CHEMICAL CONSTITUENTS AND BIOLOGICAL ACTIVITIES FROM RUTACEAE PLANTS: *ATALANTIA MONOPHYLLA*, *CLAUSENA EXCAVATA*, *FERONIELLA LUCIDA*, *GLYCOSMIS PENTAPHYLLA* AND *GLYCOSMIS COCHINCHINENSIS*

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Thesis Title	Chemical Constituents and Biological Activities from Rutaceae Plants: *Atalantia monophylla*, *Clausena excavata*, *Feroniella lucida*, *Glycosmis pentaphylla* and *Glycosmis cochinchinensis*
Author	Tawanun Sripisut
Degree	Doctor of Philosophy (Applied Chemistry)
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ABSTRACT

Phytochemical investigation and biological activities study from Rutaceae plants including *Atalantia monophylla*, *Clausena excavata*, *Feroniella lucida*, *Glycosmis pentaphylla* and *G. cochinchinensis* led to the isolation and structure elucidation of 119 compounds.

The chemical investigation of the acetone extract of *A. monophylla* roots led to isolation of 15 known compounds including eight acridone alkaloids (**AM1**-**AM8**), six coumarins (**AM9-AM14**) and a limonoid (**AM15**). All compounds, except **AM6** and **AM11** were evaluated for their antibacterial activity. Compound **AM2** exhibited strong antibacterial activity against methicillin-resistant *Straphylococcus aureus* SK1 (MRSA) and *S. aureus* with MIC values of 2 and 4 µg/mL, respectively.

Phytochemical investigation of *C. excavata* led to isolation and identification of 43 compounds. A new coumarin (**CE1**) together with two known coumarins (**CE3** and **CE4**), a known benzene derivative (**CE34**), a known monoterpene (**CE36**) and a

known steroid (**CE38**) were isolated from the hexanes-CH_2Cl_2 extract of fruits whereas a new carbazole alkaloid (**CE22**), along with 18 compounds (**CE2**, **CE5**, **CE8**, **CE11-CE16**, **CE18-CE22**, **CE23**, **CE32**, **CE33**, **CE35** and **CE37**) were isolated from the EtOAc extract of stems. The remaining 18 known compounds (**CE3**, **CE6-CE10**, **CE13**, **CE16**, **CE17** and **CE24-CE32**) were isolated from the acetone extract of roots. Some of isolated compounds were further evaluated for their cytotoxicity against KB, MCF-7 and NCI-H187 human cell lines. Compounds **CE20**, **CE21** and **CE23** showed the highest cytotoxicity against KB, NCI-H187 and MCF-7 human cell lines with IC_{50} values of 4.63, 1.07 and 0.78 µg/mL, respectively.

Thirty-six compounds were isolated and identified from *F. lucida*. Seven known compounds (**FL14**, **FL16**, **FL17**, **FL21**, **FL23**, **FL29** and **FL30**) were isolated from the acetone extract of fruits while a new furanocoumarin (**FL8**) together with 17 known compounds (**FL1**, **FL3-FL7**, **FL11**, **FL12, FL14**, **FL15**, **FL18-FL22**, **FL24** and **FL25**) were isolated from the acetone extract of roots. The remaining two new furanocoumarins (**FL9** and **FL10**) along with 9 compounds (**FL2**, **FL7**, **FL11-FL13**, **FL16** and **FL26-FL28**) were isolated from the acetone extracts of twigs. Some of the isolates were evaluated for their biological activities, including cytotoxic, antimalarial and anti-TB activities. Compound **FL25** showed strong cytotoxicity against KB (IC_{50} = 0.637 µg/mL) and NCI-H187 (IC_{50} = 0.094 µg/mL) human cancer cell lines, antimalarial activity against *Plasmodium falciparum* (IC_{50} = 0.336 µg/mL), and antituberculosis activity against *Mycobacterium tuberculosis* (MIC = 6.25 µg/mL).

A new hydroperoxyquinolone alkaloid (**GP1**) along with nine known compounds (**GP2–GP10**) were isolated from the CH_2Cl_2-MeOH extract of *G. pentaphylla* fruits. All isolates exhibited weak or inactive antibacterial activity against Gram-negative bacteria (*Escherichia coli* and *Salmonella typhimurium*) as well as Gram-positive bacteria (*Staphylococcus aureus* and MRSA).

A phytochemical investigation of the acetone extract of *G. cochinchinensis* twigs led to the isolation and identification of a new acridone alkaloid (**GC1**) and a new indole alkaloid (**GC10**), together with 13 known compounds (**GC2-GC9** and **GC11-GC15**). Some of the isolates were evaluated for their antibacterial activity. Only compound **GC8** exhibited moderate antibacterial activity against MRSA with a MIC value of 16 μg/mL.

Keywords: Rutaceae/*Atalantia monophylla*/*Clausena excavata*/*Feroniella lucida*/ *Glycosmis pentaphylla*/*Glycosmis cochinchinensis*/Cytotoxicity/ Antimalaria/Antibacteria/Antituberculosis Activity

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ABBREVIATIONS AND SYMBOLS

s	=	*singlet*
d	=	*doublet*
t	=	*triplet*
q	=	*quartet*
m	=	*multiplet*
dd	=	*doublet of doublet*
dt	=	*doublet of triplet*
br s	=	*broad singlet*
br m	=	*broad multiplet*
g	=	Gram
nm	=	Nanometer
mp	=	Melting Point
cm^{-1}	=	Reciprocol Centimeter (wave number)
δ	=	Chemical Shift Relative to TMS
J	=	Coupling Constant
$[\alpha]_D$	=	Specific Rotation
λ_{max}	=	Maximum Wavelength
ν	=	Absorption Frequencies
m/z	=	a Value of Mass Divided by Charge
°C	=	Degree Celsius
MHz	=	Megahertz
ppm	=	Part per Million
c	=	Concentration
IR	=	Infrared
UV	=	Ultraviolet-visible

ABBREVIATIONS AND SYMBOLS (continued)

HR-ESI-MS	=	High Resolution Electrospray Ionization Mass Spectroscopy
HR-TOF-MS	=	Electrospray Ionization Time-of-Fight Mass Spectroscopy
NMR	=	Nuclear Magnetic Resonance
2D NMR	=	Two Dimensional Nuclear Magnetic Resonance
COSY	=	Correlation Spectroscopy
DEPT	=	Distortionless Enhancement by Polarization Transfer
HMBC	=	Heteronuclear Multiple Bond Correlation
HMQC	=	Heteronuclear Multiple Quantum Coherence
NOE	=	Nuclear Overhauser Effect
CC	=	Column Chromatography
QCC	=	Quick Column Chromatography
PLC	=	Preparative Thin Layer Chromatography
TMS	=	Tetramethylsilane
$CDCl_3$	=	Deuterochloroform
CD_3OD	=	Deuteromethanol

CHAPTER 1

INTRODUCTION

1.1 Background

For thousands of years, natural products have afforded a rich source of compounds that have found many applications in the fields of medicine, pharmacy and biology. Terrestrial plants, terrestrial microorganisms, marine organisms, and terrestrial vertebrates and invertebrates are invaluable sources of natural product medicines as well as secondary metabolites. Along with compounds from terrestrial organisms, the constituents of higher plants have provided a substantial number of the natural product-derived drugs used currently in medicine. So far, many of medicines such as artemisinin, codeine, digitoxin, morphine, and quinine were derived from plants on the basis of natural products studies of traditional medicines and all of them are still widely used.

Interest in the elucidation of new structures of the secondary metabolite constituents of plants has remained high among the natural products community, particularly of species that are used in systems of traditional medicine or are utilized as botanical dietary supplements. There are many reasons for this, and paramount among these is a strong interest in investigating the chemical and biological properties of the constituents of medicinal plants. Furthermore, four basic reasons in which plants are needed to be studied for the discovery of lead compounds including:

1. Plants are sometimes used as sources of direct therapeutic agents.
2. Plants are also used as sources of starting points for the elaboration of semi-synthetic compounds.
3. Plants can serve as sources of substances that can be used as models for new synthetic compounds.

4. Plants can also be used as taxonomic markers for the discovery of new compounds.

Thailand is located in South East Asia. Its climate is tropical with wet and long hot dry season which exhibit a variety of tropical ecosystems. For these reasons, Thailand has an abundance of organisms including plants and animals as well as microorganisms. Thailand has approximately 15,000 species of plant which account for 8% of estimated total number of plant species found globally (OEPP, 1992). Several parts of Thailand from ancient times to the present day have used plants as a source of healthy food and medicines especially Rutaceae plants.

Plant of the family Rutaceae or Citrus is one of the world's most important fruit crop and potential economic because a large amount of this family is edible fruits or used ornamentals. It is widely grown throughout the world, especially in the tropical, subtropical, and borderline subtropical areas of the world but only 24 genera were found in Thailand (Smitinand, 2001). This family has been found to contain many secondary metabolites such as alkaloids, coumarins and lignans with a broad spectrum of biological activities (Lewis, 1983).

Among plants belonging to Rutaceae family, *Atalantia monophylla*, *Clausena excavata*, *Feroniella lucida*, *Glycosmis pentaphylla* and *G. cochinchinensis* were chosen as main plants for screening about phytochemical investigation as well as biological activity evaluation are selected from Rutaceae plants.

1.2 Botanical Description of Rutaceae Plants

The family Rutaceae consists of 150 genera and 1500 species of prickly treelets, shrub and herbs. According to the classification, Rutaceae are easily recognized by three main botanical features. Firstly, the leaves are compound and conspicuously dotted with translucent oil cell. Secondly, the flowers are pure white or light yellow, ephemeral and endowed with a conspicuous oily stigma. Lastly, the fruits are baccate or succulent (hesperidia) or capsular (Wiart, 2006).

1.2.1 *Atalantia monophylla*

A. monophylla belongs to the family Rutaceae, locally known as ‘Manao Pee’ in Thai. It is a thorny tree which distributed in Southeast Asia, East Bengal, South India and Ceylon. *Atalantia* genus contained 12 species in the world. However, *A. monophylla* is the only specie found in Thailand.

Manao Pee is a small to medium shrub, 8-15 m tall. Bark is distinct ridges and many gray brown prickles. Stem has the character of rut twists and very hard wooded. Leaves are single arrange alternate oval with concave curly end, width 3-5 cm, length 7-12 cm. Flowers are white and fragrant gathering in bouquet. Fruits are berry with round shape and small sized with the thick rough skin. Seeds have oval character.

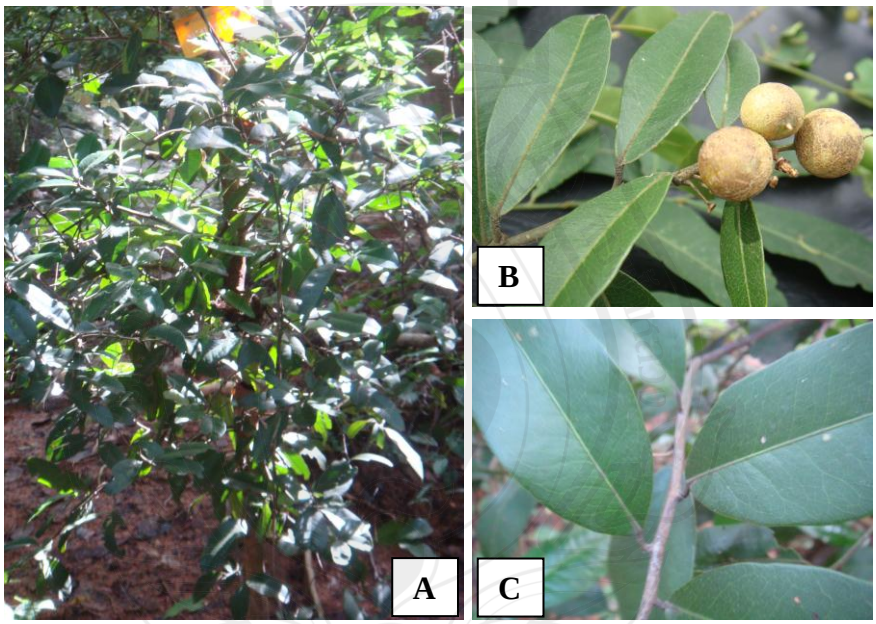


Figure 1.1 Tree, Fruits and Leaves of *A. monophylla* (A-C)

1.2.2 *Clausena excavata*

C. excavata or San Soak in Thai is a wild shrub which is widely distributed in Southern and Southeastern Asian countries including Thailand. Six species of this genus *Clausena* are found in Thailand; *C. excavata*, *C. harmandiana*, *C. lansium*, *C. lenis* and *C. wallichii* (Smitinand, 2001).

C. excavata is an aromatic shrub which grows up to 1.5 m high with bark greenish grey. Stem has soft wooded and has trunk straight or sometimes branched from base. Leaves are ovate, compound and alternate leaflets (8-15 pairs) with translucent glandular dots. Mature leaves thin, smooth or finely hairy especially below. Flowers are arranged in a many-flowered inflorescence clusters at end of twigs and upper leaf axils. Fruits are fleshy berry (0.7-2 cm), white or pale pink, and oval slightly hairy when young, later smooth and gland-dotted and juicy with 1-2 seeds.

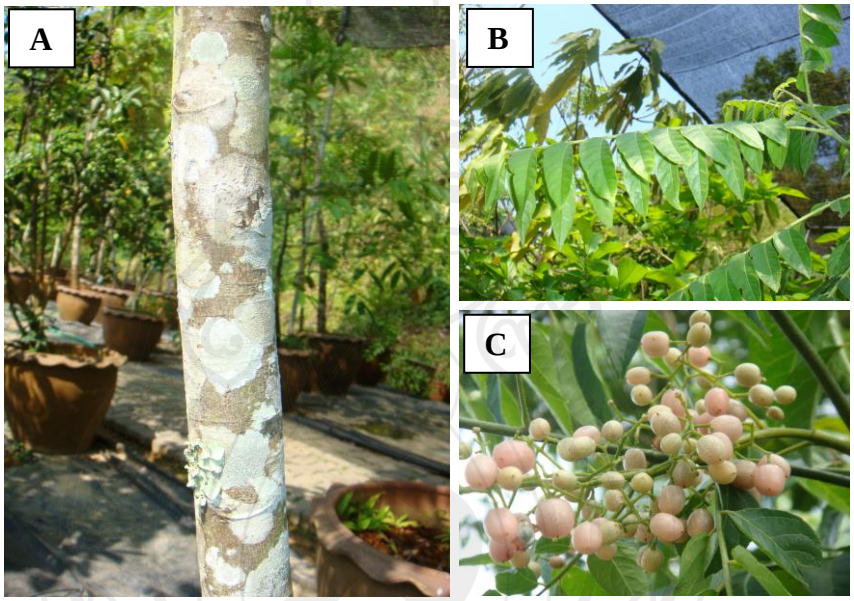


Figure 1.2 Stems, Leaves and Fruits of *C. excavata* (A-C)

1.2.3 *Feroniella lucida*

The local name of *F. lucida* is 'Masung', which is an ornamental plant. This plant is distributed widely throughout the North and Northeastern of Thailand. Even though the genus *Feroniella* comprises three species, *F. lucida* is the only species found in Thailand.

F. lucida is a medium sized tree, up to 25 m tall with horizontally arranged benches. Leaves have composite character, length about 8 cm. Flowers are white color, 2-3 cm in diameter. Fruits are berry, cluster of 5-9, with a smooth and glossy

skin hard as a coconut shell and with white or yellowish pulp. Seeds are small and flattened yellow to light green

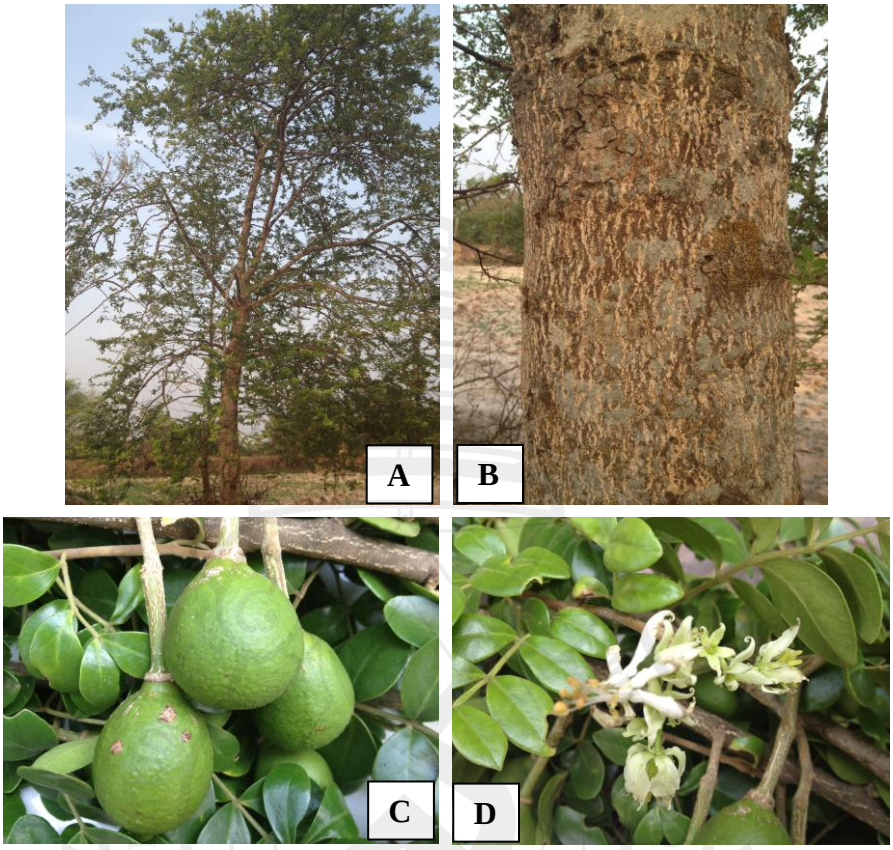


Figure 1.3 Tree, Bark, Fruits and Flowers of *F. lucida* (A-D)

1.2.4 *Glycosmis pentaphylla*

The plants of *Glycosmis* genus are unarmed small trees or shrubs occurring in Southeastern Asia as well as Northern Australia. 15 species are found in Thailand.

G. pentaphylla or Som Chuen is sometimes referred to as 'orange berry' which distributed in several Asian counties. Its stem has hard wooded, 5-10 m tall with brown and smooth bark. Leaves are alternative character and glossy leaf surface, 3-5 leaflets. Flowers are tiny white to light green and fragrant, inflorescence axillary panicales. Sepals broadly ovate to rotund, 1-1.5 mm long, margin ciliolate and petals obovate to elliptical, 5 mm x 2.5 mm, glabrous and white. Stamens are up to 3.5 mm

long; ovary ovoid, up to 2.5 mm long. Fruits are pink to red rounded berry and juicy, help in small grape-like clusters, 10-13.5 mm diameter.

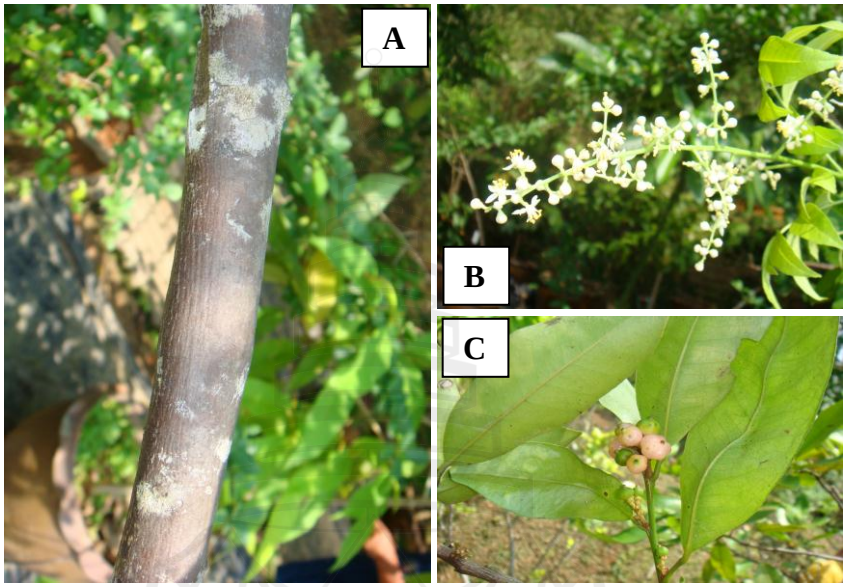


Figure 1.4 Stem, Flowers and Fruits of *G. pentaphylla* (A-C)

1.2.5 *Glycosmis cochinchinensis*

'Khoei kho' is the local name in Thailand of *G. cochinchinensis*, which is distributed in Asia countries including China, Cambodia, Laos, Myanmar and Vietnam. Botanical characteristic of this plant is similar to *G. pentaphylla*.

G. cochinchinensis is a shrub or small tree, 1-4 m tall. Leaves are simple, ovate, oblong or lanceolate, 4-26 cm length, 2-8 cm width, round base. Flowers are small white inflorescences axillary or terminal, rarely solitary. Sepals ovate, less than 1 mm. Petals white, ca. 3 mm. Stamens 10; filaments widest in ± their basal half. Ovary globose; style short, narrow; stigma slightly expanded. Fruits are edible and reddish, 0.8-1.4 cm diameter.

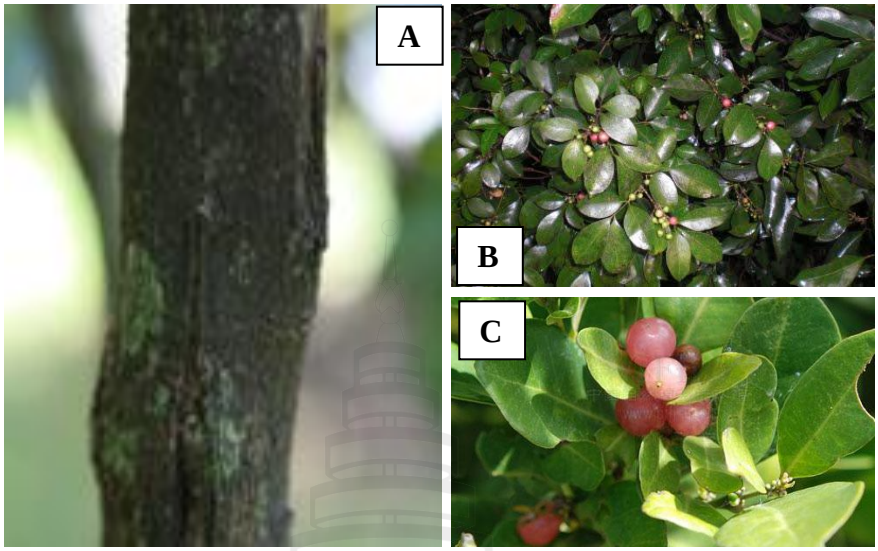


Figure 1.5 Stem, Leaves and Fruits of *G. cochinchinensis* (A-C)

1.3 Reviews of Literatures

The chemical constituents isolated from the family Rutaceae belong to different classes. Although, the main constituents are alkaloids, coumarins and terpenoids, several miscellaneous compounds also found in this family such as benzonoids, essential oil, flavonoids and steroids. Furthermore, some of these compounds showed interesting pharmacological activities.

The literature search has been done by using the SciFinder Scholar database. This review described 4 genera belonging to Rutaceae plant including *Atalantia*, *Clausena*, *Feroniella* and *Glycosmis* genera.

Chemical compounds isolated from these genera were classified in 8 groups.

a) Acridone alkaloids	b) Carbazole alkaloids	c) Quinoline alkaloids
d) Alkaloids	e) Coumarins	f) Terpenoids
g) Flavonoids	h) Benzonoids	

1.3.1 *Atalantia* Genus

The chemical constituents isolated from this genus (1972-2012) were summarized in Table 1.1.

Table 1.1 Chemical Compounds Isolated from *Atalantia* Genus

Plant	Part	Compound	Bibliography
A. ceylanica	Seeds	Ataloxime A, **1h** Ataloxime B, **2h** Citaldoxime, **3h** Bergapten, **1e** Xanthotoxin, **2e** Heraclenin, **3e** Oxypeucedanin, **4e** Imperatorin, **5e**	Bacher, Brader, Hofer, & Greger, 1999
A. monophylla	Root barks	Atalantin, **1f** Atalaphylline, **1a** *N*-Methylatalaphylline, **2a** *N*-Methylbicyclo atalaphylline, **3a**	Basu & Basa, 1972
		Xanthyletin, **6e**	Basu & Basa, 1972
		Atalantin, **1f** Dehydroatalantin, **2f** Cycloepiatalantin, **3f**	Dreyer, 1976
		Atalaphylline, **1a** *N*-Methylatalaphylline, **2a** Atalaphylline-3,5-dimethyl ether, **5a**	Kulkarni & Sabata, 1981

Table 1.1 (continued)

Plant	Part	Compound	Bibliography
A. monophylla	Roots	Atalaphyllidine, **4a**	Chatterjee & Ganguly, 1976
		Cycloatalaphylline A, **6a**	Chukaew, Ponglimanont, Karalai & Tewtrakul, 2008
		N-Methylcycloatalaphylline A, **7a**	
		N-Methylbuxifoliadine E, **9a**	
		Buxifoliadine A, **10a**	
		Buxifoliadine E, **8a**	
		N-Methylatalaphylline, **2a**	
		Atalaphylline, **1a**	
		Citrusinine I, **10a**	
		N-Methylataphyllinine, **11a**	
		Yukocitrine, **12a**	
		Junosine, **13a**	
		Auraptene, **6e**	
		7-*O*-Geranylscopoletin,**7e**	
	Heartwoods	5-Hydroxydictamine, **1c**	Kumar, Krupadanam, & Kumar, 2010
A. racemosa	Arial parts	Xanthyletin, **8e**	Luthria, Ramakrishnan, Verma, Prabhu & Banerji, 1989
		Racemosin, **9e**	
		Luvangetin, **10e**	
		Xanthotoxin, **2e**	
		Umbelliferone, **11e**	
		Rutaretin, **12e**	
		Rutarin, **13e**	

Table 1.1 (continued)

Plant	Part	Compound	Bibliography
A. zeylanica	Seeds	Cycloatalantin, **4f** Dehydrocycloatalantin, **2f** Dehydrocycloatalantin hydrate, **5f**	Bennett, Hasegawa & Wong, 1994

1.3.2 *Clausena* Genus

The chemical constituents which were isolated from this genus (2000-2012) were summarized in Table 1.2.

Table 1.2 Chemical Compounds Isolated from *Clausena* Genus

Plant	Part	Compound	Bibliography
C. anisata	Branches	Clausamine A, **1b** Clausamine B, **2b** Clausamine C, **3b** Clausamine D, **5b** Clausamine E, **7b** Clausamine F, **8b** Clausamine G, **9b** Clausine F, **6b** Ekeberginine, **10b** Methyl carbazole-3-carboxylate, **12b** Clausine E, **13b** *O*-Demethylmurrayanine (**11b**)	Ito, Katsuno et al., 2000

Table 1.2 (continued)

Plant	Part	Compound	Bibliography
C. anisata	Stems	Clausamine B, **2b** Clausamine C, **3b** Clausamine E, **7b** Furanoclausamine A, **14b** Furanoclausamine B, **15b**	Ito et al., 2009
C. anisum-olens	Aerial parts	Clausenain I, **1d**	Wang et al., 2005
		Hekumarin A, **14e** Hekumarin B, **15e**	Wang, He, Yang, Di, & Hao, 2008
		Anisumarin, **16e** Isocoumarin, **17e** Umbelliferone, **11e** Anisocoumarin H, **18e** Capnolactone, **19e** Aurapten, **20e** 7-[(*E*)-3′,7′-Dimethylocta-2′,5′-dienyloxyl]-coumarin, **21e**	Wang, Huang, Li & Yang, 2010
C. anisum-olens	Leaves & twigs	Anisucumarin A/B, **22e**	Wang, Huang, Li, Zhang & Yang, 2008
C. dunniana	Aerial parts	Dunniana acid A, **6f** Dunniana acid B, **7f**	He et al., 2002
		2-Oxoclerod-3-en-15-oic acid, **8f** 14,15-Dinorclerod-3-ene-2,13-dione, **9f**	He, Shen, Zuo, Yang & Hao, 2003

Table 1.2 (continued)

Plant	Part	Compound	Bibliography
C. dunniana	Aerial parts	2α-Methoxyclerod-3-en-15-oic acid , **10f** 2β-(Acetyloxy)clerod-3-en-15-oic acid, **11f** 2β-(Formyloxy)clerod-3-en-15-oic acid, **12f** 4α-Hydroxyclerodan-15-oic acid, **13f** 4α,18-Dihydroxyclerodan -15-oic acid, **14f** 4β-Hydroxyclerodan-15-oic acid, **15f** 3α,4α-Dihydroxyclerodan-15-oic acid, **16f** 3β-Hydroxy-clerod-4(18)-en-15-oic acid, **17f** Clerod-4(18)-en-15-oic acid, **18f** Clerod-3-en-15-oic acid, **19f** Ethyl clerod-4(18)-en-15-oate, **20f**	He, Shen, Zuo, Yang & Hao, 2003
C. excavata	Aerial parts	Excavacoumarin B, **23e** Excavacoumarin C, **24e** Excavacoumarin D, **25e** Excavacoumarin E, **26e** Excavacoumarin F, **27e** Excavacoumarin G, **28e**	He et al., 2000

Table 1.2 (continued)

Plant	Part	Compound	Bibliography
C. excavata	Aerial parts	(11*β*)-21,23-Dihydro-11,21-dihydroxy-23-oxoobacun, **22f**	He et al., 2002
		(11*β*)-21,23-Dihydro-11,23-dihydroxy-2l-oxoobactrn, **23f**	
		(1*α*,11*β*)-1,2,11,23-Tetrahydro-1,11,23-trihydroxy-21-oxoobacun, **24f**	
		(l*α*,l1*β*)-23-Ethoxy-1,2,21,23-tetrahydro-1,11-dihydroxy-21-oxoobacunone, **25f**	
		(11*β*)-1,2,21,23-Tetrahydro-11,23-dihydroxy-21-oxoobacunoic acid, **26f**	
		Excavacoumarin H, **29e**	He, Shen, Du,
		Excavacoumarin I, **30e**	Zhao, & Hao, 2004
	Branches	Cladimarin A, **31e**	Takemura et
		Cladimarin B, **32e**	al., 2004
	Leaves	Excavacoumarin A, **34e**	He, Shen, Du,
		Excavacoumarin B, **23e**	Zhao & Hao, 2000
		Clauslactone A, **38e**	Ito et al., 2000
		Clauslactone B, **39e**	
		Clauslactone C, **40e**	
		Clauslactone D, **41e**	
		Clauslactone E, **42e**	
		Clauslactone F, **33e**	
		Clauslactone G, **34e**	

Table 1.2 (continued)

Plant	Part	Compound	Bibliography
C. excavata	Leaves	Clauslactone H, **35e** Clauslactone I, **36e** Clauslactone J, **37e**	Ito et al., 2000
		Excavarin A, **43e**	Kumar, Saha & Saha, 2012
	Rhizomes	Dentatin, **45e** Nordentatin, **46e** Clausenidin, **47e** Xanthoxyletin, **44e** 3-Formylcarbazol, **16b** Mukonal, **17b** Methyl carbazole-3-carboxylate, **12b** Murrayanine, **18b** 2-Hydroxy-3-formyl-7-methoxycarbazol, **19b** Clauszoline, **20b**	Sunthitikawinsakul et al., 2003
	Roots	Clausenidin, **47e** Nordentatin, **46e** Clausarin, **48e** Xanthoxyletin, **44e**	Su et al., 2009
	Stem barks	Clausine B, **20b** Clausine H, **21b** Clausine TY, **22b**	Taufiq-Yap et al., 2007
C. harmandiana	Roots	Clausarin, **48e** Clausine B, **20b** Dentatin, **45e** Heptaphylline, **27b**	Yenjai et al., 2000

Table 1.2 (continued)

Plant	Part	Compound	Bibliography
C. harmandiana	Twigs	Harmandianamine A,**42b** Harmandianamine B, **43b** Harmandianamine C, **44b** Clausevatine D, **4b** Clausamine A, **1b** Clausamine B, **2b** Clausine S, **45b** Girinimbine, **46b** *O*-Demethylmurrayanine, **11b** Clauszoline I, **23b** Clausine Z, **24b** Clauszoline N, **25b** Clausine D, **26b** Clausine F, **6b** Clausamine, **5b** Heptaphylline, **27b** Dectamine, **3c** *γ*-Fagarine, **4c**	Maneerat et al., 2012
C. heptaphylla	Leaves	Clausmarin A, **49e**	Sohrab, Hasan & Rashid, 2000
C. lansium	Twigs	Mafaicheenamine A, **47b** Claulansine A, **48b** Mafaicheenamine C, **49b** Indizoline, **28b** Lansin, **29b** Glycozolidal, **30b** Murrayanine, **18b** Daurine, **2d**	Maneerat & Laphookhieo, 2010

Table 1.2 (continued)

Plant	Part	Compound	Bibliography
C. lansium	Twigs	Xanthotoxin, **2e** Imperatorin, **4e** Heraclenin, **3e** Heraclenol, **50e** Clausenalansimin A, **51e** Wampetin, **52e** Indicolactonediol, **53e** Isoscopoletin, **54e** Clausenalansimin A, **55e**	Maneerat, Prawat, Saewanc & Laphookhieo, 2010
	Seeds	Lansiumamide B, **3d** SB-204900, **4d** Clausenalansamide A, **5d** Clausenalansamide B, **6d** *N*-Methyl-3-phenyl-2-propanamide, **7d**	Maneerat, Ritthiwigrom, Cheenpracha, Prawat, & Laphookhieo, 2011
	Roots	Mafaicheenamine D, **50b** Mafaicheenamine E, **51b**	Maneerat, Ritthiwigrom, Cheenpracha, & Laphookhieo, 2012
C. lenis	Aerial parts	Diseselin A, **56e** Diseselin B, **57e** Lenisin A, **4h** Lenisin B, **5h** Lenisin C, **6h**	He, Shen, Chem, He, & Hao, 2006

Table 1.2 (continued)

Plant	Part	Compound	Bibliography
C. lenis	Aerial parts	Clausenawalline A, **54b** Clausenawalline B, **55b**	Maneerat, Tha-in, Cheenpracha, Prawat & Laphookhieo, 2011
C. wallichii	Roots	Clausenawalline C, **53b** Clausenawalline D, **41b** Clausenawalline E, **56b** Clausenawalline F, **57b**	Maneerat et al., 2012

1.3.3 *Feroniella* Genus

According to SciFinder Scholar database, this genus has only one species. The chemical constituents isolated from *F. lucida* (2006-2011) were summarized in Table 1.3.

