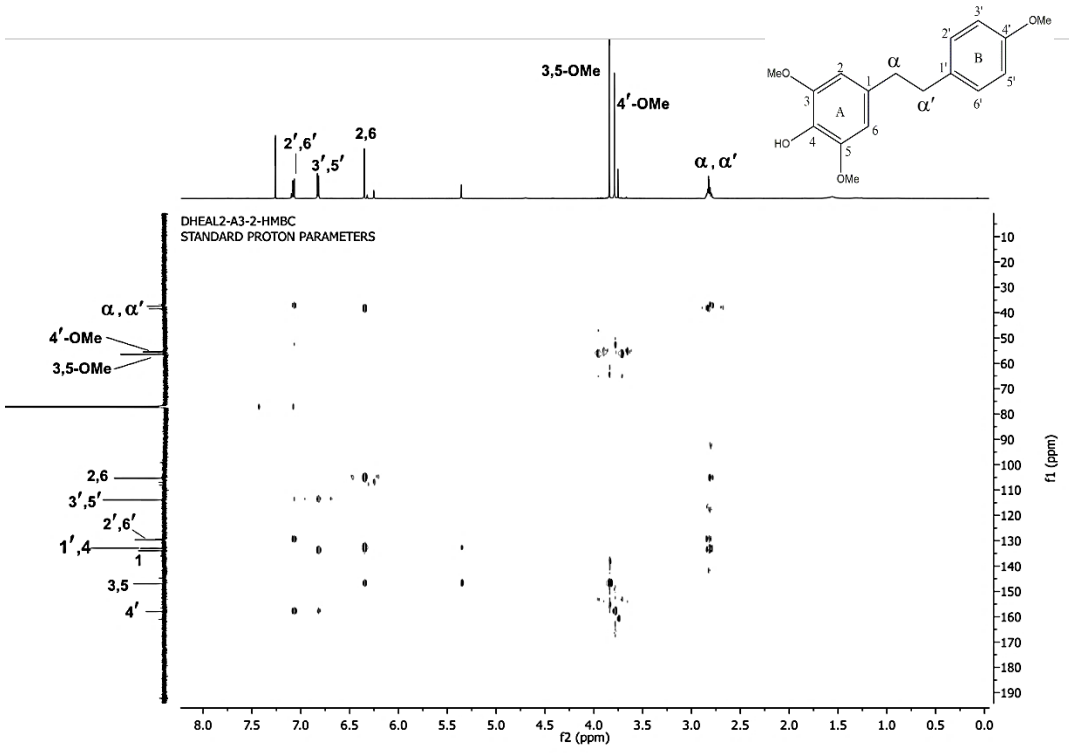


Figure 42 HMBC spectrum of compound DH-1 (in $CDCl_3$)

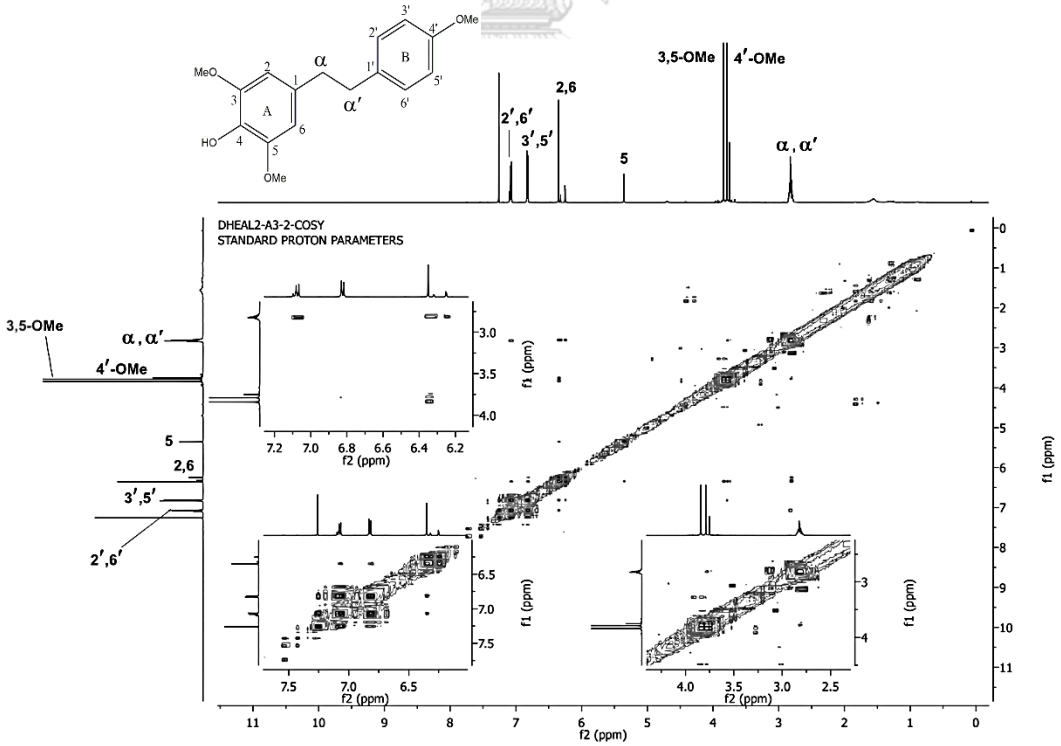


Figure 43 COSY spectrum of compound DH-1 (in $CDCl_3$)

4.9 Structure determination of compound DH-2 (methyl 3-(4-hydroxyphenyl) propionate)

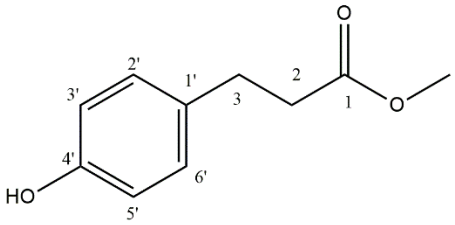
Compound DH-2 was obtained as a white powder. The HR-ESI-MS (**Figure 44**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 203.0665, suggesting the molecular formula $C_{10}H_{12}O_3$ (calculated for $C_{10}H_{12}O_3Na$, 203.0684).

The ^{1}H-NMR spectrum (**Figure 45** and **Table 10**) exhibited 11 signal protons including, one methoxy group at δ_H 3.58 (3H, s, 1-OMe), four methine protons at δ_H 6.73 (2H, *d*, *J*= 8.4 Hz, H-3′, 5′), 7.03 (2H, *d*, *J*= 8.4 Hz, H-2′, 6′), two methylene protons at δ_H 2.53 (2H, *t*, *J* = 7.8 Hz, H-2), and 2.79 (2H, *t*, *J* = 7.8 Hz, H-3).

The ^{13}C-NMR (**Figure 46** and **Table 10**) showed 10 carbons signals, including three quaternary carbons at δ_C C-1′ (131.46), C-4′ (155.7), and C-1 (172.6), four methine carbons at δ_C C-2′ (129.1), 3′ (115.1), C-5′ (115.1), C-6′ (129.1), two methylene carbon at C-3 (29.8), C-2 (35.6), and one methoxy carbons at 1-OMe (52.3), respectively.

The HSQC spectrums were used to assign a linkage of proton to carbon with a single bond (**Figures 47**). The positions of aromatic protons and methoxy groups were assigned by the correlation in HMBC spectra (**Figure 48**). The H-2 proton showed correlation cross-peak between C-1 and C-1′. The H-3 was assigned by the correlations to C-1′, C-2, C-2′, C-6′, and C-1. The H-3′ and H-5′ were assigned by the correlations to C-1′, and C-4′. The H-2′ and H-6′ were assigned by the correlations to C-4′. The location of the methoxy (1-OMe) group was confirmed by its HMBC spectrum with C-1.

Based on the above spectral data, compound DH-2 could be identified as methyl 3-(4-hydroxyphenyl) propionate. This compound has been found in *Bulbophyllum retusiusculum* (Fang et al., 2018).



Methyl 3-(4-hydroxyphenyl) propionate

Table 10 NMR spectral data of compound DH-2 (in Acetone-d_6) and methyl 3-(4-hydroxyphenyl) propionate (in $CDCl_3$)

Position	Compound DH-2		Methyl 3-(4-hydroxyphenyl) propionate*	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	172.6	-	175.4
2	2.53 (*t*, 7.8)	35.6	2.56 (*t*, 7.6)	37.2
3	2.79 (*t*, 7.8)	29.8	2.81 (*t*, 7.6)	31.2
1′	-	131.4	-	132.7
2′	7.03 (*d*, 8.4)	129.1	7.00 (*m*)	130.3
3′	6.73 (*d*, 8.4)	115.1	6.68 (*m*)	116.2
4′	-	155.7	-	156.9
5′	6.73 (*d*, 8.4)	115.1	6.68 (*m*)	116.2
6′	7.03 (*d*, 8.4)	129.1	7.00 (*m*)	130.3
1-OMe	3.58 (*s*)	52.3	3.63 (*s*)	52.0

***** (Fang et al., 2018)

Mass Spectrum List Report

Analysis Info

Analysis Name	D:\Data\Data Service\210104\DHETERO 8_RA3_01_5113.d	Acquisition Date	1/4/2021 4:04:21 PM
Method	nv_pos_5min_profile_190214.m	Operator	CU.
Sample Name	DHETERO 8	Instrument / Ser#	micrOTOF-Q II 10335
Comment			

Acquisition Parameter

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Scan End	1500 m/z	Set Collision Cell RF	250.0 Vpp	Set Divert Valve	Waste

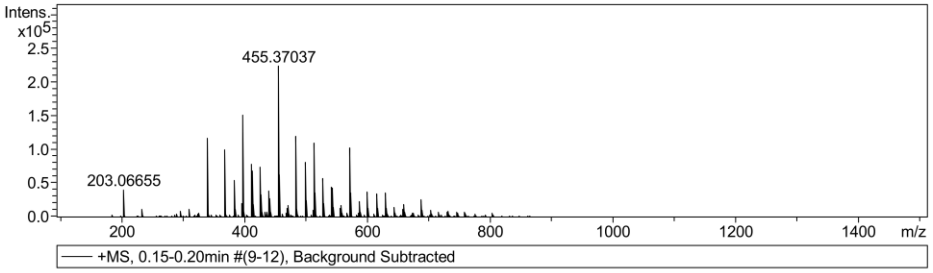


Figure 44 Mass spectrum of compound DH-2

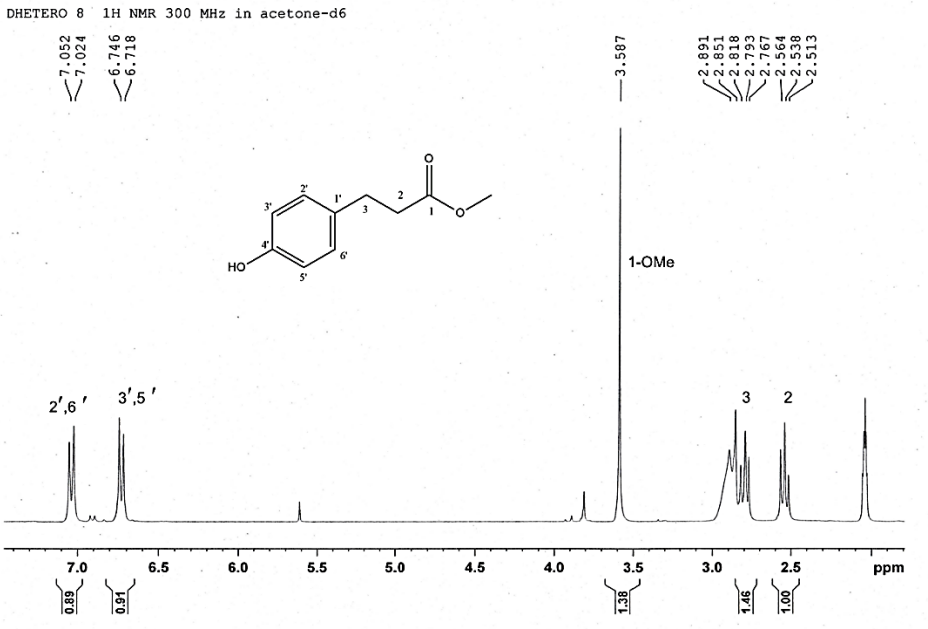


Figure 45 ^{1}H-NMR (300 MHz) spectrum of compound DH-2 (in Acetone-d_6)

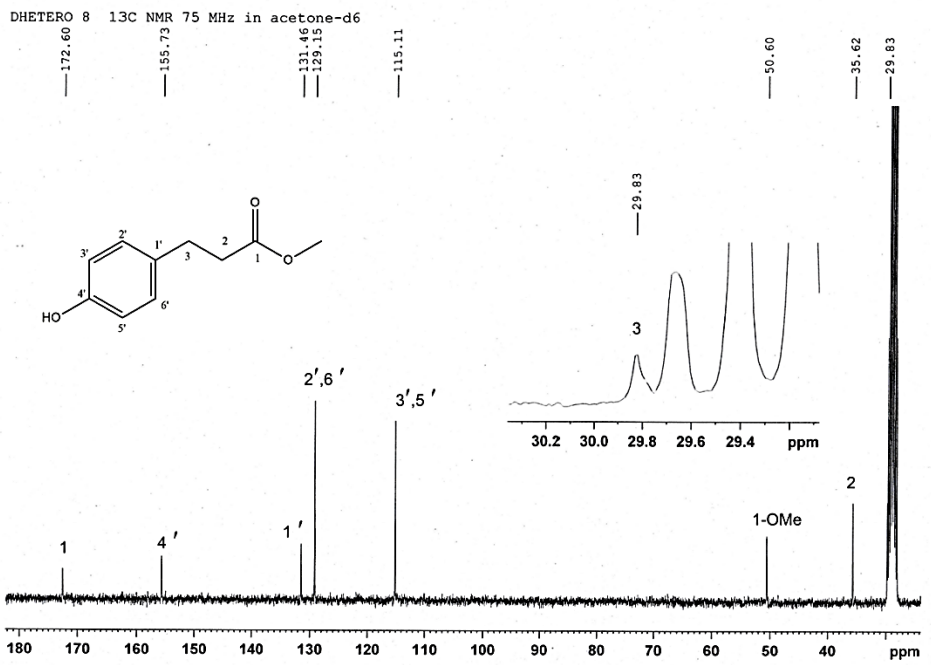


Figure 46 ^{13}C-NMR (75 MHz) spectrum of compound DH-2 (in Acetone-d_6)

Figure 47 HSQC spectrum of compound DH-2 (in Acetone-d_6)

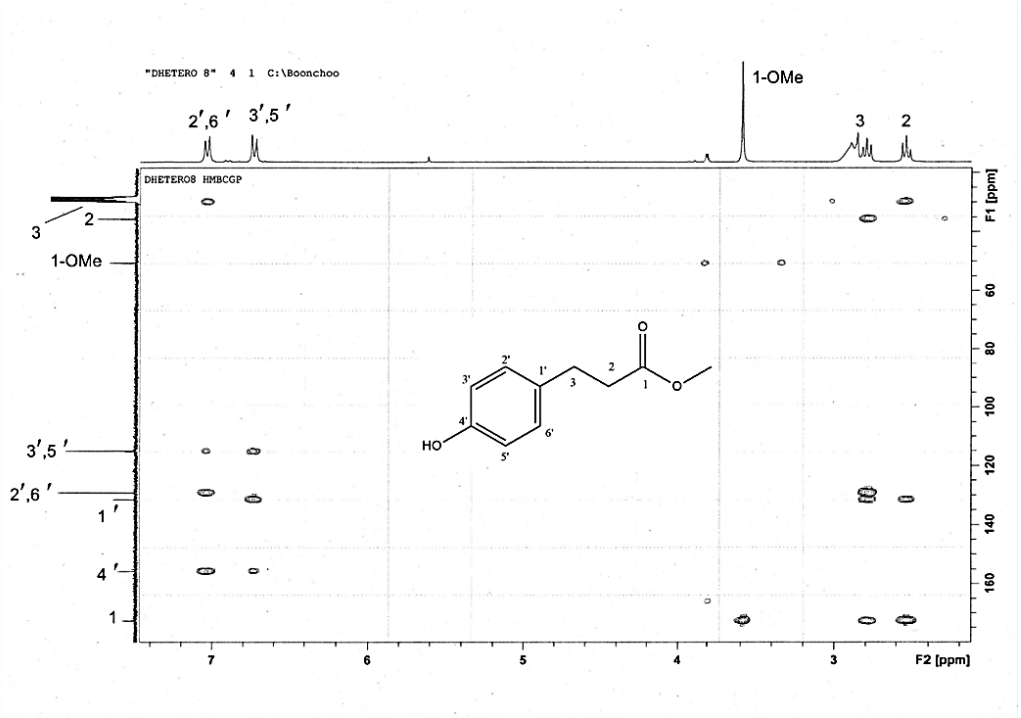


Figure 48 HMBC spectrum of compound DH-2 (in Acetone-d_6)

4.10 Structure determination of compound DH-3 (3,4-dihydroxy-5,4′dimethoxy-bibenzyl)

Compound DH-3 was isolated as a brown amorphous solid. The HR-ESI mass spectrum (**Figure 49**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 297.1127, suggesting the molecular formula $C_{16}H_{18}O_4$ (calculated for $C_{16}H_{18}O_4Na$, 297.1102).