Table 1.3 Chemical Compounds Isolated from *F. lucida*

Plant	Part	Compound	Bibliography
F. lucida	Roots	Feroniellin A, **58e** Feroniellin B, **59e** Feroniellin C, **60e**	Phuwapraisirisan, Surapinit, Sombund, Siripong & Tip-pyang, 2006
		Feroniellide A, **27f** Feroniellide B, **28f**	Phuwapraisirisan, Surapinit, Siripong, Tip-pyang & Kokpol, 2007

Table 1.3 (continued)

Plant	Part	Compound	Bibliography
F. lucida	Roots	Feroniellic acid A, **61e** Feroniellic acid B, **62e** Feroniellic acid C, **63e** Feronielloside, **64e**	Phuwapraisirisan, Phoopichayanun, & Supudompol, 2008 Phoopichayanun, Phuwapraisirisan, Tip-Pyang & Jongaramruong, 2012

1.3.4 *Glycosmis* Genus

The chemical constituents which were isolated from this genus (2004-2012) were summarized in Table 1.4.

Table 1.4 Chemical Compounds Isolated from *Glycosmis* Genus

Plant	Part	Compound	Bibliography
G. arborea	Stems	Glybomine A, **31b** Glybomine B, **32b** Glybomine C, **33b** Glycoborinine, **52b** Arborine, **8d** 4,8-Dimethoxyfuro[2,3-*b*] quinolone, **4c** Arborinine, **14a**	Ito et al., 2004

Table 1.4 (continued)

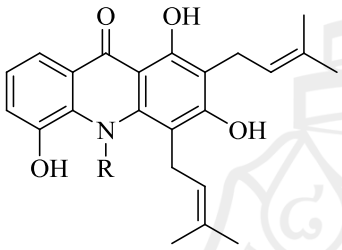
Plant	Part	Compound	Bibliography
G. arborea	Leaves	7,4′-Dihydroxy-5-methoxy flavone-6-C-*β*-*D*-gluco pyranoside,**1g** 2′-Hydroxy-4,6′-dimethoxy-3′,4′-(2″,2″-dimethylpyrano)dihydro chalcone, **2g**	Sharma, Semwal, Negi, 2010 Rahmaniz et al., 2010
G. chlorosperma	Roots & twigs	Glycrophylamine, **34b** 2-Methoxy-3-methylcarbazole, **35b** 3-Methylcabazole, **36b** Skimianine, **5c** Glycrophylamide, **9d** Dehydrothalebanin B, **10d**	Cheenpracha & Laphookhieo, 2011
G. macrophylla	Roots	Luteolin-8-*C*-glucoside, **3g**	Intekhab & Aslam, 2011
G. mauritiana	Twigs & leaves	(*E*)-3-(3-Hydroxymethyl-2-butenyl)-7-(3-methyl-2-butenyl)-1*H*-indole, **11d** Glybomine B, **32b** Glycoborinine, **52b** Carbalexine B, **37b** Carbalexine A, **38b**	Wang et al., 2005
G. montana	Twigs & leaves	Carbalexine C, **39b** 2-Hydroxy-3-methyl-9*H*-carbazole, **40b**	Wang et al., 2005
G. pentaphylla	Stems	Glypentoside A, **7h** Glypentoside B, **8h** Glypentoside C, **9h**	Wang et al., 2006

Table 1.4 (continued)

Plant	Part	Compound	Bibliography
G. pentaphylla	Stems	Seguinoside F, **10h**	Wang et al., 2006

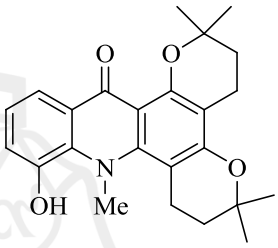
1.3.5 The Chemical Constituents of Selected Rutaceae Plants

a) Acridone Alkaloids

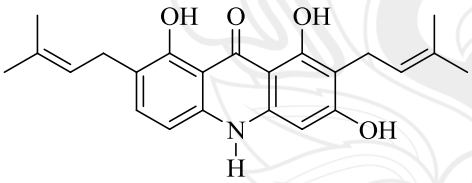


R = H; Atalaphylline (**1a**)

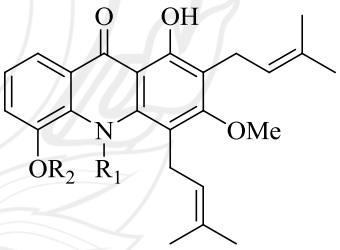
R = Me; *N*-Methylatalaphylline (**2a**)



N-Methylbicycloatalaphylline (**3a**)

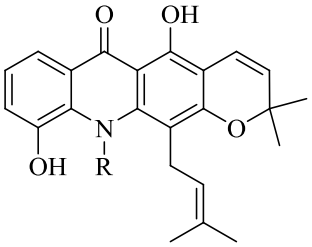


Atalaphyllidine (**4a**)



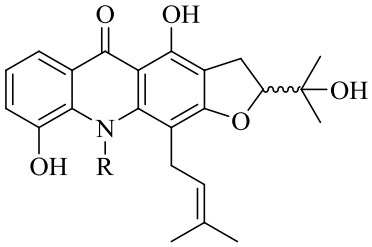
R_1 = H, R_2 = Me; Atalaphylline-3,5-dimethyl ether (**5a**)

R_1 = Me, R_2 = H; Buxifoliadine A (**10a**)



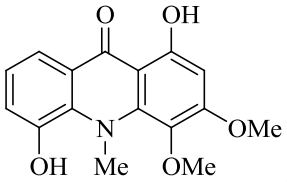
R = H; Cycloatalaphylline A (**6a**)

R = Me; *N*-Methylcycloatalaphylline A (**7a**)

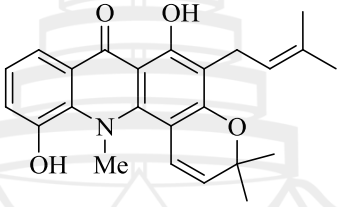


R = H; Buxifoliadine E (**8a**)

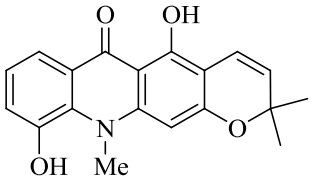
R = Me; *N*-Methylbuxifoliadine E (**9a**)



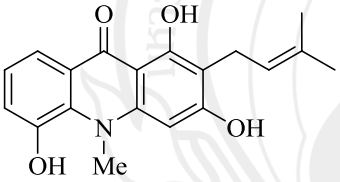
Citrusinine I (**10a**)



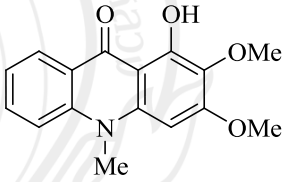
N-Methylataphyllinine (**11a**)



Yukocitrine (**12a**)

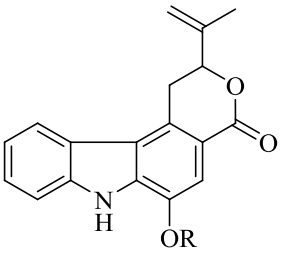


Junosine (**13a**)



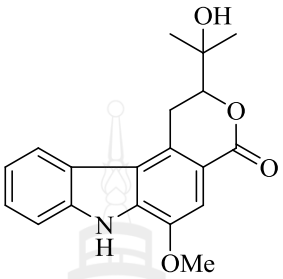
Arborinine (**14a**)

b) Carbazole Alkaloids



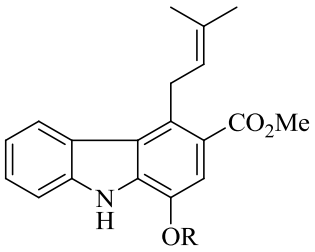
R = H; Clausamine A (**1b**)

R = Me; Clausamine B (**2b**)



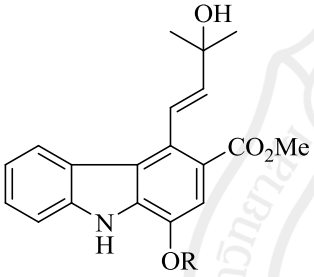
R = Me; Clausamine C (**3b**)

R = H; Clausevatine D (**4b**)



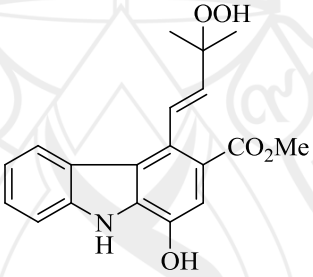
R = Me; Clausamine D (**5b**)

R = H; Clausine F (**6b**)

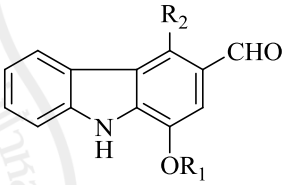


R = Me; Clausamine E (**7b**)

R = H; Clausamine F (**8b**)

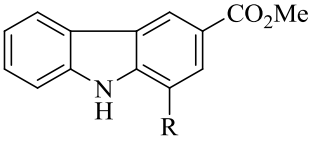


Clausamine G (**9b**)



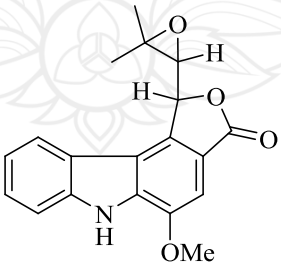
R_1 = Me, R_2 = prenyl; Ekeberginine (**10b**)

R_1 = H, R_2 = H; *O*-Demethylmurrayanine; (**11b**)

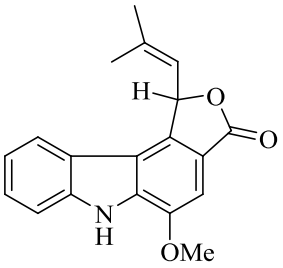


R = H; Methyl carbazole-3-carboxylate (**12b**)

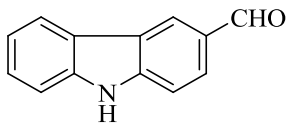
R = OH; Clausine E (**13b**)



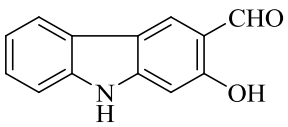
Furanoclausamine A (**14b**)



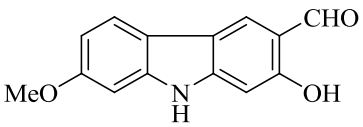
Furanoclausamine B (**15b**)



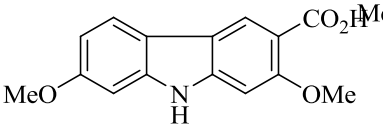
3-Formylcarbazol (**16b**)



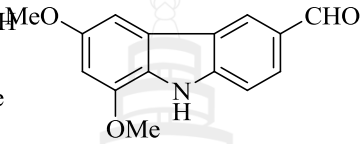
Mukonal (**17b**)



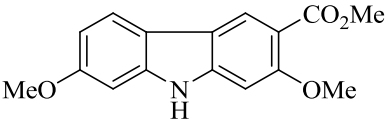
Murrayanine (**18b**)



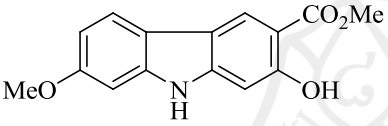
2-Hydroxy-3-formyl-7-methoxycarbazol (**19b**)



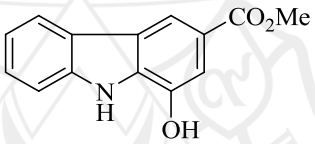
Clausine B (**20b**)



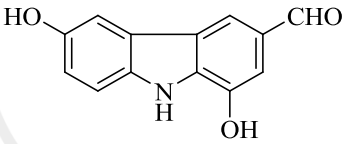
Clausine H (**21b**)



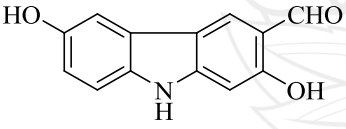
Clausine TY (**22b**)



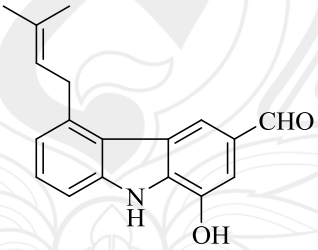
Clauszoline I (**23b**)



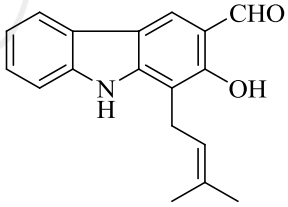
Clausine Z (**24b**)



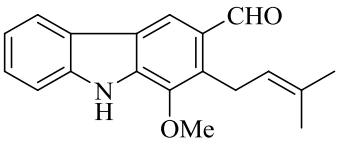
Clauszoline N (**25b**)



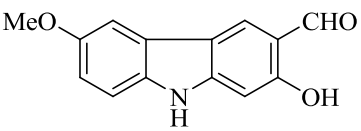
Clausine D (**26b**)



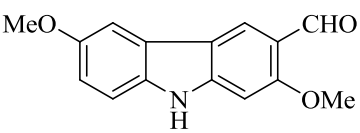
Heptaphylline (**27b**)



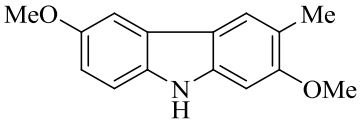
Indizoline (**28b**)



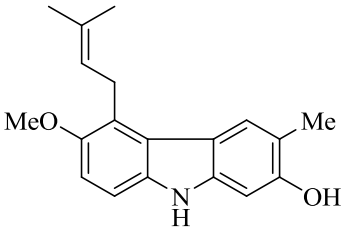
Lansin (**29b**)



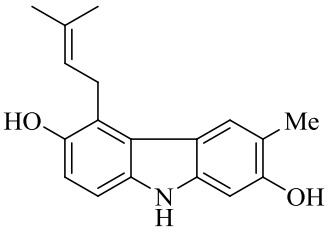
Glycozolidal (**30b**)



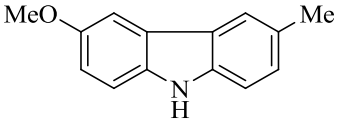
Glybomine A (**31b**)



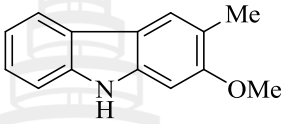
Glybomine B (**32b**)



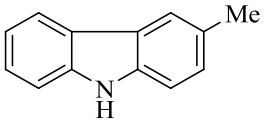
Glybomine C (**33b**)



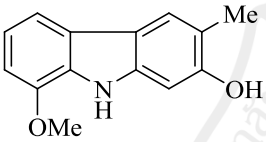
Glycrophylamine (**34b**)



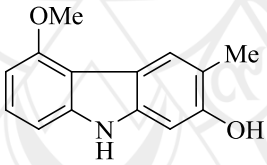
2-Methoxy-3-methyl carbazole (**35b**)



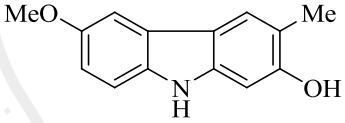
3-Methylcabazole (**36b**)



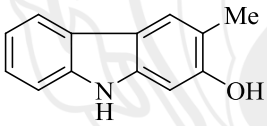
Carbalexine B (**37b**)



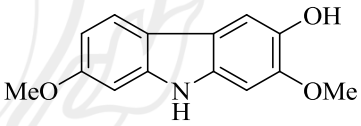
Carbalexine A (**38b**)



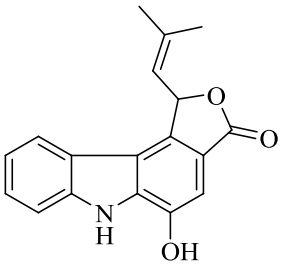
Carbalexine C (**39b**)



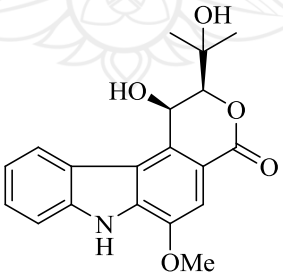
2-Hydroxy-3-methyl-9*H*-carbazole (**40b**)



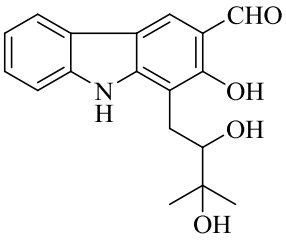
Clausenawalline D (**41b**)



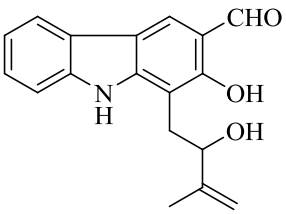
Harmandianamine A (**42b**)



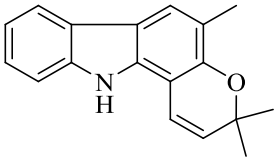
Harmandianamine B (**43b**)



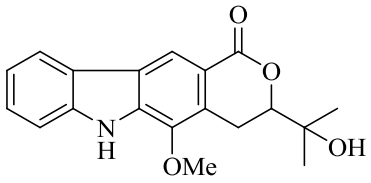
Harmandianamine C (**44b**)



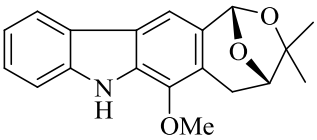
Clausine S (**45b**)



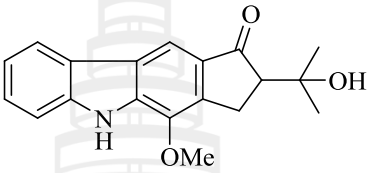
Girinimbine (**46b**)



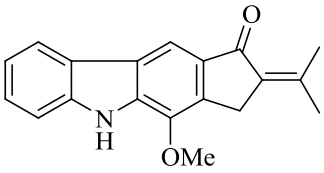
Mafaicheenamine A (**47b**)



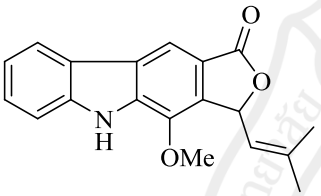
Mafaicheenamine B (**48b**)



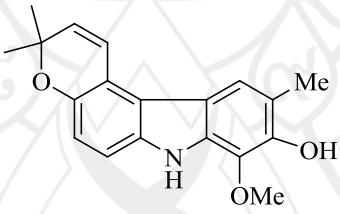
Mafaicheenamine C (**49b**)



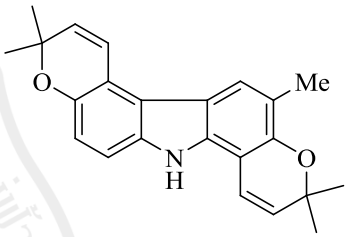
Mafaicheenamine D (**50b**)



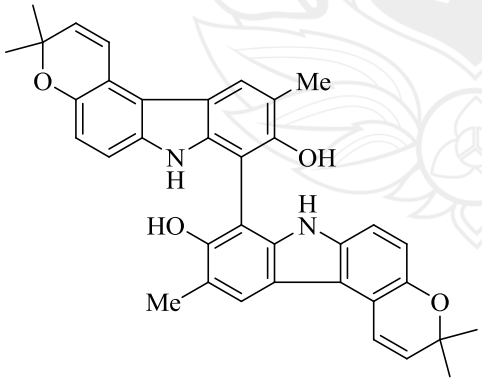
Mafaicheenamine E (**51b**)



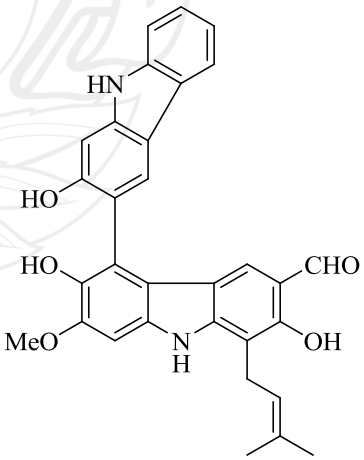
Glycoborinine (**52b**)



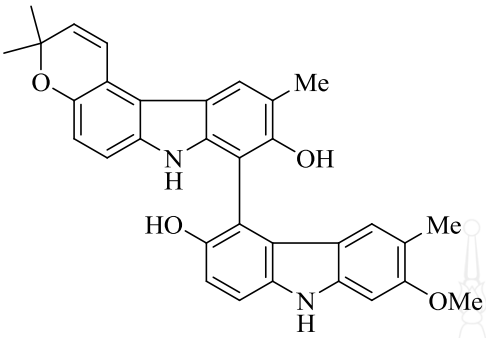
Clausenawalline C (**53b**)



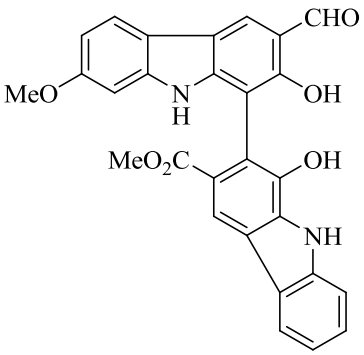
Clausenawalline A (**54b**)



Clausenawalline B (**55b**)

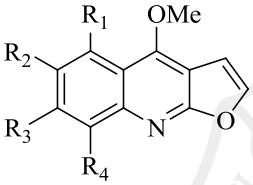


Clausenawalline E (**56b**)



Clausenawalline F (**57b**)

c) Quinoline Alkaloids

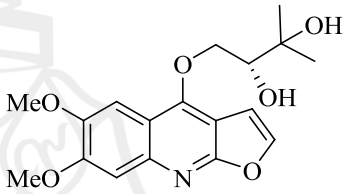


R_1 = OH, R_2 = R_3 = R_4 = H;
5-Hydroxydictamine (**1c**)

R_1 = R_2 = R_3 = R_4 = H; Dictamine (**3c**)

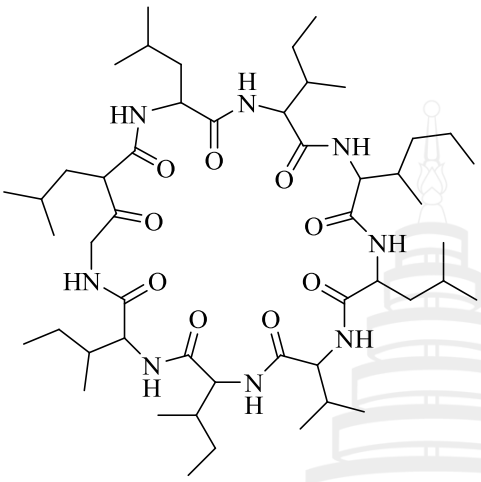
R_1 = R_2 = R_3 = H, R_4 = OMe; *γ*-Fagarine (**4c**)

R_1 = R_2 =H, R_3 = R_4 = OMe; Skimianine (**5c**)

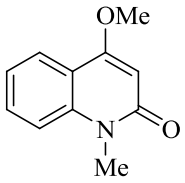


(2*S*)-1-[(6,7-Dimethoxyfuro[2,3-*b*]
quinolin-4-yl)oxyl-3-methylbutane-
2,3-diol (**2c**)

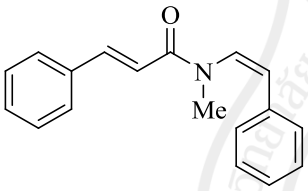
d) Alkaloids



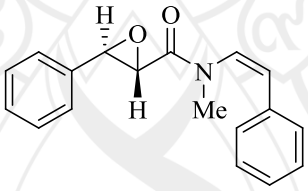
Clausenain I (**1d**)



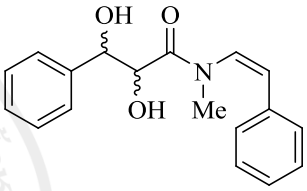
Daurine (**2d**)



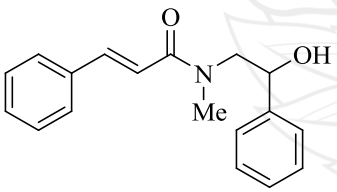
Lansiumamide B (**3d**)



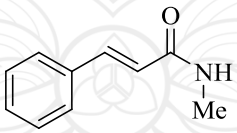
SB-204900 (**4d**)



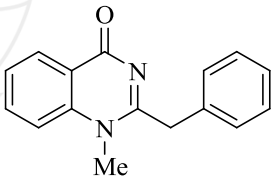
Clausenalansamide A (**5d**)



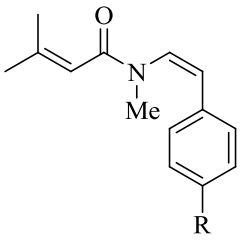
Clausenalansamide B (**6d**)



N-Methyl-3-phenyl-2-propanamide (**7d**)

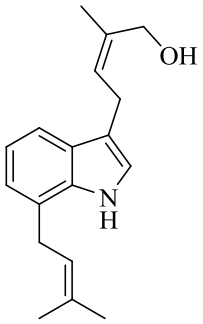


Arborine (**8d**)



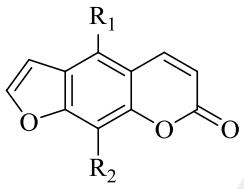
R = H; Glycrophylamide (**11d**)

R = OMe; Dehydrothalebanin B (**12d**)



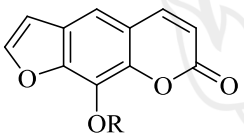
(*E*)-3-(3-Hydroxymethyl-2-butenyl)-7-(3-methyl-2-butenyl)-1*H*-indole (**13d**)

e) Coumarins

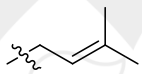


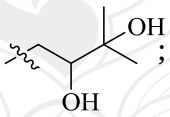
R_1 = OMe, R_2 = H; Bergapten (**1e**)

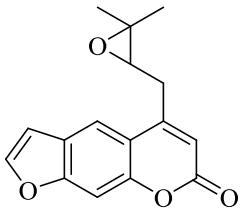
R_1 = H, R_2 = OMe; Xanthotoxin (**2e**)



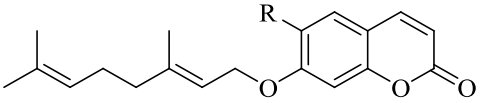
R =  ; Heraclenin (**3e**)

R =  ; Imperatorin (**4e**)

R =  ; Heraclenol (**50e**)

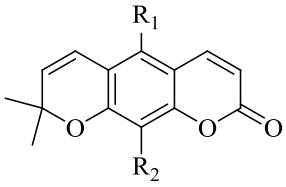


Oxypeucedanin (**5e**)



R = H; Auraptene (**6e**)

R = OMe; 7-*O*-Geranylscopoletin (**7e**)

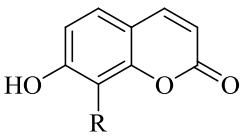


$R_1 = R_2 = H$; Xanthyletin (**8e**)

$R_1 = R_2 = OMe$; Racemosin (**9e)**

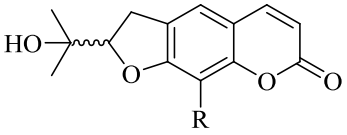
$R_1 = H$, $R_2 = OMe$; Luvangetin (**10e**)

$R_1 = OMe$, $R_2 = H$; Xanthoxyletin, (**44e**)



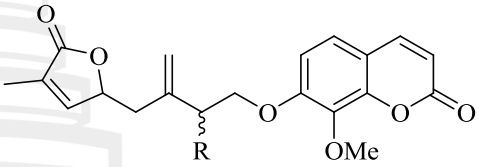
R = H; Umbelliferone (**11e**)

R = OMe; Isocoumarin (**17e**)



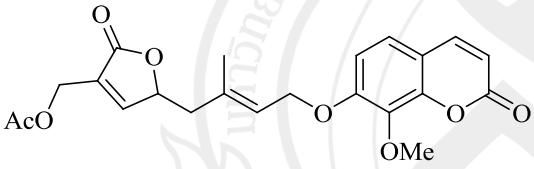
R = OH; Rutaretin (**12e**)

R = *O*-Glu; Rutarin (**13e**)

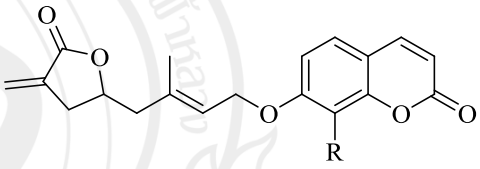


R = α-OH; Hekumarin A (**14e**)

R = β-OH; Hekumarin B (**15e**)

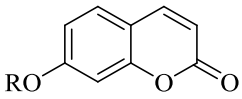


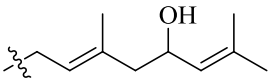
Anisumarin (**16e**)

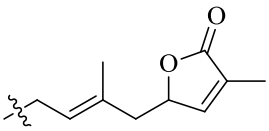


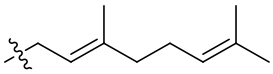
R = OH; Clauslactone E (**42e**)

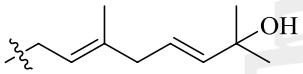
R = H; Excavarin A (**43e**)

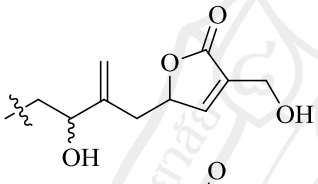


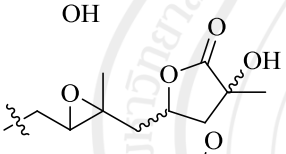
R =  ; Anisocoumarin H (**18e**)

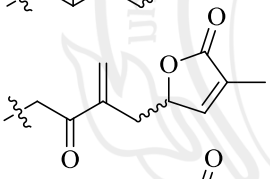
R =  ; Capnolactone (**19e**)

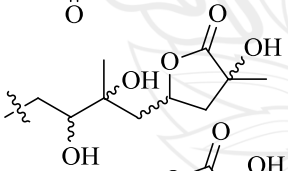
R =  ; Aurapten (**20e**)

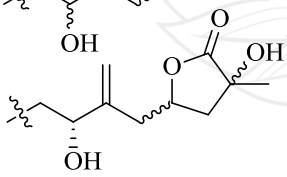
R=  ; 7-[(*E*)-3′,7′-Dimethylocta-2′,5′-dienyloxyl]-coumarin (**21e**)

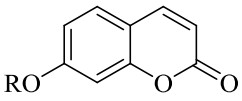
R =  ; Anisucumarin A/B (**22e**)

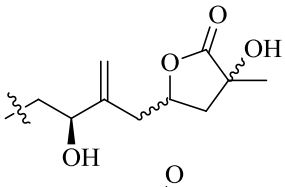
R =  ; Excavacoumarin A (**34e**)

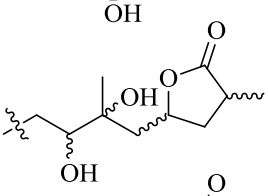
R =  ; Excavacoumarin B (**23e**)

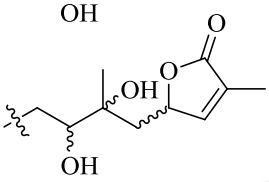
R =  ; Excavacoumarin C (**24e**)

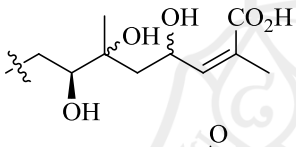
R =  ; Excavacoumarin D (**25e**)