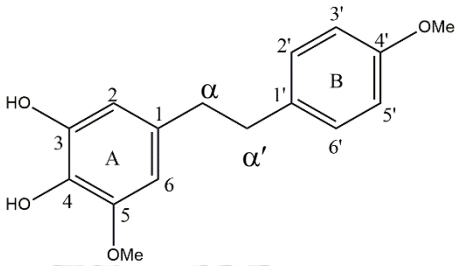
The ^{1}H-NMR signals (**Figure 50** and **Table 11**) were observed for two pairs of methylene protons at δ_H 2.73, 2.81 (4H, *m*, H_2-α, H_2-α'), and two methoxy groups at δ_C 3.72 (3H, s, 5-OMe) and 3.74 (3H, s, OMe-4′). The ^{1}H NMR spectrum of ring A, presented two doublet protons at δ_H 6.35 (1H, *d*, *J*=1.8 Hz, H-2) and 6.42 (1H, *d*, *J*=1.8 Hz, H-6). On the ring B, ^{1}H NMR spectrum showed two doublets at δ_H 6.83 (2H, *d*, *J*=8.4 Hz, H-3′, H-5′) and 7.12 (2H, *d*, *J*=8.4 Hz, H-2′, H-6′).

The ^{13}C NMR spectrum (**Figure 51** and **Table 11**) exhibited sixteen carbon signals, including two signals for two methoxyl groups at δ_C 55.3 and 56.2, two methylene carbon signals at 37.7 (C-α') and 38.6 (C-α), six methine carbon signals at 104.4 (C-2), 109.6 (C-6), 114.3 (C-3′), 114.3 (C-5′), 130.0 (C-2′) and 130.0 (C-6′), and six quaternary carbon at 132.5 (C-1), 133.5 (C-1′), 134.6 (C-4), 145.9 (C-5), 148.6 (C-3) and 158.6 (C-4′).

The HSQC spectrum were used to assign a linkage of proton to carbon (**Figure 52**). The positions of aromatic protons and methoxy groups were assigned by the correlation in HMBC spectra (**Figure 53**). The H-2 and H-6 protons were observed by the correlations to C-α, C-1, C-3, and C-5. The H-3′ and H-5′ were assigned by the correlations to C-1′, and C-4′. The H-2′ and H-6′ were assigned by the correlations to C-α' and C-4′. The first methoxy (4′-OMe) could be located at C-4′. The other methoxy group (5-OMe) was assigned by the correlations to C-3.

The position of aromatic protons and methoxy groups were confirmed by NOESY spectrum (**Figure 54**). On ring A, the 5-OMe substitution was showed correlation with H-6. On of ring B, the 4′-OMe showed correlation-cross peak to H-3′ and H-5′.

From the above data and through comparison of its ^{1}H, ^{13}C NMR and MS with previously reported data (Ming *et al*., 2004), DH-3 was identified as 3,4-dihydroxy-5,4′dimethoxybibenzyl [**32**], which have been found in *D. moniliforme* (Ming et al., 2004), *D. candidum* (Li et al., 2008) *D. signatum* (Mittraphab et al., 2015), and *D. officinale* (Xiaomei et al., 2012).



3,4-dihydroxy-5,4′dimethoxybibenzyl [**32**]

Table 11 NMR spectral data of compound DH-3 (in Acetone-d_6) and 3,4-dihydroxy-5,4′dimethoxybibenzyl (in $CDCl_3$)

Position	Compound DH-3		3,4-dihydroxy-5,4′-dimethoxybibenzyl*	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	132.5	-	133.4
2	6.35 (*d*, 1.8)	104.4	6.20 (*d*, 1.3)	103.6
3	-	148.6	-	143.7
4	-	134.6	-	130.5
5	-	145.9	-	143.7
6	6.42 (*d*, 1.8)	109.6	6.42 (*d*, 1.3)	108.7
α	2.73 (*m*)	38.6	2.71 (*m*)	37.6
α′	2.81 (*m*)	37.5	2.71 (*m)*	36.7
1′	-	133.5	-	133.7
2′	7.12 (*d*, 8.4)	130.0	7.01 (*d*, 8.2)	129.3
3′	6.83 (*d*, 8.4)	114.3	6.78 (*d*, 8.2)	113.4
4′	-	158.6	-	157.3
5′	6.83 (*d*, 8.4)	114.3	6.78 (*d*, 8.2)	113.4
6′	7.12 (*d*, 8.4)	130.0	7.01 (*d*, 8.2)	129.3
4′-OMe	3.72 (*s*)	55.3	3.66 (*s*)	55.7
5-OMe	3.74 (*s*)	56.3	3.69 (*s*)	54.9

*(Bi et al., 2004)

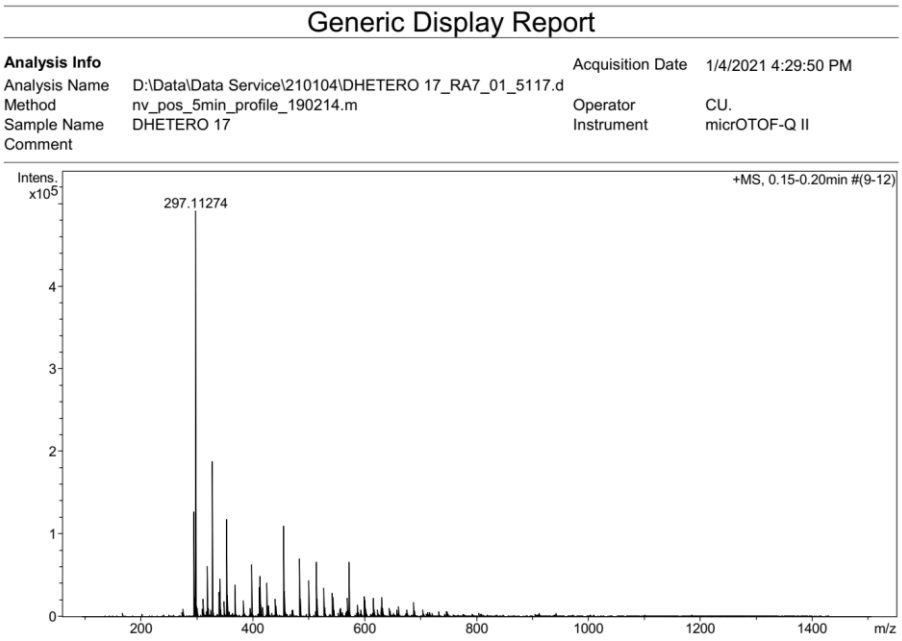


Figure 49 Mass spectrum of compound DH-3

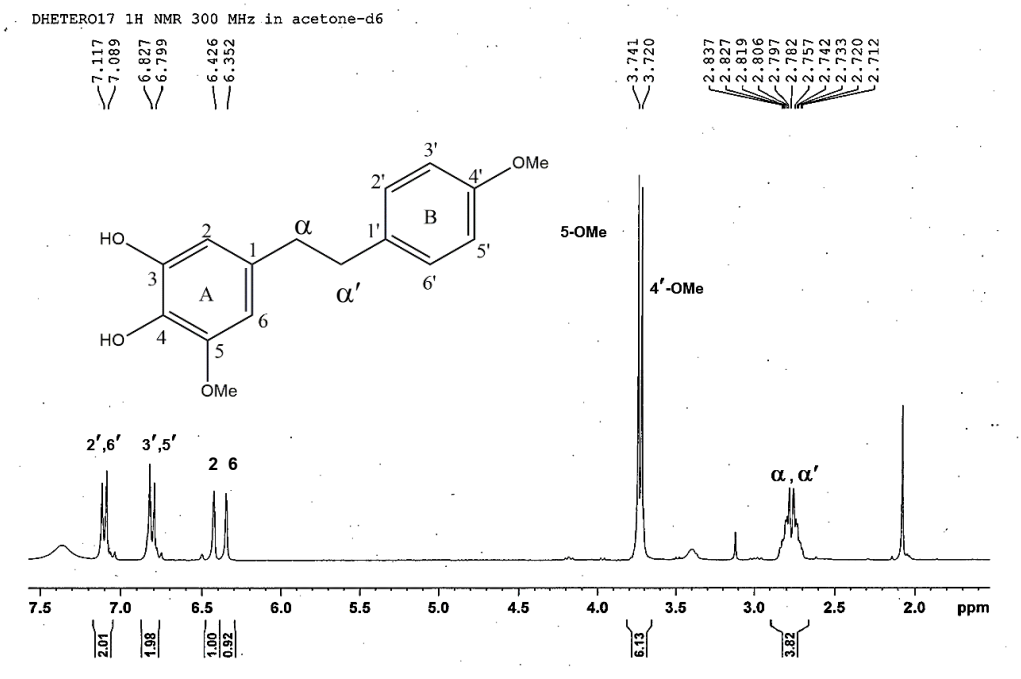


Figure 50 ^{1}H-NMR (300 MHz) spectrum of compound DH-3 (in Acetone-d_6)

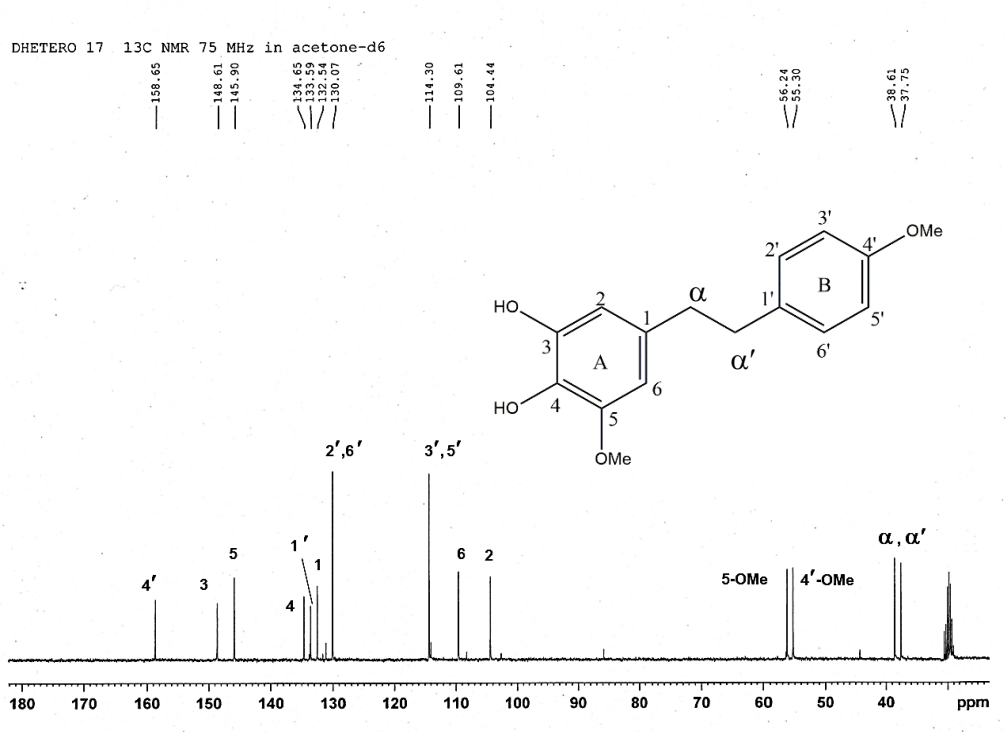


Figure 51 ^{13}C-NMR (75 MHz) spectrum of compound DH-3 (in Acetone-d_6)

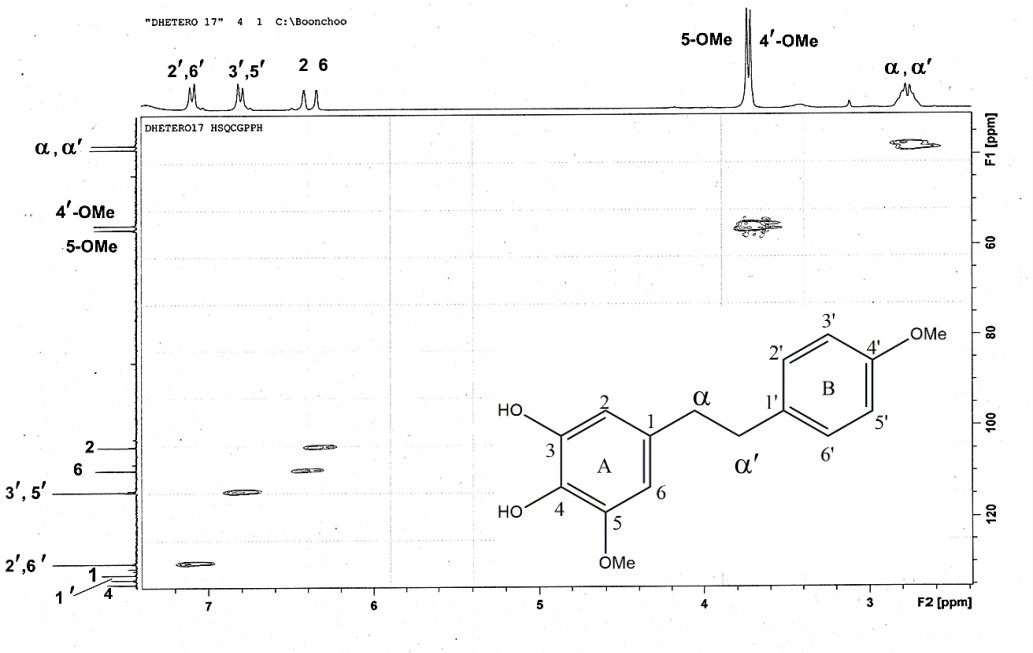


Figure 52 HSQC spectrum of compound DH-3 (in Acetone-d_6)

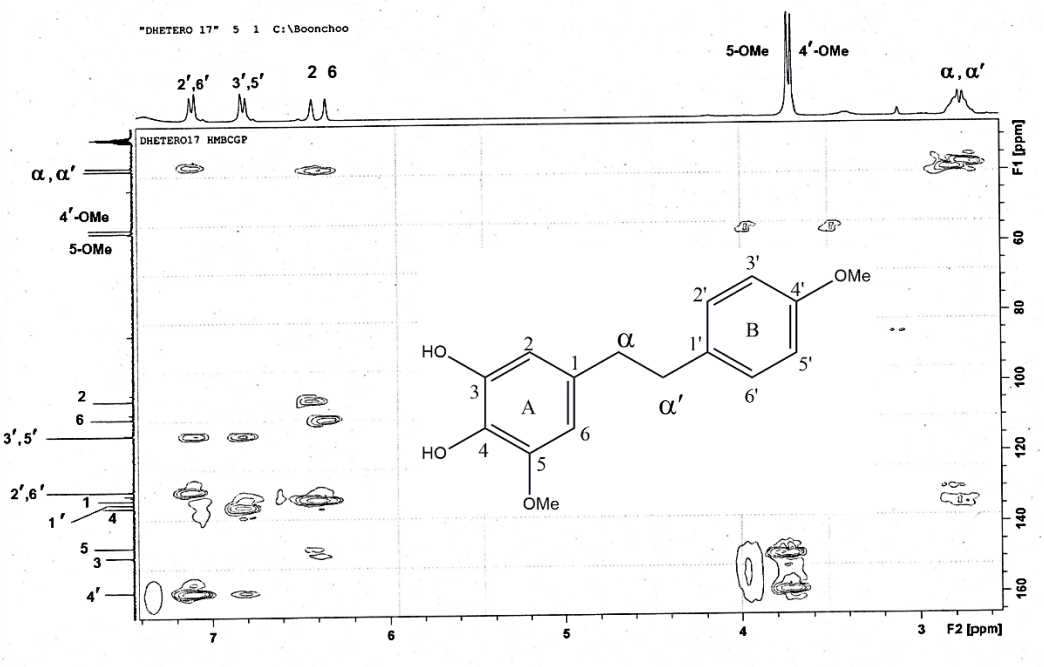


Figure 53 HMBC spectrum of compound DH-3 (in Acetone-d_6)

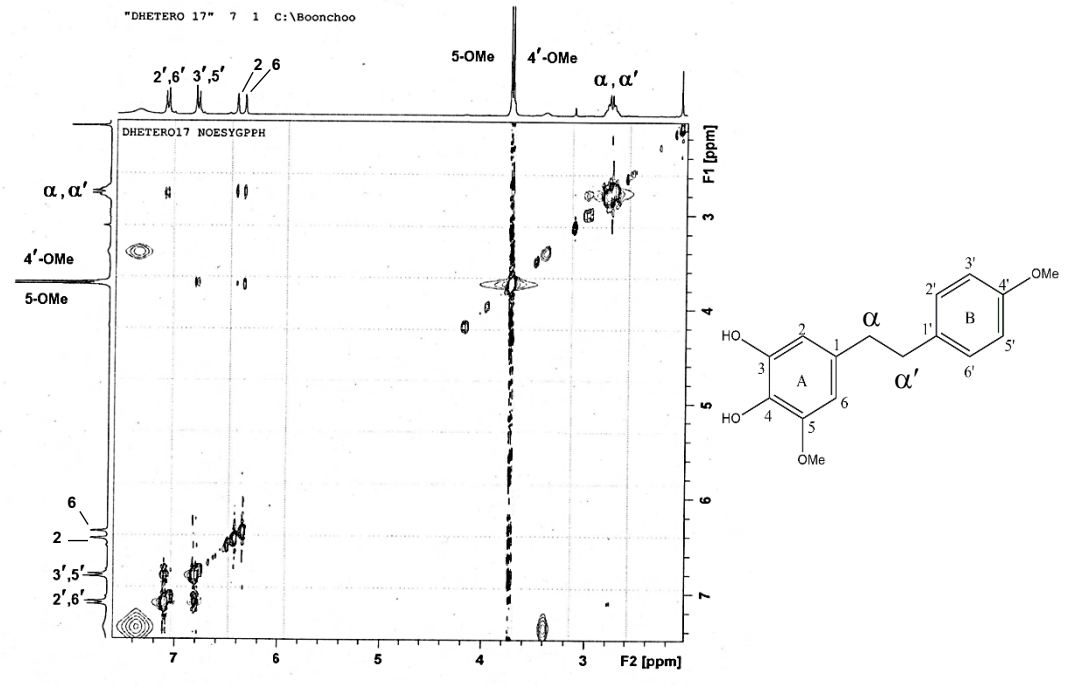


Figure 54 NOSEY spectrum of compound DH-3 (in Acetone-d_6)

4.11 Structure determination of compound DH-4 (Dendrocandin B)

Compound DH-4 was obtained as a white powder. Its specific rotation $[\alpha]_D^{20}$ was found to be -6.79° (c = 0.05, MeOH). The HR-ESI mass spectrum (**Figure 55**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 505.1850, suggesting the molecular formula $C_{27}H_{30}O_8$ (calculated for $C_{27}H_{30}O_8Na$, 505.1838).

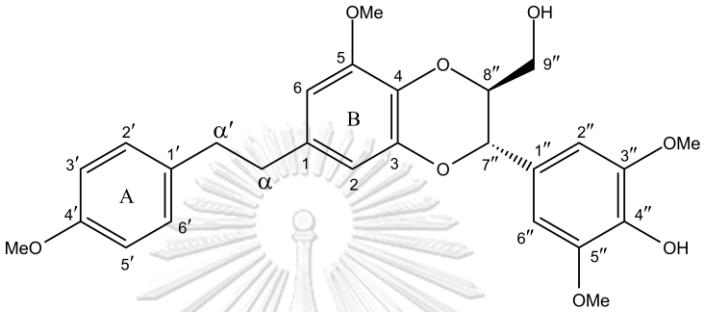
The ^{1}H-NMR data (**Figure 56** and **Table 12**) of DH-4 showed similar structure to DP-6 including bibenzyls and phenylpropanoid signals. The ^{1}H NMR spectrum of ring A presented four protons at δ_H 7.11 (2H, *d*, *J*=8.4 Hz, H-2′, H-6′) and δ_H 6.84 (2H, *d*, *J*=8.4 Hz, H-3′, H-5′). On ring B, the ^{1}H NMR spectrum exhibited proton signals at δ_H 6.33 (1H, *d*, *J*=1.8 Hz, H-6) and δ_H 6.53 (1H, *d*, *J*=1.8 Hz, H-2). The ^{1}H-NMR proton of methylene protons was assigned at δ_H 2.84 (4H, m, H_2-α, -α′), and three methoxy groups at δ_H 3.99 (6H, s, 3″,5″-OMe), 3.87 (3H, s, 5-OMe) and 3.80 (3H, s, 4′-OMe) were observed. In addition, the ^{1}H-NMR spectrum also appeared *o*-coupled signals of one aromatic ring (ring A) at H-3′, H-5′, H-2′, and H-6′, suggesting the presence of a 1,4 disubstituted aromatic ring, and *m*-coupled signals exhibited at H-6 and H-2, indicating the presence of 1,3,4,5-tetrasubstituted aromatic ring (ring B), and two protons showed at δ_H 6.69 (2H, s, 2″,6″), suggesting of a symmetrically tetra substituted aromatic ring (Li et al., 2008).

The ^{13}C NMR spectrum (**Figure 57** and **Table 12**) of DH-4 indicated the presence of four methoxy groups (δ_C 55.5, 56.3 and 56.6), three methylene groups (δ_C 37.2, 38.2 and 61.8) and two oxygenated methine groups at δ_C 76.7 (C-7″) and 78.5 (C-8″).

The HSQC spectrum were used to assign a one bond linkage of proton to carbon (**Figure 58**). The HMBC correlation (**Figure 59**) peaks between H-7″ and C-1″, C-2″, and C-8″ deducted presences of a phenylpropanoid unit, which were linked to each other, suggested the presence of a 1,4-dioxane ring between a bibenzyl moiety and a phenyl ring (Li et al., 2008). The H-2″and H-6″ were assigned by the correlations to C-7″.The position of aromatic protons and methoxy groups were

confirmed by NOESY spectrum (**Figure 60**). The H-8′′ was assigned by the correlations to H-2′′ and H-6′′.

Based on the above mentioned spectroscopic properties, compound DH-4 was determined as dendrocandin B [**56**], which was first reported from *Dendrobium candidum* (Li et al., 2008).



Dendrocandin B [**56**]

Table 12 NMR spectral data of compound DH-4 (in $CDCl_3$) and dendrocandin B (in $CDCl_3$)

Positions	Compound DH-4		Dendrocandin B*	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	134.8	-	134.5
2	6.53 (*d*, 1.8)	109.8	6.52 (*d*, 1.0)	109.5
3	-	144.4	-	144.1
4	-	131.2	-	131.0
5	-	148.6	-	148.4
6	6.33 (*d*, 1.8)	104.4	6.32 (*d*, 1.5)	104.8
1′	-	134.0	-	133.7
2′	7.11 (*d*, 8.4)	129.6	7.10 (*d*, 8.0)	129.4
3′	6.84 (*d*, 8.4)	114.0	6.83 (*d*, 8.0)	113.7
4′	-	158.1	-	160.1
5′	6.84 (*d*, 8.4)	114.0	6.83 (*d*, 8.0)	113.7
6′	7.11 (*d*, 8.4)	129.6	7.10 (*d*, 8.0)	129.4
α	2.84 (*m*)	38.2	2.82 (*m*)	38.0
α′	2.84 (*m*)	37.2	2.82 (*m*)	37.0
5-OMe	3.87 (*s*)	56.3	3.85 (*s*)	56.0
4′-OMe	3.80 (*s*)	55.5	3.79 (*s*)	55.3

*(Li et al., 2008)

Table 12 NMR spectral data of compound DH-4 (in $CDCl_3$) and dendrocandin B (in $CDCl_3$)

Positions	Compound DH-4		Dendrocandin B[a]	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1″	-	127.6	-	127.3
2″	6.69 (*s*)	105.1	6.68 (s)	104.0
3″	-	147.5	-	147.2
4″	-	135.5	-	135.2
5″	-	147.5	-	147.2
6″	6.69 (s)	105.1	6.68	104.0
7″	4.96 (*d*, 8.1)	76.7	4.96 (*d*, 8.5)	76.4
8″	4.02 (*m*)	78.5	3.98 (*m*, 8.0, 3.0, 3.0)	78.2
9″	3.54 (*m*)	61.8	3.55 (*dd*, 12.0, 3.0)	61.5
	3.83 (*m*)	-	3.90 (m)	-
3″-OMe	3.99 (s)	56.6	3.92 (s)	56.4
5″-OMe	3.99 (s)	56.6	3.92 (s)	56.4

*(Li et al., 2008)

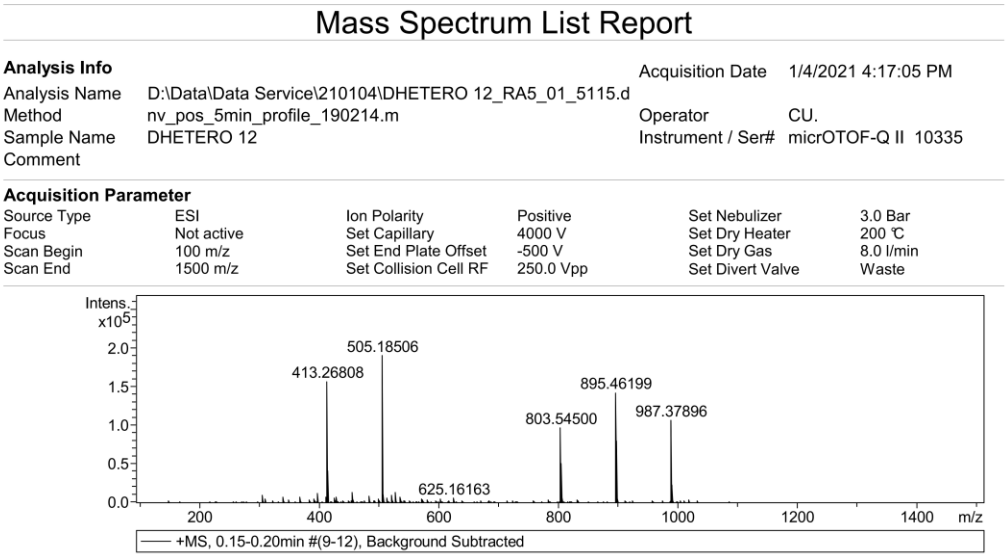


Figure 55 Mass spectrum of compound DH-4

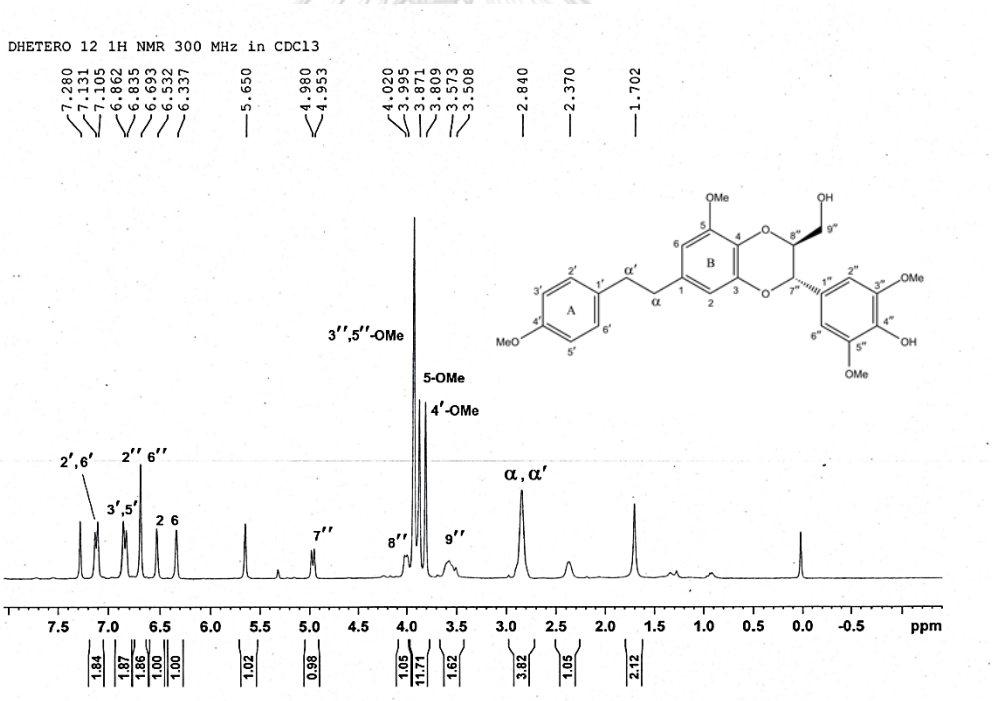


Figure 56 ^{1}H-NMR (300 MHz) spectrum of compound DH-4 (in $CDCl_3$)