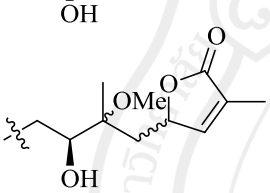


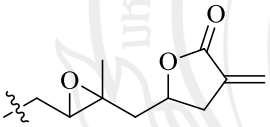
R =  ; Excavacoumarin E (**26e**)

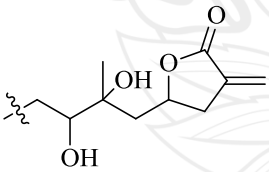
R =  ; Excavacoumarin F (**27e**)

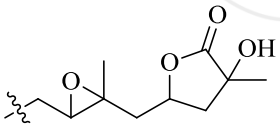
R =  ; Excavacoumarin G (**28e**)

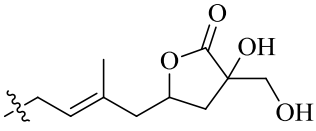
R =  ; Excavacoumarin H (**29e**)

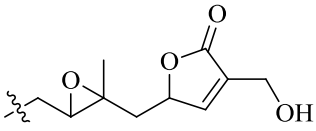
R =  ; Excavacoumarin I (**30e**)

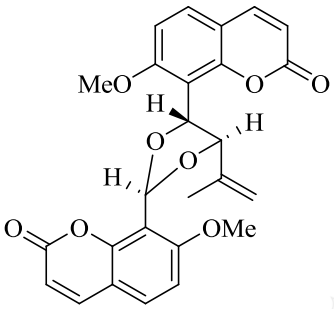
R =  ; Clauslactone F (**33e**)

R =  ; Clauslactone G (**34e**)

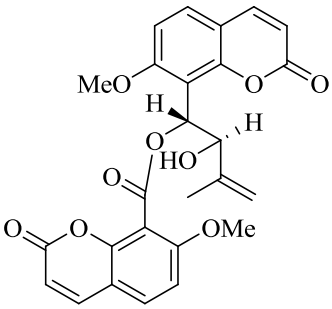
R =  ; Clauslactone H (**35e**)

R =  ; Clauslactone I (**36e**)

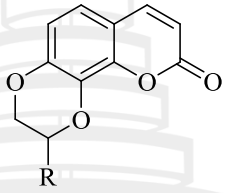
R =  ; Clauslactone J (**37e**)

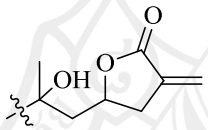


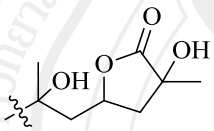
Cladimarin A (**31e**)

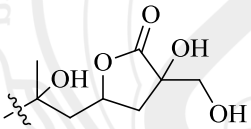


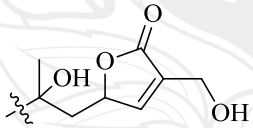
Cladimarin B (**32e**)

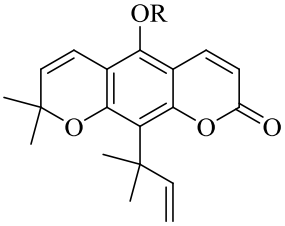


R =  ; Clauslactone A (**38e**)

R =  ; Clauslactone B (**39e**)

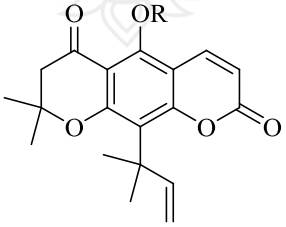
R =  ; Clauslactone C (**40e**)

R =  ; Clauslactone D (**41e**)

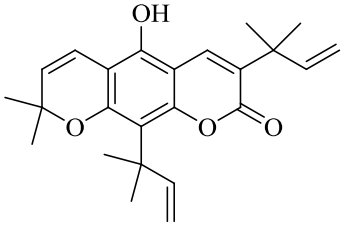


R = Me; Dentatin (**45e**)

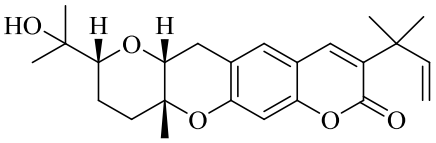
R = H; Nordentatin (**46e**)



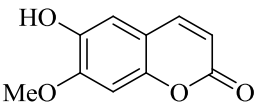
Clausenidin (**47e**)



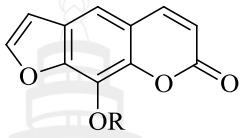
Clausarin (**48e**)

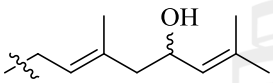


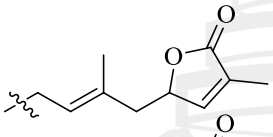
Clausmarin A (**49e**)

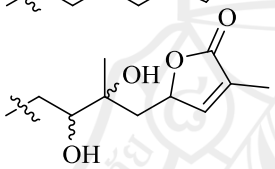


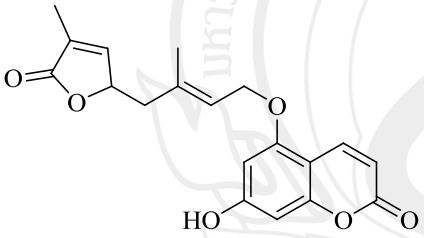
Isoscopoletin (**54e**)



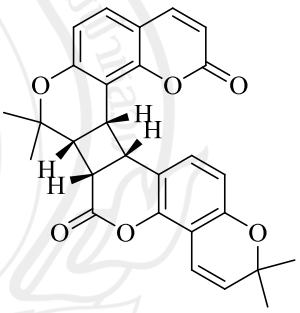
R =  ; Clausenalansimin A (**51e**)

R =  ; Wampetin (**52e**)

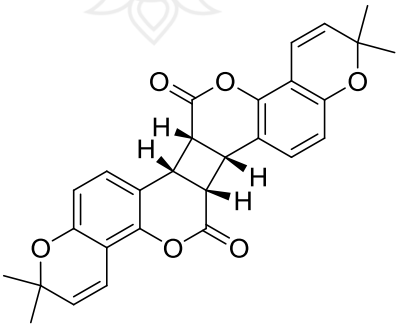
R =  ; Indicolactonediol (**53e**)



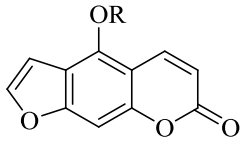
Clausenalansimin A (**55e**)

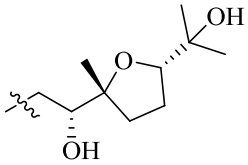


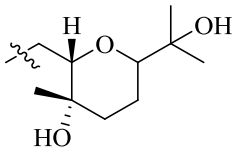
Diseselin A (**56e**)

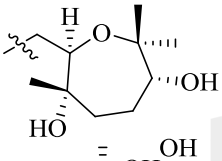


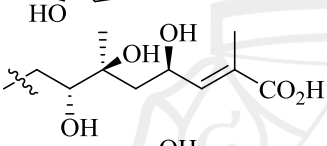
Diseselin B (**57e**)

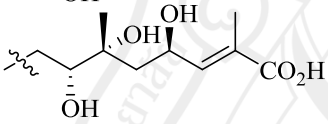


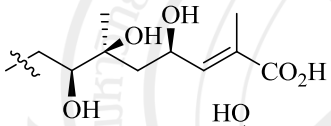
R =  ; Feroniellin A (**58e**)

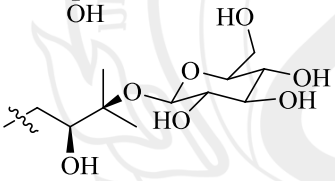
R =  ; Feroniellin B (**59e**)

R =  ; Feroniellin C (**60e**)

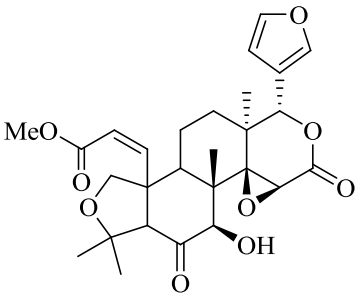
R =  ; Feroniellic acid A (**61e**)

R =  ; Feroniellic acid B (**62e**)

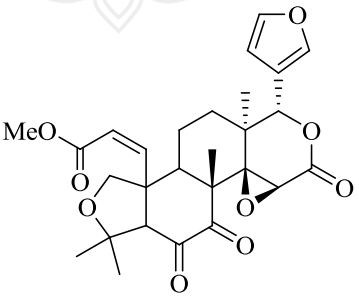
R =  ; Feroniellic acid C (**63e**)

R =  ; Feronielloside **(64e**)

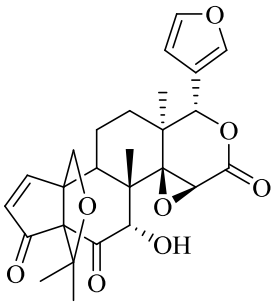
f) Terpenoids



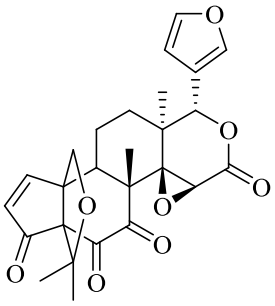
Atalantin (**1f**)



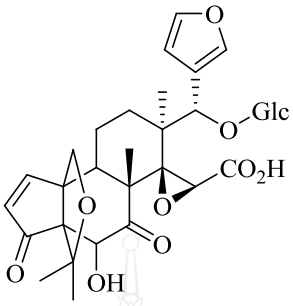
Dehydroatalantin (**2f**)



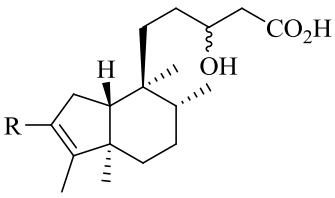
Cycloepiatalantin (**3f**)



Cycloatalantin (**4f**)

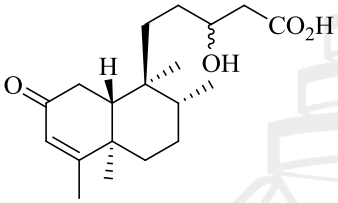


Dehydrocycloatalantin hydrate (**5f**)

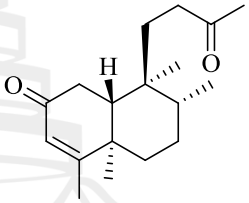


R = CO_2H; Dunniana acid A (**6f**)

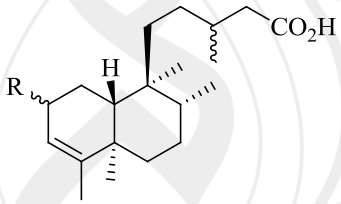
R = CHO; Dunniana acid B (**7f**)



2-Oxoclerod-3-en-15-oic acid (**8f**)



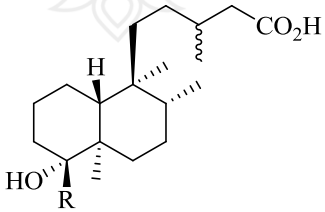
14,15-Dinorclerod-3-ene-2,13-dione (**9f**)



R = α-OMe; 2α-Methoxyclerod-3-en-15-oic acid (**10f**)

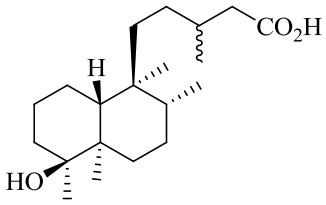
R = β-OAc; 2β-(Acetyloxy)clerod-3-en-15-oic acid (**11f**)

R = β-OCHO; 2β-(Formyloxy)clerod-3-en-15-oic acid (**12f**)

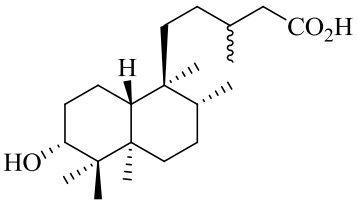


R = Me; 4α-Hydroxyclerodan-15-oic acid (**13f**)

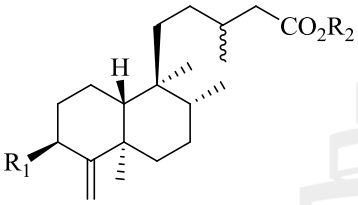
R = CH_2OH; 4α,18-Dihydroxyclerodan -15-oic acid (**14f**)



4β-Hydroxyclerodan-15-oic acid (**15f**)



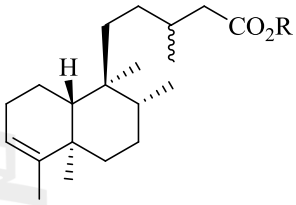
3α,4α-Dihydroxyclerodan-15-oic acid (**16f**)



R_1 = OH, R_2 = H; 3β-Hydroxy-clerod-4 (18)-en-15-oic acid (**17f**)

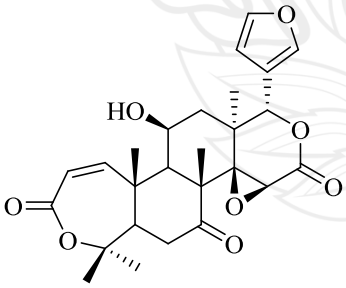
R_1 = H, R_2 =H; Clerod-4(18)-en-15-oic acid (**18f**)

R_1 = H, R_2 = Et; Ethyl clerod-4(18)-en-15-oate (**20f**)

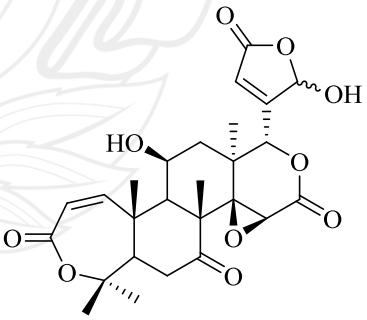


R = H; Clerod-3-en-15-oic acid (**19f**)

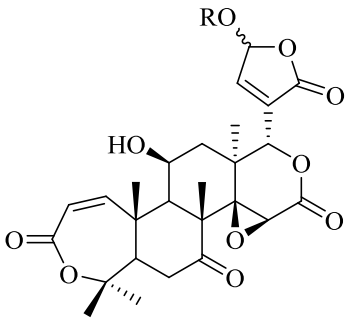
R = Et; Ethyl clerod-3-en-15-oate (**21f**)



(11β)-21,23-Dihydro-11,21-dihydroxy-23-oxoobacun (**22f**)

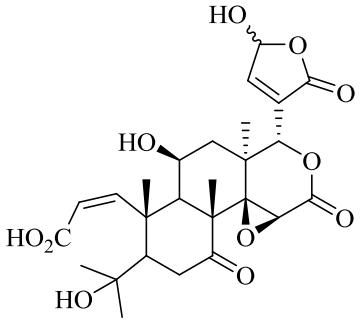


(11β)-21,23-Dihydro-11,23-dihydroxy-2l-oxoobactrn (**23f**)

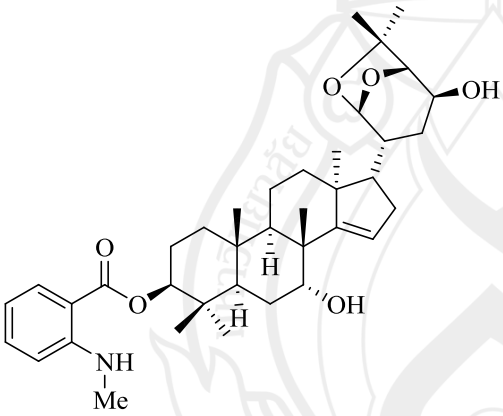


R = H; Tetrahydro-1,11,23-trihydroxy-21-oxoobacun (**24f**)

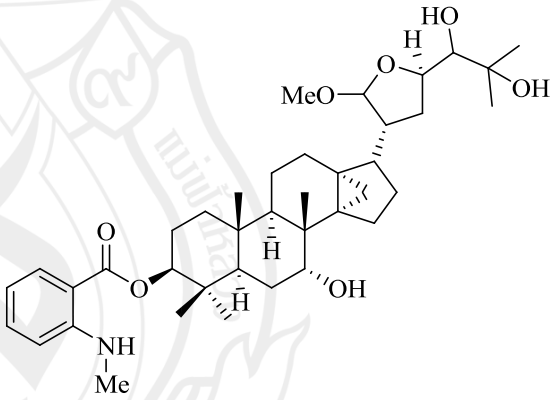
R = Et; (l*α*,l1*β*)-23-Ethoxy-1,2,21,23-tetrahydro-1,11-dihydroxy-21-oxoobacunone (**25f**)



(11*β*)-1,2,21,23-Tetrahydro-11,23-dihydroxy-21-Oxoobacunoic acid (**26f**)

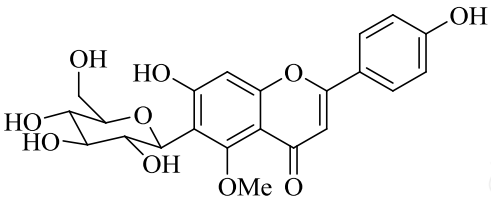


Feroniellide A (**27f**)

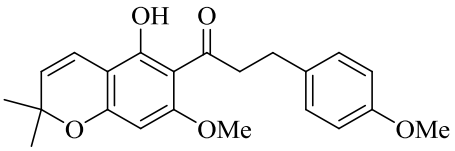


Feroniellide B (**28f**)

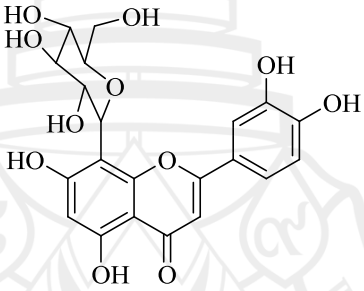
g) Flavonoids



7,4′-Dihydroxy-5-methoxyflavone-6-*C*-*β*-*D*-glucopyranoside (**1g**)

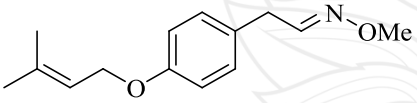


2′-Hydroxy-4,6′-dimethoxy-3′,4′-(2″,2″-dimethylpyrano)dihydrochalcone (**2g**)

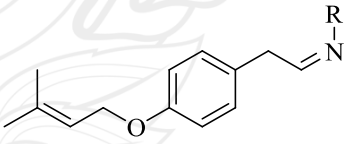


Luteolin-8-*C*-glucoside (**3g**)

h) Benzonoids

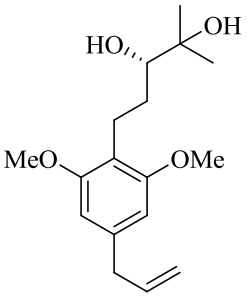


Ataloxime A (**1h**)

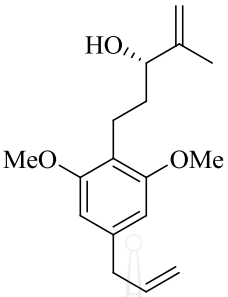


R = OMe; Ataloxime B (**2h**)

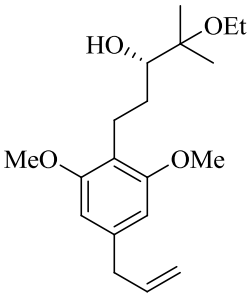
R = OH; Citadoxime (**3h**)



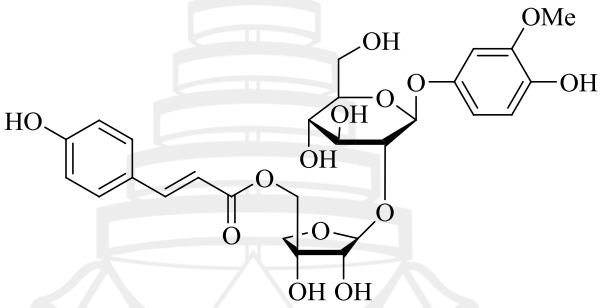
Lenisin A (**4h**)



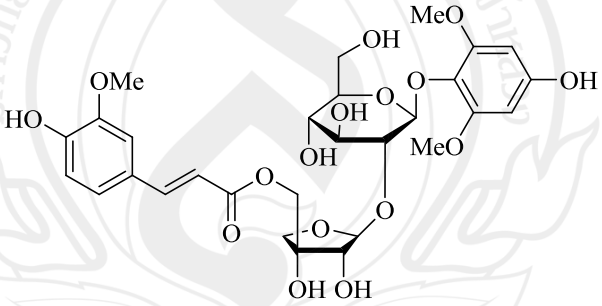
Lenisin B (**5h**)



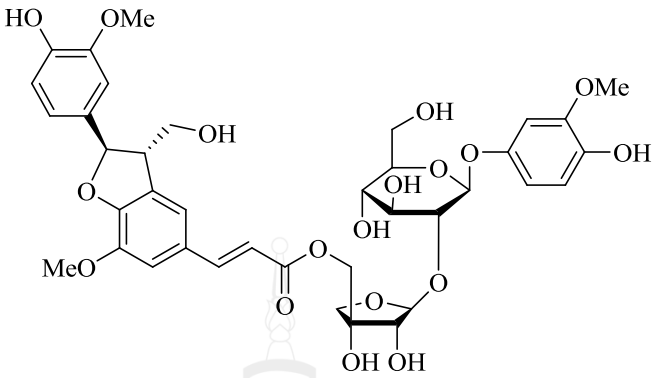
Lenisin C (**6h**)



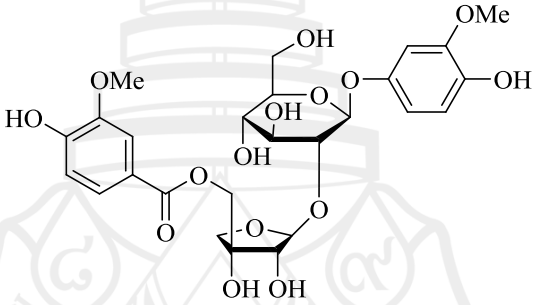
Glypentoside A (**7h**)



Glypentoside B (**8h**)



Glypentoside C (**9h**)



Seguinoside F (**10h**)

1.3.6 The Biological Activities of Selected Rutaceae Plants

1.3.6.1 Insect Antifeedant

Luthria et al. (1989) reported that xanthotoxin (**2e**) showed good antifeedant activity against *Spodoptera litura* F. larvae while luvangetin (**10e**) was moderately active, whereas xanthyletin (**8e**) and racemosin (**9e**) were active only at higher concentrations.

The oximes (**1h-3h**) (Bacher et al., 1999) displayed contact toxicity against freshly hatched larvae of the pest insect *Spodoptera littoralis*. The *cis* isomer (**2h)** (LC_{50} of 0.44 µg/cm^2 (1.0 nmol/cm^2)) was slightly more active than the *trans* isomer **(1h)** (LC_{50} of 0.65 µg/cm^2 (2.8 nmol/cm^2).

1.3.6.2 Anti-Allergic

Acridone alkaloids **7a**, **8a** and **10a** (Chukaew et al., 2008) possessed appreciable anti-allergic activity in RBL-2H3 cells model with IC_{50} values of 40.1, 6.1 and 18.7 µM, respectively.

1.3.6.3 Cytotoxicity

Chalcone **2g** (Rahmaniz et al., 2010) exhibited moderate cytoxicity against T-lymphoblastic leukemia cell (CEM-SS) with IC_{50} value of 2.8 µg/mL.

Phuwapraisirisan et al. (2006 & 2007) reported that feroniellins A (**58e**) and B (**59e**) exhibited cytotoxicity against human KB carcinoma cell lines, with IC_{50} values of 0.13 and 0.23 mM, respectively. They also exhibited cytotoxic activity against HeLa carcinoma cell line with IC_{50} values of 0.14 and 0.19 mM, respectively. Apotirucallane triterpenes, feroniellides A (**27f**) and B (**28f**) exhibited cytotoxicity against KB and HeLa cell lines with IC_{50} range from 40-60 µg/mL.

Ito et al. (2009) reported that clausamine E (**6b**) exhibited cytotoxicity against the human leukemia cell line HL-60 at cell viability 47.3% (concentration of 30 µM for cell lines). In the same year, Su et al. (2009) also reported that three coumarins, clausenidin (**47e**), nordentatin (**46e**) and clausarin (**48e**) showed cytotoxic activity against four human cancer cell lines (A549, MCF7, KB, and KB-VIN) with EC_{50} values ranging from 1.59-19.83 µg/mL. Compound **47e** also exhibited cytotoxicity against the multi-drug resistant cell line, KB-VIN with EC_{50} values of 2.25 µg/mL.

Maneerat et al. (2010 & 2011) reported that compounds **3d**, **4d** and **6d** showed cytotoxicity against KB and NCI-H187 cancer cell lines with IC_{50} values ranging from 13.73 to 28.48 µg/mL. Compound **3d** was also exhibited weakly cytotoxicity against MCF7 cell line with the IC_{50} value of 48.67 µg/mL. Clausenawalline A (**52c**) was evaluated for cytotoxicity against KB (IC_{50} 7.87 µg/mL), MCF7 (IC_{50} 25.43 µg/mL), and NCI-H187 (IC_{50} 10.97 µg/mL). Furthermore, mafaicheenamine E (**38c**) exhibited cytotoxicity against MCF7 cell line with IC_{50} value of 3.1 µg/mL. Compounds **46c** and **10d** were found to be weakly active.

1.3.6.4 Antifungal Activity

Sunthitikawinsakul et al. (2002) reported that 3-formylcarbazol (**16b)**, mukonal (**17b)**, methyl carbazole-3-carboxylate (**12b**) and 2-hydroxy-3-formyl-7-methoxycarbazol **(19b)** showed antifungal activity against *Candida albicans* with IC_{50} values of 13.6, 29.3, 9.5 and 2.8 µg/mL, respectively.

Excavarin A **(43e**) (Kumar et al., 2012) showed good antifungal activities against human pathogens, *Aspergillus fumigatus* (MIC = 0.625 mg/mL) and

Mucor circinelloides (MIC = 0.078 mg/mL) and plant pathogens, *Colletotrichum gloeosporioides* (MIC = 0.039 mg/mL), *Lasiodiplodia theobromae* (MIC = 0.039 mg/mL), *Fusarium oxysporum* (MIC = 0.019 mg/mL) and *Rhizopus stolonifer* (MIC = 0.019 mg/mL).

1.3.6.5 Antimycobacterial Activity

Sunthitikawinsakul et al. (2002) have reported that dentatin (**45e**), nordentatin (**46e**), clausenidin (**47e**), 3-formylcarbazol (**15b**), mukonal (**16b**), methyl carbazole-3-carboxylate (**11b**) and 2-hydroxy-3-formyl-7-methoxycarbazol (**18b**) against *Mycobacterum tuberculosis* H37Ra with MIC ranging from 50-200 µg/mL.

1.3.6.6 Antibacterial Activity

Maneerat et al. (2012) showed that clausamine B (**2b**) exhibited significant antibacterial activity against MRSA SK1 with an MIC value of 0.25 µg/mL which was higher than that of standard drug, vancomycin (MIC value = 1 µg/mL) whereas compounds clausine F (**5b**), clausamine A (**1b**) and clausenawalline E (**56c**) showed strong activity with MIC values of 4, 8 and 8 µg/mL, respectively. Furthermore, compounds **5b** and **56c** showed strong antibacterial activity against *S. aureus* TISTR 1466 with MIC values of 4 and 8 µg/mL, respectively.

1.3.6.7 Acetylcholinesterase Inhibition

Coumarin glycoside namely feronielloside (**64e**) (Phoopichayanun et al., 2008) inhibited acetylcholinesterase with IC_{50} value of 24.7 mM.

1.3.6.8 Antiviral Activity

Su et al. (2009) showed that clausenidin (**47e**) and nordentatin (**46e**) exhibited antiviral activity against hepatitis B virus with EC_{50} values of 1.88 and 6.38 µM, respectively.

1.3.6.9 Anti-HIV Activity

The new diprenylated indole alkaloid **11d** (Wang et al., 2005) exhibited anti-HIV activity with an IC_{50} value of 1.17 µg/mL.

1.3.6.10 Anti-Malarial Activity

Maneerat et al. (2011) reported that clausenawalline A (**52c**) showed antimalarial activity against *Plasmodium falciparum* with IC_{50} value of 2.46 µg/mL.

1.3.6.11 Anti-TB Activity

Maneerat et al. (2011) reported that the dimeric carbazole alkaloid **52c** showed antituberculosis activity against *Mycobacterium tuberculosis* with MIC value of 12.50 µg/mL.

1.4 The Objectives of Research

The main research objective was to extract, isolate, purify and identify chemical constituents from *Atalantia monophylla*, *Clausena excavata*, *Feroniella lucida*, *Glycosmis pentaphylla* and *G. cochinchinensis*. Selected compounds will be further evaluated for their cytotoxic, antimalarial, antibacterial and anti-TB activities as well.

CHAPTER 2

EXPERIMENTAL

2.1 Instrument and Chemical

Melting points were measured with a Buchi melting point B-540. The optical rotation $[\alpha]_D$ values were determined with a Bellingham Stanley ADP440 or JASCO P-1020 digital polarimeter. The UV-vis spectra were recorded with Perkin-Elmer UV-vis or SPECORD S100 (Analytikjena) spectrophotometers. The IR spectra were recorded using a Perkin-Elmer FTS FT-IR spectrophotometer. The NMR spectra were recorded using 400 MHz Bruker FTNMR Ultra Shield and 500 MHz Varian UNITY INOVA spectrometers. Chemical shifts were recorded in parts per million (δ) in $CDCl_3$ or CD_3OD with tetramethylsilane (TMS) as an internal reference. The HRMS was obtained from MicroTOF, Bruker Daltonics or MAT 95 XL spectrometers. Column chromatography was performed by using quick column chromatography (QCC) and column chromatography (CC) on silica gel 60 H (Merck, 5-40 μm) and silica gel 100 (Merck, 63-200 μm), respectively. Precoated plates of silica gel 60 F_{254} were used for analytical purposes. Sephadex^{TM} LH-20 was used for isolation proceduce.

2.2 Plant Materials

2.2.1 The Roots of *A. monophylla*

The roots of *A. monophylla* were collected in July 2010 from Chachoengsao Province, Eastern Thailand. The plant specimen (MFU-NPR0032) was deposited at

Natural Products Research Laboratory, School of Science, Mae Fah Luang University, Thailand.

2.2.2 The Fruits, Stems and Roots of *C. excavata*

The fruits and stems of *C. excavata* were collected in May 2008 from Satoon Province, whereas the roots of *C. excavata* were collected from Suratthani Province, Southern of Thailand, in June 2010. Botanical identification was achieved through comparison with the voucher specimen number QBG 6277 in herbarium collection of Queen Sirikit Garden, Mae Rim District, Chiang Mai Province, Thailand.

2.2.3 The Fruits, Roots and Twigs of *F. lucida*

The fruits, roots and twigs of *F. lucida* were collected from Nong Khai Province, Northeastern part of Thailand, in May 2008. Botanical identification was achieved through comparison with the voucher specimen number QBG 30251 in the herbarium collection of Queen Sirikit Botanic Garden, Mae Rim District, Chiang Mai, Thailand.

2.2.4 The Fruits of *G. pentaphylla*

The fruits of *G. pentaphylla* were collected in February 2011 from Chiang Rai Province, Northern Thailand. The plant was identified by Mr. James Maxwell, Chiang Mai University Herbarium and the specimen (MFU-NPR0022) was deposited at Natural Products Research Laboratory, School of Science, Mae Fah Luang University, Thailand.

2.2.5 The Twigs of *G. cochinchinensis*

The twigs of *G. cochinchinensis* were collected in September 2011 from Chiang Rai Province, Northern Thailand. The plant was identified by Mr. Martin van de Bult, and the specimen (MFU-NPR0028) was deposited at the Natural Products Research Laboratory, School of Science, Mae Fah Luang University, Thailand.