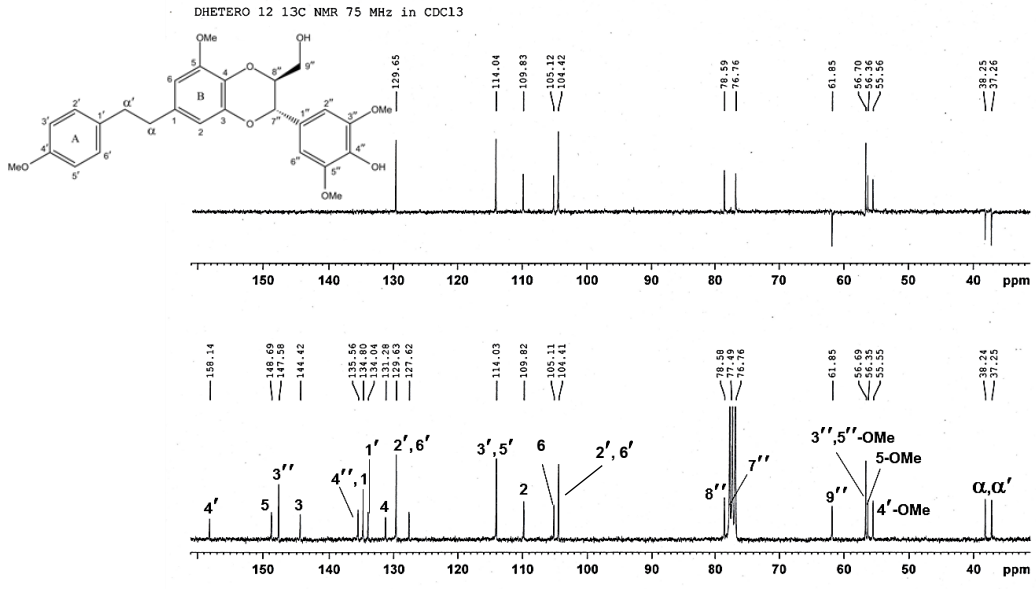


Figure 57 ^{13}C-NMR (75 MHz) spectrum of compound DH-4 (in $CDCl_3$)

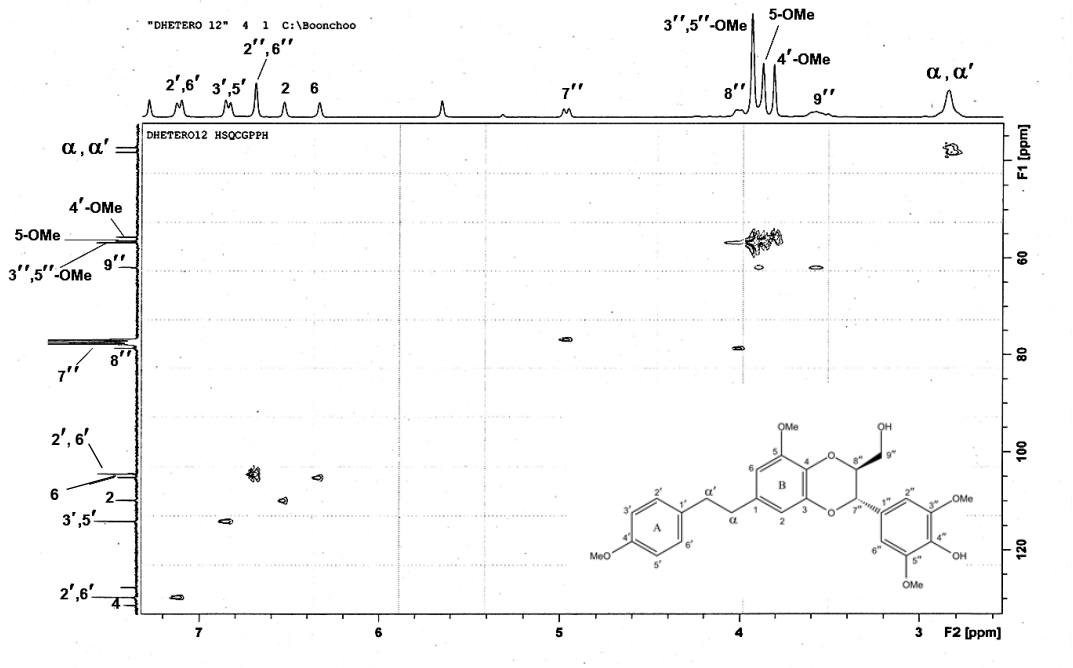


Figure 58 HSQC spectrum of compound DH-4 (in $CDCl_3$)

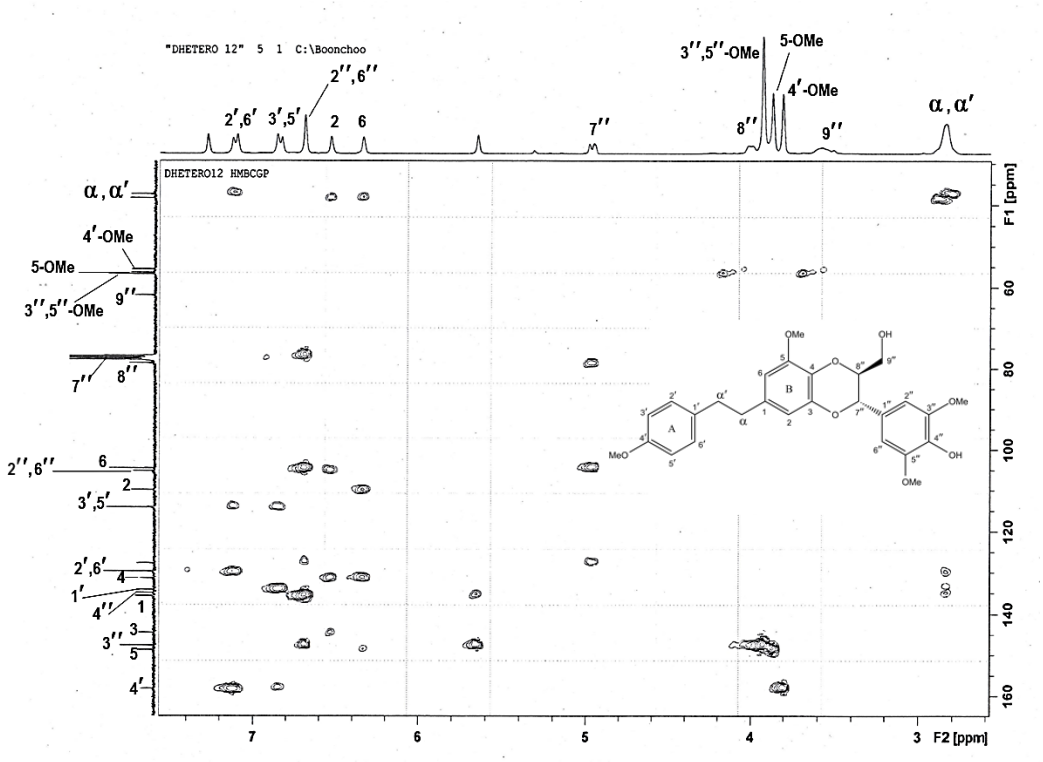


Figure 59 HMBC spectrum of compound DH-4 (in $CDCl_3$)

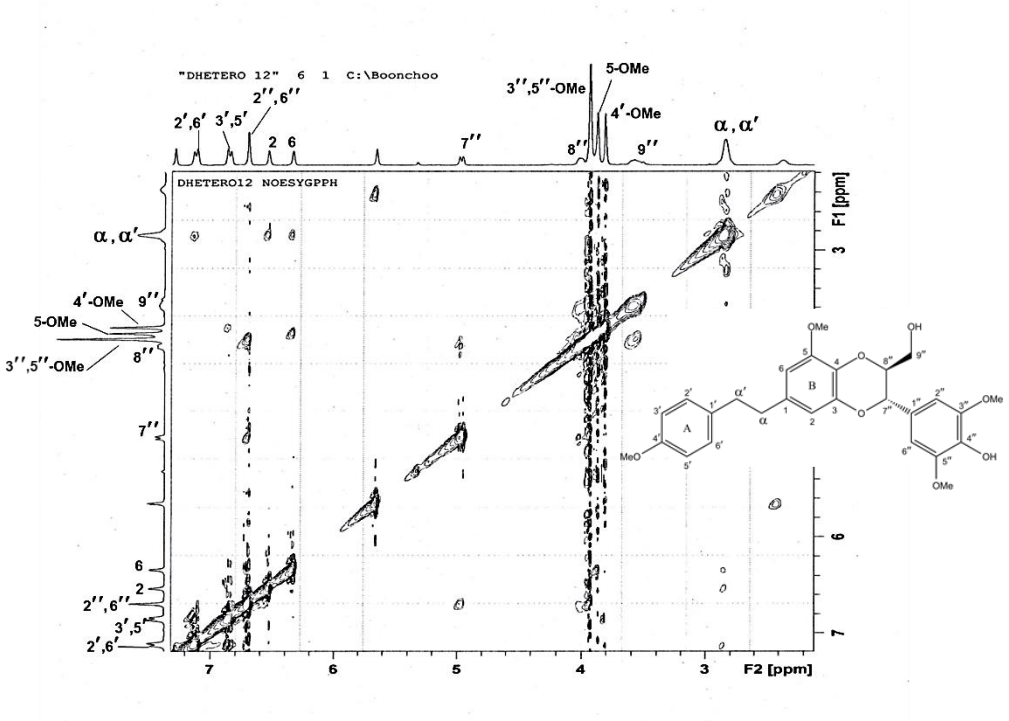


Figure 60 NOESY spectrum of compound DH-4 (in $CDCl_3$)

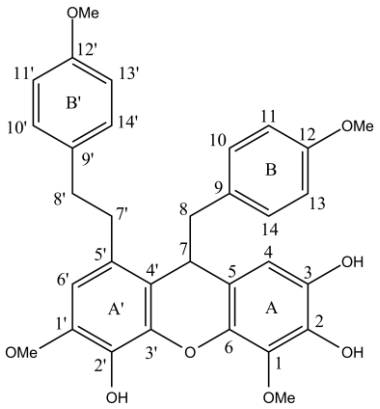
4.12 Structure determination of compound DH-5 (Dendrofalconerol A)

Compound DH-5 was obtained as a brown amorphous powder. Its HR-ESI-MS (**Figure 61**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 567.2003, suggesting the molecular formula $C_{32}H_{32}O_8$ (calculated for $C_{32}H_{32}O_8Na$, 567.1994).

The ^{1}H-NMR spectrum (**Figure 62** and **Table 13**) showed the presence of aliphatic protons at δ_H 2.64-2.83 (*m*, H-8), 2.66-2.70 (*m*, H-8), 2.78-2.81 (*m*, H-7′), 2.83-2.85 (*m*, H-7′) and 2.81-2.85 (*m*, H-8′), a methine proton at δ_H 4.09 (*dd*, *J* = 5.7, 6.6 Hz, H-7), four methoxy groups at δ_H 3.70 (s, MeO-12), 3.73 (s, MeO-12′), 3.80 (s, MeO-1′) and 3.89 (s, MeO-1).

The ^{13}C-NMR (**Figure 63** and **Table 13**) spectra exhibited 32 signals, including four methoxy groups (δ_C 55.3, 55.4, 56.62, and 61.1), ten methine carbon groups at δ_C C-6′ (108.4), C-4 (109.7), C-11/-13 (113.9), C-10/-14 (131.3), C-11′/- C-13′(114.9), and C-14′/-10′(130.1), three methylene carbons at δ_C C-7′(34.4), C-8′(37.5) and, C-8 (45.3), one aliphatic CH carbon at δ_C C-7 (39.6), and 14 aromatic quaternary carbons. From the constitutional formula, compound DH-5 was proposed to be a bis-bibenzyl structure with three OH and four MeO groups. The NOESY spectrum (**Figure 64**) of ring A displayed correlation between δ_H H-7/H4. On ring A′, the proton correlation peaks between at δ_H H-6′/ MeO-1′.

Based on the ^{1}H- and ^{13}C-NMR data, compound DH-5 was identified as dendrofalconerol A [**153**] which was previously reported from *Dendrobium falconeri* (Sritularak et al., 2009).



Dendrofalconerol A [**153**]

Table 13 NMR spectral data of compound DH-5 (in Acetone-d_6) and dendrofalconerol A (in Acetone-d_6)

Position	Compound DH-5		Dendrofalconerol A *	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1	-	136.4	-	136.8
2	-	137.3	-	137.3
3	-	141.6	-	141.6
4	6.13 (*s*)	109.7	6.14 (*s*)	109.7
5	-	117.8	-	117.8
6	-	139.9	-	139.9
7	4.09 (*dd*, 5.7, 6.9)	39.6	4.09 (*dd*, 5.5,7.0)	39.6
8	2.74-2.83 (*m*)	45.3	2.76-2.82 (*m*)	45.4
	2.65-2.71 (*m*)		2.66-2.72 (*m*)	
9	-	131.5	-	131.6
10	6.60 (*d*, 8.4)	131.3	6.61 (*d*, 8.5)	131.3
11	6.68 (*d*, 8.4)	113.9	6.67 (*d*, 8.5)	113.9
12	-	159.1	-	159.1
13	6.68 (*d*, 8.4)	113.9	6.67 (*d*, 8.5)	113.9
14	6.60 (*d*, 8.4)	131.3	6.61 (*d*, 8.5)	131.3
1′	-	147.1	-	147.1
2′	-	134.0	-	134.0
3′	-	142.3	-	142.3
4′	-	119.0	-	119.1
5′	-	129.5	-	129.5
6′	6.65 (*s*)	108.4	6.65 (*s*)	108.5
7′	2.87-2.90 (*m*)	34.4	2.86-2.90 (*m*)	34.4
	2.78-2.86 (*m*)		2.79-2.85 (*m*)	
8′	2.80-2.86 (*m*)	37.5	2.73-2.84 (*m*)	37.5
9′	-	134.6	-	134.6
10′	7.13 (*d*, 8.4)	130.1	7.12 (*d*, 8.5)	130.2
11′	6.82 (*d*, 8.4)	114.9	6.82 (*d*, 8.5)	114.5
12′	-	158.9	-	158.9
13′	6.82 (*d*, 8.4)	114.9	6.82 (*d*, 8.5)	114.5
14′	7.13 (*d*, 8.4)	130.1	7.12 (*d*, 8.5)	130.2
1-MeO	3.89 (*s*)	61.1	3.89 (*s*)	61.2
1′-MeO	3.81 (*s*)	56.2	3.82 (*s*)	56.6
12-MeO	3.70 (*s*)	55.3	3.70 (*s*)	55.3
12′-MeO	3.73 (*s*)	55.4	3.73 (*s*)	55.4

*(Sritularak et al., 2009)