2.3 Plants Extraction and Isolation

2.3.1 Extraction and Isolation of Compounds from the Roots of *A. monophylla*

The air-dried roots of *A. monophylla* (687.0 g) were extracted with acetone over a period of three days at room temperature. Acetone extract (14.6 g) was subjected to QCC over silica gel using hexanes as eluent and increasing the polarity with EtOAc to afford 17 fractions (A–Q). Fraction G (675.1 mg) was performed by repeated CC with 11% EtOAc–hexanes and followed by CC with 35% CH_2Cl_2–hexanes to afford compound **AM10** (130.7 mg). Compounds **AM1** (4.1 mg), **AM3** (25.0 mg) and **AM13** (10.8 mg) were obtained from fraction I (375.7 mg) by repeated CC with 50% CH_2Cl_2–hexanes. Fraction K (933.0 mg) was fractioned by repeated CC with 80% CH_2Cl_2–hexanes to give eleven subfractions (K1-K11). Subfraction K2 (16.0 mg) was repeated CC with 16% acetone–hexanes to give compound **AM11** (2.0 mg) while compound **AM12** (26.4 mg) was obtained from subfraction K11 (32.0 mg) by repeated CC with 2% EtOAc–CH_2Cl_2. Upon standing at room temperature, compound **AM2** (7.7 mg) precipitated from subfractions K7 (20.0 mg). Purification of fraction N (432.2 mg) by repeated CC with 2% EtOAc–CH_2Cl_2 yielded compounds **AM4** (14.9 mg), **AM7** (54.5 mg) and **AM9** (1.4 mg). Fraction P (840.0 mg) was subjected to QCC with 2% EtOAc–CH_2Cl_2 to afford four subfractions (P1-P4). Compounds **AM5** (2.5 mg), **AM6** (7.0 mg), **AM8** (1.1 mg) and **AM15** (61.4 mg) were obtained from subfraction P3 (200.0 mg) by repeated CC with 30% acetone–hexanes. Fraction Q (845.3 mg) was purified by CC with 4% acetone–CH_2Cl_2 and followed by Sephadex LH-20 using MeOH as eluent to afford compound **AM14** (56.2 mg) (see Figure 2.1).

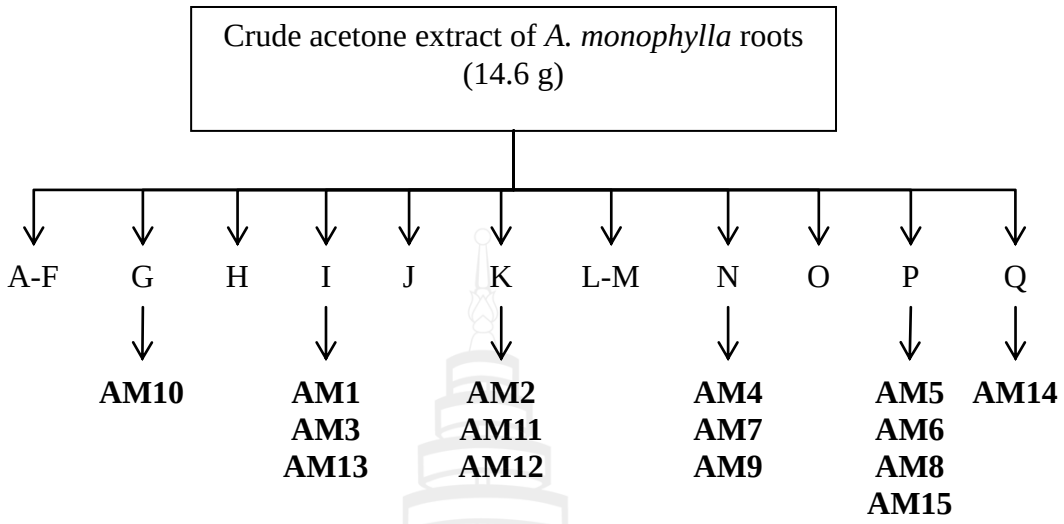


Figure 2.1 Isolation of Compounds **AM1-AM15**

Compound **AM1** (Cycloatalaphylline A): Yellow solid; mp 239-240°C; UV λ_{max} (MeOH): 213, 229, 305, 336 and 422 nm; IR (neat) ν_{max}: 3209 (O–H stretching) and 1641 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.3.

Compound **AM2** (*N*-Methylataphyllinine): Orange solid; mp 194-196°C; UV λ_{max} (MeOH): 211, 239, 292, 324, 347 and 422 nm; IR (neat) ν_{max}: 3207 (O–H stretching) and 1634 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.2.

Compound **AM3** (*N*-Methylataphylline): Yellow solid; mp 190-191°C; UV λ_{max} (MeOH): 210, 229, 272, 335 and 415 nm; IR (neat) ν_{max}: 3280 and 3232 (O–H stretching) and 1626 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.4.

Compound **AM4** (Atalaphylline): Yellow solid; mp 240-242°C; UV λ_{max} (MeOH): 205, 210, 252, 265, 283, 304 and 402 nm; IR (neat) ν_{max}: 3396 (N–H stretching), 3347 and 3290 (O–H stretching) and 1638 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.5.

Compound **AM5** (Atalaphyllidine): Yellow solid; mp 275-276°C; UV λ_{max} (MeOH): 210, 259, 271 and 407 nm; IR (neat) ν_{max}: 3386 (N–H stretching), 3280 (O–H stretching) and 1620 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) spectral data see Table 3.6.

Compound **AM6** (Buxifoliadine C): Yellow solid; mp 280-281°C; UV λ_{max} (MeOH): 206, 232, 266, 286, 309 and 408 nm; IR (neat) ν_{max}: 3330 (N–H stretching), 3270 (O–H stretching) and 1638 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) spectral data see Table 3.7.

Compound **AM7** (Citrusinine I): Yellow viscous oil; UV λ_{max} (MeOH): 202, 204, 264, 319, 334 and 416 nm; IR (neat) ν_{max}: 3290 and 3243 (O–H stretching) and 1630 (>C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.8.

Compound **AM8** (Citrusinine II): Yellow viscous oil; UV λ_{max} (MeOH): 204, 210, 264, 316, 336 and 409 nm; IR (neat) ν_{max}: 3298 and 3280 (O–H stretching) and 1628 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) spectral data see Table 3.9.

Compound **AM9** (Umbelliferone): White solid; mp 220-223°C; UV λ_{max} (MeOH): 207, 268 and 295 nm; IR (neat) ν_{max}: 3290 (O–H stretching) and 1734 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 9.46 (1H, *s*, 7-OH), 7.88 (1H, *d*, *J* = 9.2 Hz, H-4), 7.53 (1H, *d*, *J* = 8.8 Hz, H-5), 6.85 (1H, *dd*, *J* = 8.8, 2.0 Hz, H-6), 6.78 (1H, *d*, *J* = 2.0 Hz, H-8), 6.18 (1H, *d*, *J* = 9.2 Hz, H-3).

Compound **AM10** (Aureptene): Light yellow viscous oil; UV λ_{max} (MeOH): 214 and 323 nm; IR (neat) ν_{max}: 1708 (C=O stretching) and cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.64 (1H, *d*, *J* = 9.6 Hz, H-4), 7.36 (1H, *d*, *J* = 8.4 Hz, H-5), 6.85 (1H, *dd*, *J* = 8.4, 2.4 Hz, H-6), 6.82 (1H, *d*, *J* = 2.4 Hz, H-8), 6.25 (1H, *d*, *J* = 9.6 Hz, H-3), 5.47 (1H, *br t*, *J* = 6.8 Hz, H-2′), 5.08 (1H, *br t*, *J* = 6.4 Hz, H-4′), 4.60 (1H, *d*, *J* = 6.8 Hz, H-1′), 2.10 (4H, *m*, H-4′ and H-5′), 1.76 (3H, *s*, Me-9′), 1.67 (3H, *s*, Me-10′), 1.59 (3H, *s*, Me-8′).

Compound **AM11** (7-*O*-Geranylscopoletin): Yellow viscous oil; UV λ_{max} (MeOH): 204, 211, 226, 261, 283 and 344 nm; IR (neat) ν_{max}: 3380 (O–H stretching) and 1724 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.63 (1H, *d*, *J* = 9.6 Hz, H-4), 6.29 (1H, *d*, *J* = 9.6 Hz, H-3), 6.86 (1H, *s*, H-5), 6.85 (1H, *s*, H-8), 4.71

(2H, *br d*, *J* = 6.4 Hz, H-1′), 5.50 (1H, *br t*, *J* = 6.4 Hz, H-2′), 5.08 (1H, *m*, H-6′), 3.91 (3H, *s*, 6-OMe), 2.13 (4H, *m*, H-4′ and H-5′), 1.79 (3H, *s*, Me-8′), 1.61 (3H, *s*, Me-10′), 1.59 (3H, *s*, Me-9′).

Compound **AM12** (Demethyl suberosin): White solid; mp 123.0-124.0°C; UV λ_{max} (MeOH): 205 and 332 nm; IR (neat) ν_{max}: 3414 (O–H stretching) and 1735 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.09 (1H, br s, 7-O*H*), 7.67 (1H, d, *J* = 9.2 Hz, H-4), 6.23 (1H, d, *J* = 9.2 Hz, H-3), 7.19 (1H, s, H-5), 7.09 (1H, s, H-8), 5.33 (1H, br t, *J* = 3.2 Hz, H-2′), 3.36 (2H, d, *J* = 6.8 Hz, H-1′), 1.77 (3H, s, H-5'), 1.72 (3H, s, H-4′); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 162.9 (C-2), 158.9 (C-7), 154.0 (C-8a), 144.7 (C-4), 134.4 (C-3′), 128.1 (C-2′), 126.3 (C-6), 121.1 (C-5), 112.0 (C-3), 28.1 (C-5′), 25.8 (C-1′), 17.8 (C-4′).

Compound **AM13** (Xanthyletin): Colorless viscous oil; UV λ_{max} (MeOH): 224, 265 and 347 nm; IR (neat) ν_{max}: IR (neat) ν_{max}: 1730 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.59 (1H, *d*, *J* = 9.6 Hz, H-4), 7.20 (1H, *d*, *J* = 8.4 Hz, H-5), 6.71 (1H, *d*, *J* = 8.4 Hz, H-6), 6.88 (1H, *d*, *J* = 10.0 Hz, H-4′), 6.22 (1H, *d*, *J* = 9.6 Hz, H-3), 5.72 (1H, *d*, *J* = 10.0 Hz, H-3′); ^{13}C NMR ($CDCl_3$, 400 MHz) δ 161.1 (C-2), 156.8 (C-7), 143.3 (C-4), 131.2 (C-3), 124.7 (C-5), 120.7 (C-8), 118.5 (C-6), 113.0 (C-2′), 104.3 (C-1′), 77.7 (C-3′), 28.9 (Me-4′ and Me-5′).

Compound **AM14** (Marmisn): White solid; mp 143.0-145.0°C; UV λ_{max} (MeOH): 205, 224 and 332 nm; IR (neat) ν_{max}: 1731 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.58 (1H, *d*, *J* = 8.8 Hz, H-4), 7.21 (1H, *s*, H-4), 6.71 (1H, *s*, H-4), 6.19 (1H, *d*, *J* = 8.8 Hz, H-3), 4.73 (1H, *t*, *J* = 2.2 Hz, H-2′), 3.27 (1H, *m*, H-3′), 1.37 (3H, *s*, H-3″), 1.23 (3H, *s*, H-2″); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 163.1 (C-7), 161.4 (C-2), 155.6 (C-8a), 143.7 (C-4), 125.0 (C-6),123.4 (C-5), 112.7 (C-4a), 112.3 (C-3), 97.9 (C-8), 91.9 (C-2′), 71.6 (C-1′), 29.5 (C-3′), 26.1 (C-3″), 24.2 (C-2″).

Compound **AM15** (Cycloepiatalantin): White solid; mp >300°C; UV λ_{max} (MeOH): 202 and 214 nm; IR (neat) ν_{max}: 3388 (O–H stretching) and 1732 (C=O stretching) cm^{-1}; ^{1}H NMR (acetone-d_6, 400 MHz) δ 7.72 (1H, *d*, *J* = 5.2 Hz, H-1), 7.63 (1H, *br s*, H-23), 7.60 (1H, *br s*, H-21), 6.51 (1H, *br s*, H-22), 6.16 (1H, *d*, *J* = 5.2 Hz, H-2), 5.63 (1H, *s*, H-17), 4.03 (1H, *d*, *J* = 10.0 Hz, H-19a), 3.90 (1H, *d*, *J* = 10.0 Hz, H-19b), 3.87 (1H, *s*, H-15), 3.40 (1H, *s*, H-7), 3.03 (1H, *m*, H-9), 2.28 (1H,

m, H-11a), 1.93 (1H, *m*, H-11b), 1.89 (1H, *m*, H-12a), 1.54(1H, *m*, H-12b), 1.32 (3H, *s*, Me-26), 1.23 (3H, *s*, Me-18), 1.11 (3H, *s*, Me-24), 1.14 (3H, *br s*, Me-25).

2.3.2 Extraction and Isolation of Compounds from the Fruits, Stems and Roots of *C. excavata*

The fruits of *C. excavata* (250.0 g) were extracted with hexanes and CH_2Cl_2, respectively, over a period of three days at room temperature. The hexanes and CH_2Cl_2 extracts were combined (987.7 mg) and chromatographed by CC over silica gel eluting with a gradient solvent system of EtOAc–hexanes (20% EtOAc–hexanes to 100% MeOH) to give 21 fractions (A-U). Fraction D (168.0 mg) was chromatographed by CC with 15% CH_2Cl_2–hexanes to yield compound **CE34** (2.9 mg). Compound **CE38** (13.7 mg) was obtained from fraction F (312.5 mg) by CC with 40% CH_2Cl_2–hexanes. Fraction I (168.0 mg) was separated by Sephadex LH-20 with 60% CH_2Cl_2–MeOH to provide five subfractions (I1-I5). Subfraction I3 (85.0 mg) was purified by CC using 8% $CHCl_3$–hexanes to afford compound **CE4** (8.2 mg). Fraction T (384.8 mg) was also separated by Sephadex LH-20 eluting with 60% CH_2Cl_2–MeOH to obtain four subfractions (T1-T4). Compounds **CE1** (4.2 mg), **CE3** (1.5 mg) and **CE36** (5.7 mg) were isolated from subfraction T1 (173.4 mg) by CC with 3% acetone–CH_2Cl_2 (see Figure 2.2).

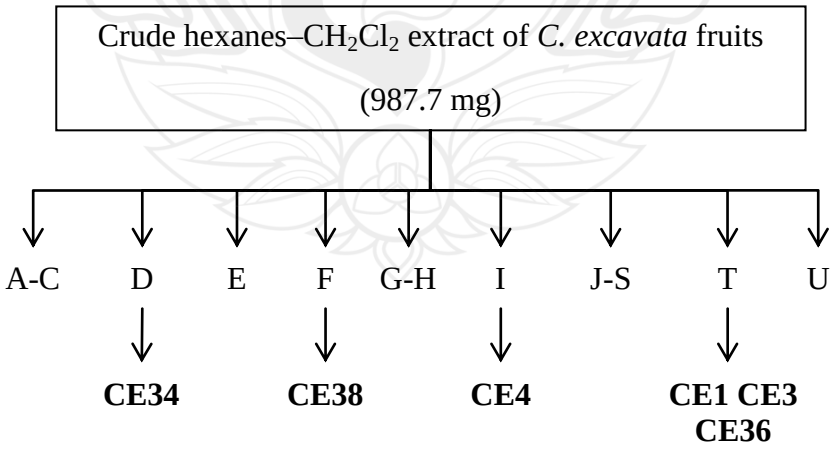


Figure 2.2 Isolation of Compounds **CE1**, **CE3**, **CE4**, **CE6**, **CE34** and **CE38**

Compound **CE1** (Clausenaexcavin): Colorless viscous oil; $[\alpha]_D^{29}$ -223.4 (*c* 0.04, $CHCl_3$).UV λ_{max} ($CHCl_3$): 207, 230, 258, 318 nm. IR (neat) ν_{max}: 3408 (O–H stretching), 1718 (C=O stretching) cm^{-1}. For ^1H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.40. EIMS *m/z* (% intensity) 346 (M^+-H_2O, 10), 331 (75), 247 (100), 204 (89), 175 (53). HREIMS *m/z* 346.1422 [M-H_2O]$^+$ (calcd. for $C_{19}H_{22}O_6$, 346.1416).

Compound **CE3** (Scopoletin): White solid; mp 202.0-203.0°C; UV λ_{max} (MeOH): 205, 228, 260, 286 and 344 nm; IR (neat) ν_{max}: 3290 (O–H stretching) and 1715 (C=O stretching) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.60 (1H, *d*, *J* = 9.6 Hz, H-4), 6.92 (1H, *s*, H-8), 6.84 (1H, *s*, H-5), 6.27 (1H, *d*, *J* = 9.6 Hz, H-3), 6.14 (1H, *br s*, 7-OH), 3.95 (3H, *s*, 6-OMe).

Compound **CE4** (Seselin): Colorless viscous oil; UV λ_{max} (MeOH): 207, 283 and 327 nm; IR (neat) ν_{max}: 1732 (C=O stretching) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.59 (1H, *d*, *J* = 9.6 Hz, H-4), 7.20 (1H, *d*, *J* = 8.4 Hz, H-5), 6.71 (1H, *d*, *J* = 8.4 Hz, H-6), 6.22 (1H, *d*, *J* = 9.6 Hz, H-3), 6.88 (1H, *d*, *J* = 10.0 Hz, H-4′), 5.72 (1H, *d*, *J* = 10.0 Hz, H-3′), 1.47 (6H, *s*, *J* = 8.4 Hz, 2x2′-Me).

Compound **CE34** (3,4-Dimethoxybenzaldehyde): Colorless viscous oil; UV λ_{max} (MeOH): 205, 225, 272 and 308 nm; IR (neat) ν_{max}: 1682 (C=O stretching) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 9.86 (1H, *s*, 1-CHO), 7.47 (1H, *dd*, *J* = 8.0, 2.0 Hz, H-6), 7.42 (1H, *d*, *J* = 2.0 Hz, H-2), 6.99 (1H, *d*, *J* = 8.0 Hz, H-5), 3.97 (3H, *s*, 4-OMe), 3.95 (3H, *s*, 3-OMe).

Compound **CE36** ((*R*)-6-hydroxy-3-(2-hydroxypropan-2-yl)-6-methyl-cyclo-hex-2-enone): Yellow viscous oil; UV λ_{max} (MeOH): 203 and 233 nm; IR (neat) ν_{max}: 3418 (O–H stretching), 1727 (C=O stretching) cm^{-1}. For ^1H NMR ($CDCl_3$, 400 MHz) δ 6.19 (1H, *s*, H-3), 2.62 (1H, *m*, H-5a), 2.57 (1H, *m*, H-5b), 2.18 (1H, *m*, H-6a), 1.98 (1H, *m*, H-6b), 1.44 (3H, *m*, Me-10), 1.43 (1H, *s*, Me-9), 1.31 (3H, *s*, H-7).

The stems of *C. excavata* (3.2 kg) were extracted with EtOAc over a period of three days at room temperature. Removal the solvent under reduced pressure provided EtOAc extract (70.5 g). This extract was chromatographed by QCC over silica gel and eluted with a gradient solvent system of hexanes–acetone (100% hexanes to 100% acetone) to afford 26 fractions (A-Z). Fraction D (455.0 mg) was subjected to CC

with 20% CH_2Cl_2–hexanes to afford compounds **CE35** (5.0 mg) and **CE37** (143.0 mg). Fraction I (297.3 mg) was performed by QCC with 27% CH_2Cl_2–hexanes to yield twelve subfractions (I1-I12). Subfraction I4 (27.0 mg) was recrystallized from hexanes to give compound **CE15** (4.4 mg). Fraction J (230.0 mg) was purified by CC with 15% acetone–hexanes to give six subfractions (J1-J6). Subfraction J2 (16.0 mg) was further purified by CC with 50% $CHCl_3$–hexanes to give compound **CE5** (2.0 mg). Fractions K and L were combined (1.15 g) and subjected to Sephadex LH-20 with 60% CH_2Cl_2–MeOH to give five subfractions (KL1-KL5). Subfraction KL4 (250.0 mg) was fractionated by repeated QCC with 25% CH_2Cl_2–hexanes and gave six subfractions (KL4.1-KL4.6). Subfraction KL4.3 (80.7 mg) was purified by CC with 60% CH_2Cl_2–hexanes to give compound **CE11** (7.3 mg) whereas compound **CE23** (2.6 mg) was obtained from subfraction KL4.5 (55.4 mg) by repeated CC using 80% CH_2Cl_2–hexanes as eluent. Subfraction KL4.6 (130.0 mg) was further purified by CC with 40% CH_2Cl_2–hexanes to give compound **CE16** (5.0 mg), along with three subfractions (KL4.6.1-KL4.6.3). Compound **CE12** (17.6 mg) was obtained from subfraction KL4.6.3 by repeated CC with 70% CH_2Cl_2–hexanes. Fraction N (387.4 mg) was subjected to QCC with 45% CH_2Cl_2–hexanes to afford nine subfractions (N1-N9). Subfraction N4 (41.9 mg) was purified by CC with 12% acetone–hexanes to yield compound **CE32** (12.5 mg). Subfraction N8 (75.0 mg) was recrystallized from CH_2Cl_2 to give solid and mother liqour. The solid of subfraction N8 (21.5 mg) was further purified by CC with 45% CH_2Cl_2–hexanes to give compound **CE2** (4.3 mg). Fractions P and Q were combined (842.0 mg) and subjected to QCC with 75% CH_2Cl_2–hexanes to afford eight subfractions (PQ1-PQ8). Subfraction PQ2 (103.9 mg) was purified by CC with 80% CH_2Cl_2–hexanes to give compounds **CE18** (6.0 mg) and **CE19** (51.0 mg). Subfraction PQ5 (65.8 mg) was recrystallized from CH_2Cl_2 obtained compound **CE22** (8.0 mg). The mother liquor of subfraction PQ5 (55.0 mg) was subjected to CC with 23% acetone–hexanes to yield six subfractions (PQ5.1-PQ5.6). Subfraction PQ5.2 (10.0 mg) was recrystallized from CH_2Cl_2 to give compound **CE8** (3.0 mg). Compound **CE13** (12.0 mg) was isolated from subfraction PQ8 (73.0 mg) by repeated CC with 23% EtOAc–CH_2Cl_2, while compound **CE14**

(10.0 mg) was obtained from subfraction PQ13 (40.4 mg) by CC with 18% EtOAc–CH_2Cl_2. Fraction S (445.0 mg) was subjected to QCC with 10% EtOAc–CH_2Cl_2 to afford four subfractions (S1-S4). Subfraction S2 (20.0 mg) was further purified by CC with 30% acetone–hexanes to give compound **CE20** (2.4 mg). Fraction U (561.0 mg) was subjected to Sephadex LH-20 with 60% CH_2Cl_2–MeOH to obtain three subfractions (U1-U3). Subfraction U3 (145.1 mg) was recrystallized from 50% acetone–CH_2Cl_2 to give compound **CE21** (62.0 mg). Compound **CE33** (5.0 mg) was isolated from fraction Y (1.40 g) by Sephadex LH-20 with 60% CH_2Cl_2–MeOH as eluent (see Figure 2.3).

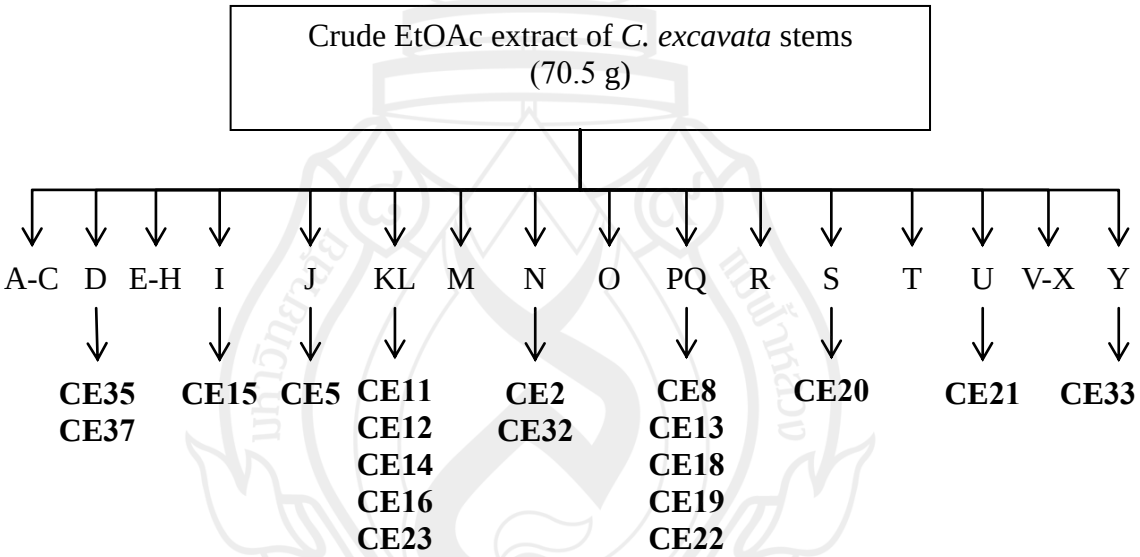


Figure 2.3 Isolation of Compounds **CE2**, **CE5**, **CE8**, **CE11-CE16**, **CE18-CE22**, **CE32**, **CE33**, **CE35** and **CE37**

Compound **CE2** (Aureptene): See compound **AM10**

Compound **CE5** (Xanthyletin): See compound **AM13**

Compound **CE8** (Nordentatin): White solid; mp 184.0-185.0°C; UV λ_{max} (MeOH): 209, 227, 279 and 337 nm; IR (neat) ν_{max}: 3340 (O–H stretching) and 1691

(C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.50.

Compound **CE11** (Methylcarbazole-3-carboxylate): White solid; mp 140.5-141.3°C UV λ_{max} (MeOH): 232, 274 and 323 nm; IR (neat) ν_{max}: 3331 (N–H stretching) and 1689 (C=O stretching). For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.13.

Compound **CE12** (3-Formylcarbazole): White solid; mp 159.5-160.5°C; UV λ_{max} (MeOH): 242, 272, 287 and 325 nm; IR (neat) ν_{max}: 3307 (N–H stretching) and 1675 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.14.

Compound CE13 (Clauszoline I): Yellow solid; mp 198.0-199.0°C; UV λ_{max} (MeOH): 218, 238, 248, 275, 309 and 336 nm; IR (neat) ν_{max}: 3331 (N–H stretching), 3320 (O–H stretching) and 1686 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.15.

Compound **CE14** (*O*-Demethylmurrayanine): A light brown solid; mp 238.8-240.2°C; UV λ_{max} (MeOH): 221, 239, 249, 273, 287, 332 and 343 nm; IR (neat) ν_{max}: 3350 (N–H stretching), 3330 (O–H stretching), 1668 (>C=O stretching), 1580 and 1499 (C=C ring stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.16.

Compound **CE15** (Mukonine): White solid; mp 199.0-200.9°C; UV λ_{max} (MeOH): 236, 246, 267, 275, 310 and 319 nm; IR (neat) ν_{max}: 3320 (N–H stretching) and 1692 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.17.

Compound **CE16** (Murrayanine): Light yellow solid; mp 168.4-170°C; UV λ_{max} (MeOH): 237, 247, 272, 286, 329 and 338 nm; IR (neat) ν_{max}: 3222 (N–H stretching) and 1662 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.18.

Compound **CE18** (Mukonidine): Colorless solid; UV λ_{max} (MeOH): 214, 234, 264 and 305 nm; IR (neat) ν_{max}: 3420 (N–H stretching), 3290 (O–H stretching) and 1645 (C=O stretching). For ^{1}H NMR (acetone-d_6, 400 MHz) spectral data see Table 3.20.

Compound **CE19** (*O*-Methylmukonal): Light yellow solid; mp 196.5-198.0°C; UV λ_{max} (MeOH): 234, 275, 295 and 350 nm; IR (neat) ν_{max}: 1665 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.21.

Compound **CE20** (Methyl-1,6-dihydroxy-9*H*-carbazole-3-carboxylate): Yellow viscous oil; UV λ_{max} (MeOH): 224, 241, 251, 268, 284 and 338 nm; IR (neat) ν_{max}: 3350 (N–H stretching and O–H stretching) and 1688 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) spectral data see Table 3.22.

Compound **CE21** (Clausine Z): Light brown solid; mp 285.2-290.0°C; UV λ_{max} (MeOH): 203, 223, 243, 256, 278, 297 and 356 nm; IR (neat) ν_{max}: 3372 (N–H stretching), 3182 (O–H stretching) and 1651 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.23.

Compound **CE22** (Sansoakamine): Light brown solid; mp 243.8-245.6°C; UV λ_{max} (MeOH): 223, 243, 256, 278, 297, 356 nm; IR (neat) ν_{max}: 3357 (N–H stretching), 3290 (O–H stretching) and 1659 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.24. HR-EI-MS *m*/*z*: 257.0683 $[M]^+$ (calcd for $C_{14}H_{11}NO_4$, 257.0688).

Compound **CE23** (Lansine): White solid; mp 224-225°C; UV λ_{max} (MeOH): 205, 231, 281, 307 and 338 nm; IR (neat) ν_{max}: 3340 (N–H stretching), 3250 (O–H stretching) and 1633 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.25.

Compound **CE32** (Dictamine): White solid; mp 131-132°C; UV λ_{max} (MeOH): 236, 308, 314 and 329 nm; IR (neat) ν_{max}: 1625 and 1582 (C=C ring stretching), 1087 (C–O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.30.

Compound **CE33** (*N*-(*p-trans*-coumaronyl)tyramine): White solid; mp 248.1-249.5°C; UV λ_{max} (MeOH): 224, 291 and 307 nm; IR (neat) ν_{max}: 3432 (N–H stretching), 3330 (O–H stretching), 1660 (C=O stretching) cm^{-1}; ^{1}H NMR (acetone-d_6, 400 MHz) δ 8.81 (1H, *br s*, 16-OH), 8.20 (1H, *br s*, 4-OH), 7.45 (1H, *d*, *J* = 15.6 Hz, H-12), 7.41 (2H, *d*, *J* = 8.4 Hz, H-14 and H-18), 7.23 (1H, *br s*, 9-NH),7.06 (2H, *d*, *J* = 8.4 Hz, H-2 and H-6), 6.85 (2H, *d*, *J* = 8.4 Hz, H-15 and H-17), 6.74 (2H, *d*, *J* = 8.4

Hz, H-3 and H-5), 6.47 (1H, *d*, *J* = 15.6 Hz, H-11), 3.47 (2H, *m*, H_2-8), 2.73 (2H, *m*, H_2-7).

Compound **CE35** (4-(3-Methylbut-2-enyloxy)benzaldehyde): Yellow viscous oil; UV λ_{max} (MeOH): 204 and 266 nm; IR (neat) ν_{max}: 1686 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 9.88 (1H, *s*, 1-CHO), 7.83 (2H, *d*, *J* = 8.8 Hz, H-2 and H-6), 7.01 (2H, *d*, *J* = 8.8 Hz, H-3 and H-5), 5.49 (1H, *br t*, *J* = 7.2 Hz, H-2′), 4.59 (2H, *br d*, *J* = 7.2 Hz, H_2-1′), 1.81 (3H, *s*, Me-4′), 1.76 (3H, *s*, Me-5′).

The air-dried roots (3.8 kg) of *C. excavata* were extracted with acetone over a period of three days at room temperature. Removal of the solvent under reduced pressure provided acetone extract (288.0 g) which was chromatographed by QCC over silica gel eluting with a gradient solvent system of hexanes–acetone (100% hexanes to 100% acetone) to afford 19 fractions (A-S). Fraction G (10.68 g) was performed by QCC with 2% EtOAc–hexanes to 100% EtOAc which yielded six subfractions (G1-G6). Subfraction G2 (23.9 mg) was fractionated by repeated CC with 24% CH_2Cl_2–hexanes to give compound **CE17** (2.6 mg) whereas compounds **CE7** (17.3 mg), **CE9** (30.0 mg) and **CE30** (39.8 mg) were obtained from subfraction G4 (1.82 g) by repeated CC using 6% EtOAc–hexanes. Subfraction G6 (400.5 mg) was washed with hexanes to give compound **CE6** (308. 2 mg). Fraction J (5.74 g) was subjected to QCC with a gradient of EtOAc and hexanes (100% hexanes to 100% EtOAc) which afforded eight subfractions (J1-J8). Subfraction J5 (292.7 mg) was further purified by QCC with 12% EtOAc–hexanes to give compound **CE24** (46.0 mg) and ten subfractions (J5.1-J5.10). Subfraction J5.5 (10.0 mg) was washed with hexanes to yield compound **CE31** (4.4 mg). Compounds **CE32** (4.6 mg) and **CE16** (29.1 mg) were obtained from subfractions J5.9 (22.8 mg) and J5.7 (35.5 mg), respectively by CC with 12% acetone–hexanes. Subfraction J5.7 (2.50 g) was recrystallized from CH_2Cl_2 to yield compound **CE8** (2.24 g). Subfraction J5.9 (192.7 mg) was subjected to CC with 4% acetone–CH_2Cl_2 to give six subfractions (J5.9.1-J5.9.6). Compounds **CE10** (4.4 mg) and **CE13** (13.5 mg) were obtained from subfractions J5.9.3 (22.0 mg) and J5.9.4 (38.0 mg) by recrystallized from CH_2Cl_2 while compound **CE29** (2.9 mg) was isolated from subfraction J5.9.6 (17.0 mg) by

CC with 22% acetone–hexanes. Subfraction J5.10 (59.1 mg) was further purified by CC with 3% acetone–hexanes to give compound **CE28** (8.5 mg). Fraction N (8.11 g) was chromatographed by QCC with 20% EtOAc–hexanes to 100% EtOAc to afford five subfractions (N1-N5). Subfraction N5 (200.0 mg) was purified by CC with 90% CH_2Cl_2–hexanes to yield five subfractions (N5.1-N5.5). Compounds **CE3** (8.1 mg) and **CE25** (12.0 mg) were obtained from subfractions N5.3 (10.0 mg) and N5.1 (20.0 mg), respectively, by recrystallization from CH_2Cl_2. Compound **CE27** (17.6 mg) was isolated from subfraction N5.5 (32.0 mg) by CC with 30% acetone–hexanes whereas compound **CE26** (39.0 mg) was isolated from fraction S (1.05 g) by CC with 30% acetone–hexanes (see Figure 2.4).

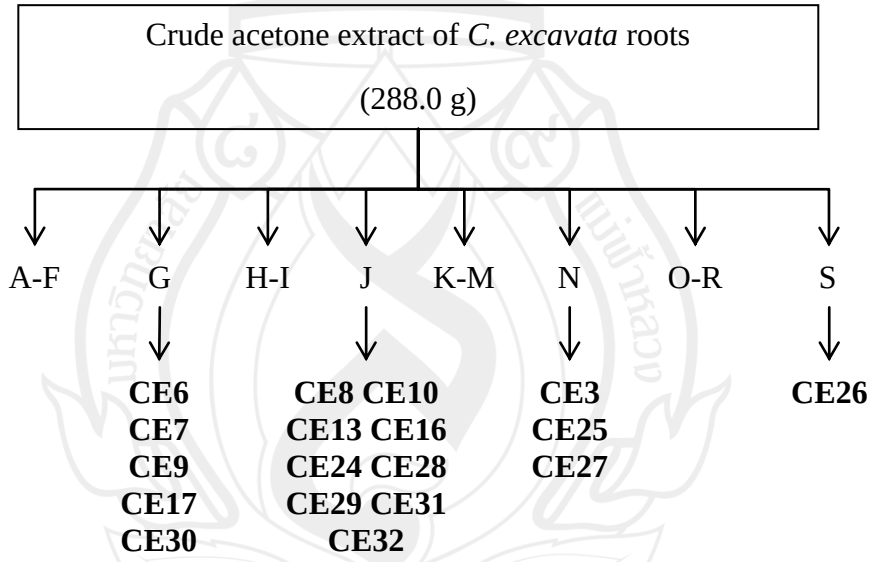


Figure 2.4 Isolation of Compounds **CE3**, **CE6-CE10**, **CE13**, **CE16**, **CE17** and **CE24-CE32**

Compound **CE3** (Scopoletin): White solid; mp 202.0-203.0°C; UV λ_{max} (MeOH): 205, 228, 260, 286 and 344 nm; IR (neat) ν_{max}: 3290 (O–H stretching) and 1715 (C=O stretching) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.60 (1H, *d*, *J* = 9.6 Hz,

H-4), 6.92 (1H, *s*, H-8), 6.84 (1H, *s*, H-5), 6.27 (1H, *d*, *J* = 9.6 Hz, H-3), 6.14 (1H, *br s*, 7-OH), 3.95 (3H, *s*, 6-OMe).

Compound **CE6** (Xanthoxyletin): Colorless solid; mp 130.0-131.0°C; UV λ_{max} (MeOH): 225, 268 and 346 nm; IR (neat) ν_{max}: 3425 (O–H stretching) and 1720 (C=O stretching) cm^{-1}. ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.84 (1H, *d*, *J* = 9.6 Hz, H-4), 6.56 (1H, *d*, *J* = 10.0 Hz, H-1′), 6.54 (1H, *s*, H-8), 6.19 (1H, *d*, *J* = 9.6 Hz, H-3), 5.70 (1H, *d*, *J* = 10.0 Hz, H-2′), 3.85 (3H, *s*, OMe-5), 1.45 (6H, *s*, Me-4′ and Me-5′).

Compound **CE7** (Dentatin): Light yellow solid; mp 88.0-89.0°C; UV λ_{max} (MeOH): 227, 271 and 327 nm; IR (neat) ν_{max}: 1730 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.8 (1H, *d*, *J* = 9.2 Hz, H-4), 6.56 (1H, *d*, *J* = 9.6 Hz, H-4′), 6.29 (1H, *dd*, *J* = 17.6, 10.8 Hz, H-2″), 6.18 (1H, *d*, *J* = 9.2 Hz, H-3), 5.68 (1H, *d*, *J* = 9.6 Hz, H-3′), 4.93 (1H, *dd*, *J* = 17.6, 1.2 Hz, H-3″a), 4.87 (1H, *dd*, *J* = 10.8, 1.2 Hz, H-3″b), 3.82 (3H, *s*, OMe-5), 1.65 (6H, *s*, Me-4″ and Me-5″), 1.44 (6H, *s*, Me-5′ and Me-6′)**.**

Compound **CE8** (Nordentatin): White solid; mp 184.0-185.0°C; UV λ_{max} (MeOH): 209, 227, 279 and 337 nm; IR (neat) ν_{max}: 3340 (O–H stretching) and 1691 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.50.

Compound **CE9** (Clausenidin): Light yellow solid; mp 136.0-137.0°C; UV λ_{max} (MeOH): 203, 284 and 327 nm; IR (neat) ν_{max}: 3330 (O–H stretching) and 1731 and 1650 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 12.98 (1H, *s*, 5-OH), 8.04 (1H, *d*, *J* = 9.6 Hz, H-4), 6.22 (1H, *dd*, *J* = 17.2, 10.4 Hz, H-2″), 6.16 (1H, *d*, *J* = 9.6 Hz, H-3), 4.92 (1H, *dd*, *J* = 17.2, 1.2 Hz, H-3″a), 4.88 (1H, *dd*, *J* = 10.4, 1.2 Hz, H-3″b), 2.75 (2H, *s*, H-2′), 1.63 (6H, *s*, Me-2″ and Me-3″), 1.49 (6H, *s*, Me-5′ and Me-6′); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 198.2 (C-4′), 160.6 (C-2), 160.0 (C-7), 159.9 (C-5), 159.0 (C-8a), 149.5 (C-4″), 138.5 (C-4), 110.7 (C-3), 108.5 (C-5″), 104.0 (C-6), 103.2 (C-4a), 80.2 (C-2′), 47.6 (C-3′), 40.9 (C-1″), 29.3 (Me-2″ and Me-3″), 26.3 (Me-5′ and Me-6′).

Compound **CE10** (Binorponcitrin): White solid; mp 223-224°C; $[\alpha]_D^{29}$ ±0 (*c* 0.01, MeOH); UV λ_{max} (MeOH): 205, 280 and 340 nm; IR (neat) ν_{max}: 3370 (O–H

stretching) and 1680 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 125 MHz) spectral data see Table 3.51.

Compound **CE13** (Clauszoline I): Yellow solid; mp 198.0-199.0°C; UV λ_{max} (MeOH): 218, 238, 248, 275, 309 and 336 nm; IR (neat) ν_{max}: 3331 (N–H stretching), 3320 (O–H stretching) and 1686 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.15.

Compound **CE16** (Murrayanine): Light yellow solid; mp 168.4-170°C; UV λ_{max} (MeOH): 237, 247, 272, 286, 329 and 338 nm; IR (neat) ν_{max}: 3222 (N–H stretching) and 1662 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.18.

Compound **CE17** (Murrayafoline A): Colorless viscous oil; UV λ_{max} (MeOH): 223, 241, 252, 290 and 328 nm; IR (neat) ν_{max}: 3415 (N–H stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) spectral data see Table 3.19.

Compound **CE24** (2-Hydroxy-3-formyl-7-methoxycarbazole): Yellow solid; mp 226.0-227.0°C; UV λ_{max} (MeOH): 224, 240, 299 and 338 nm; IR (neat) ν_{max}: 3383 (O–H stretching), 3290 (N–H stretching) and 1619 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.26.

Compound **CE25** (3-Formyl-2,7-dimethoxycarbazole): Yellow solid; mp 223.0-224.0°C; UV λ_{max} (MeOH): 240, 298 and 346 nm; IR (neat) ν_{max}: 3391 (N–H stretching) and 1736 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.27.

Compound **CE26** (Clauszoline J): White solid; mp 256.0-257.0°C; UV λ_{max} (MeOH): 245 and 278 nm; IR (neat) ν_{max}: 3374 (O–H stretching), 3312 (N–H stretching) and 1737 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.28.

Compound **CE27** (Clausine H): Yellow solid; mp 192.0-193.0°C; UV λ_{max} (MeOH): 246 and 279 nm; IR (neat) ν_{max}: 3400 (N–H stretching) and 1701 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.29.

Compound **CE28** (Clausine F): Colorless viscous oil; UV λ_{max} (MeOH): 207, 243, 250, 269 and 312 nm; IR (neat) ν_{max}: 3373 (N–H and O–H stretching) and 1681

(C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) δ 10.65 (1H, *br s*, NH), 8.87 (1H, *br s*, OH), 8.12 (1H, *d*, *J* = 8.0 Hz, H-5), 7.64 (1H, *d*, *J* = 8.0 Hz, H-8), 7.47 (1H, *s*, H-2), 7.42 (1H, *t*, *J* = 8.0 Hz, H-7), 7.22 (1H, *t*, *J* = 8.0 Hz, H-6), 5.24 (1H, *m*, H-2′), 4.33 (2H, *br d*, *J* = 5.6 Hz, H-8), 3.83 (3H, *s*, 3-CO_2Me), 1.89 (3H, *s*, Me-4′), 1.67 (3H, *s*, Me-5′).

Compound **CE29** (*O*-Demethylekeberginine): Light brown solid; mp >300°C; UV λ_{max} (MeOH): 204, 224, 241, 275 and 339 nm; IR (neat) ν_{max}: 3379 (N–H stretching), 3350 (O–H stretching) and 1654 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) δ 10.87 (1H, *br s*, NH), 10.39 (1H, *s*, 3-CHO), 8.16 (1H, *d*, *J* = 8.0 Hz, H-5), 7.67 (1H, *d*, *J* = 8.0 Hz, H-8), 7.46 (1H, *t*, *J* = 8.0 Hz, H-7), 7.42 (1H, *s*, H-2), 7.26 (1H, *t*, *J* = 8.0 Hz, H-6), 5.31 (1H, *m*, H-2′), 4.39 (2H, *br d*, *J* = 6.0 Hz, H-1′), 1.93 (3H, *s*, Me-4′), 1.70 (3H, *s*, Me-5′).

Compound **CE30** (Heptaphylline): Yellow solid; mp 169.0-170°C; UV λ_{max} (MeOH): 202, 236, 248, 278, 298 and 341 nm; IR (neat) ν_{max}: 3380 (N–H stretching), 3305 (O–H stretching) and 1613 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) δ 11.65 (1H, *s*, NH), 9.87 (1H, *br s*, 3-CHO), 8.23 (1H, *br s*, 2-OH), 7.99 (1H, *s*, H-4), 7.95 (1H, *d*, *J* = 6.8 Hz, H-5), 7.39 (1H, *m*, H-8), 7.38 (1H, *m*, H-7), 7.25 (1H, *m*, H-6), 5.30 (1H, *m*, H-2′), 3.62 (2H, *br d*, *J* = 6.8 Hz, H-1′), 1.85 (3H, *s*, Me-4′), 1.71 (3H, *s*, Me-5′).

Compound **CE31** (Murrayacine): Yellow solid; mp 232-233°C; UV λ_{max} (MeOH): 225, 281, 298 and 360 nm; IR (neat) ν_{max}: 3174 (N–H stretching) and 1664 (C=O stretching) cm^{-1}. For ^{1}H NMR (acetone-d_6, 400 MHz) δ 11.82 (1H, *s*, NH), 10.47 (1H, *br s*, 3-CHO), 8.37 (1H, *s*, H-4), 8.13 (1H, *d*, *J* = 8.0 Hz, H-5), 7.47 (1H, *d*, *J* = 8.0 Hz, H-8), 7.38 (1H, *t*, *J* = 8.0 Hz, H-7), 7.22 (1H, *t*, *J* = 8.0 Hz, H-6), 6.96 (1H, *d*, *J* = 10.0 Hz, H-1′), 5.93 (1H, *d*, *J* = 10.0 Hz, H-2′), 1.65 (3H, *s*, Me-4′ and Me-5′); ^{13}C NMR (acetone-d_6, 100 MHz) δ 198.0 (3-CHO), 159.4 (C-2), 145.9 (C-8a), 145.6 (C-1a), 135.6 (C-2′), 131.0 (C-7), 128.6 (C-5a), 125.5 (C-3), 125.0 (C-6), 124.6 (C-5), 123.4 (C-4), 123.3 (C-4a), 121.9 (C-1′), 116.1 (C-8), 109.5 (C-1), 82.0 (C-3′), 31.9 (Me-4′ and Me-5′).

Compound **CE32** (Dictamine): White solid; mp 131-132°C; UV λ_{max} (MeOH): 236, 308, 314 and 329 nm; IR (neat) ν_{max}: 1625 and 1582 (C=C ring

stretching), 1087 (C–O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.30.

2.3.3 Extraction and Isolation of Compounds from the Fruits, Roots and Twigs of *F. lucida*

The fruits of *F. lucida* (300.0 g) were extracted with acetone over a period of three days at room temperature. The acetone extract (12.1 g) was chromatographed by CC over silica gel eluting with a gradient solvent system of hexanes–EtOAc (100% hexanes to 100% EtOAc) to give 12 fractions (A-L). Fraction B (320.5 mg) was washed with hexanes to afford compound **FL30** (34.4 mg). Compound **FL29** (54.7 mg) was obtained from fraction D (250.0 mg) by recrystallized from hexanes whereas compound **FL23** (6.9 mg) was isolated from fraction G (170.0 mg) by CC with 47% CH_2Cl_2–hexanes. Fraction I (20.8 mg) was recrystallized from hexanes to yield compound **FL21** (2.3 mg). Fraction K (300.0 mg) was further purified by CC with 12% EtOAc–CH_2Cl_2 to give compounds **FL14** (6.0 mg), **FL16** (3.7 mg) and **FL17** (2.5 mg) (see Figure 2.5).

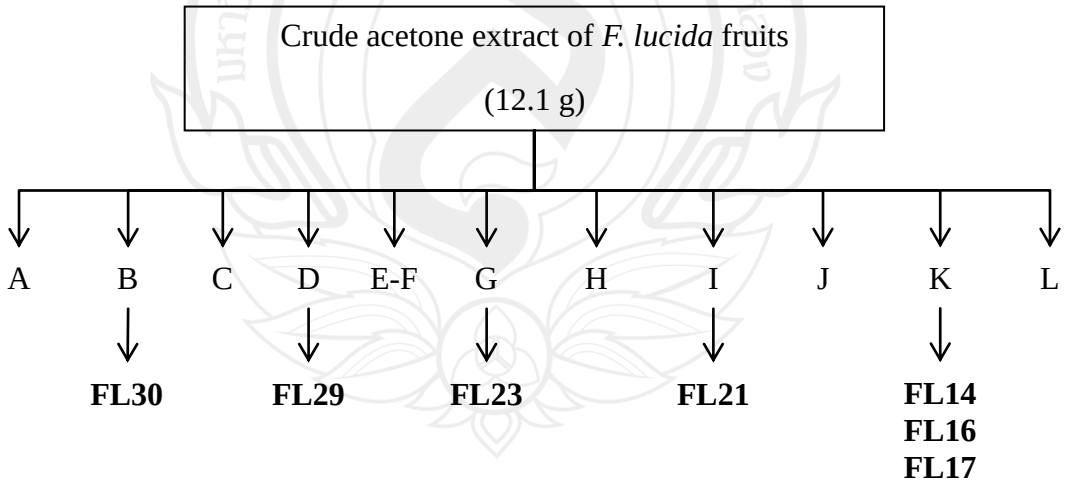


Figure 2.5 Isolation of Compounds **FL14**, **FL16**, **FL17**, **FL21**, **FL23**, **FL29** and **FL30**

Compound **FL14** (Marmisn): See compound **AM14**

Compound **FL16** (Umbelliferone): See compound **AM9**

Compound **FL17** (Scopoletin): See compound **CE3**

Compound **FL21** (*N*-[2-(4-Methoxyphenyl)ethyl]benzamide): Colorless solid; mp 119.0-120.0°C; UV λ_{max} (MeOH): 202, 225 and 279 nm; IR (neat) ν_{max}: 3317 (N–H stretching) and 1635 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.10.

Compound **FL23** ((2*E*,4*E*)-Deca-2,4-dienoic acid 2-phenylethyl amide): Colorless viscus; UV λ_{max} (MeOH): 207 nm; IR (neat) ν_{max}: 3293 (N–H stretching) and 1667 (C=O stretching) cm^{-1}. For ^{1}H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectral data see Table 3.12.

Air-dried roots of *F. lucida* (7.54 kg) were extracted with acetone over a period of three days at room temperature. Removal of the solvent under reduced pressure provided the acetone extract (200.5 g). This extract was chromatographed by QCC over silica gel eluting with a gradient of hexanes–EtOAc (100% hexanes to 100% EtOAc) to provide 22 fractions (A-V). Upon standing at room temperature, a solid was precipitated from fraction F (550.0 mg), which was further recrystallized from CH_2Cl_2 to give compound **FL12** (499.0 mg). Fraction G (15.82 g) was further performed by QCC with a gradient solvent system of 100% hexanes to 50% EtOAc–hexanes to give 12 subfractions (G1-G12). Compounds **FL6** (215.0 mg), **FL7** (13.2 mg), and **FL15** (16.5 mg) were obtained from subfraction G4 (799.9 mg) by repeated CC using 10% EtOAc–hexanes. Fraction G10 (1.05 g) was subjected to CC with 12% EtOAc–hexanes to provide 14 subfractions (G10.1-G10.14). Subfraction G10.5 (100.0 mg) was further purified by CC with 25% CH_2Cl_2–hexanes to give compounds **FL3** (4.0 mg) and **FL8** (54.7 mg). Subfractions G10.8 (6.0mg), G10.12 (30.0 mg), and G10.14 (35.2 mg) were recrystallized from hexanes to yield compounds **FL4** (2.5 mg), **FL5** (10.4 mg), and **FL1** (22.4mg), respectively. Subfraction G10.11 (32.1 mg) was subjected to CC with 30% CH_2Cl_2–hexanes to yield compound **FL24** (7.3 mg). Subfraction G12 (1.60 g) was purified by CC with 70% CH_2Cl_2–hexanes to give 12 subfractions (G12.1-G12.12). Subfraction G12.2 (34.0 mg) was purified by CC with 18% EtOAc–hexanes to give compound **FL19**

(4.2 mg), whereas compound **FL20** (4.0 mg) was obtained from subfraction G12.4 (51.7 mg) by repeated CC with 38% EtOAc–hexanes. Subfraction G12.7 (20.0 mg) was recrystallized from hexanes to yield compound **FL21** (12.9 mg). Subfraction G12.12 (266.7 mg) was subjected to CC with 18% EtOAc–hexanes to obtain compound **FL18** (141.7 mg). Fraction N (3.27 g) was subjected to QCC with 20% EtOAc–hexanes as eluent to afford five subfractions (N1-N5). Compounds **FL14** (22.6 mg) and **FL22** (13.6 mg) were obtained from subfraction N2 (160.0 mg) by repeated CC with 2% acetone–hexanes, whereas compound **FL11** (34.4mg) was obtained from subfraction N4 (266.9 mg) by repeated CC with 2% EtOAc–CH_2Cl_2. Fraction V (2.06 g) was fractionated by repeated QCC with 5% EtOAc–hexanes to give three subfractions (V1-V3). Subfraction V2 (44.5 mg) was further purified by CC with 40% $CHCl_3$–hexanes to give compound **FL25** (35.2 mg) (see Figure 2.6).

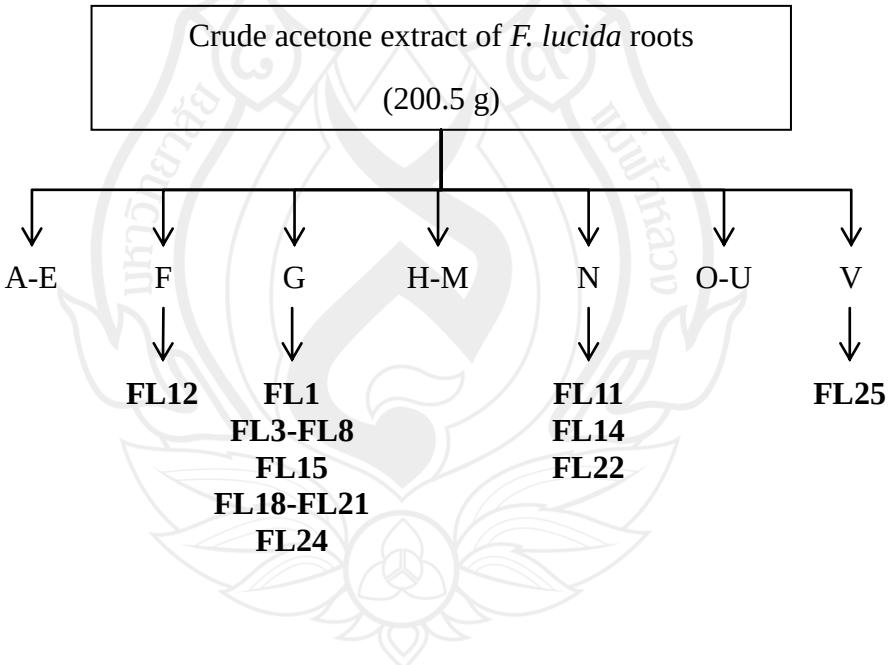


Figure 2.6 Isolation of Compounds **FL1**, **FL3-FL8**, **FL11**, **FL12**, **FL14**, **FL15**, **FL18-FL22**, **FL24** and **FL25**

Compound **FL1** (Xanthotoxin): White solid; mp 145.0-146.0°C; UV λ_{max} (MeOH): 217, 248, 262 and 298 nm; IR (neat) ν_{max}: 1716 (C=O stretching) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.69 (1H, *d*, *J* = 2.4 Hz, H-2′), 7.77 (1H, *d*, *J* = 9.6 Hz, H-

4), 7.35 (1H, *s*, H-5), 6.82 (1H, *d*, *J* = 2.4 Hz, H-3′), 6.37 (1H, *d*, *J* = 9.6 Hz, H-3), 4.30 (3H, *s*, 8-OMe); 1^3C NMR ($CDCl_3$, 100 MHz) δ 160.5 (C-1), 147.7 (C-7), 146.6 (C-2′), 144.3 (C-4), 143.0 (C-8a), 132.8 (C-8), 126.1 (C-6), 116.5 (C-4a), 114.7 (C-3), 112.9 (C-5), 106.7 (C-3′), 61.3 (8-OMe).

Compound **FL3** (8-Geranyloxypsolaren): Light yellow viscous oil; UV λ_{max} (MeOH): 203, 248, 263 and 297 nm; IR (neat) ν_{max}: 1729 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.77 (1H, *d*, *J* = 9.6 Hz, H-4), 7.69 (1H, *d*, *J* = 2.0 Hz, H-2′), 7.36 (1H, *s*, H-5), 6.81 (1H, *d*, *J* = 2.4 Hz, H-3′), 6.37 (1H, *d*, *J* = 9.6 Hz, H-3), 5.60 (1H, *m*, H-2″), 5.01 (1H, *m*, H-6″), 5.00 (2H, *br t*, *J* = 6.4 Hz, H-1″), 2.01 (4H, *m*, H-4″ and H-5″), 1.69 (3H, *s*, H-9″), 1.64 (3H, *s*, H-10″), 1.59 (3H, *s*, H-8″).

Compound **FL4** (Psolaren): White solid; mp 165.0-166.0°C; UV λ_{max} (MeOH): 204, 245, 289 and 325 nm; IR (neat) ν_{max}: 1723 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.70 (1H, *d*, *J* = 2.0 Hz, H-2′), 7.81 (1H, *d*, *J* = 9.6 Hz, H-4), 7.69 (1H, *s*, H-5), 7.48 (1H, *s*, H-8), 6.84 (1H, *d*, *J* = 2.0 Hz, H-3′), 6.39 (1H, *d*, *J* = 9.6 Hz, H-3).

Compound **FL5** (Bergapten): White solid; mp 189.0-190.0°C; UV λ_{max} (MeOH): 221, 249, 259, 267 and 308 nm; IR (neat) ν_{max}: 1725 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) spectral data see Table 3.44.

Compound **FL6** (Isoimperatorin): White solid; mp 103.0-104.0°C; UV λ_{max} (MeOH): 201, 221, 249, 258, 268 and 308 nm; IR (neat) ν_{max}: 3450 (N–H stretching), 3330 (O–H stretching) and 1668 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.45.

Compound **FL7** (Bergamottin): Yellow viscous oil; UV λ_{max} (MeOH): 200, 249, 257, 267 and 308 nm; IR (neat) ν_{max}: 1733 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) spectral data see Table 3.46.

Compound **FL8** (Lucidafuranocoumarin A): Colorless viscous oil; $[\alpha]_D^{25}$ -76 (*c* 0.053, $CHCl_3$); UV λ_{max} (MeOH): 306, 266, 259, 249, 219, 202 nm; IR (neat) ν_{max}: 1732 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.41. ESI-TOF-MS: *m/z* 355.1531 $[M+ H]^+$ (calcd for $C_{21}H_{23}O_5$, 355.1545).

Compound **FL11** (Anisolactone): White solid; mp 157.0-158.0°C; $[\alpha]_D^{25}$ +21.0 (*c* 0.04, $CHCl_3$); UV λ_{max} (MeOH): 216, 250, 258, 268 and 307 nm; IR (neat)

ν_{max}: 1754 and 1732 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.47.

Compound **FL12** (2″,3″-Dihydroxyanisolactone): Light yellow solid; mp 177.0-178.0°C; $[\alpha]_D^{25}$ ±0 (*c* 0.02, $CHCl_3$); UV λ_{max} (MeOH): 212, 249, 265 and 306 nm; IR (neat) ν_{max}: 3396 (O–H stretching) and 1759 and 1723 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.48.

Compound **FL14** (Marmisn): See compound **AM14**

Compound **FL15** (Xanthyletin): See compound **AM13**

Compound **FL18** (Demethyl suberosin): See compound **AM12**

Compound **FL19** (8-Geranyloxy-7-hydroxycoumarin): Light yellow viscous oil; UV λ_{max} (MeOH): 205 and 326 nm; IR (neat) ν_{max}: 3381 (O–H stretching) and 1715 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.64 (1H, *d*, *J* = 9.6 Hz, H-4), 7.25 (1H, *d*, *J* = 8.4 Hz, H-5), 6.81 (1H, *d*, *J* = 8.4 Hz, H-6), 6.25 (1H, *d*, *J* = 9.6 Hz, H-3), 5.28 (1H, *m*, H-2′), 5.05 (1H, *m*, H-6′), 4.94 (2H, *d*, *J* = 6.8 Hz, H-1′), 2.09 (4H, *m*, H-4′ and H-5′), 1.85 (3H, *s*, H-9'), 1.64 (3H, *s*, H-10′), 1.59 (3H, *s*, H-8′).

Compound **FL20** (Osthenol): White solid; mp 90-91°C; UV λ_{max} (MeOH): 206, 259 and 326 nm; IR (neat) ν_{max}: 3345 (O–H stretching) and 1697 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.64 (1H, *d*, *J* = 9.6 Hz, H-4), 7.25 (1H, *d*, *J* = 8.0 Hz, H-5), 6.79 (1H, *d*, *J* = 8.0 Hz, H-6), 6.24 (1H, *d*, *J* = 9.6 Hz, H-3), 5.28 (1H, *t*, *J* = 7.2 Hz, H-2′), 3.63 (2H, *d*, *J* = 7.2 Hz, H-1′), 1.86 (3H, *s*, H-4′), 1.76 (3H, *s*, H-5′).

Compound **FL21** (*N*-[2-(4-Methoxyphenyl)ethyl]benzamide): Colorless solid; mp 119.0-120.0°C; UV λ_{max} (MeOH): 202, 225 and 279 nm; IR (neat) ν_{max}: 3317 (N–H stretching) and 1635 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.10.

Compound **FL22** (Tembamide): White solid; mp 120.0-121.0°C; $[\alpha]_D^{25}$ +52.0 (*c* 0.01, $CHCl_3$); UV λ_{max} (MeOH): 202 and 226 nm; IR (neat) ν_{max}: 3423 (O–H stretching), 3326 (N–H stretching) and 1621 (C=O stretching) cm^{-1}. For ^{1}H NMR (400 MHz, acetone-d_6) and ^{13}C NMR (100 MHz, acetone-d_6) spectral data see Table 3.11.

Compound **FL24** (6-Acetonyldihydrochelerythrine): White solid; mp 191.0-192.0°C; $[\alpha]_D^{25}$ -10.8 (*c* 0.01, $CHCl_3$); UV λ_{max} (MeOH): 229 and 282 nm; IR (neat) ν_{max}: 1715 (C=O stretching) cm^{-1}. For ^1H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectral data see Table 3.33.

Compound **FL25** (8-Acetonyldihydronitidine): A light yellow solid; mp 162.0-163.0°C; $[\alpha]_D^{25}$ -8.2 (*c* 0.01, $CHCl_3$); UV λ_{max} (MeOH): 230, 279 and 311 nm; IR (neat) ν_{max}: 1712 (C=O stretching) cm^{-1}. For ^1H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectral data see Table 3.34.

Air-dried twigs of *F. lucida* (3.1 kg) were extracted with acetone over a period of three days at room temperature. The acetone extract (35.4 g) was subjected to QCC over silica gel eluting with a gradient of hexanes–EtOAc (100% hexanes to 100% EtOAc) to yield 18 fractions (A–R). Fraction E (261.5 mg) was separated by repeated CC with 10% EtOAc–hexanes to afford compounds **FL2** (6.0 mg) and **FL7** (16.4 mg). Compound **FL16** (2.3 mg) was obtained from fraction K (508.7 mg) by CC with 36% EtOAc–hexanes. Fraction L (890.0 mg) was further purified by CC with 20% acetone–hexanes and followed by repeated CC with 30% EtOAc–hexanes to give compounds **FL9** (7.9 mg) and **FL11** (61.3 mg). Fraction M (1.08 g) was performed by CC with 1% acetone–$CHCl_3$ to yield compounds **FL12** (23.0 mg) and **FL13** (13.8 mg). Compound **FL10** (78.2 mg) was isolated from fraction Q (1.62 g) by CC with 70% EtOAc–hexanes and followed by CC with 16% acetone–CH_2Cl_2. Fraction R (1.05 g) was purified by CC with 5% acetone–$CHCl_3$ and followed by Sephadex LH-20 with 100% MeOH as solvent to obtain compounds **FL26** (6.0 mg), **FL27** (7.2 mg) and **FL28** (2.7 mg) (see Figure 2.7)

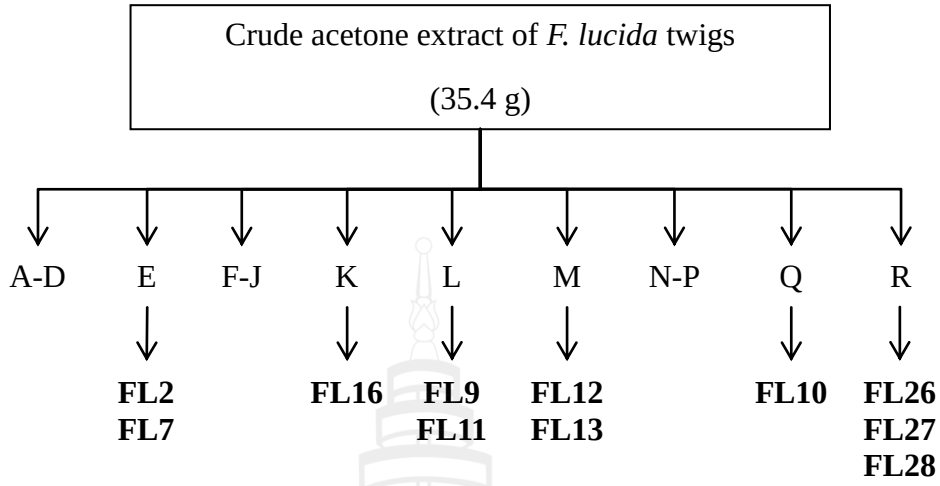


Figure 2.7 Isolation of Compounds **FL2**, **FL7**, **FL9-FL13**, **FL16** and **FL26-FL28**

Compound **FL2** (Imperatorin): Colorless viscous oil; UV λ_{max} (MeOH): 207, 250 and 308 nm; IR (neat) ν_{max}: 1733 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.23 (1H, *d*, *J* = 9.6 Hz, H-4), 7.65 (1H, *d*, *J* = 2.4 Hz, H-2′), 7.32 (1H, *s*, H-5),7.02 (1H, d, *J* = 2.4 Hz, H-3'), 5.60 (1H, *m*, H-2′), 4.98 (2H, *d*, *J* = 7.2 Hz, H-1′), 1.86 (3H, *s*, Me-4′), 1.76 (3H, *s*, Me-5′).