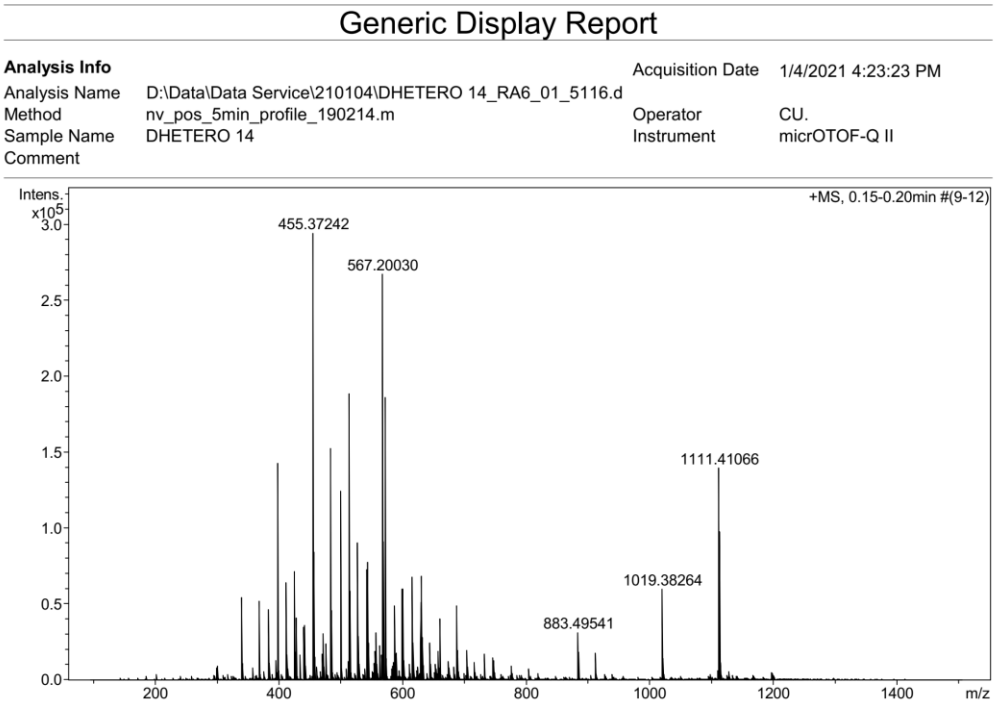


Figure 61 Mass spectrum of compound DH-5

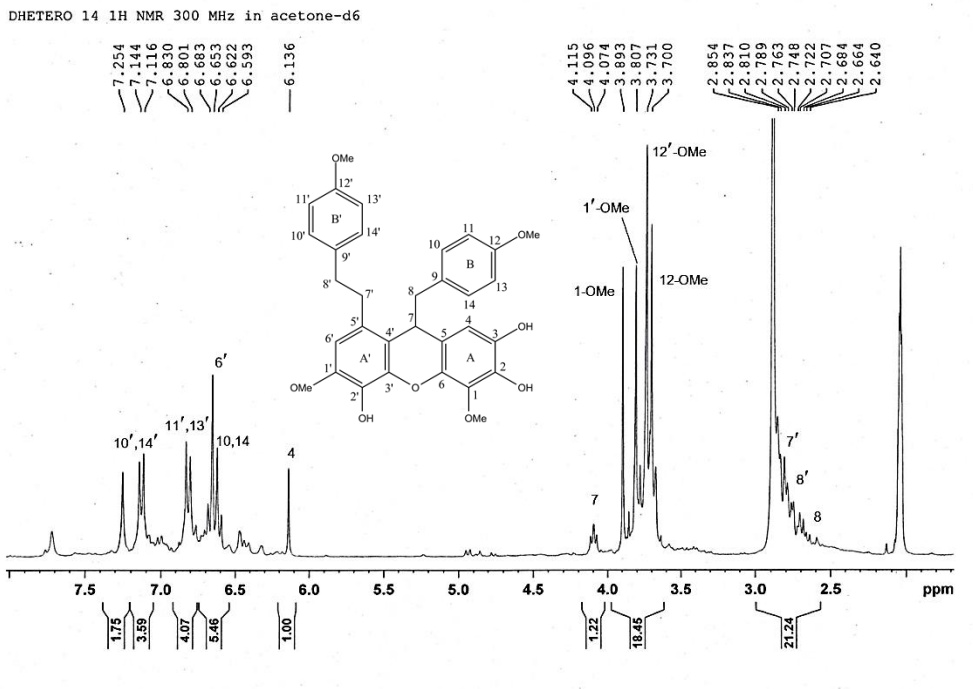


Figure 62 ^{1}H-NMR (300 MHz) spectrum of compound DH-5 (in Acetone-d_6)

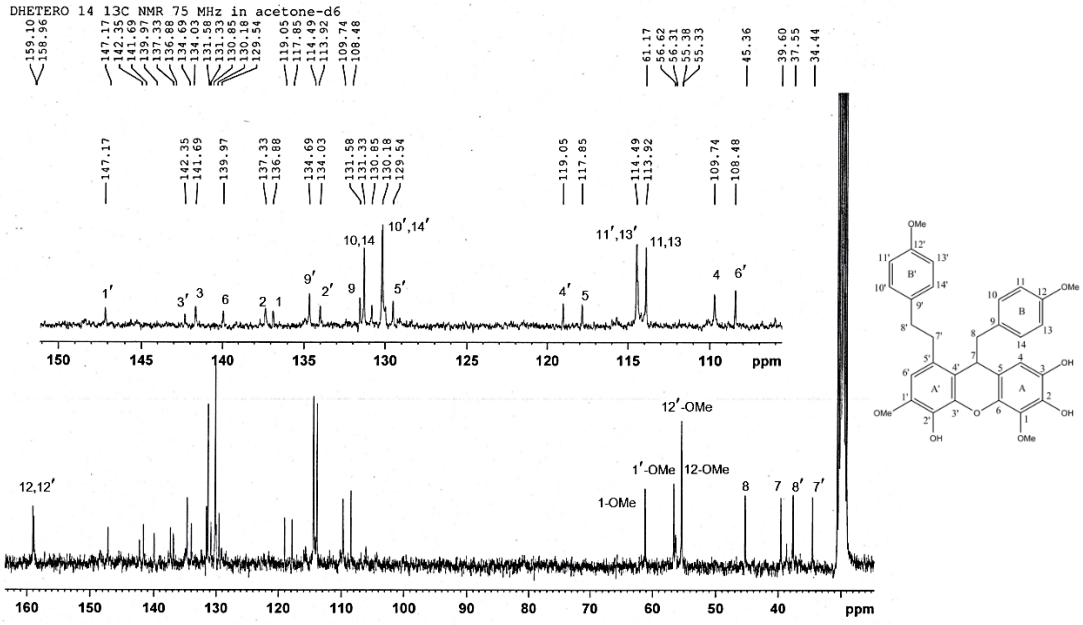


Figure 63 ^{13}C-NMR (75 MHz) spectrum of compound DH-5 (in Acetone-d_6)

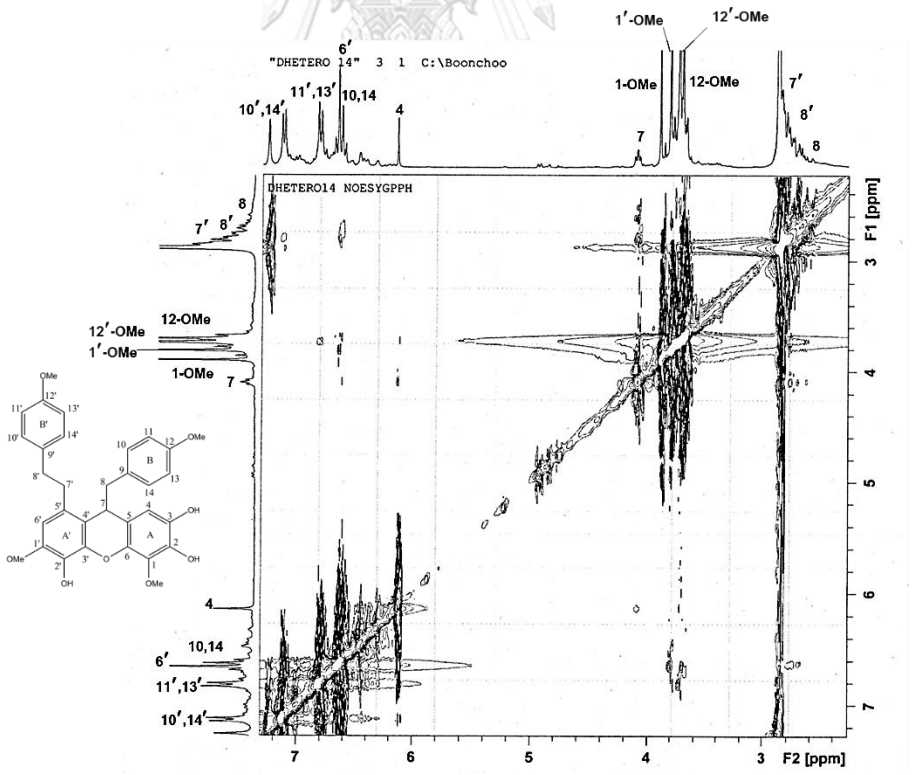


Figure 64 NOESY spectrum of compound DH-5 (in Acetone-d_6)

4.13 Structure determination of compound DH-6 (Syringaresinol)

Compound DH-6 was obtained as a yellow brown amorphous solid. Its specific optical rotation $[\alpha]_D^{20}$ was found to be -1.210° (*c* = 0.05, MeOH). The HR-ESI-MS (**Figure 65**) showed a sodium-adduct molecular ion $[M+Na]^+$ at *m/z* 441.1527, suggesting the molecular formula $C_{22}H_{26}O_8$ (calculated for $C_{22}H_{26}O_8Na$, 441.1525).

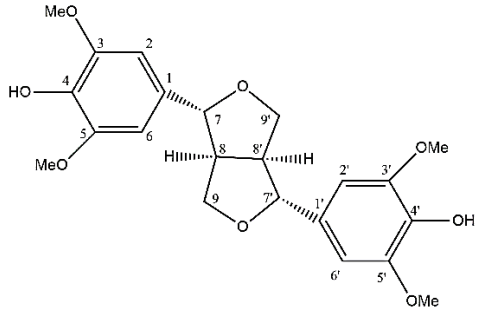
The ^{1}H-NMR spectrum (**Figure 66** and **Table 14**) showed the presence of four methoxy groups at δ_H 3.81 (s, 12H, 3-OMe, 5-OMe, 3′-OMe, 5′-OMe). The protons spectrum also presented for four aromatic positions, indicating as a board singlet at δ_H 6.67 (4H, s, H-2,H-6, H-2′, H-6′).

The ^{13}C-NMR (**Figure 67** and **Table 14**) spectra exhibited eight signals, corresponding to eight quaternary carbons at δ_C 132.2 (C-1,1′), 147.7 (C-3,3′,5,5′), and 135.2 (C-4,4′); six methylene groups at δ_C 105.5 (C-2,2′,6,6′), and 85.8 (C-7, 7′), and one methine groups at δ_C 71.4 (C-9), respectively.

The HSQC spectrum were used to assign a one bond correlation between proton and carbon (**Figure 68**). The positions of aromatic protons and methoxy groups were assigned by the correlation in HMBC spectra (**Figure 69**). The HMBC spectrum showed correlations from the proton at δ_H 4.65 (*s*, H-7 and H-7′) to C-9, and C-9′. The signal proton at δ_H 6.67 (*s*, H-2, H-2′, H-6, and H-6′) was assigned by the correlations to C-7 and C-7′.

The NOESY spectrum (**Figure 70**) displayed cross peaks H-2 and H-6 protons to 3-OMe, 5-OMe, and H-9. The H-2′and H-6′ protons were assigned by the correlations to 3′-OMe, 5′-OMe, and H-9′.

Based on the above spectral data, and comparison with a previous report (Rueda et al., 2014), DH-6 could be identified as syringaresinol [**279**]. This compound has been found in some *Dendrobium* plants, including *D. nobile* (Zhang et al., 2008) and *D. secudum* (Sritularak et al., 2011).



Syringaresinol [**279**]

Table 14 NMR spectral data of compound DH-6 (in Acetone-d_6) and syringaresinol (in $CDCl_3$)

Position	Compound DH-6		syringaresinol*	
	δ_H (mult., *J* in Hz)	δ_C	δ_H (mult., *J* in Hz)	δ_C
1,1′	-	132.2	-	132.1
2,2′	6.67 (*s*)	103.5	6.58 (*s*)	102.7
3,3′	-	147.7	-	147.2
4,4′	-	135.2	-	134.3
5,5′	-	147.7	-	147.2
6,6′	6.67 (*s*)	103.5	6.58 (*s*)	102.7
7,7′	4.65 (*s*)	85.8	4.73 (*d*, *J*= 4.3)	86.1
8,8′	3.07 (*m*)	54.3	3.09 (*m*)	54.3
9,9′	4.21 (*m*)	71.4	4.28 (*m*)	71.8
3,5-OMe	3.81 (*s*)	55.7	3.90 (*s*)	56.4
3′,5′-OMe	3.81 (*s*)	55.7	3.90 (*s*)	56.4

*(Zhang et al., 2008a)

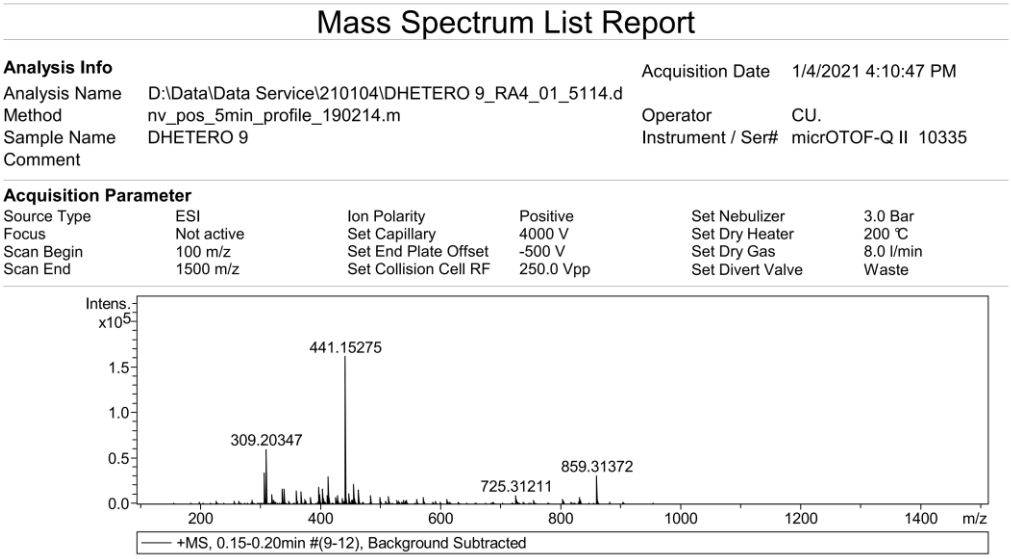


Figure 65 Mass spectrum of compound DH-6

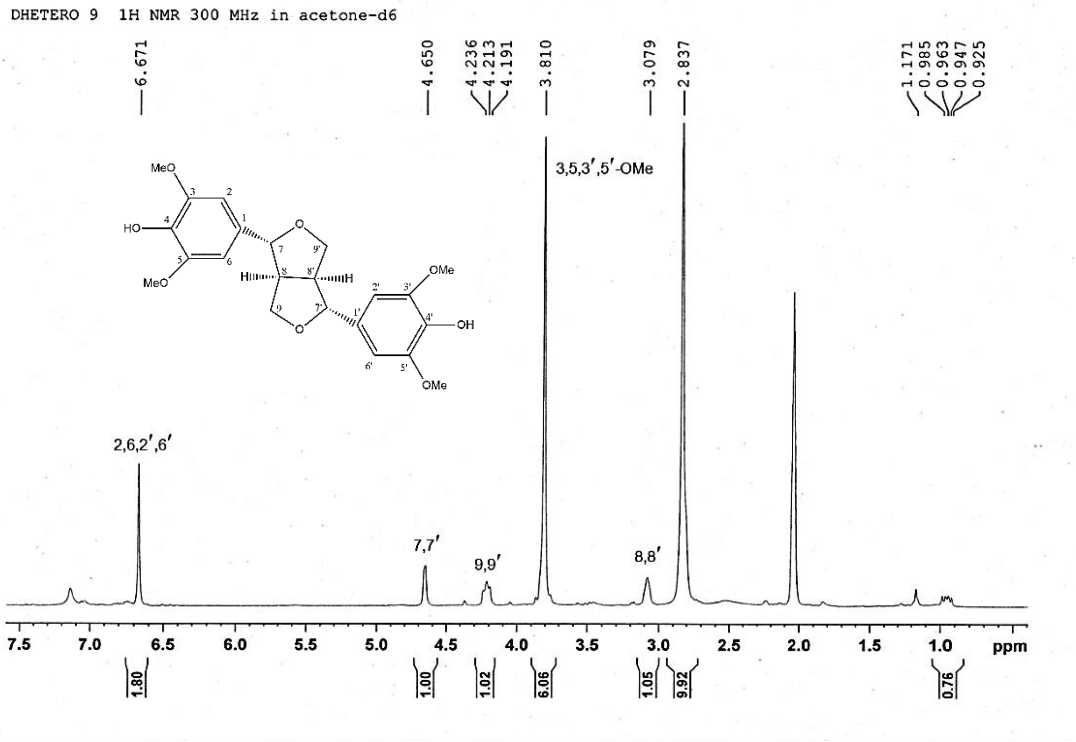


Figure 66 ^{1}H-NMR (300 MHz) spectrum of compound DH-6 (in Acetone-d_6)