Compound **FL7** (Bergamottin): Yellow viscus oil; UV λ_{max} (MeOH): 210, 222, 249, 250, 268 and 308 nm; IR (neat) ν_{max}: 1733 (C=O stretching) cm^{-1}. ; For ^{1}H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectral data see Table 3.46

Compound **FL9** (Lucidafuranocoumarin B): Light yellow gum; $[\alpha]_D^{30}$ -147.1 (*c* 0.024, MeOH); UV (MeOH) λ_{max}: 267, 282 nm; IR (neat) ν_{max}: 1765 and 1735 (C=O stretching) cm^{-1}; For ^{1}H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectral data see Table 3.42; HR-EI-MS *m*/*z* 368.1256 $[M]^+$ (calcd. for $C_{21}H_{20}O_6$, 368.1260).

Compound **FL10** (Lucidafuranocoumarin C): Light yellow gum; $[\alpha]_D^{30}$ -177.7 (*c* 0.015, MeOH); UV (MeOH) λ_{max}: 203, 313 nm; IR (neat) ν_{max}: 3426 (O–H stretching), 1734 and 1700 (C=O stretching) cm^{-1}; For ^{1}H NMR (400 MHz, $CDCl_3$)

and ^{13}C NMR (100 MHz, $CDCl_3$) spectral data see Table 3.43; ESI-TOF-MS *m*/*z* 423.1052 $[M\text{-}H_2O+ Na]^+$ (calcd. for $C_{21}H_{20}O_8Na$, 423.1050).

Preparation of (*R*)- and (*S*)-MTPA esters **FL10a** and **FL10b** from **FL10**: A solution of furanocoumarin **FL10** (1.6 mg) in dried pyridine was separated into two round bottom glasses. The (*R*)- and (*S*)-MTPA-Cl (30 µL, excess) were added in each bottom at 0°C and the mixture were stirred for 5 min. Stirring continued at ambient temperature and the completion of reaction was monitored by TLC. Two milliliters of hexanes were added to the reaction mixture and the hexanes soluble parts were dried to give (*S*)- and (*R*)-bis-MTPA esters **FL10a** (1.1 mg) and **FL10b** (0.7 mg), respectively. The chemical shift differences of the proton resonances between the (*S*)-MTPA ester **FL10a** and the (*R*)-MTPA ester **FL10b**, $\Delta\delta_{SR}$: +0.103 (H-1″a), +0.162 (H-1″b), -0.043 (H-2″), -0.121 (H-9″), -0.061 (H-4″a), -0.097 (H-4″b), +0.024 (H-5″), +0.011 (H-6″) and +0.003 (H-10″).

Compound **FL11** (Anisolactone): White solid; mp 157.0-158.0°C; $[\alpha]_D^{25}$ +21.0 (*c* 0.04, $CHCl_3$); UV λ_{max} (MeOH): 216, 250, 258, 268 and 307 nm; IR (neat) ν_{max}: 1754 and 1732 (C=O stretching) cm^{-1}. For ^1H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectral data see Table 3.47.

Compound **FL12** (2″,3″-Dihydroxyanisolactone): Light yellow solid; mp 177.0-178.0°C; $[\alpha]_D^{25}$ ±0 (*c* 0.02, $CHCl_3$); UV λ_{max} (MeOH): 212, 249, 265 and 306 nm; IR (neat) ν_{max}: 3396 (O–H stretching) and 1759 and 1723 (C=O stretching) cm^{-1}. For ^1H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectral data see Table 3.48.

Compound **FL13** (Feroniellin A): White solid; mp 143.0-145.0°C; $[\alpha]_D^{30}$ +20.1 (*c* 0.01, MeOH); UV λ_{max} (MeOH): 211, 255 and 308 nm; IR (neat) ν_{max}: 3362 (O–H stretching) and 1721 (C=O stretching) cm^{-1}. For ^1H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, acetone-d_6) spectral data see Table 3.49.

Compound **FL16** (Umbelliferone): See compound **AM9**

Compound **FL26** (Vanillin): Yellow viscous oil; UV λ_{max} (MeOH): 206, 230, 277 and 307 nm; IR (neat) ν_{max}: 3336 (O–H stretching) and 1672 (C=O stretching) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.60 (1H, *dd*, *J* = 8.0, 2.0 Hz, H-6), 7.57 (1H, *d*, *J* = 2.0 Hz, H-2), 6.92 (1H, *d*, *J* = 8.0 Hz, H-5), 3.91 (1H, *s*, 3-Me).

Compound **FL27** (Vanillic acid): Light yellow solid; mp 200-202°C; UV λ_{max} (MeOH): 207, 258 and 288 nm; IR (neat) ν_{max}: 3484 (O–H stretching) and 1678 (C=O stretching) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 9.85 (1H, *s*, 1-CHO), 7.57 (1H, *d*, *J* = 2.0 Hz, H-2), 6.92 (1H, *d*, *J* = 8.0 Hz, H-5), 3.91 (1H, *s*, 3-Me).7.45 (1H, *dd*, *J* = 8.0, 2.0 Hz, H-6), 7.05 (1H, *d*, *J* = 2.0 Hz, H-2), 6.25 (1H, *d*, *J* = 8.0 Hz, H-5), 3.99 (1H, *s*, 3-Me).

Compound **FL28** (Citflavanone): Yellow solid; mp 162-163°C; $[\alpha]_D^{30}$ -8.5 (*c* 0.010, $CHCl_3$); UV λ_{max} (MeOH): 207 and 269 nm; IR (neat) ν_{max}: 3348 (O–H stretching) and 1641 (C=O stretching) cm^{-1}. For ^1H NMR ($CDCl_3$, 400 MHz) δ 7.36 (2H, *d*, *J* = 7.6 Hz, H-2′ and H-6′), 6.91 (2H, *d*, *J* = 7.6 Hz, H-3′ and H-5′), 6.55 (1H, *d*, *J* = 10.0 Hz, H-1″), 6.01 (1H, *s*, H-6), 5.48 (1H, *d*, *J* = 10.0 Hz, H-2″), 5.38 (1H, *dd*, *J* = 13.2, 2.8 Hz, H-2), 3.08 (1H, *dd*, *J* = 17.2, 13.2 Hz, H-3a), 2.81 (1H, *dd*, *J* = 17.2, 2.8 Hz, H-3b), 1.46 (3H, *s*, H-4″), 1.44 (3H, *s*, H-5″).

2.3.4 Extraction and Isolation of Compounds from the Fruits of *G. pentaphylla*

The fruits of *G. pentaphylla* (378.9 g) were extracted with 50% CH_2Cl_2–MeOH (800 mL) over a period of three days at room temperature. The CH_2Cl_2–MeOH extract (30.7 g) was subjected to QCC on silica gel using hexanes as eluent and increasing the polarity with EtOAc to yield 24 fractions (A-X). Fraction F (105.0 mg) was performed by repeated CC eluting with 30% EtOAc–hexanes to afford compounds **GP1** (7.1 mg) and **GP3** (4.7 mg). Fraction H (50.0 mg) was subjected to Sephadex LH-20 using MeOH as eluent to give compound **GP6** (8.6 mg). Compound **GP2** (8.4 mg) was obtained from fraction L (99.0 mg) by Sephadex LH-20 eluting with MeOH and followed by CC with 65% CH_2Cl_2–hexanes. Fraction Q (290.0 mg) was isolated by repeated CC with 25% EtOAc–CH_2Cl_2 to yield thirteen subfractions (Q1-Q13). Upon standing at room temperature, compounds **GP8** (41.0 mg) and **GP9** (14.0 mg) were precipitated from subfractions Q7 (55.2 mg) and Q3 (20.0 mg), respectively. Purification of subfraction Q5 (45.0 mg) by Sephadex LH-20 using MeOH as eluent afforded compounds **GP7** (9.6 mg) and **GP10** (4.5 mg) while compound **GP4** (8.5 mg) was obtained from subfraction Q13 (20.0 mg) by repeated CC with 25% EtOAc–CH_2Cl_2. Compound **GP5** (115.3 mg) was obtained from

fraction X (677.0 mg) by repeated CC eluting with 10% acetone–CH_2Cl_2 (see Figure 2.8).

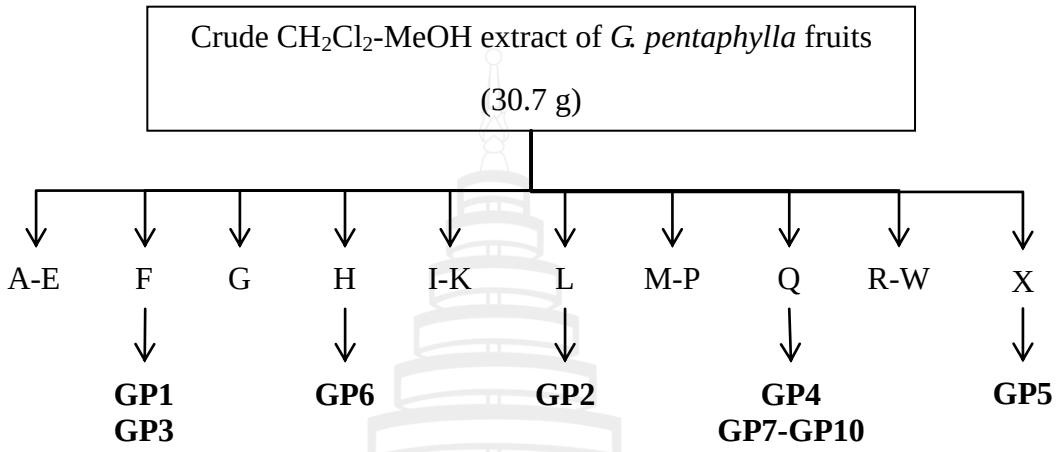


Figure 2.8 Isolation of Compounds **GP1-GP10**

Compound **GP1** (Glycopentaphyllone): Light yellow viscous oil; $[\alpha]_D^{28}$ +17.31 (c 0.01, MeOH); UV (MeOH) λ_{max}: 215, 231, 256, 283, 295, 330 nm; IR (neat) ν_{max}: 3409 (O–H stretching) and 1729 (C=O stretching) cm^{-1}; For ^1H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.36; ESI-TOF-MS m/z 320.1495 $[M+H]^+$ (calcd. for $C_{17}H_{22}NO_5$, 320.1498).

Reduction of **GP1**: Compound **GP1** (6.0 mg) was treated with 25.0 mg of triphenylphosphine in 1 mL of dichloromethane for 6 h at room temperature. The solution was evaporated to dryness and separated by CC with the elution of 30% EtOAc–hexanes to give **GP2** (2.0 mg).

Compound **GP2** (Acutifolin): Yellow viscous oil; $[\alpha]_D^{28}$ +10 (c 0.01, MeOH); UV λ_{max} (MeOH): 218, 238, 257, 284 and 333 nm; IR (neat) ν_{max}: 3345 (O–H stretching), 1680 (C=O stretching) cm^{-1}. For ^1H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.37.

Preparation of (*R*)- and (*S*)-MTPA esters **GP2a** and **GP2b** from **GP2**: To a solution of quinolone **GP2** (1.6 mg) in dry pyridine was separated to two round bottoms. The (*R*)- and (*S*)-MTPA-Cl (30 µL, excess) were added in each bottom at 0

°C and the mixture was stirred for 5 min. Stirring continued at ambient temperature and the completion of reaction was monitored by TLC. Two milliliters of hexanes were added to the reaction mixture and the hexanes soluble part was dried to give (*S*)- and (*R*)-bis-MTPA esters **GP2a** (1.1 mg) and **GP2b** (1.0 mg), respectively. The chemical shift differences of the proton resonances between the (*S*)-MTPA ester **GP2a** and the (*R*)-MTPA ester **GP2b**, $\Delta\delta_{SR}$: -0.0002 (H-1′a), -0.0002 (H-1′b), +0.0004 (H-2′), +0.0008 (H-4′a), +0.0001 (H-4′b) and +0.0003 (H-5′).

Compound **GP3** (3-(3′,3′-Dimethyl-allyl)-4,8-dimethoxy-*N*-methyl quinolin -2-one): Colorless viscous oil; UV λ_{max} (MeOH): 218, 240, 250, 286 and 335 nm; IR (neat) ν_{max}: 1725 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) spectral data see Table 3.38.

Compound **GP4** (Glycocitlone C): Colorless viscous oil; UV λ_{max} (MeOH): 228, 257, 306 and 320 nm; IR (neat) ν_{max}: 3399 (O–H stretching) and 1733 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.39.

Compound **GP5** (Arborine): Colorless viscous; UV λ_{max} (MeOH): 204, 230, 276 and 305 nm; IR (neat) ν_{max}: 1700 (C=O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.35.

Compound **GP6** (Dictamine): See compound **CE32**

Compound **GP7** (*γ*-Fagarine): Colorless solid; mp 155-156°C; UV λ_{max} (MeOH): 243 and 310 nm; IR (neat) ν_{max}: 1621 and 1518 (C=C ring stretching), 1095 (C–O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* 7.84 (1H, *dd*, *J* = 8.4, 1.2 Hz, H-5), 7.64(1H, *d*, *J* = 2.8 Hz, H-2′), 7.35 (1H, *t*, *J* = 8.4 Hz, H-6), 7.06 (1H, *br d*, *J* = 8.4 Hz, H-7), 7.07 (1H, *d*, *J* = 2.8 Hz, H-3′), 4.44 (3H, *s*, 4-OMe), 4.08 (3H, *s*, 8-OMe).

Compound **GP8** (Skimmianine): Light yellow solid; mp 179-180°C; UV λ_{max} (MeOH): 248 and 331 nm; IR (neat) ν_{max}: 1614 and 1579 (C=C ring stretching), 1092 (C–O stretching) cm^{-1}. For ^{1}H NMR ($CDCl_3$, 400 MHz) and ^{13}C NMR ($CDCl_3$, 100 MHz) spectral data see Table 3.31.

Compound **GP9** (1-Hydroxy-3,4-dimethoxy-*N*-methylacridone): Yellow solid; mp 130-132°C; UV λ_{max} (MeOH): 228, 274 and 398 nm; IR (neat) ν_{max}: 3388 (O–H stretching), 1739 (C=O stretching) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) *δ* 14.76 (1H, *s*,

1-OH), 8.37 (1H, *d*, *J* = 8.0 Hz, H-8), 7.70 (1H, *m*, H-6), 7.47 (1H, *d*, *J* = 8.8 Hz, H-5), 7.26 (1H, *t*, *J* = 8.0 Hz, H-7), 6.20 (1H, *s*, H-3), 4.01 (3H, *s*, 1-OMe), 3.93 (3H, *s*, 2-OMe), 3.79 (3H, *s*, 10-NMe).

Compound **GP10** (Arborinine): Yellow solid; mp 177-178°C; UV λ_{max} (MeOH): 274 and 398 nm; IR (neat) ν_{max}: 3370 (O–H stretching) and 1735 (>C=O stretching) cm^{-1}. For ^1H NMR ($CDCl_3$, 400 MHz) δ 14.76 (1H, *s*, 1-OH), 8.43 (1H, *d*, *J* = 8.0 Hz, H-8), 7.73 (1H, *m*, H-6), 7.50(1H, *d*, *J* = 8.8 Hz, H-5), 7.29 (1H, *t*, *J* = 8.0 Hz, H-7), 6.26 (1H, *s*, H-1), 4.02 (3H, *s*, 2-OMe), 3.94 (3H, *s*, 3-OMe), 3.83 (3H, *s*, 10-NMe).

2.3.5 Extraction and Isolation of Compounds from the Twigs of *G. cochinchinensis*

Air-dried twigs of *G. cochinchinensis* (8.7 kg) were extracted with acetone over a period of three days at room temperature. The acetone extract (111.0 g) was subjected to QCC on silica gel using hexanes as eluent and then increasing the polarity with EtOAc (100% hexanes to 100% EtOAc) to yield 11 fractions (A-K). Fraction E (2.40 g) was separated by repeated CC eluting with 10% acetone–hexanes and followed by Sephadex LH-20 eluting with MeOH to afford compounds **GC3** (8.3 mg), **GC4** (1.6 mg), **GC12** (15.0 mg) and **GC14** (7.7 mg). Fraction G (0.80 g) was separated by QCC eluting with a gradient of acetone–hexanes to give five subfractions (G1-G5). Compounds **GC2** (3.8 mg) and **GC9** (17.9 mg) were derived from subfraction G2 (0.44 g) by Sephadex LH-20 eluting with MeOH and followed by CC with 30% CH_2Cl_2–hexanes. Fraction I (9.68 g) was subjected to QCC eluting with a gradient of CH_2Cl_2–hexanes to give ten subfractions (I1-I10). Purification of subfraction I3 (362 mg) directly afforded compounds **GC5** (37.5 mg), **GC6** (12.4 mg) **GC11** (2.0 mg) while compounds **GC7** (9.4 mg), **GC8** (22.0 mg) and **GC13** (34.8 mg) were derived from subfraction I5 (339 mg) by repeated CC with 2% acetone–CH_2Cl_2. Compound **GC1** (3.2 mg) was obtained from subfraction I8 (504 mg) by Sephadex LH-20 eluting with MeOH and followed by CC with 10% acetone–CH_2Cl_2 whereas compound **GC10** (8.7 mg) was obtained from subfraction I9 (187 mg) by repeated CC with 10% acetone–hexanes. Fraction K (22.4 mg) was

purified by Sephadex LH-20 using MeOH as eluent to afford compound **GC15** (1.8 mg) (see Figure 2.9).

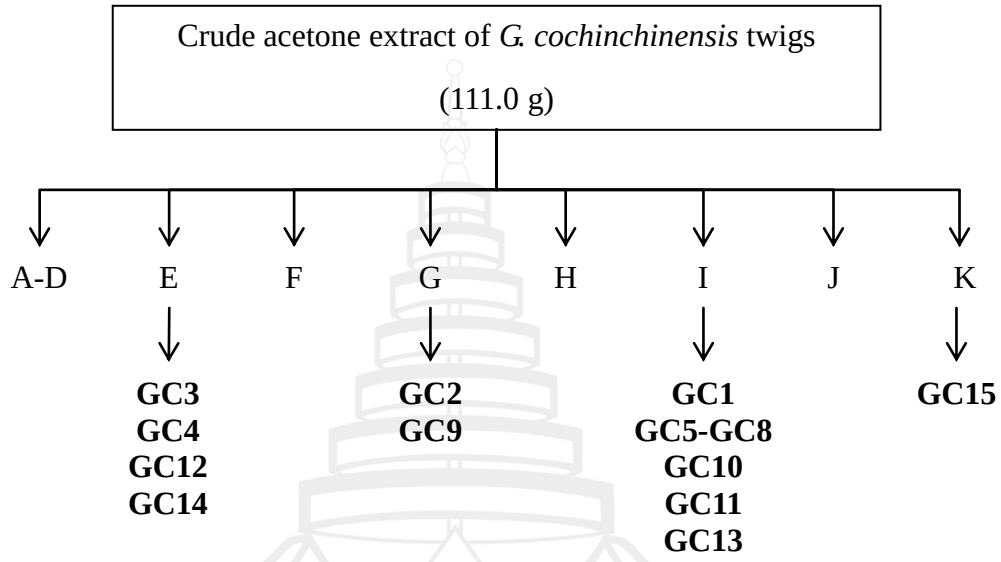


Figure 2.9 Isolation of Compounds **GC1-GC10**

Compound **GC1** (Glycosmisacridone): Yellow solid; mp 235-236°C; $[\alpha]_D^{25}$ +19 (*c* 0.1, MeOH); UV λ_{max} (MeOH): 272, 295 and 404 nm; IR (neat) ν_{max}: 3305 (O–H stretching) and 1639 (C=O stretching) cm^{-1}; For ^1H NMR (acetone-d_6, 400 MHz) and ^{13}C NMR (acetone-d_6, 100 MHz) spectral data see Table 3.1; EST-TOF-MS *m/z* 310.1077 $[M+H]^+$ (calcd for $C_{18}H_{16}NO_5$, 310.1079).

Compound **GC2** (des-*N*-Methylnoracronycine): White solid; mp 249-250°C; UV λ_{max} (MeOH): 204, 223, 251, 272, 294 and 404 nm; IR (neat) ν_{max}: 3304 (O–H stretching) and 1644 (C=O stretching) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 14.61 (1H, *s*, 1-OH), 10.34 (1H, *br s*, 10-NH), 8.28 (1H, *d*, *J* = 8.0 Hz, H-8), 7.73 (1H, *m*, H-6), 7.72 (1H, *m*, H-5), 7.32 (1H, *m*, H-7), 6.98 (1H, *d*, *J* = 10.0 Hz, H-1′), 6.07 (1H, *s*, H-2), 5.70 (1H, *d*, *J* = 10.0 Hz, H-2′), 1.47 (6H, *s*, Me-4′ and Me-5′).

Compound **GC3** (Noracronycine): Yellow solid; mp 201-202°C; UV λ_{max} (MeOH): 206, 226, 255, 283, 312 and 410 nm; IR (neat) ν_{max}: 3200 (O–H stretching)

and 1715 (C=O stretching) cm^{-1}. For ^1H NMR ($CDCl_3$, 400 MHz) δ 14.70 (1H, *s*, 1-OH), 8.38 (1H, *d*, *J* = 8.0 Hz, H-8), 7.72 (1H, *m*, H-6), 7.43 (1H, *d*, *J* = 8.8 Hz, H-5), 7.31 (1H, *m*, H-7), 6.56 (1H, *d*, *J* = 9.6 Hz, H-1′), 6.27 (1H, *s*, H-2), 5.50 (1H, *d*, *J* = 9.6 Hz, H-2′), 3.91 (3H, *s*, 10-*N*Me).1.53 (6H, *s*, Me-4′ and Me-5′).

Compound **GC4** (Ataphyllidine): See compound **AM5**

Compound **GC5** (1-Hydroxy-3,4-dimethoxy-*N*-methylacridone):

See compound **GP9**

Compound **GC6** (γ-Fagarine): See compound **GP7**

Compound **GC7** (Skimmianine): See compound **GP8**

Compound **GC8** (Kokusaginine): White solid; mp 160-162°C; UV λ_{max} (MeOH): 244, 250, 294, 308, 320 and 336 nm; IR (neat) ν_{max}: 1589, 1508 and 1483 (C=C ring stretching), 1092 (C–O stretching) cm^{-1}; For ^1H NMR ($CDCl_3$, 400 MHz) δ 7.56 (1H, *d*, *J* = 2.4 Hz, H-2′), 7.47(1H, *s*, H-5), 7.33 (1H, *s*, H-8), 7.04 (1H, *d*, *J* = 2.4 Hz, H-7), 4.43 (3H, *s*, 4-OMe), 4.02 (6H, *s*, 6-OMe and 7-OMe).

Compound **GC9** (Integriquinolone): Light yellow viscous oil; UV λ_{max} (MeOH): 206, 218, 261 and 291 nm; IR (neat) ν_{max}: 3397 (O–H stretching) and 1712 (C=O stretching) cm^{-1}; For ^1H NMR ($CDCl_3$, 400 MHz) δ 7.63 (1H, *dd*, *J* = 8.4, 2.0 Hz, H-7), 7.55 (1H, *d*, *J* = 2.0 Hz, H-5), 6.93 (1H, *d*, *J* = 8.4 Hz, H-8), 6.09 (1H, *s*, H-3), 3.94 (3H, *s*, 4-OMe), 3.88 (3H, *s*, 1-*N*Me).

Compound **GC10** (Glycosmisindole): Light yellow viscous oil; UV (MeOH) λ_{max} : 223, 271, 280 and 291 nm; IR (neat) ν_{max}: 3342 (O–H stretching) cm^{-1}; For ^1H NMR (400 MHz, $CDCl_3$) and ^{13}C NMR (100 MHz, $CDCl_3$) spectral data see Table 3.32; EST-TOF-MS *m/z* 286.1800 $[M+H]^+$ (calcd for $C_{18}H_{24}NO_2$, 286.1807).

Compound **GC11** (Scopoletin): See compound **CE3**

Compound **GC12** (Demethyl suberosin): See compound **AM12**

Compound **GC13** (Marmisn): See compound **AM14**

Compound **GC14** (Bergapten): See compound **FL5**

Compound **GC15** (Mexoticin): White solid; mp 182-184°C; $[\alpha]_D^{28}$ +39.8 (c 0.01, $CHCl_3$); UV λ_{max} (MeOH): 207, 260 and 327 nm; IR (neat) ν_{max}: 3424 (O–H stretching) and 1716 (C=O stretching) cm^{-1}; For ^1H NMR ($CDCl_3$, 400 MHz) δ 8.00 (1H, *d*, *J* = 9.6 Hz, H-4), 6.35 (1H, *s*, H-6), 6.16 (1H, *d*, *J* = 9.6 Hz, H-3), 3.61 (1H, *m*,

H-2′), 3.03 (1H, *d*, *J* = 14.0 Hz, H-1′a), 2.89 (1H, *m*, H-1′b), 1.60 (6H, *s*, Me-4′ and Me-5′).

2.4 Biological Assays

2.4.1 Cytotoxic Assay

The procedures for cytotoxic assay were performed by the resazurin microplate assay as described by O'Brien, Wilson, Orton and Pognan (2000). Ellipticine was the reference substance in this study for KB and NCI-H187, respectively, whereas doxorubicin was the reference substance.

2.4.2 Antimalarial Assay

Antimalarial activity was evaluated against *Plasmodium falciparum* (K1, multidrug resistant), using the method of Trager and Jensen (1976). Quantitative assessment of in *vitro* malarial activity was determined by means of the microculture radioisotope technique based on the method described by Desjardins et al., 1979. The inhibitory concentration (IC_{50}) represented the concentration that caused 50% reduction in parasite growth, which was indicated by the in vitro uptake of [^{3}H]-hypoxanthine by *P. falciparum*. The standard compound was dihydroartemisinin.

2.4.3 Antibacterial Assay

Escherichia coli TISTR 780, *Salmonella typhimurium* TISTR 292, and *Staphylococcus aureus* TISTR 1466 were obtained from the Microbiological Resources Center of the Thailand Institute of Scientific and Technological Research, whereas MRSA SK1 was obtained from the Department of Microbiology, Faculty of Science, Prince of Songkla University, Thailand. The minimum inhibitory concentrations (MICs) were determined by a 2-fold serial dilution method using Mueller-Hinton broth, according to the Clinical and Laboratory Standards Institute recommendations (CLSI, 2002). The test substances were dissolved in DMSO. Vancomycin and gentamycin were used as standard drugs.

2.4.4 Antimycobacterial Assay

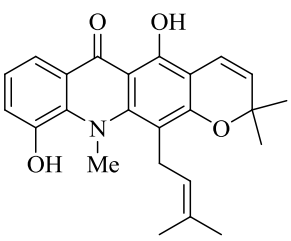
Antimycobacterial activity was evaluated against *Mycobacterium tuberculosis* (H37Ra strain) employing the green fluorescent protein microplate assay by Changsen, Franzblau and Palittapongarnpim (2003). The reference drug is isoniazid.

CHAPTER 3

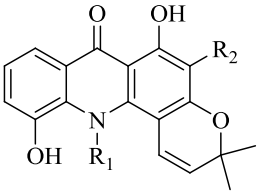
RESULTS AND DISCUSSIONS

3.1 Isolated Compounds from the Roots of *A. monophylla*

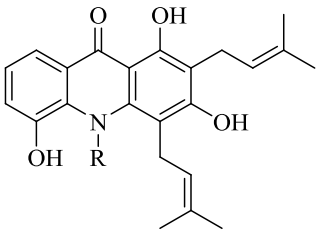
The air-dried roots of *A. monophylla* (687.09 g) were extracted with acetone over a period of three days at room temperature. This extract (14.69 g) was subjected to chromatography and/or recrystallization to yield eight known acridone alkaloids: cycloatalaphylline A (**AM1**) (Chukaew et al., 2008), *N*-methylataphyllinine (**AM2**) (Auzi, Hartley, Waigh & Waterman, 1996), *N*-methylataphylline (**AM3**) (Govindachari, Viswannathan, Pai, Ramachandran, & Subramanium, 1970), atalaphylline (**AM4**) (Govindachari et al., 1970), atalaphyllidine (Yahayu et al., 2011) (**AM5**), buxifoliadine C (**AM6**) (Wu & Chen, 2000), citrusinine I (**AM7**) (Kawaii et al., 1999) and citrusinine II (**AM8**) (Weniger et al., 2001), six known coumarins: umbelliferone (**AM9**) (Ngadjui, Mouncherou, Ayafor, Sondengam & Tillequin, 1991), aureptene (**AM10**) (Monoz, Toress & Cassels, 1982), 7-*O*-geranylscopoletin (**AM11**) (Torres, Monache & Marini-Bettolo, 1979), demethylsuberosin (**AM12**) (Steck, 1971), xanthyletin (**AM13**) (Cazal et al., 2009) and marmisn (**AM14**) (Jimenez, Grande, Anaya, Torres & Grande, 2000), and a known limonoid compound: cycloepiatalantin (**AM15**) (Dreyer & Bennew, 1976). All compounds were characterized by spectroscopic methods as well as comparison of their NMR spectral data with reported values.



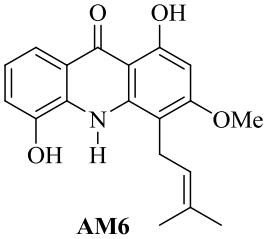
AM1



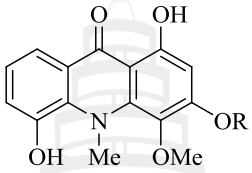
AM2: R_1 = Me, R_2 = prenyl
AM5: R_1 = R_2 = H



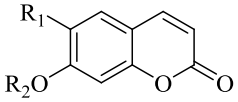
AM3: R = Me
AM4: R = H



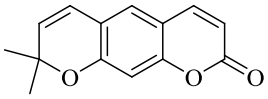
AM6



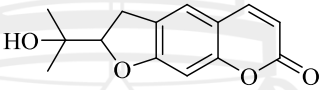
AM7: R = Me
AM8: R = H



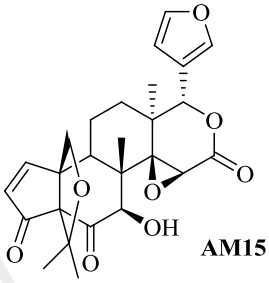
AM9 : R_1 = R_2 = H
AM10: R_1 = H, R_2 = geranyl
AM11: R_1 = OMe, R_2 = geranyl
AM12: R_1 = prenyl, R_2 = H



AM13



AM14

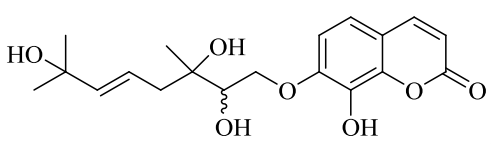


AM15

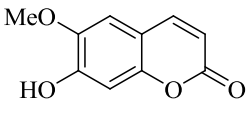
3.2 Isolated Compounds from the Fruits, Stems and Roots of *C. excavata*

Three parts of *C. excavata* (fruits, stems and roots) were investigated for chemical constituents. *C. excavata* fruits (250.00 g) were extracted with hexanes and CH_2Cl_2, respectively, over a period of three days at room temperature. The hexanes and CH_2Cl_2 extracts were combined (987.70 mg) and purified by chromatography and/or recrystallization to give a new coumarin (**CE1**) together with two known coumarins: scopoletin (**CE3**) (Cassady, Ojima, Chang & McLaughlin, 1979) and seselin (**CE4**) (Ito et al., 2000), a known benzene derivative: 3,4-dimethoxybenzaldehyde (**CE34**) (Koning, Michael & Rousseau, 1997), a known monoterpenoid: (*R*)-6-hydroxy-3-(2-hydroxypropan-2-yl)-6-methylcyclohex-2-enone (**CE36**) (Tan, Shanhao & Dayuan, 2005), and a well-known steroid: *β*-sitostenone

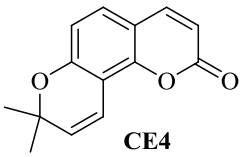
(**CE38**) (Prachayasittikul et al., 2009). All compounds were characterized by spectroscopic methods as well as comparison of their NMR spectral data with reported values.