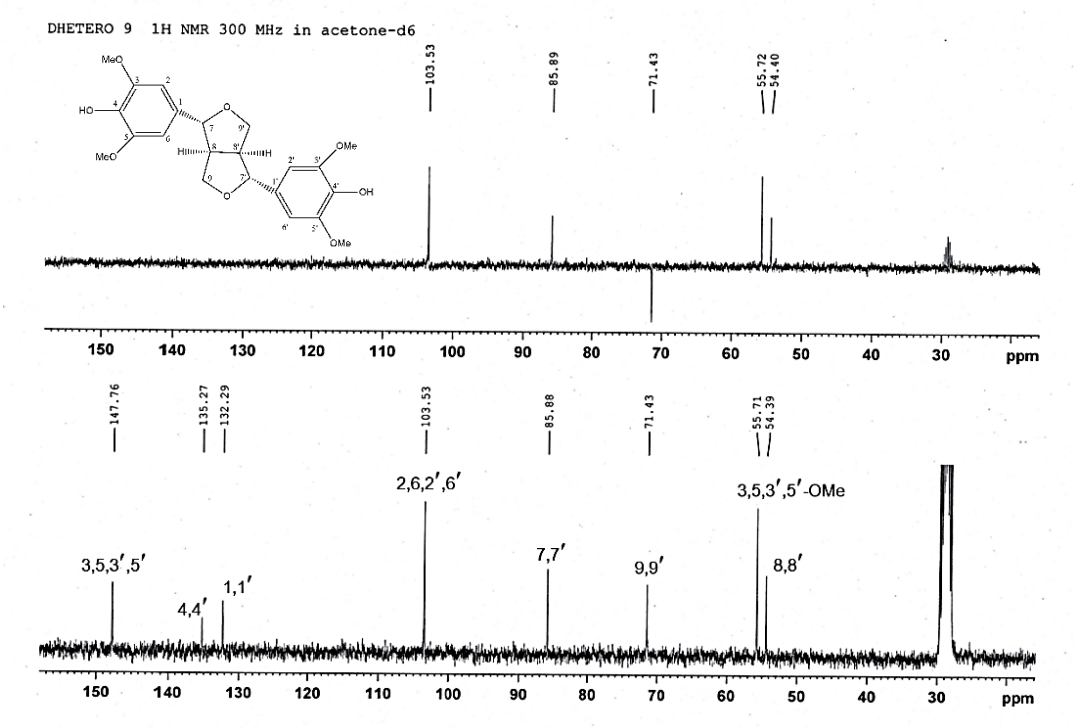


Figure 67 ^{13}C-NMR (75 MHz) spectrum of compound DH-6 (in Acetone-d_6)

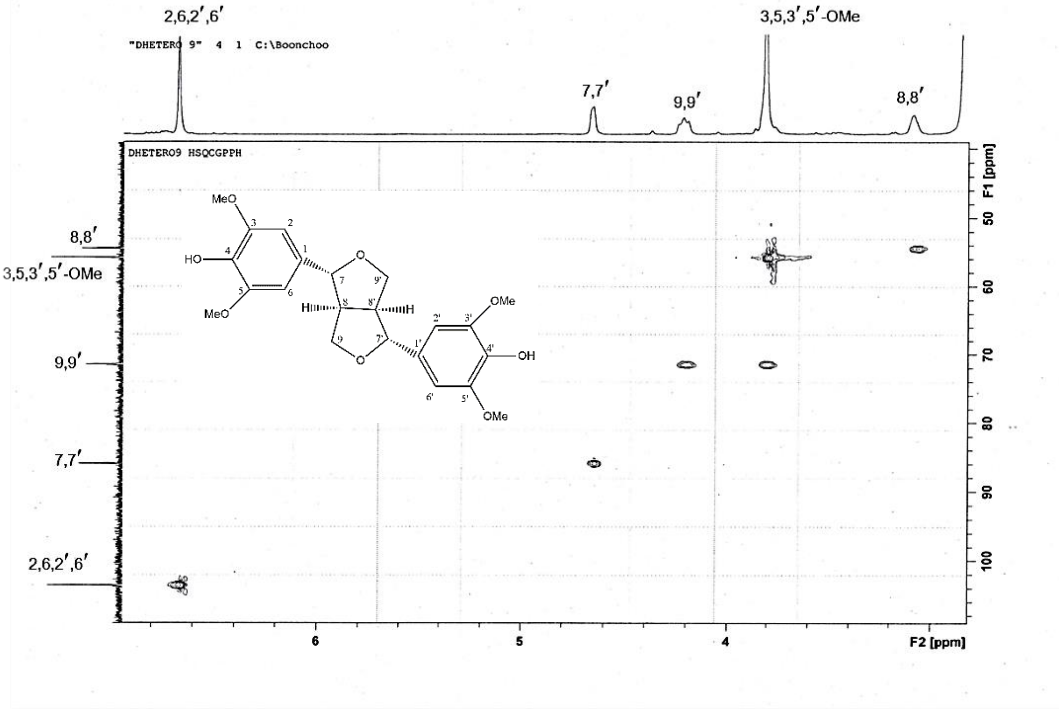


Figure 68 HSQC spectrum of compound DH-6 (in Acetone-d_6)

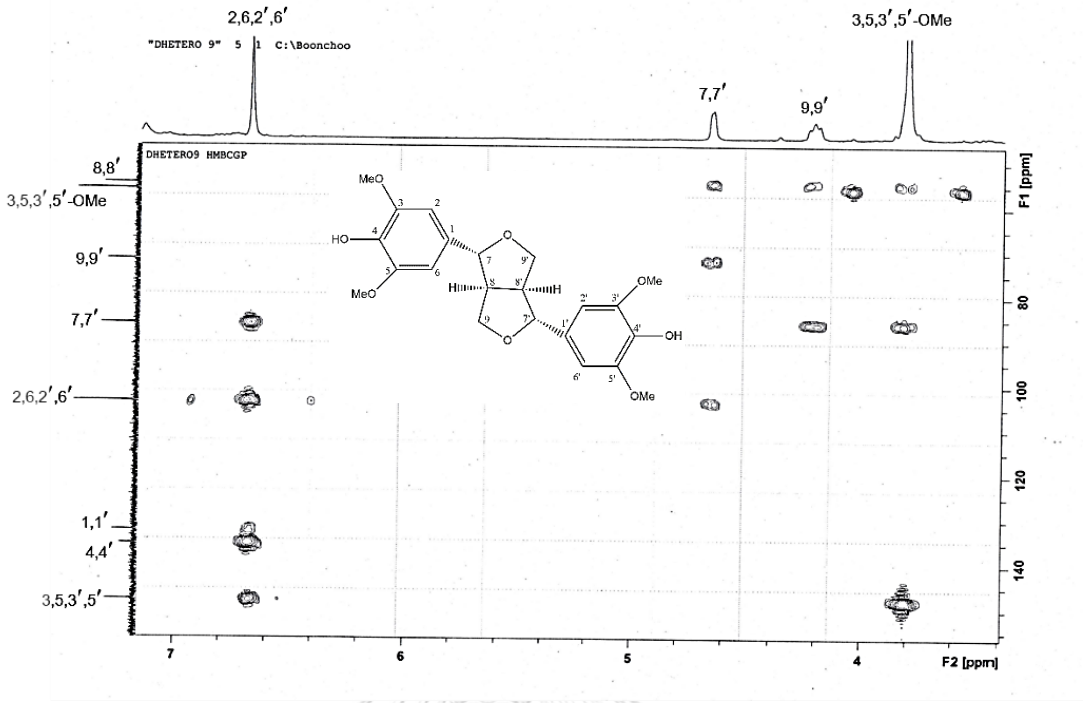


Figure 69 HMBC spectrum of compound DH-6 (in Acetone-d_6)

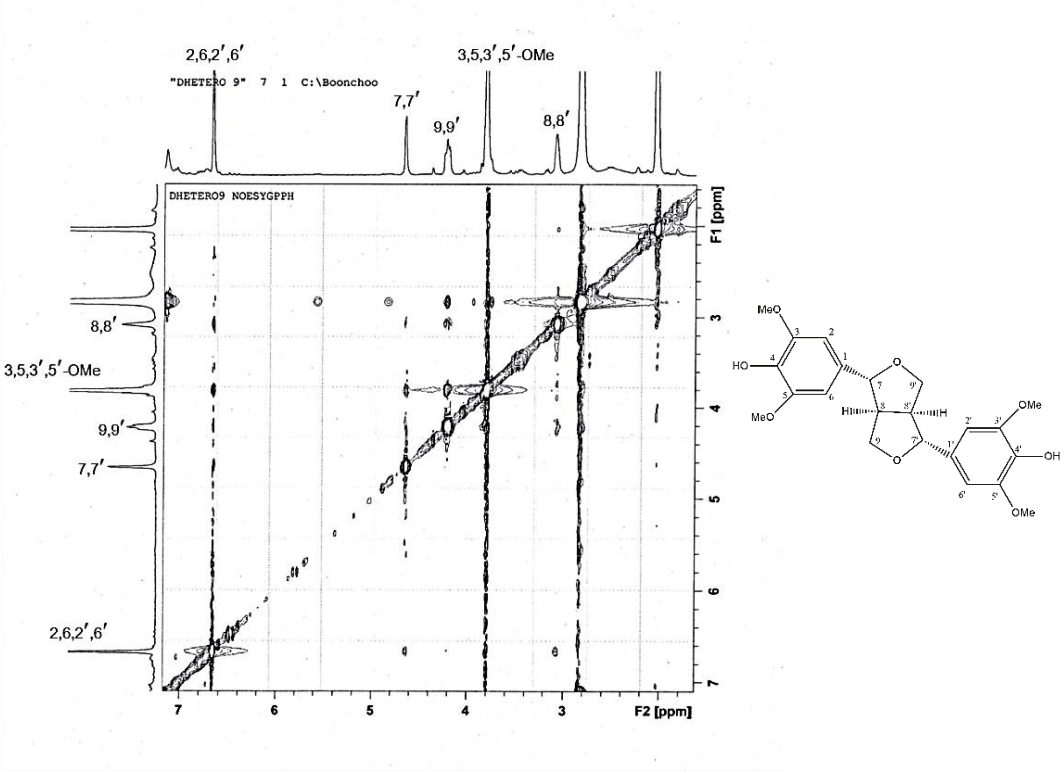


Figure 70 NOESY spectrum of compound DH-6 (in Acetone-d_6)

4.14 Cytotoxic effect of isolated compounds on HaCaT keratinocytes cells

In the present study, twelve isolated compounds from *D. pachyglossum* (DP 1-5 and DP-7) and D. *heterocarpum* (DH 1-6) were investigated for their cytotoxicity activity against HaCaT cells by using MTT-assay. To confirm the safety dose of all compounds, the high concentration (50 and 100 µg/mL) was used to ensure that they are safe for cosmetic applications. After pre-treatment with isolated compounds concentrations at 50 and 100 µg/mL for 24 h., only the new compounds (dendropachol), isovitexin, 3-(4-hydroxyphenyl) propionate, and syringaresinol significantly exhibited cell viability over than 80% compared to the untreated group (*p>0.05*) (**Table 15-16**). As the result of the above, there have been reported that 4,5-dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene, moscatilin, gigantol, amoenylin, dendrofalconerol A, 4,5,4′-trihydroxy-3-3′dimethoxybibenzyl, 3,4-dihydroxy-5,4′dimethoxybibenzyl, and dendrocandin B, were toxicity in different cell types, including cancer cells (Chaotham et al., 2014; Klongkumnuankarn et al., 2015; Losuwannarak et al., 2019; Mittraphab et al., 2016; Tanagornmetar et al., 2014). Therefore, it's possible that the toxicity of isolated compounds might be due to potentiated in the toxicity against H_2O_2-induced oxidative stress in HaCaT cells. Thus, we mainly focused on the new compounds (dendropachol), isovitexin, 3-(4-hydroxyphenyl) propionate, and syringaresinol at concentration of 50 µg/mL for further investigation.

4.15 Cytoprotective effect of isolated compounds on cell viability of HaCaT keratinocytes by H_2O_2 induced oxidative stress

H_2O_2 is the one most common oxidant used in the oxidative stress models (Liu et al., 2016). The increase of the intracellular H_2O_2 level in response of various pro-oxidant can further induce excessive oxidative stress production in the cells (Bae et al., 2014). H_2O_2 and its corresponding ROS create oxidative stress in keratinocytes and lead to cell integrity damage, lipid peroxidation, and apoptosis induction, leading to aging of skin (Zuliani et al., 2005). To investigate the suitable concentration to cause an ~50% decreased in HaCaT cell viability (Muangnoi et al., 2019). The concentration of H_2O_2 at 100-500 µmol/L is predominantly used for inducing

oxidative stress in HaCaT keratinocytes (Ransy et al., 2020). The results demonstrated that 500 µmol/L of H_2O_2 reduced cell viability to ~50% compared to the untreated group (**Figure 71**). Our results agree with the previous reported demonstrating that H_2O_2 at concentration of 500 µmol/L diminished cell viability in the range between 50-65% compared to the control groups (Yoon et al., 2018; Lee et al., 2020; Ransy et al., 2020). Therefore, H_2O_2 at concentration of 500 µmol/L was used for further studies.

Pre-treatment with isolated compounds showed that dendropachol (DP-5) (25 and 50 µg/mL) and methyl 3-(4-hydroxyphenyl) propionate (DH-2) (12.5, 25 and 50 µg/mL) significantly ($p < 0.05$) enhanced cell survival to 11-23%, and syringaresinol (DH-6) (12.5, 25 and 50 µg/mL) can increase 5-15% compared with untreated group, while isovitexin (DP-7) not significantly ($p > 0.05$) increased cell viability (**Figure 72**). It is possible that compound DP-5, DH-2 and DH-6 prevents HaCaT cells from oxidative stress might be derived from the number and position of methoxyl and hydroxyl groups contribute to the antioxidant properties of polyphenolic compounds (Hidalgo et al., 2009; Zheng et al., 2010; Al Habsi et al., 2018). Our results agree with previous reported that compounds could reduce the accumulated ROS level in cells, which are related to prevent oxidative stress and apoptosis (Choi et al., 2003). Therefore, it is possible that compounds DP-5, DH-2, and DH-6 protects HaCaT cells by reducing H_2O_2 -induced oxidative stress.

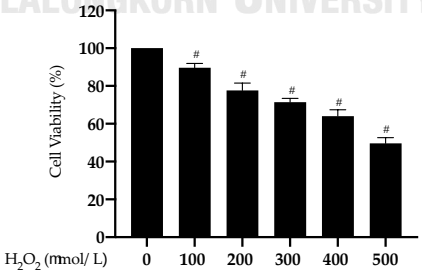


Figure 71 HaCaT keratinocyte cells were treated with H_2O_2 at various concentration (100-500 µmol/L) Graph exhibited mean ± S.D. values of four replications. $^{*}p < 0.05$ indicates significant differences from the H_2O_2 induction group, $^{\#}p < 0.05$ indicates significant differences from the control group.

Table 15 Cytotoxicity of isolated compounds from *D. pachyglossum* (DP) on HaCaT cells

Compounds	% cell viability (50 μg/mL)*	% cell viability (100 μg/mL)*
4,5-dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene (DP-1)	71.6 ± 2.8	44.9 ± 1.2
Moscatilin (DP-2)	64.5 ± 1.8	42.7 ± 1.0
Gigantol (DP-3)	65.8 ± 1.9	34.7 ± 1.0
4-5-4′-trihydroxy-3-3′-dimethoxybibenzyl (DP-4)	75.8 ± 1.5	45.0 ± 0.7
Dendropachol (DP-5)	97.1 ± 1.6	73.1 ± 1.4
Isovitexin (DP-7)	98.2 ± 1.1	95.4 ± 1.7
Control (D0.5% DMSO)	100.0	100.0

* mean ± S.D. (n=4)

Table 16 Cytotoxicity of isolated compounds from *D. heterocarpum* (DH) on HaCaT cells

Compounds	% cell viability (50 μg/mL)*	% cell viability (100 μg/mL)*
Amoenylin (DH-1)	26.0 ± 10.2	13.4 ± 4.3
Methyl 3-(4-hydroxyphenyl) propionate (DH-2)	94.5 ± 1.5	90.7 ± 1.3
3,4-dihydroxy-5,4′-dimethoxy bibenzyl (DH-3)	26.3 ± 5.4	11.8 ± 1.0
Dendrocandin B (DH-4)	52.1 ± 5.4	50.8 ± 6.1
Dendrofalconerol A (DH-5)	48.8 ± 7.8	29.0 ± 9.4
Syringaresinol (DH-6)	84.5 ± 2.5	80.4 ± 4.1
Control (0.5% DMSO)	100.0	100.0

* mean ± S.D. (n=4)

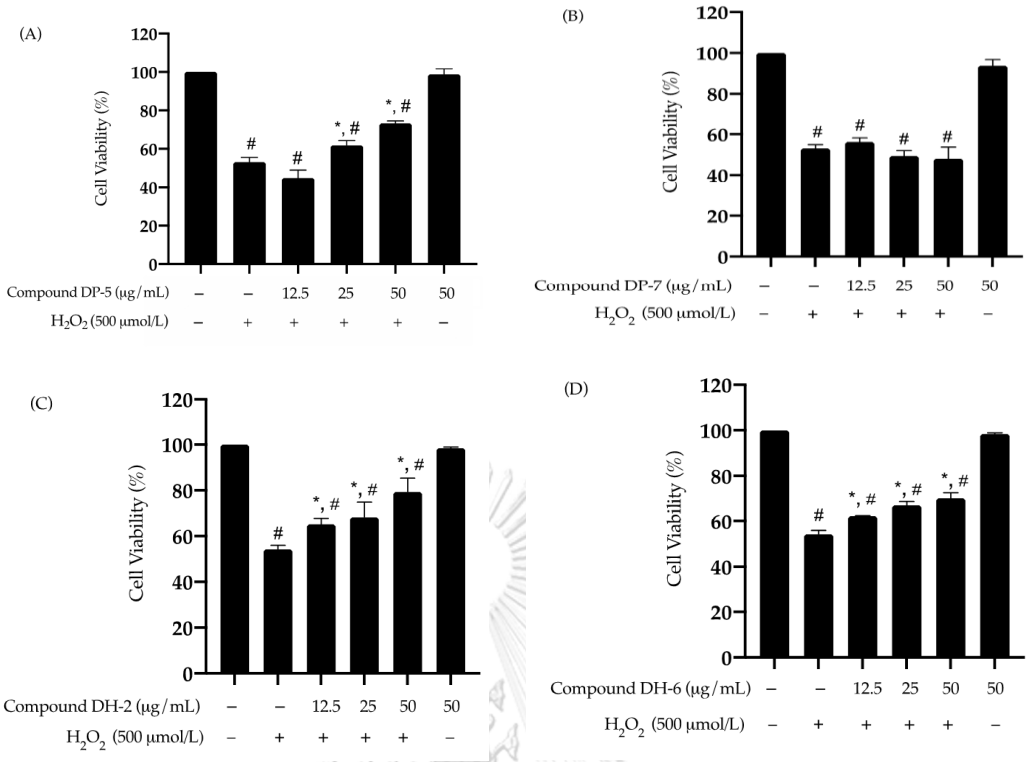


Figure 72 Cytoprotective effect of dendropachol (DP-5) (A), isovitexin (DP-7) (B), methyl 3-(4-hydroxyphenyl) propionate (DH-2) (C), and syringaresinol (D) against H_2O_2 -induced oxidative stress on HaCaT cells for 24 h. After the treatment, the percentage of cell viability was determined using MTT assay. Graph exhibited mean ± S.D. values of four replications. $^{*}p < 0.05$ indicates significant differences from the H_2O_2 induction group, $^{\#}p < 0.05$ indicates significant differences from the control group.

CHAPTER V

CONCLUTION

This research initially aimed to investigate the chemical constituents of two plants, including *Dendrobium pachyglossum* and *Dendrobium heterocarpum*, and study their cytoprotective effect against H_2O_2-indued oxidative stress on HaCaT cells. A total of thirteen compounds have been reported, including one new compound and twelve known compounds. The isolated compounds were evaluated for cytoprotective effect against H_2O_2-induced senescence of HaCaT keratinocytes.

Dendrobium pachyglossum was subjected to phytochemical evaluation, and this led to the isolation of one new bisbibenzyl dendropachol, and six known compounds including, moscatilin, gigantol, 4,5-dihydroxy-2,3-dimethoxy-9,10-dihydrophenanthrene, 4,5,4′-trihydroxy-3-3′dimethoxybibenzyl, dendrocandin T, and isovitexin, respectively. In addition, the EtOAc extract from *D. heterocarpum* also isolated to led six known compounds. They could be amoenylin, 3,4-dihydroxy-5,4′-dimethoxybibenzyl, dendrofalconerol A, dendrocandin B, methyl 3-(4-hydroxyphenyl) propionate, and syringaresinol, respectively.

Among the isolates dendropachol, isovitexin, methyl 3-(4 hydroxyphenyl) propionate, and syringaresinol showed non-toxicity concentration at 50 μg/mL as compared with untreated groups. Four isolated compounds were evaluated for their cytoprotective effect against H_2O_2-induced oxidative stress on HaCaT cells. After pre-treatment with compounds at concentration of 12.5, 25, and 50 μg/mL, dendropachol, methyl 3-(4-hydroxyphenyl) propionate, and syringaresinol showed preventive oxidative stress on HaCaT keratinocyte cells.

In summary, the chemical data of the phytochemicals obtained in this study would be useful for the chemical constituents study of *Dendrobium* plants. The considered as potential skin care from natural sources. The biological data on cytotoxicity and cytoprotective effect of the isolated compounds would be considered as a potential skin care from natural sources.

REFERENCES

Abu, F., Taib, M., Norma, C., Moklas, M., Aris, M., Mohd Akhir, S. (2017). Antioxidant properties of crude extract, partition extract, and fermented medium of *Dendrobium sabin* flower. *Evidence-Based Complementary and Alternative Medicine, 2017*.

Bae, S., Lee, E.-J., Lee, J. H., Park, I.-C., Lee, S.-J., Hahn, H. J., Ahn,J., An, S., Cha, H. J. (2014). Oridonin protects HaCaT keratinocytes against hydrogen peroxide-induced oxidative stress by altering microRNA expression. *International Journal of Molecular Medicine, 33*(1), 185-193.

Bendary, E., Francis, R. R., Ali, H. M. G., Sarwat, M. I., & El Hady, S. (2013). Antioxidant and structure–activity relationships (SARs) of some phenolic and anilines compounds. *Annals of Agricultural Sciences, 58*(2), 173-181.

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

Chan, C.-F., Wu, C.-T., Huang, W.-Y., Lin, W.-S., Wu, H.-W., Huang, T.-K., Chang, Y.-M., Lin, Y.-S. (2018). Antioxidation and melanogenesis inhibition of various *Dendrobium tosaense* extracts. *Molecules, 23*(7), 1810.

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

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

Chanvorachote, P., Kowitdamrong, A., Ruanghirun, T., Sritularak, B., Mungmee, C., Likhitwitayawuid, K. (2013). Anti-metastatic activities of bibenzyls from *Dendrobium pulchellum*. *Natural Product Communications, 8*(1), 115-118.

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

Chen, X.-J., Mei, W.-L., Cai, C.-H., Guo, Z.-K., Song, X.-Q., & Dai, H.-F. (2014). Four new

bibenzyl derivatives from *Dendrobium sinense*. *Phytochemistry Letters, 9*, 107-112.

Chen, X. J., Mei, W. L., Zuo, W. J., Zeng, Y. B., Guo, Z. K., Song, X. Q., & Dai, H. F. (2013). A new antibacterial phenanthrenequinone from *Dendrobium sinense*. *Journal of Asian Natural Products Research, 15*(1), 67-70.

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

Chen, Y., Li, Y., Qing, C., Zhang, Y., Wang, L., Liu, Y. (2008b). 1,4,5-Trihydroxy-7-methoxy-9H-fluoren-9-one, a new cytotoxic compound from *Dendrobium chrysotoxum*. *Food Chemistry, 108*(3), 973-976.

Chen, Y., Liu, Y., Jiang, J., Zhang, Y., & Yin, B. (2008c). Dendronone, a new phenanthrenequinone from *Dendrobium cariniferum*. *Food Chemistry, 111*(1), 11-12.

Choi, Y.-J., Kang, J.-S., Park, J. H. Y., Lee, Y.-J., Choi, J.-S., & Kang, Y.-H. (2003). Polyphenolic flavonoids differ in their antiapoptotic efficacy in hydrogen peroxide–treated human vascular endothelial cells. *The Journal of Nutrition, 133*(4), 985-991.

Covarrubias, L., Hernández-García, D., Schnabel, D., Salas-Vidal, E., & Castro-Obregón, S. (2008). Function of reactive oxygen species during animal development: passive or active?. *Developmental biology, 320(1)*, 1-11.

Cuc, N. T., Nhiem, N. X., Yen, P. H., Anh, H. L. T., Van Minh, C., Van Kiem, P. (2015). Flavonoid glycosides from *Antidesma ghaesembilla*. *Vietnam Journal of Chemistry, 53*(2e).

Dahmen, J., & Leander, K. (1978). Amotin and amoenin, two sesquiterpenes of the picrotoxane group from *Dendrobium amoenum*. *Phytochemistry, 17*(11), 1949-1952.

Dubrovina, A. S., & Kiselev, K. V. (2017). Regulation of stilbene biosynthesis in plants. *Planta, 246*(4), 597-623. doi:10.1007/s00425-017-2730-8

Fan, Wang, W., Wang, Y., Qin, G., Zhao, W. (2001). Chemical constituents from *Dendrobium densiflorum*. *Phytochemistry, 57*, 1225-1258.

Fan, W.-W., Xu, F.-Q., Dong, F.-W., Li, X.-N., Li, Y., Liu, Y.-Q., Zhou, J., Hu, J.-M. (2013).

Dendrowardol C, a novel sesquiterpenoid from *Dendrobium wardianum* Warner. *Natural Products and Bioprospecting, 3*(3), 89-92.

Fang, Y.-S., Yang, M.-H., Cai, L., Wang, J.-P., Yin, T.-P., Yu, J., Ding, Z.-T. (2018). New phenylpropanoids from *Bulbophyllum retusiusculum*. *Archives of Pharmacal Research, 41*(11), 1074-1081.

Ganbaatar, C., Gruner, M., Mishig, D., Duger, R., Schmidt, A. W., & Knölker, H.-J. (2015). Flavonoid glycosides from the aerial parts of *Polygonatum odoratum* (Mill.) Druce growing in Mongolia. *The Open Natural Products Journal, 8*(1).

Han, H. S., Kim, K. B., Jung, J. H., An, I. S., Kim, Y.-J., An, S. (2018). Anti-apoptotic, antioxidant and anti-aging effects of 6-shogaol on human dermal fibroblasts. *Biomedical Dermatology, 2*(1), 27. doi:10.1186/s41702-018-0037-4

Hidalgo, M. E., De la Rosa, C., Carrasco, H., Cardona, W., Gallardo, C., & Espinoza, L. (2009). Antioxidant capacity of eugenol derivatives. *Quimica Nova*, *32(6)*, 1467-1470.

Hirobe, T. (2014). Keratinocytes regulate the function of melanocytes. *Dermatologica Sinica*, 32(4), 200-204.

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

Hu, J.-M., Zhao, Y.-X., Miao, Z.-H., Zhou, J. (2009). Chemical components of *Dendrobium polyanthum*. *Bulletin of the Korean Chemical Society, 30*(9), 2098-2100.

Hu, J. M., Chen, J. J., Yu, H., Zhao, Y. X., Zhou, J. (2008a). Five new compounds from *Dendrobium longicornu*. *Planta Medica, 74*(5), 535-539. doi:10.1055/s-2008-1074492

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

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

Hu, Y., Ma, Y., Wu, S., Chen, T., He, Y., Sun, J., Jiao, R., Jiang, X., Huang, Y., Deng, L., Bai, W. (2016). Protective effect of cyanidin-3-O-Glucoside against ultraviolet B radiation-induced cell damage in human HaCaT keratinocytes. *Frontiers in*

Pharmacology, 7(301). doi:10.3389/fphar.2016.00301

Hu, Y., Zhang, C., Zhao, X., Wang, Y., Feng, D., Zhang, M., Xie, H. (2016). (±)-Homocrepidine A, a pair of anti-inflammatory enantiomeric octahydroindolizine alkaloid dimers from *Dendrobium crepidatum. Journal of Natural Products*, 79(1), 252-256.

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

Inthongkaew, P., Chatsumpun, N., Supasuteekul, C., Kitisripanya, T., Putalun, W., Likhitwitayawuid, K., & Sritularak, B. (2017). α-Glucosidase and pancreatic lipase inhibitory activities and glucose uptake stimulatory effect of phenolic compounds from *Dendrobium formosum*. *Revista Brasileira de Farmacognosia, 27*(4), 480-487.

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

Kammeyer, A., & Luiten, R. (2015). Oxidation events and skin aging. *Ageing Research Reviews, 21*, 16-29.

Kanlayavattanakul, M., Lourith, N., & Chaikul, P. (2018). Biological activity and phytochemical profiles of *Dendrobium*: a new source for specialty cosmetic materials. *Industrial Crops and Products, 120*, 61-70.

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

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

And Alternative Medicine, 2015, 350410.

Ko, Y.-J., Yang, S. K., Song, S.-M., Yoon, W.-J., Bae, K.-H. (2015). Effect of *Dendrobium moniliforme* on melanogenic protein expression in B16F10 melanoma cells. *Journal of Biologically Active Products from Nature, 5*(1), 12-17.

Kongkatitham, V., Muangnoi, C., Kyokong, N., Thaweesest, W., Likhitwitayawuid, K., Rojsitthisak, P., Sritularak, B. (2018). Anti-oxidant and anti-inflammatory effects of new bibenzyl derivatives from *Dendrobium parishii* in hydrogen peroxide and lipopolysaccharide treated RAW264.7 cells. *Phytochemistry Letters, 24*, 31-38.

Kyokong, N., Muangnoi, C., Thaweesest, W., Kongkatitham, V., Likhitwitayawuid, K., Rojsitthisak, P., Sritularak, B. (2018). A new phenanthrene dimer from *Dendrobium palpebrae*. *Journal of Asian Natural Products Research*, 1-7.

Lam, Y., Ng, T. B., Yao, R. M., Shi, J., Xu, K., Sze, S. C. W., & Zhang, K. Y. (2015). Evaluation of chemical constituents and important mechanism of pharmacological biology in *Dendrobium* plants. *Evidence-Based Complementary and Alternative Medicine, 2015*, 841752.