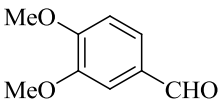
CE1



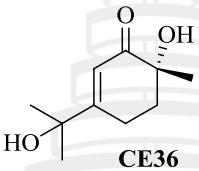
CE3



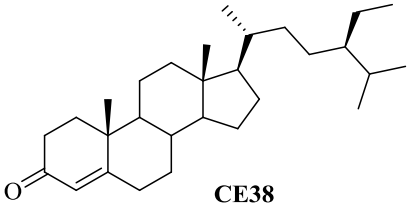
CE4



CE34



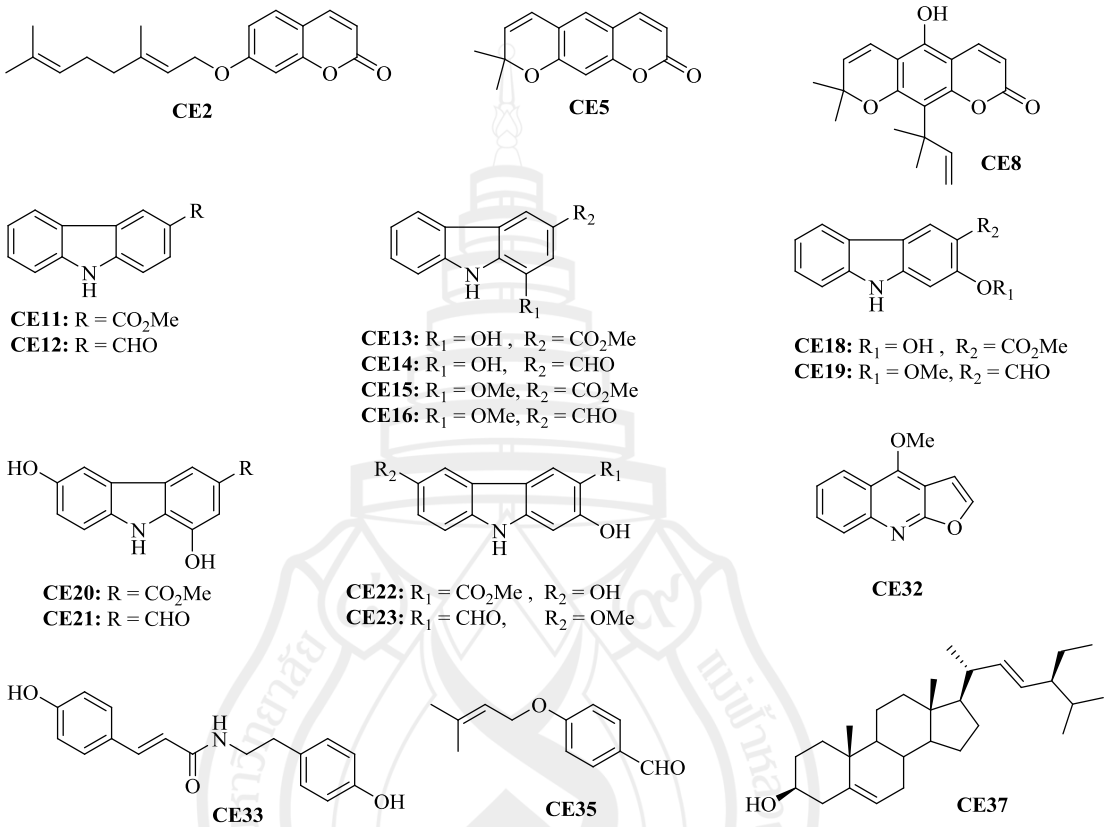
CE36



CE38

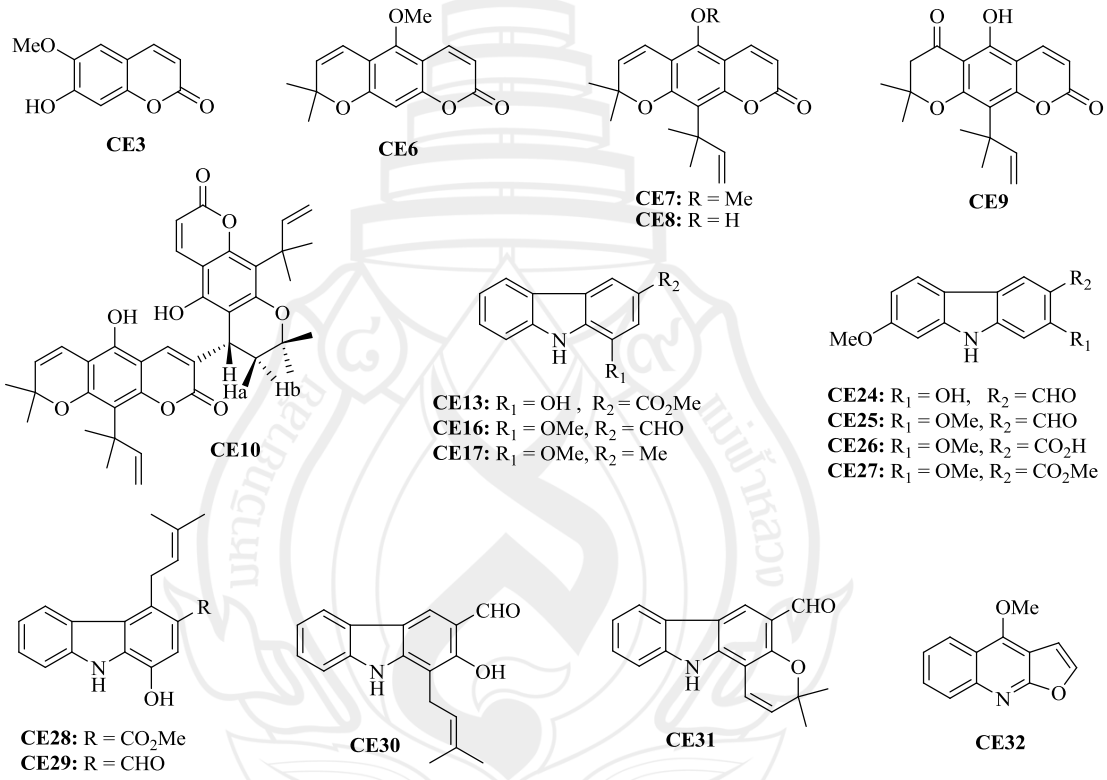
The stems of *C. excavata* (3.20 kg) were extracted with EtOAc over a period of three days at room temperature. Removal of the the solvent under reduced pressure provided EtOAc extract (70.50 g). This extracted was applied to chromatography and/or recrystallization to afford a novel carbazole alkaloid (**CE22**) along with three known coumarins: aureptene (**CE2**) (Monoz et al., 1982), xanthyletin (**CE5**) (Cazal et al., 2009) and nordentatin (**CE8**) (Huang, Wu, P. L. & Wu, T. S., 1997), 11 known carbazole alkaloids: methyl carbazole-3-carboxylate (**CE11**) (Wu, Huang, Wu & Teng, 1996), 3-formylcarbazole (**CE12**) (Sunthitikawinsakul et al., 2003), clauszoline I (**CE13**) (Liger et al., 2007), *O*-demethylmurrayanine (**CE14**) (Ito et al., 2000), mukonine (**CE15**) (Liger et al., 2007), murrayanine (**CE16**) (Sunthitikawinsakul et al., 2003), mukonidine (**CE18**) (Wu, T. S., Huang, Wu, P. L. & Kuoh, 1999), *O*-methylmukonal (**CE19**) (Kongkathip, N. & Kongkathip, B., 2009), methyl 1, 6-dihydroxy-9*H*-carbazole-3-carboxylate (**CE20**) (Borger & Knolker, 2008), clausine Z (**CE21**) (Potterat et al., 2005) and lansine (**CE23**) (Wu et al., 1996), a known furanoquinoline: dictamine (**CE32**) (Terezan et al., 2010), a known amide derivative: *N*-(*p-trans*-coumaronyl)tyramine (**CE33**) (Tomosaka et al., 2008), a known benzene derivative: 4-(3-methylbut-2-enyloxy)benzaldehyde (**CE35**) (Fernández-Martínez, Bobadilla, Morales-Ríos, Muriel & Pérez-Alvarez, 2007), and a well-known steroid, stigmasterol (**CE37**) (De-Eknamkul & Potduang, 2003). All compounds were

characterized by spectroscopic methods as well as comparison of their NMR spectral data with reported values.



The air-dried roots (3.80 kg) of *C. excavata* were extracted with acetone over the periods of three days at room temperature. Removal of the solvent under reduced pressure provided acetone extract (288.02 g) which was purified by chromatography and/or recrystallization to yield six known coumarins: scopoletin (**CE3**) (Cassady et al., 1979), xanthoxyletin (**CE6**) (Wu & Furukawa, 1982), dentatin (**CE7**) (Su et al., 2009), nordentatin (**CE8**) (Huang et al., 1997), clausenidin (**CE9**) (Huang et al., 1997), binorponcitrin (**CE10**) (Huang et al 1997), 11 known carbazole alkaloids: clauszoline I (**CE13**) (Liger et al., 2007), murrayanine (**CE16**) (Sunthitikawinsakul et al., 2003), murrayafoline A (**CE17**) (Furukawa, Wu, Ohta & Kuoh, 1985), 2-hydroxy-3-formyl-7-methoxycarbazole (**CE24**) (Ruangrungsi & Ariyaprayoon, 1990), 3-formyl-2,7-dimethoxycarbazole (**CE25**) (Ruangrungsi & Ariyaprayoon, 1990),

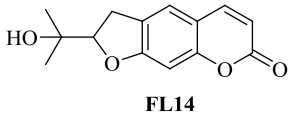
clauszoline J (**CE26**) (Ito, Katsuno & Furukawa, 1998), clausine H (**CE27**) (Wu, T. S., Huang, Wu, P. L. & Lee, 1994), clausine F (**CE28**) (Wu et al., 1994), *O*-demethylekeberginine (**CE29**) (Wu et al., 1994), heptaphylline (**CE30**) (Ruangrungsi & Ariyaprayoon, 1990) and murrayacine (**CE31**) (Ray & Chakraborty, 1976), and a known furanoquinoline: dictamine (**CE32**) (Terezan et al., 2010). All compounds were characterized by spectroscopic methods as well as comparison of their NMR spectral data with reported values.



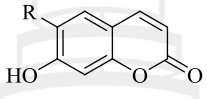
3.3 Isolated Compounds from the Fruits, Roots and Twigs of *F. lucida*

F. lucida fruits (300.00 g) were extracted with acetone over a period of three days at room temperature. This extract (12.12 g) was subjected to chromatography and/or recrystallization to obtain three known coumarins: marmisn (**FL14**) (Jimenez et al., 2000), umbelliferone (**FL16**) (Ngadjui et al., 1991) and scopoletin (**FL17**)

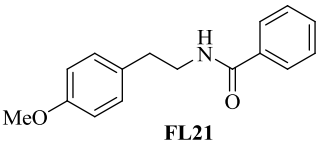
(Cassady et al., 1979), two known amide derivatives: *N*-[2-(4-methoxyphenyl)-ethyl]benzamide (**FL 21**) (Vargas, Toledo & Comasseto, 2010) and (2*E*,4*E*)-deca-2,4-dienoic acid 2-phenylethyl amide (**FL23**) (Greger, 1987), and two well-known steroids: stigmasterol (**FL29**) (De-Eknamkul & Potduang, 2003) and *β*-sitostenone (**FL30**) (Prachayasittikul et al., 2009). All compounds were characterized by spectroscopic methods as well as comparison of their NMR spectral data with reported values.



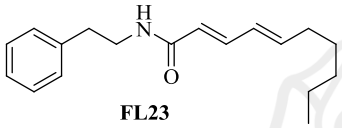
FL14



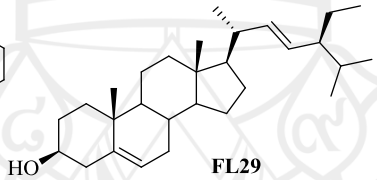
FL16: R = H
FL17: R = OMe



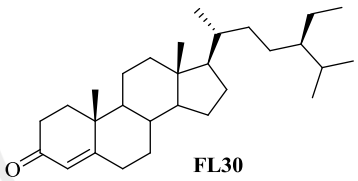
FL21



FL23



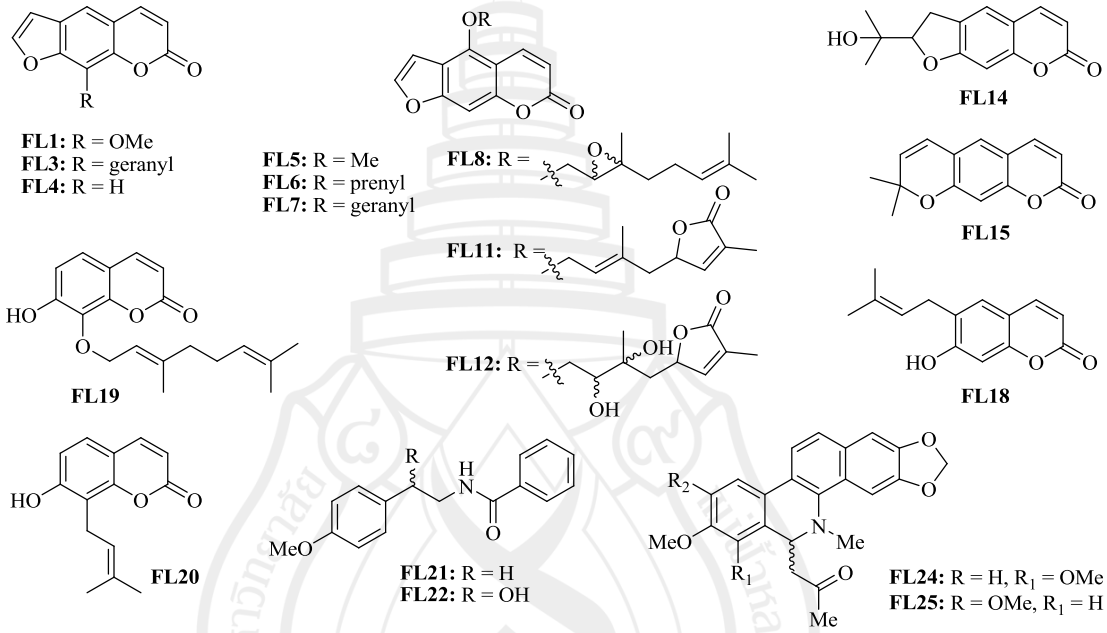
FL29



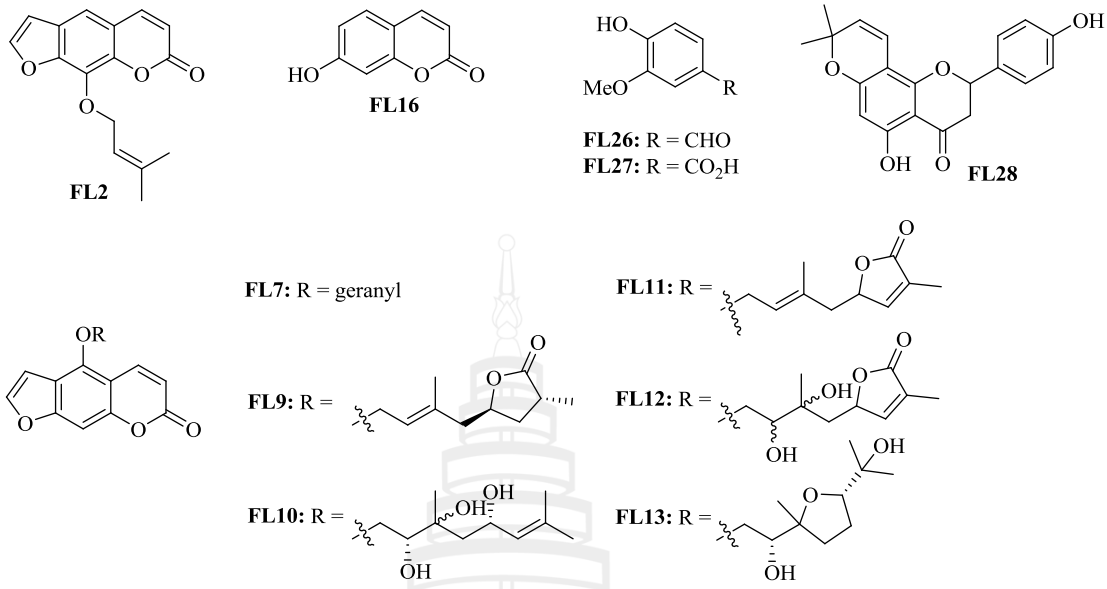
FL30

Air-dried roots of *F. lucida* (7.54 kg) were extracted with acetone over the period of three days at room temperature. Removal of the solvent under reduced pressure provided the acetone extract (200.54 g). This extract was isolated by chromatography and/or recrystallization to yield a new furanocoumarin (**FL8**) together with 13 known coumarins: xanthotoxin (**FL1**) (Masuda, Takasugi & Anetai, 1998), 8-geranyloxypsolaren (**FL3**) (Miyake et al., 1999), psolaren (**FL4**) (Masuda *et al.*, 1998), bergapten (**FL5**) (Masuda et al., 1998), isoimperatorin (**FL6**) (Masuda et al., 1998), bergamottin (**FL7**) (Girennavar, Poulose, Jayaprakasha, Bhat & Patil, 2006), anisolactone (**FL11**) (Lakshmi et al., 1984), 2″,3″-dihydroxyanisolactone (**FL12**) (Phuwapraisirisan et al., 2007), marmisn (**FL14**) (Jimenez et al., 2000), xanthyletin (**FL15**) (Cazal et al., 2009), demethylsuberosin (**FL18**) (Steck, 1971), 8-geranyloxy-7-hydroxycoumarin (**FL19**) (Cravotto, Chimichi, Robaldo & Boccalini, 2003) and osthenol (**FL20**) (Magolan & Coster 2009), two known amide derivatives: *N*-[2-(4-methoxyphenyl)ethyl]benzamide (**FL 21**) (Vargas et al., 2010) and

tembamide (**FL22**) (Kamal et al., 2004), and two known phenanthridine alkaloids: 6-acetonyldihydrochelerythrine (**FL24**) (Julian & Delgado, 2001) and 8-acetonyldihydronitidine (**FL25**) (Nissanka, et al., 2001). All compounds were characterized by spectroscopic methods as well as comparison of their NMR spectral data with reported values.

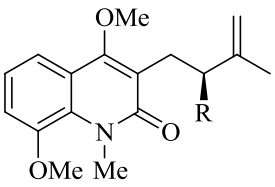


Air-dried twigs of *F. lucida* (3.14 kg) were extracted with acetone over a period of three days at room temperature. The acetone extract (35.44 g) was subjected to chromatography and/or recrystallization to give two new furanocoumarins (**FL9** and **FL10**) along with six known coumarins: imperatorin (**FL2**) (Masuda et al., 1998), bergamottin (**FL7**) (Girennavar et al., 2006), anisolactone (**FL11**) (Lakshmi, Prakash, Raj, Kapil & Popli, 1984), 2″,3″-dihydroxyanisolactone (**FL12**) (Phuwapraisirisan et al., 2007), feroniellin A (**FL13**) (Phuwapraisirisan et al., 2006), umbelliferone (**FL16**) (Ngadjui et al., 1991), two know benzene derivatives: vanillin (**FL26**) (Tan et al., 2004) and vanillic acid (**FL27**) (Tan et al., 2004), and a known flavanone: citflavanone (**FL28**) (Wu, 1989). All compounds were characterized by spectroscopic methods as well as comparison of their NMR spectral data with reported values.

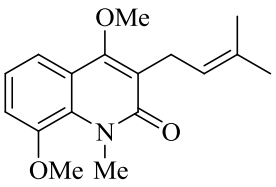


3.4 Isolated Compounds from the Fruits of *G. pentaphylla*

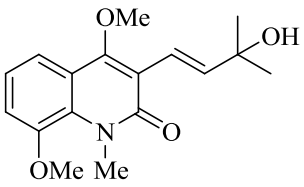
The fruits of *G. pentaphylla* (378.99 g) were extracted with 50% CH_2Cl_2–MeOH over a period of three days at room temperature. The extract (30.76 g) was subjected to chromatography and/or recrystallization to obtain a new quinolone alkaloid (**GP1**) together with three known quinolones: acutifolin (**GP2**) (Arruda, Fernandes, Silva, Vieira & Pirani, 1992), 3-(3′,3′-dimethylallyl)-4,8-dimethoxy-*N*-methyl-quinolin-2-one (**GP3**) (Chakravarty, Sarkar, Masuda & Shiojima, 1999), glycocitlone C (**GP4**) (Kobayashi & Harayama, 2009), a known quinazolinone: arborine (**GP5**) (Bowen, Perera & Lewis 1978), three known pyranoquinolines: dictamine (**GP6**) (Terezan et al., 2010), *γ*-fagarine (**GP7**) (Terezan et al., 2010) and skimmianine (**GP8**) (Chakravarty et al., 1999), and two known acridone alkaloids: 1-hydroxy-3,4-dimethoxy-*N*-methylacridone (**GP9**) (Baudouin, Tillequin & Koch, 1985) and arborinine (**GP10**) (Pal, Kunda, Bandyopadhyay & Adhikari, 2011). All compounds were characterized by spectroscopic methods as well as comparison of their NMR spectral data with reported values.



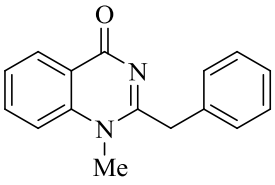
GP1: R = OOH
GP2: R = OH



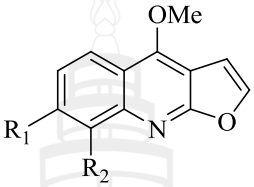
GP3



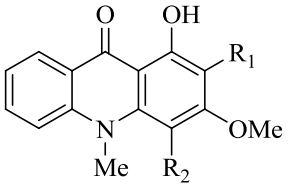
GP4



GP5



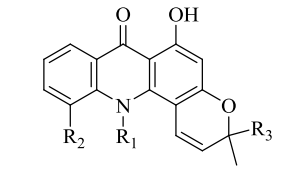
GP6: $R_1 = R_2 = H$
GP7: $R_1 = H, R_2 = OMe$
GP8: $R_1 = R_2 = OMe$



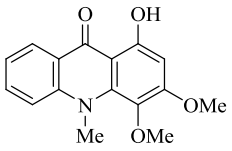
GP9: $R_1 = H, R_2 = OMe$
GP10: $R_1 = OMe, R_2 = H$

3.5 Isolated Compounds from the Fruits of *G. cochinchinensis*

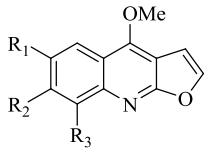
Air-dried twigs of *G. cochinchinensis* (8.77 kg) were extracted with acetone over a period of three days at room temperature. The acetone extract (111.04 g) was purified by chromatography and/or recrystallization to yield a new acridone alkaloid (**GC1**) and a new indole alkaloid (**GC10**) along with four known acridones: des-*N*-methylnoracronycine (**GC2**) (Govindachari, Pai & Subramaniam, 1966), noracronycine (**GC3**), atalaphyllidine (Yahayu et al., 2011) (**GC4**), 1-hydroxy-3,4-dimethoxy-*N*-methylacridone (**GC5**) (Baudouin et al., 1985), three furanoquinolines: *γ*-fagarine (**GC6**) (Terezan et al., 2010), skimmianine (**GC7**) (Chakravarty et al., 1999) and kokusaginine (**GC8**) (Cardoso-Lopes et al., 2010), a known quinolone alkaloid: integriquinolone (**GC9**) (Ishii, Koyama, Chen, Lu & Ishikawa, 1992) and five known coumarins: scopoletin (**GC11**) (Cassady et al., 1979), demethylsuberosin (**GC12**) (Steck, 1971), marmisn (**GC13**) (Jimenez et al., 2000), bergapten (**GC14**) (Masuda et al., 1997), mexoticin (**GC15**) (Chakraborty & Chowdhury, 1967). All compounds were characterized by spectroscopic methods as well as comparison of their NMR spectral data with reported values.



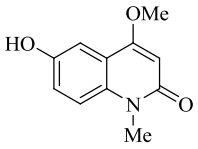
GC1: R = H, R_1= H, R_2 = CH_2OH
GC2: R = H, R_1 = H, R_2 = Me
GC3: R = Me, R_1 = H, R_2 = Me
GC4: R = H, R_1 = OH, R_2 = Me



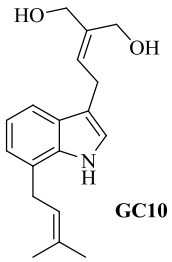
GC5



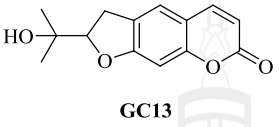
GC6: R_1 = R_2 = H, R_3 = OMe
GC7: R_1 = H, R_2 = R_3 = OMe
GC8: R_1 = R_2 = OMe, R_3 = H



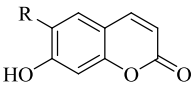
GC9



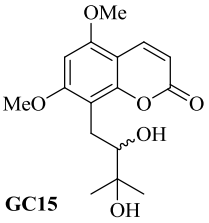
GC10



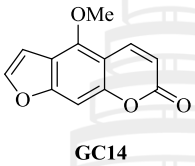
GC13



GC11: R = OMe
GC12: R = prenyl



GC15

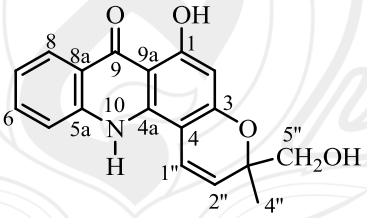


GC14

3.6 Structural Elucidation of Selected Compounds

3.6.1 Acridone Alkaloids

3.6.1.1 Compound **GC1** (Glycosmisacridone)



Compound **GC1** was isolated as yellow solid. It showed a $[M+H]^+$ ion at *m/z* 310.1077 (calcd for $C_{18}H_{16}NO_4$, 310.1079) in the ESI-TOF-MS spectrum. Analysis of its NMR spectroscopic data including, COSY, HMQC, and HMBC spectra, allowed unambiguous assignment of all proton and carbon signals. The ^{1}H NMR (Table 3.1) displayed a signal for a N*H* at δ 10.27 (*br s*), a set of signals consistent with a 1,2-disubstituted benzene ring at δ_H 8.13 (*d*, *J* = 8.0 Hz, H-8), 7.59 (*m*, H-6), 7.58 (*m*, H-5), and 7.18 (*m*, H-7), an aromatic proton at δ_H 5.91 (s, H-2),

and a hydrogen bonded hydroxyl group at δ_H 14.48 (*s*, 1-OH). These data suggested that **GC1** was a 1,3,4-trisubstituted acridone nucleus. The ^{1}H NMR spectrum also showed signals for two olefinic protons of a pyranyl unit [δ_H 6.94 (*d*, *J* = 10.0 Hz, H-1″) and 5.54 (*d*, *J* = 10.0 Hz, H-2″)] which was beared one methyl group (δ_H 1.28, *s*, H-4″) and one oxymethylene group [δ_H 3.55 (*dd*, *J* = 11.5, 5.0 Hz) and 3.46 (*dd*, *J* = 11.5, 5.0 Hz), H-5″] at C-3″. The pyranyl ring was placed at C-4, 3 of the acridone nucleus because of the HMBC correlation of H-1″ (δ_H 6.94) with C-3 (δ_C 160.8), C-4 (δ_C 98.8) and C-4a (δ_C 139.0) (Table 3.1). Lastly, the proton NMR signal at δ_H 4.08 (*m*) was identified to a hydroxy proton (5″-OH) because this signal showed no cross peaks with any carbon signal in the HMQC spectrum. Therefore, compound **GC1** was a new compound and name as glycosmisacridone.

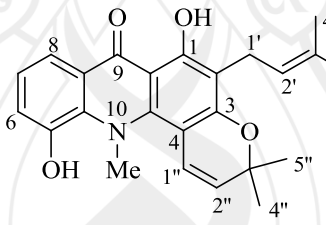
Table 3.1 NMR Spectroscopic Data of **GC1** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	165.6	–	–
2	97.4	5.91 (*s*)	C-1, C-3, C-4, C-9a
3	160.8	–	–
4	98.8	–	–
4a	139.0	–	–
5	118.1	7.58 (*m*)	C-5a, C-7, C-8a
5a	141.0	–	–
6	134.7	7.59 (*m*)	C-5a, C-7, C-8
7	122.6	7.18 (*m*)	C-5, C-6
8	126.1	8.13 (*d*, 8.0)	C-5a, C-6, C-9
8a	122.6	–	–
9	182.1	–	–
9a	105.0	–	–
1″	117.7	6.94 (*d*, 10.0)	C-3, C-3′, C-4, C-4a
2″	123.9	5.54 (*d*, 10.0)	C-3′, C-4

Table 3.1 (continued)

Position	δ_C	δ_H *(mult., J* in Hz)	HMBC
3″	81.1	–	–
4″	23.1	1.28 (*s*)	C-2′, C-3′, C-5′
5″	68.1	3.55 (*dd*, 11.5, 5.0)	C-2′
		3.59 (*dd*, 11.5, 5.0)	
1-OH	–	14.48 (*s*)	–
9-NH	–	10.27 (*br s*)	C-4a, C-5a
5″-OH	–	4.08 (*m*)	–

3.6.1.2 Compound **AM2** (*N*-Methylataphyllinine)



Compound **AM2** ($C_{24}H_{25}NO_4$) was isolated as orange solid. The IR spectrum displayed the hydroxyl and chelated carbonyl functionalities at 3207 and 1634 cm^{-1}, respectively. The UV spectrum showed the maximum absorbances at 211, 239, 292, 324, 347 and 422 nm, suggesting that compound **AM2** contained acridone skeleton (Chukaew et al., 2008). The ^{1}H NMR spectral data of **AM2** (Table 3.2) exhibited a set of ABC-type aromatic protons [δ_H 7.81 (*d*, *J* = 8.0 Hz, H-8), 7.21 (*d*, *J* = 7.6 Hz, H-6) and 7.20 (*dd*, *J* = 8.0, 7.6 Hz, H-7)], one *N*-Me (δ_H 3.83 (*s*)), one chelated hydroxyl proton (δ_H 14.78) and one hydroxyl proton (δ_H 9.73). Furthermore, the presence of a 2,2-dimethylpyrano unit [δ_H 6.76 (*d*, *J* = 9.6 Hz, H-1″), 5.69 (*d*, *J* = 9.6 Hz, H-2″) and 1.54 (*s*, Me-4″ and -5″)] and a prenyl unit [δ_H 5.28 (*br t*, *J* = 7.2 Hz, H-2′), 3.35 (*br d*, *J* = 7.2 Hz, H-1′), 1.82 (*s*, Me-4′) and 1.66 (*s*, Me-5′)] were observed

in the ^{1}H NMR spectrum. The dimethylpyrano unit was fused on C-3/C-4 of the acridone skeleton due to the ^{3}J HMBC correlations of H-1″ (δ_H 6.76) with C-3 (δ_C 158.9) and C-4a (δ_C 145.0) whereas the prenyl unit was placed on C-2 because of the ^{3}J HMBC correlations of H-1′ (δ_H 3.35) with C-1 (δ_C 161.3) and C-3 (δ_C 158.9). Therefore, compound **AM2** was deduced as *N*-methylataphyllinine (Auzi et al., 1996).

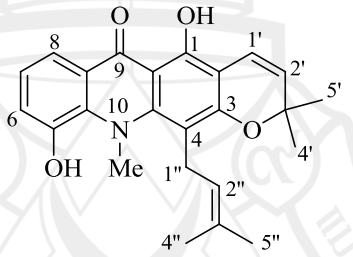
Table 3.2 NMR Spectroscopic Data of **AM2** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
1	161.3	–	–
2	106.4	–	–
3	158.9	–	–
4	101.9	–	–
4a	145.0	–	–
5	148.0	–	–
5a	137.0	–	–
6	119.2	7.21 (*d*, 7.6)	C-5, C-5a, C-8
7	123.1	7.20 (*dd*, 8.0, 7.6)	C-5, C-8a
8	116.2	7.81 (*d*, 8.0)	C-5a, C-6, C-9
8a	124.5	–	–
9	182.0	–	–
9a	109.5	–	–
1′	21.1	3.35 (*br d*, 7.2)	C-1, C-2, C-2′, C-3, C-3′, C-9a
2′	122.6	5.28 (*br t*, 7.2)	C-2, C-4′, C-5′
3′	130.0	–	–
4′	17.1	1.82 (*s*)	C-2′, C-3′, C-4′
5′	25.0	1.66 (*s*)	C-2′, C-3′, C-5′
1″	121.1	6.76 (*d*, 9.6)	C-3, C-3″, C-4, C-4a
2″	123.7	5.69 (*d*, 9.6)	C-3″, C-4, C-4″
3″	76.5	–	–

Table 3.2 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
4″/5″	26.5	1.54 (*s*)	C-2″, C-3″, C-5″/C-4″
1-OH	–	14.78 (*s*)	–
5-OH	–	9.73 (*br s*)	–
9-NMe	48.0	3.83 (*s*)	C-4a, C-5a

3.6.1.3 Compound **AM1** (Cycloatalaphylline A)

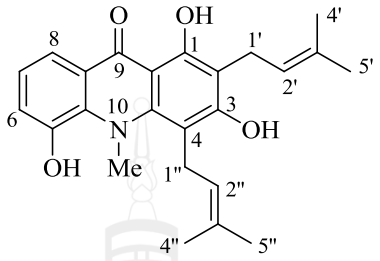


Compound **AM1** ($C_{24}H_{25}NO_4$) was isolated as yellow solid. The ^{1}H NMR spectral data of **AM1** (Table 3.3) were closely related to those of **AM2** except for the location of the prenyl and the 2,2-dimethylpyrano units. Compound **AM1** showed ^3J HMBC correlations (Table 3.3) of H-1″ (δ_H 3.51) with C-3 (δ_C 157.5) and C-4a (150.2) suggesting that the prenyl unit was located on C-4 of the acridone framework whereas the 2,2-dimethylpyrano unit was placed on C-2/C-3 due to the ^3J HMBC correlation of H-1′ (δ_H 6.73) with C-1 (δ_C 158.9) and C-3 (δ_C 157.5). Therefore, compound **AM1** was deduced as cycloatalaphylline A (Chukaew et al., 2008).