Lee, S. Y., Kim, C. H., Hwang, B. S., Choi, K. M., Yang, I. J., Kim, G. Y., ... & Jeong, J. W. (2020). Protective Effects of Oenothera biennis against Hydrogen Peroxide-Induced Oxidative Stress and Cell Death in Skin Keratinocytes. *Life*, *10(11)*, 255.

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

Li, Wang, C. H., Wang, Y. J., Wang, F. F., Guo, S. X., Yang, J. S., & G, X. P. (2009b). Four New Bibenzyl Derivatives from *Dendrobium candidum*. *Chemical and Pharmaceutical Bulletin, 57*(2), 218-219.

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

Li, L., Xue, Y., Zhang, H., Liu, Y., Yi, F., Dong, Y. (2020). A new polysaccharide isolated from *Dendrobium offcinale*, stimulates aquaporin-3 expression in human keratinocytes. *Food Science and Technology*. *41* (1), 91-95.

Li, X. H., Guo, L., Yang, L., Peng, C., He, C. J., Zhou, Q. M., Xiong, L., Liu, J., Zhang, T. M. (2014). Three new neolignan glucosides from the stems of *Dendrobium*

aurantiacum var. *denneanum Phytochemistry Letters, 9*, 37-40.

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

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

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

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

Liu, Y.-H., Lin, Y.-S., Huang, Y.-W., Fang, S.-U., Lin, S.-Y., Hou, W.-C. (2016). Protective effects of minor components of curcuminoids on hydrogen peroxide-treated human HaCaT keratinocytes. *Journal of agricultural and food chemistry, 64*(18), 3598-3608.

Liu, Y., Jiang, J. H., Zhang, Y., Chen, Y. G. (2009). Chemical Constituents of *Dendrobium aurantiacum* var. *denneanum*. *Chemistry of Natural Compounds, 45*(4), 525-527.

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

Luo, A., Ge, Z., Fan, Y., Luo, A., Chun, Z., He, X. (2011). *In vitro* and *in vivo* antioxidant activity of a water-soluble polysaccharide from *Dendrobium denneanum*. *Molecules, 16*(2), 1579-1592.

Ma, R.-J., Yang, L., Bai, X., Li, J.-Y., Yuan, M.-Y., Wang, Y.-Q., Xie, Y., Zhou, J. (2019). Phenolic constituents with antioxidative, tyrosinase inhibitory and anti-aging activities from *Dendrobium loddigesii* Rolfe. *Natural products and*

bioprospecting, 9(5), 329-336.

Majumder, & Pal. (1992). Rotundatin, a new 9,10-dihydrophenanthrene derivative was isolated from the orchid, *Dendrobium rotundatum*. *Phytochemistry, 31*(9), 3225-3228.

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

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

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

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

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

Maoka, T., Mochida, K., Kozuka, M., Ito, Y., Fujiwara, Y., Hashimoto, K., Enjo, F., Ogata, M., Nobukuni, Y., Tokuda, H. (2001). Cancer chemopreventive activity of carotenoids in the fruits of red paprika *Capsicum annuum* L. *Cancer Letters, 172*(2), 103-109.

Markiewicz, E., & Idowu, O. C. (2019). DNA damage in human skin and the capacities of natural compounds to modulate the bystander signalling. *Open biology, 9(12)*, 190208.

Meng, C. W., He, Y. L., Peng, C., Ding, X. J., Guo, L., Xiong, L. (2017). Picrotoxane sesquiterpenoids from the stems of *Dendrobium nobile* and their absolute configurations and angiogenesis effect. *Fitoterapia, 121*, 206-211.

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

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

Molagoda, I. M. N., Lee, K. T., Choi, Y. H., & Kim, G.-Y. (2020). Anthocyanins from *Hibiscus syriacus* L. inhibit oxidative stress-mediated apoptosis by activating the Nrf2/HO-1 signaling pathway. *Antioxidants, 9*(1), 42.

Muangnoi, C., Sharif, U., Ratnatilaka Na Bhuket, P., Rojsitthisak, P., & Paraoan, L. (2019). Protective effects of curcumin ester prodrug, curcumin diethyl disuccinate against H2O2-induced oxidative stress in human retinal pigment epithelial cells: potential therapeutic avenues for age-related macular degeneration. I*nternational Journal of Molecular Sciences*, *20(13)*, 3367.

Na Ranong, S., Likhitwitayawuid, K., Mekboonsonglarp, W., Sritularak, B. (2019). New dihydrophenanthrenes from *Dendrobium infundibulum*. *Natural Product Research, 33*(3), 420-426.

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

Paudel, M. R., Chand, M. B., Pant, B., Pant, B. (2018). Antioxidant and cytotoxic activities of *Dendrobium moniliforme* extracts and the detection of related compounds by GC-MS. *BMC complementary and alternative medicine, 18*(1), 134-134.

Pelle, E., Mammone, T., Maes, D., Frenkel, K. (2005). Keratinocytes act as a source of reactive oxygen species by transferring hydrogen peroxide to melanocytes. *Journal of Investigative Dermatology, 124*(4), 793-797.

Poljšak, B., & Dahmane, R. (2012). Free radicals and extrinsic skin aging. *Dermatology research and practice*, *2012*, 1-4.

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

Proksch, E., Brandner, J. M., Jensen, J.-M. (2008). The skin: an indispensable barrier. *Experimental Dermatology, 17*(12), 1063-1072.

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

Ramarathnam, N., Osawa, T., Namiki, M., Kawakishi, S. (1989). Chemical studies on novel rice hull antioxidants. 2. Identification of isovitexin, a C-glycosyl flavonoid.

Journal of Agricultural and Food Chemistry, 37(2), 316-319.

Ransy, C., Vaz, C., Lombès, A., & Bouillaud, F. (2020). Use of H_2O_2 to Cause Oxidative Stress, the Catalase Issue. *International Journal of Molecular Sciences*, *21(23)*, 9149.

Ren, Z., Ji, X., Jiao, Z., Luo, Y., Zhang, G.-Q., Tao, S., Lei, Z., Zhang, J., Wang, Y., Liu, J.-Z., Wei, G. (2020). Functional analysis of a novel C-glycosyltransferase in the orchid *Dendrobium catenatum*. *Horticulture Research, 7*(1), 111.

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

Saito, K., Yonekura-Sakakibara, K., Nakabayashi, R., Higashi, Y., Yamazaki, M., Tohge, T., Fernie, A. R. (2013). The flavonoid biosynthetic pathway in Arabidopsis: structural and genetic diversity. *Plant Physiology and Biochemistry, 72*, 21-34.

Sarakulwattana, C., Mekboonsonglarp, W., Likhitwitayawuid, K., Rojsitthisak, P., & Sritularak, B. (2018). New bisbibenzyl and phenanthrene derivatives from *Dendrobium scabrilingue* and their α-glucosidase inhibitory activity. *Natural Product Research*, 1-8.

Schrader, J., & Bohlmann, J. *Biotechnology of isoprenoids* (Vol. 149): Springer.

Shang, Z., Li, X., & Xiao, S. (2020). Two new bibenzyl compounds from *Dendrobium lindleyi*. *Records of Natural Products, 14*(6), 420.

Sritularak, Duangrak, N., & Likhitwitayawuid, K. (2011a). A New bibenzyl from *Dendrobium secundum*. *Zeitschrift für Naturforschung C, 66*(5), 205-208.

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

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

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

Talapatra, B., Das, A. K., & Talapatra, S. K. (1989). Defuscin, a new phenolic ester from

Dendrobium fuscescens: Conformation of shikimic acid. *Phytochemistry, 28*(1), 290-292.

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

Taylor, J. K., Zhang, Q. Q., Monia, B. P., Marcusson, E. G., Dean, N. M. (1999). Inhibition of Bcl-xL expression sensitizes normal human keratinocytes and epithelial cells to apoptotic stimuli. *Oncogene, 18*(31), 4495-4504.

Thant, M. T., Chatsumpun, N., Mekboonsonglarp, W., Sritularak, B., Likhitwitayawuid, K. (2020). New fluorene derivatives from *Dendrobium gibsonii* and their α-glucosidase inhibitory activity. *Molecules, 25*(21), 4931.

Tobin, D. J. (2017). Introduction to skin aging. *Journal of Tissue Viability, 26*(1), 37-46.

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

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

Wagener, F. A., Carels, C. E., & Lundvig, D. (2013). Targeting the redox balance in inflammatory skin conditions. *International Journal of Molecular Sciences*, *14(5),* 9126-9167.

Wang, H., Zhao, T., & Che, C. T. (1985). Dendrobine and 3-hydroxy-2-oxodendrobine from *Dendrobium nobile*. *Journal of natural products, 48*, 796-801.

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

Wollenweber, E., Dörr, M., Stelzer, R., Arriaga-Giner, F. J. (1992). Lipophilic phenolics from the leaves of *Empetrum nigrum*-chemical structures and exudate localization. *Botanica Acta, 105*(4), 300-305.

Wu, L., Lu, Y., Ding, Y., Zhao, J., Xu, H., Chou, G. (2019). Four new compounds from *Dendrobium devonianum*. *Natural Product Research, 33*(15), 2160-2168.

Xiaohua, J., Singchi, C., & Yibo, L. (2009). Taxonomic revision of *Dendrobium moniliforme complex* (Orchidaceae). *Scientia Horticulturae, 120*(1), 143-145.

Xiaomei, C., Fangfei, W., Yunqiang, W., Xuelan, L., Airong, W., Chunlan, W., Shunxing, G. (2012). Discrimination of the rare medicinal plant *Dendrobium officinale* based on naringenin, bibenzyl, and polysaccharides. *Life Sciences, 55*, 1092-1099.

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

Xu, F. Q., Fan, W. W., Zi, C. T., Dong, F. W., Yang, D., Zhou, J., Hu, J. M. (2017). Four new glycosides from the stems of *Dendrobium fimbriatum* Hook. *Natural Product Research, 31*(7), 797-801.

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

Xu, J., Han, Q.-B., Li, S.-L., Chen, X.-J., Wang, X.-N., Zhao, Z.-Z., Chen, H.-B. (2013). Chemistry, bioactivity and quality control of *Dendrobium*, a commonly used tonic herb in traditional Chinese medicine. *Phytochemistry Reviews, 12*(2), 341-367.

Xu, X., Chen, X., Yang, R., Li, Z., Zhou, H., Bai, Y., Meng, Y., Ding, G. (2020). Crepidtumines A and B, two novel indolizidine alkaloids from D*endrobium crepidatum*. *Scientific Reports, 10*(1), 1-8.

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

Yan Li, Chun-Lun Wang, Shun-Xing Guo, Jun-Shan Yang, Xiao, P.-G. (2008). Two new compounds from *Dendrobium candidum*. *Chemical and Pharmaceutical Bulletin, 56*, 1477-1479.

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

Yang, Liu, S. J., Luo, H. R., Cui, J., Zhou, J., Wang, X. J.,Sheng, J., Hu, J. M. (2015). Two new dendrocandins with neurite outgrowth-promoting activity from *Dendrobium*

officinale. *Journal of Asian Natural Products Research, 17*(2), 125-131.

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

Yang, Wang, Z., & Xu, L. (2006b). Phenols and a triterpene from *Dendrobium aurantiacum* var. *denneanum* (Orchidaceae). *Biochemical Systematics and Ecology, 34*(8), 658-660.

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

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

Yang, H. H., Hwangbo, K., Zheng, M. S., Son, J.-K., Kim, H. Y., Baek, S. H., Choi, C. H., Park, Y. S., Kim, J.-R. (2014). Inhibitory effects of juglanin on cellular senescence in human dermal fibroblasts. *Journal of Natural Medicines, 68*(3), 473-480.

Yang, M., Chen, L. J., Zhang, Y., & Chen, Y. G. (2017a). Two new picrotoxane-type sesquiterpenoid lactones from *Dendrobium williamsonii*. *Journal of Asian Natural Products Research*, 1-5.

Yang, M., Zhang, Y., Chen, L., Chen, Y. (2017b). A new (propylphenyl) bibenzyl derivative from *Dendrobium williamsonii*. *Natural Product Research*, 1-7.

Yang, M., Zhang, Y., Chen, L., & Chen, Y. (2018). A new (propylphenyl) bibenzyl derivative from *Dendrobium williamsonii*. *Natural Product Research, 32*(14), 1699-1705.

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

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

Ye, Q., & Zhao, W. (2002). New alloaromadendrane, cadinene and cyclocopacamphane type sesquiterpene derivatives and bibenzyls from *Dendrobium nobile*. *Planta*

Medica, 68, 723-729.

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

Yoon, Y., Lee, Y. M., Song, S., Lee, Y. Y., & Yeum, K. J. (2018). Black soybeans protect human keratinocytes from oxidative stress-induced cell death. *Food Science & Nutrition*, *6(8)*, 2423-2430.

Zhang, Liu, S. J., Yang, L., Yuan, M. Y., Li, J. Y., Hou, B., Li, M.-H., Yang, X.-Z., Ding, C.-C., Hu, J. M. (2017). Sesquiterpene amino ether and cytotoxic phenols from *Dendrobium wardianum* Warner. *Fitoterapia, 122*, 76-79.

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

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

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

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

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

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

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

Zhang, Y., Zhang, L., Liu, J., Liang, J., Si, J., Wu, S. (2017). *Dendrobium officinale* leaves

as a new antioxidant source. *Journal of Functional Foods, 37*, 400-415.

Zhang, Y. Y., Wang, P., Song, X. Q., Zuo, W. J., Wang, H., Chen, L. L., Mei, W.-L., Dai, H. F. (2018). Chemical constituents from *Dendrobium hainanense*. *Journal of Asian Natural Products Research*, 1-8.

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

Zhao, G. Y., Deng, B. W., Zhang, C. Y., Cui, Y. D., Bi, J. Y., Zhang, G. G. (2018). New phenanthrene and 9, 10-dihydrophenanthrene derivatives from the stems of *Dendrobium officinale* with their cytotoxic activities. *Journal Of Natural Medicines, 72*(1), 246-251.

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

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

Zheng, C. D., Li, G., Li, H. Q., Xu, X. J., Gao, J. M., & Zhang, A. L. (2010). DPPH-scavenging activities and structure-activity relationships of phenolic compounds. Natural Product Communications, 5(11), 1759-1765.

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

Zhou, X. M., Zheng, C. J., Wu, J. T., Chen, G. Y., Chen, J., Sun, C. G. (2016). Five new lactone derivatives from the stems of *Dendrobium nobile*. *Fitoterapia, 115*, 96-100.

Zhou, X. M., Zheng, C. J., Wu, J. T., Chen, G. Y., Zhang, B., Sun, C. G. (2017). A new phenolic glycoside from the stem of *Dendrobium nobile*. *Natural Product Research, 31*(9), 1042-1046.

Zielinska-Pisklak, M. A., Kaliszewska, D., Stolarczyk, M., Kiss, A. K. (2015). Activity-guided isolation, identification and quantification of biologically active isomeric

compounds from folk medicinal plant *Desmodium adscendens* using high performance liquid chromatography with diode array detector, mass spectrometry and multidimentional nuclear magnetic resonance spectroscopy. *Journal of Pharmaceutical and Biomedical Analysis*, *102*, 54-63.

Zuliani, T., Denis, V., Noblesse, E., Schnebert, S., Andre, P., Dumas, M., Ratinaud, M.-H. (2005). Hydrogen peroxide-induced cell death in normal human keratinocytes is differentiation dependent. *Free Radical Biology and Medicine, 38*(3), 307-316.

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