Table 3.3 NMR Spectroscopic Data of **AM1** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
1	158.9	–	–
2	102.9	–	–
3	157.5	–	–
4	108.2	–	–
4a	150.2	–	–
5	148.9	–	–
5a	137.0	–	–
6	119.7	7.30 (*d*, 8.0)	C-5, C-5a, C-8
7	122.9	7.18 (*t*, 8.0)	C-5, C-8, C-8a
8	116.2	7.75 (*d*, 8.0)	C-5a, C-6, C-9
8a	124.6	–	–
9	182.6	–	–
9a	106.9	–	–
1′	115.4	6.73 (*d*, 9.6)	C-1, C-2, C-3, C-3′
2′	123.7	5.71 (*d*, 9.6)	C-2, C-3′
3′	77.6	–	–
4′/5′	27.4	1.48 (*s*)	C-2′, C-3′, C-5′/C-4′
1″	25.5	3.51 (*br d*, 6.4)	C-2′, C-3, C-3′, C-4, C-4a
2″	123.7	5.35 (*m*)	C-2′, C-4, C-4′, C-5′
3″	130.7	–	–
4″	17.1	1.79 (*s*)	C-2′, C-3′, C-4′
5″	24.7	1.70 (*s*)	C-2′, C-3′, C-5′
1-OH	–	14.68 (*s*)	–
5-OH	–	9.73 (*br s*)	–
10-NMe	48.0	3.83 (*s*)	C-4a, C-5a

3.6.1.4 Compound **AM3** (*N*-Methylataphylline)



Compound **AM3** ($C_{24}H_{27}NO_4$) was isolated as yellow solid. The ^{1}H NMR spectral data (Table 3.4) was similar to that of **AM2** except that compound **AM3** showed an additional prenyl group [δ_H 5.26 (*m*, H-2′), 3.45 (*br d*, *J* = 6.8 Hz, H_2-1′), 1.80 (*s*, Me-4′) and 1.67 (*s*, Me-5′)] and a hydroxyl [δ_H 7.97 (*br s*, 3-OH) instead of 2,2-dimethylpyrano unit at C-2/C-3. Therefore, **AM3** was assigned as *N*-methylataphylline (Govindachari et al., 1970).

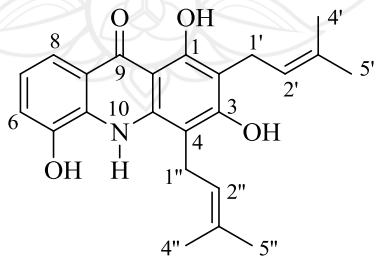
Table 3.4 NMR Spectroscopic Data of **AM3** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
1	159.4	–	–
2	107.1	–	–
3	161.1	–	–
4	107.4	–	–
4a	148.8	–	–
5	148.6	–	–
5a	138.2	–	–
6	119.4	7.27 (*dd*, 8.0, 1.2)	C-5, C-5a, C-7, C-8
7	123.0	7.16 (*t*, 8.0)	C-5, C-6, C-8, C-8a
8	116.0	7.77 (*dd*, 8.0, 1.2)	C-5a, C-6, C-9
8a	124.1	–	–

Table 3.4 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
9	182.6	–	–
9a	109.2	–	–
1′	21.1	3.45 (*br d*, 6.8)	C-1, C-2, C-2′, C-3, C-3′
2′	122.2	5.26 (*m*)	C-2, C-1′, C-4′, C-5′
3′	131.3	–	–
4′	16.9	1.80 (*s*)	C-2′, C-3′, C-5′
5′	24.7	1.67 (*s*)	C-2′, C-3′, C-4′
1″	26.1	3.60 (*br d*, 6.0)	C-3, C-3″, C-4, C-4a
2″	123.3	5.38 (*m*)	C-4, C-4″ C-5″
3″	132.4	–	–
4″	16.9	1.80 (*s*)	C-2″, C-3″, C-5″
5″	24.7	1.72 (*s*)	C-2″, C-3″, C-4″
1-OH	–	14.65 (*s*)	–
3-OH	–	7.97 (*br s*)	–
5-OH	–	9.47 (*br s*)	–
9-NMe	47.5	3.67 (*s*)	C-4a, C-5a

3.6.1.5 Compound **AM4** (Atalaphylline)

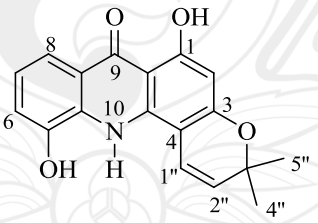


Compound **AM4** ($C_{23}H_{25}NO_4$) was isolated as yellow solid. The ^{1}H NMR spectral data (Table 3.5) were closely related to that of **AM3** except for the disappearance of *N*-Me signal in the ^{1}H NMR spectrum of compound **AM4**. Thus, **AM4** was assigned as atalaphylline (Govindachari et al., 1970).

Table 3.5 ^{1}H NMR Spectroscopic Data of **AM4** in Acetone-d_6

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
6	7.21 (*d*, 8.0)	1″	3.66 (*br d*, 6.4)
7	7.08 (*t*, 8.0)	2″	5.28 (*m*)
8	7.77 (*d*, 8.0)	4″	1.99 (*s*)
1′	3.48 (*br d*, 6.8)	5″	1.76 (*s*)
2′	5.16 (*m*)	1-OH	14.65 (*s*)
4′	1.82 (*s*)	5-OH	9.77 (*br s*)
5′	1.68 (*s*)	10-NH	8.95 (*br s*)

3.6.1.6 Compound **AM5** (Atalaphyllidine)

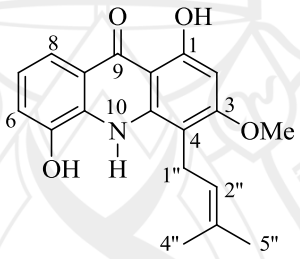


Compound **AM5** ($C_{18}H_{15}NO_4$) was isolated as yellow solid. The ^{1}H NMR spectral data (Table 3.6) was similar to that of **AM**2 except that compound **AM5** showed the signal of an aromatic proton [δ_H 6.07 (*s*, H-2)] instead of a prenyl unit as appeared in **AM2**. Thus, **AM5** was deduced as atalaphyllidine (Yahayu et al., 2011).

Table 3.6 ^{1}H NMR Spectroscopic Data of **AM5** in Acetone-d_6

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
2	6.07 (*s*)	2″	5.73 (*d*, 10)
6	7.20 (*d*, 8.0)	4″/5″	1.47 (*s*)
7	7.14 (*t*, 8.0)	1-OH	14.60 (*s*)
8	7.77 (*d*, 8.0)	5-OH	9.23 (*br s*)
1″	6.94 (*d*, 10.0)		

3.6.1.7 Compound **AM6** (Buxifoliadine C)

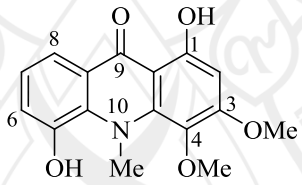


Compound **AM6** ($C_{19}H_{19}NO_4$) was isolated as yellow solid. The ^{1}H NMR spectral data (Table 3.7) was closely related to that of **AM3** except that compound **AM6** showed the signal of an aromatic proton [δ_H 6.50 (*s*, H-2)] instead of prenyl unit and was not observed the *N*-Me group in the ^{1}H NMR spectrum as appeared in **AM3**. In addition, this compound also showed an additional OMe group (δ_H 4.04) which was located on C-3 by comparison with NMR spectral data of buxifoliadine C (Wu & Chen, 2000). Thus, **AM6** was assigned as buxifoliadine C (Wu & Chen, 2000).

Table 3.7 ^{1}H NMR Spectroscopic Data of **AM6** in Acetone-d_6

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
2	6.50 (*s*)	4″	1.66 (*s*)
6	7.28 (*d*, 8.0)	5″	1.48 (*s*)
7	7.13 (*t*, 8.0)	1-OH	15.00 (*s*)
8	7.92 (*d*, 8.0)	3-OMe	4.04 (*s*)
1″	3.39 (*br d*, 7.2)	5-OH	9.39 (*br s*)
2″	5.33 (*m*)		

3.6.1.8 Compound **AM7** (Citrusinine I)



Compound **AM7** ($C_{16}H_{15}NO_5$) was isolated as yellow viscous oil. The ^{1}H NMR spectral data (Table 3.8) was closely related to that of **AM6** except that compound **AM7** showed the signal of 4-OMe (δ_H 3.77) instead of the prenyl unit. In addition, a *N*-Me group (δ_H 3.67) was also observed in the ^{1}H NMR spectrum. The structure of **AM7** was finally confirmed by HMBC correlation as shown in Table 3.8. Therefore, **AM7** was assigned as citrusinine I (Kawaii et al., 1999).

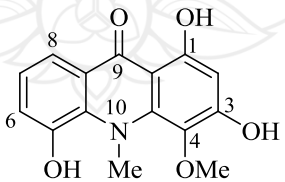
Table 3.8 NMR Spectroscopic Data of **AM7** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	160.3	–	–
2	93.6	6.41 (*s*)	C-1, C-3, C-4, C-9a

Table 3.8 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
3	160.0	–	–
4	130.1	–	–
4a	148.8	–	–
5	148.1	–	–
5a	137.4	–	–
6	119.9	7.31 (*dd*, 8.0, 1.2)	C-5, C-5a, C-7, C-8
7	122.5	7.16 (*t*, 8.0)	C-5, C-8, C-8a
8	116.0	7.78 (*dd*, 8.0, 1.2)	C-5a, C-6, C-9
8a	124.7	–	–
9	182.4	–	–
9a	105.6	–	–
1-OH	–	14.19 (*s*)	–
3-OMe	55.5	3.98 (*s*)	C-3
4-OMe	59.3	3.77 (*s*)	C-4
5-OH	–	9.60 (*br s*)	–
10-NMe	47.5	3.67 (*s*)	C-4a, C-5a

3.6.1.9 Compound **AM8** (Citrusinine II)



Compound **AM8** ($C_{15}H_{13}NO_5$) was isolated as yellow viscous oil. The ^1H NMR spectral data (Table 3.9) was similar to that of **AM7** except that compound

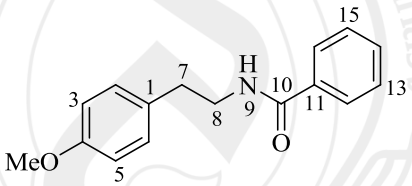
AM8 showed only one OMe group which was located on C-4. Therefore, **AM8** was identified as citrusinine II (Weniger et al., 2001).

Table 3.9 ^{1}H NMR Spectroscopic Data of **AM8** in Acetone-d_6

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
2	6.24 (*s*)	3-OH	9.15 (*br s*)
6	7.32 (*dd*, 7.8, 1.2)	4-OMe	3.87 (*s*)
7	7.18 (*t*, 8.0, 7.8)	5-OH	9.37 (*br s*)
8	7.81 (*d*, 8.0, 1.2)	10-NMe	3.78 (*s*)
1-OH	14.10 (*s*)		

3.6.2 Amide Derivatives

3.6.2.1 Compound **FL21** (*N*-[2-(4-Methoxyphenyl)ethyl]benzamide)



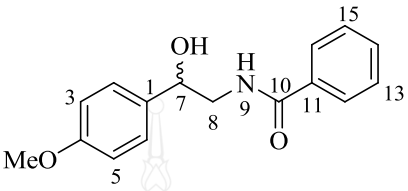
Compound **FL21** ($C_{16}H_{17}NO_2$) was isolated as colorless solid. The UV spectrum showed the maxima absorbances at 202, 225 and 279 nm, while the IR spectrum revealed the NH and aryl amide functionalities at 3317 and 1635 cm^{-1}, respectively. The ^{1}H NMR spectral (Table 3.10) data of **FL21** displayed signals of NH at δ_H 6.20 (*br s*) and a set of monosubstituted benzene ring at δ_H 7.68 (*d*, *J* = 8.8 Hz, H-12 and H-16), 7.47 (*m*, H-14) and 7.39 (*m*, H-13 and H-15). In addition, a 4-methoxyphenylethyl group [δ_H 7.15 (*d*, *J* = 8.4 Hz, H-2 and H-6), 6.86 (*d*, *J* = 8.4 Hz, H-3 and H-5) , 3.79 (*s*, 4-OMe), 3.68 (*dd*, *J* = 6.8, 6.0 Hz, H-8) and 2.87 (*dd*, *J* = 7.2, 6.8 Hz, H-7)] was also observed in the ^{1}H NMR spectrum. These finding were

supported by COSY and HMBC correlation (Table 3.10). The ^{3}J HMBC correlations of H-8 (δ_H 3.68) and H-12/H-16 (δ_H 7.68) with carbonyl C-10 (δ_C 167.4) indicated monosubstituent benzene ring and 4-methoxyphenylethyl unit were linked to each other by amide linkage. Therefore, compound **FL21** was assigned *N*-[2-(4-methoxyphenyl)ethyl]benzamide (Vargas et al., 2010).

Table 3.10 NMR Spectroscopic Data of **FL21** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**	**COSY**
1	130.8	–	–	–
2/6	129.7	7.15 (*d*, 8.4)	C-3, C-4, C-6/C-2, C-7	H-3/H-5
3/5	114.1	6.86 (*d*, 8.4)	C-1, C-2, C-4, C-5/C-3	H-2/H-6
4	158.3	–	–	–
7	34.7	2.87 (*d*, 7.2, 6.8)	C-1, C-2, C-6, C-8	H-8
8	41.3	3.68 (*dd*, 6.8, 6.0)	C-1, C-7, C-10	H-7
10	167.4	–	–	–
11	134.7	–	–	–
12/16	126.8	7.68 (*d*, 8.8)	C-10, C-13, C-14, C-16/C-12	H-13/ H-14
13/15	128.5	7.39 (*m*)	C-11, C-12, C-15/C-13	H-12/H-16, H-14
14	131.3	7.47 (*m*)	C-12, C-16	H-13/H-15
4-OMe	55.2	3.79 (*s*)	C-4	–
9-NH	–	6.20 (*br s*)	–	–

3.6.2.2 Compound **FL22** (Tembamide)



Compound **FL22** ($C_{16}H_{17}NO_3$) was isolated as white solid. The ^{1}H and ^{13}C NMR spectral data (Table 3.11) of **FL22** were closely related to those of **FL21** except compound **FL22** showed a hydroxyl group on C-7 (δ_H 8.98) instead of methylene protons as in **FL21**. This ^{1}H NMR signal (δ_H 8.98) showed ^{2}J HMBC correlation with C-1 (δ_C 135.4) and C-8 (δ_C 48.2). The completed HMBC correlations of **FL22** was shown in Table 3.11. Therefore, **FL22** was assigned as tembamide (Kamal et al., 2012).

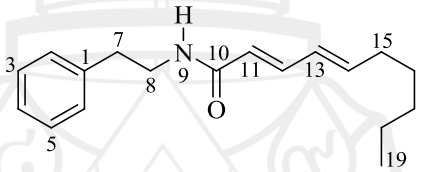
Table 3.11 NMR Spectroscopic Data of **FL22** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
1	135.4	–	–
2/6	127.0	7.35 (*d*, 9.2)	C-1, C-3, C-6 (C-2)
3/5	113.4	6.90 (*d*, 9.2)	C-1, C-4, C-5 (C-3)
4	159.0	–	–
7	72.8	4.88 (*m*)	C-1, C-8
8	48.2	3.68 (*m*), 3.49 (*m*)	C-7, C-10
10	167.2	–	–
11	134.8	–	–
12/16	127.1	7.89 (*d*, 8.0)	C-10, C-14, C-16/C-12
13/15	128.2	7.45 (*m*)	C-11, C-12, C-14, C-15/C-13
14	131.1	7.52 (*m*)	C-12, C-13, C-15, C-16

Table 3.11 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
4-OMe	54.5	3.77 (*s*)	C-4
7-OH	–	8.98 (*s*)	–
9-NH	–	7.88 (*br s*)	–

3.6.2.3 Compound **FL23** ((2*E*,4*E*)-Deca-2,4-dienoic acid 2-phenylethyl amide)



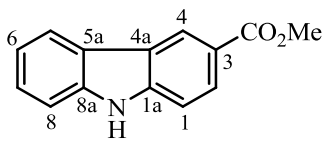
Compound **FL23** ($C_{18}H_{25}NO$) was isolated as colorless viscous oil. The ^{1}H and ^{13}C NMR spectral data (Table 3.12) of **FL23** were similar to that of **FL21** except compound **FL23** showed a (2*E*,4*E*)-deca-2,4-dienoyl unit [δ_H 7.51 (*dd*, *J* = 14.8, 12.4 Hz, H-12), 6.05 (*br t*, *J* = 12.6 Hz, H-13), 5.80 (*br t*, *J* = 12.6 Hz, H-14), 5.75 (*d*, *J* = 14.8 Hz, H-11), 2.24 (*m*, H_2-15 and H_2-16), 1.39 (*m*, H_2-16) and 1.29 (*m*, Me-17 and Me-18) instead of benzoyl group. In addition, this compound was not observed the 4-OMe group. Finally, the structure of **FL23** was confirmed by HMBC and COSY as shown in Table 3.12. Thus, compound **FL23** was identified as (2*E*,4*E*)-deca-2,4-dienoic acid 2-phenylethyl amide (Greger, 1987).

Table 3.12 NMR Spectroscopic Data of **FL23** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC	COSY
1	138.8	–	–	–
2/6	128.5	7.33 (*br d*, 6.8)	C-1, C-3/C-5, C-6/C-2	C-3/C-5
3/5	128.8	7.21 (*m*)	C-1, C-2/C-6, C-4, C-5/ C-3	C-2/C-6, C-4
4	126.6	7.23 (*m*)	C-2/C-6, C-3/C-5	C-3/C-5
7	35.6	2.85 (*br d*, 7.2)	C-1, C-2/C-6, C-8	C-8
8	40.6	3.62 (*m*)	C-1, C-7, C-10	C-7, 9-NH
10	166.0	–	–	–
11	123.5	5.75 (*d*, 14.8)	C-10, C-12, C13	C-12
12	136.2	7.51 (*dd*, 14.8, 12.4)	C-10, C-11, C-13, C-14	C-11, C-13
13	126.2	6.05 (*br t*, 12.6)	C-11, C-12, C-15	C-12, C-14
14	140.4	5.80 (*br t*, 12.6)	C-12, C-15, C-16	C-13, C-15
15	28.1	2.24 (*m*)	C-13, C-14, C-16, C-17	C-14, C-16
16	28.9	1.39 (*m*)	C-14, C-15, C-17, C-18	C-15, C-17
17	31.3	1.29 (*m*)	C-16, C-18, C-19	C-16, C-18
18	22.2	1.29 (*m*)	C-16, C-17, C-19	C-17, C-19
19	13.9	0.94 (*t*, 3.6)	C-17, C-18	C-18
9-NH	–	5.49 (*br s*)	–	C-8

3.6.3 Carbazole Alkaloids

3.6.3.1 Compound **CE11** (Methylcarbazole-3-carboxylate)



Compound **CE11** ($C_{14}H_{11}NO_2$) was isolated as white solid. The UV spectrum showed the maximum absorbances at 232, 274 and 323 nm. The IR spectrum indicated the presence of a NH stretching at 3331 cm^{-1}, corresponding with the NH signal at δ_H 8.27 (*br s*) in the ^{1}H NMR spectrum (Table 3.13). The ^{1}H NMR spectral data of **CE11** exhibited a set of 1,2-disubstituent benzene ring at δ_H 8.05 (*d*, *J* = 7.6 Hz, H-5), 7.39 (*d*, *J* = 7.6 Hz, H-8), 7.38 (*m*, H-7) and 7.22 (*m*, H-6) and a set of ABX aromatic protons at δ_H 8.75 (*br s*, H-4), 8.06 (*dd*, *J* = 8.4, 1.6 Hz, H-2) and 7.36 (*d*, *J* = 8.4 Hz, H-1). Moreover, the ^{1}H NMR spectrum also showed methyl ester moiety at δ_H 3.90 (*s*), which located on C-3 because of the ^3J HMBC correlations of H-2 (δ_H 8.06) and H-4 (δ_H 8.75) with carbonyl carbon 3-*C*O_2Me (δ_C 167.9). Therefore, methyl carbazole-3-carboxylate was identified to be **CE11** (Wu et al., 1996).

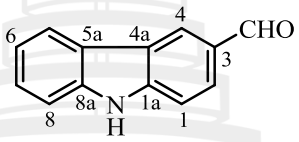
Table 3.13 NMR Spectroscopic Data of **CE11** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	110.1	7.36 (*d*, 8.4)	C-3, C-4a
1a	142.3	–	–
2	127.4	8.06 (*dd*, 8.4, 1.6)	C-1a, C-4, 3-*C*O_2Me
3	121.5	–	–
4	122.9	8.75 (*br s*)	C-1a, C-2, C-5a, 3-*C*O_2Me
4a	123.0	–	–
5	120.6	8.05 (*d*, 7.6)	C-7, C-8a
5a	123.4	–	–
6	120.3	7.22 (*m*)	C-8
7	126.5	7.38 (*m*)	C-5
8	110.9	7.39 (*d*, 7.6)	C-7, C-8a
8a	139.8	–	–
3-*C*O_2Me	167.9	–	–

Table 3.13 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
3-CO_2*Me*	51.9	3.90 (*s*)	3-*C*O_2Me
NH	–	8.27 (*br s*)	–

3.6.3.2 Compound **CE12** (3-Formylcarbazole)



Compound **CE12** ($C_{13}H_9NO$) was isolated as white solid. All ^1H and ^{13}C NMR spectral data (Table 3.14) were closely related to those of **CE11** except that compound **CE12** showed a signal of a formyl group (δ_H 10.10/δ_C 191.9) instead of a methyl ester group at C-3.. Thus, 3-formylcarbazole was characterized to be **CE12** (Sunthitikawinsakul et al., 2002).

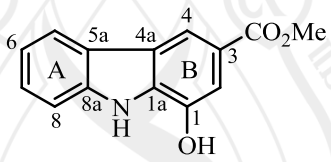
Table 3.14 NMR Spectroscopic Data of **CE12** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	111.1	7.49 (*d*, 8.8)	C-4a
1a	143.3	–	–
2	127.3	7.97 (*dd*, 8.8, 1.6)	C-1a, C-3, C-4, 3-CHO
3	129.1	–	–
4	124.0	8.60 (*d*, 0.8)	C-3, 3-CHO
4a	123.5	–	–
5	120.7	8.13 (*d*, 8.4)	C-7, C-8a

Table 3.14 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
5a	123.0	–	–
6	120.7	7.32 (*m*)	C-7
7	110.9	7.48 (*m*)	C-5, C-8a
8	126.9	7.51(*d*, 8.4)	C-5a
8a	140.0	–	–
3-CHO	191.9	10.10 (*s*)	C-4
NH	–	8.55 (*br s*)	–

3.6.3.3 Compound **CE13** (Clauszoline I)



Compound **CE13** ($C_{14}H_{11}NO_3$) was isolated as yellow solid. The ^{1}H NMR spectral data (Table 3.15) was similar to that of **CE11** except that compound **CE13** showed *meta*-coupled aromatic protons [δ_H 8.44 (*br s*, H-4) and 7.61 (*d*, *J* = 2.4 Hz, H-2] instead of ABX aromatic protons of ring B. Thus, clauszoline I was characterized to be **CE13** (Liger et al., 2007).

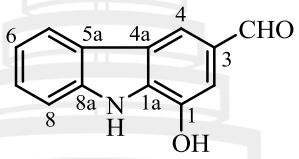
Table 3.15 ^{1}H NMR Spectroscopic Data of **CE13** in Acetone-d_6

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
2	7.61 (*d*, 2.4)	7	7.50 (*m*)
4	8.44 (*br s*)	8	7.29 (*d*, 8.4)

Table 3.15 (continued)

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
5	8.09 (*d*, 8.0)	3-CO_2Me	3.97 (*s*)
6	7.46 (*m*)		

3.6.3.4 Compound **CE14** (*O*-Demethylmurrayanine)

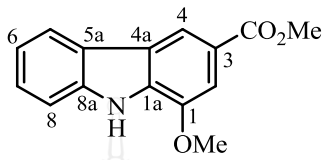


Compound **CE14** ($C_{13}H_9NO_2$) was isolated as light brown solid. The ^{1}H NMR spectral data (Table 3.16) was closely related to that of **CE13** except that compound **CE14** showed a formyl proton (δ_H 10.02) instead of a methyl ester at C-3. Thus, *O*-demethylmurrayanine was assigned to be **CE14** (Ito et al., 2000).

Table 3.16 ^{1}H NMR Spectroscopic Data of **CE14** in Acetone-d_6

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
2	7.43 (*d*, 1.2)	7	7.47 (*m*)
4	8.21 (*d*, 1.2)	8	7.65 (*d*, 8.0)
5	8.21 (*d*, 7.6)	3-CHO	10.02 (*s*)
6	7.27 (*m*)		

3.6.3.5 Compound **CE15** (Mukonine)



Compound **CE15** ($C_{15}H_{13}NO_3$) was isolated as white solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.17) were similar to that of **CE13** except that compound **CE15** showed a methoxyl group (δ_H 4.06/δ_H 55.7) instead of hydroxyl group at C-1. The structure of **CE15** was also confirmed by HMBC spectrum as shown in Table 3.17. Therefore, mukonine was characterized to be **CE15** (Liger et al., 2007).

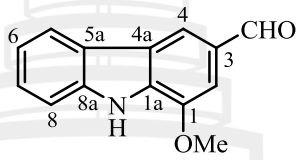
Table 3.17 NMR Spectroscopic Data of **CE15** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
1	145.0	–	–
1a	132.9	–	–
2	106.7	7.59 (*d*, 1.2)	C-1, C-4, C-4a, 3-*C*O_2Me
3	123.7	–	–
4	116.2	8.47 (*d*, 1.2)	C-1a, C-2, C-3, 3-*C*O_2Me
4a	121.9	–	–
5	120.7	8.12 (*d*, 8.0)	C-5a, C-7, C-8a
5a	123.5	–	–
6	120.3	7.28 (*dd*, 8.4, 8.0)	C-5a
7	126.3	7.45 (*dd*, 8.0, 6.8)	C-6, C-8, C-8a
8	111.2	7.49 (*d*, 6.8)	C-5a
8a	139.5	–	–
1-OMe	55.7	4.06 (*s*)	C-1
3-*C*O_2Me	167.9	–	–

Table 3.17 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
3-CO_2*Me*	52.0	3.98 (*s*)	3-*C*O_2Me
NH	–	8.48 (*br s*)	–

3.6.3.6 Compound **CE16** (Murrayanine)



Compound **CE16** ($C_{14}H_{11}NO_2$) was isolated as light yellow solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.18) were similar to those of **CE15** except that compound **CE16** showed a formyl group (δ_H 10.05/ δ_C 191.9) instead of a methyl ester group at C-3. The structure of **CE16** was also confirmed by HMBC correlation as shown in Table 3.18. Therefore, murrayanine was deduced to be **CE16** (Sunthitikawinsakul et al., 2002).

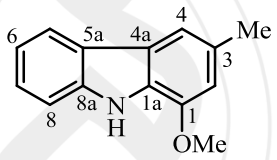
Table 3.18 NMR Spectroscopic Data of **CE16** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	146.1	–	–
1a	134	–	–
2	103.5	7.46 (*d*, 0.8)	C-1a, C-4, 3-CHO
3	130.1	–	–
4	120.4	8.19 (*d*, 0.8)	C-4a, 3-CHO
4a	123.6	–	–

Table 3.18 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
5	120.7	8.11 (*d*, 8.0)	C-5a, C-7
5a	124.0	–	–
6	120.7	7.32 (*m*)	C-5a, C-8
7	126.6	7.48 (*m*)	C-8a
8	111.5	7.52 (*d*, 8.0)	C-5a, C-6
8a	139.4	–	–
1-OMe	55.8	4.07 (*s*)	C-1
3-CHO	191.9	10.05 (*s*)	C-2, C-3, C-4
NH	–	8.64 (*br s*)	–

3.6.3.7 Compound **CE17** (Murrayafoline A)



Compound **CE17** ($C_{14}H_{13}NO$) was isolated as colorless viscous oil. The ^{1}H NMR spectral data (Table 3.19) was similar to that of **CE15** except that compound **CE17** showed a methyl proton (δ_H 2.53) instead of a methyl ester group at C-3. Therefore, murrayafoline A was characterized to be **CE17** (Furukawa et al., 1985).

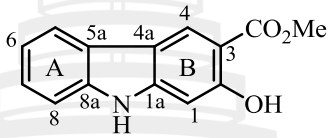
Table 3.19 ^{1}H NMR Spectroscopic Data of **CE17** in $CDCl_3$

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
2	6.73 (*br s*)	7	7.38 (*m*)
4	7.47 (*br s*)	8	7.43 (*d*, 8.0)

Table 3.19 (continued)

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
5	8.01 (*d*, 7.6)	1-OMe	3.99 (*s*)
6	7.19 (*m*)	3-Me	2.53 (*s*)

3.6.3.8 Compound **CE18** (Mukonidine)

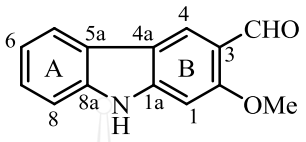


Compound **CE18** ($C_{14}H_{11}NO_3$) was isolated as colorless solid. The ^{1}H NMR spectral data (Table 3.20) was similar to that of **CE11** except that compound **CE18** showed *para*-coupled aromatic protons [δ_H 7.51 (*s*, H-4) and 7.08 (*s*, H-1)] instead of *meta*-coupled aromatic protons of ring B. The structure of **CE18** was also confirmed by HMBC correlations as shown in Table 3.20. Thus, mukonidine was characterized to be **CE18** (Wu et al., 1999).

Table 3.20 ^{1}H NMR Spectroscopic Data of **CE18** in Acetone-d_6

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
1	7.08 (*s*)	7	7.24 (*d*, 8.0, 7.2)
4	7.51 (*s*)	8	7.40 (*d*, 8.0)
5	7.93 (*d*, 8.0)	3-CO_2Me	3.92 (*s*)
6	7.07 (*d*, 8.0, 7.2)		

3.6.3.9 Compound **CE19** (*O*-Methylmukonal)



Compound **CE19** ($C_{14}H_{11}NO_2$) was isolated as light yellow solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.21) were similar to those of **CE16** except that compound **CE19** showed *para*-coupled aromatic protons [δ_H 8.56 (*s*, H-4) and 6.87 (*s*, H-1)] instead of *meta*-coupled aromatic protons of ring B. The structure of **CE19** was also confirmed by HMBC correlations as shown in Table 3.21. Therefore, *O*-methylmukonal was identified to be **CE19** (Kongkathip, N. & Kongkathip, B., 2009).

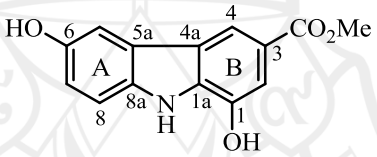
Table 3.21 NMR Spectroscopic Data of **CE19** in $CDCl_3$

Position	δ_C	δ_H **(*mult.*, *J* in Hz)**	**HMBC**
1	92.4	6.87 (*s*)	C-1a, C-2, C-3
1a	144.9	–	–
2	161.6	–	–
3	119.1	–	–
4	121.8	8.56 (*s*)	3-CHO
4a	117.4	–	–
5	120.2	8.00 (*d*, 8.0)	C-4a, C-7, C-8, C-8a
5a	128.0	–	–
6	125.9	7.39 (*m*)	C-5a
7	120.8	7.40 (*m*)	C-8a
8	139.9	7.26 (*d*, 7.6)	C-5a, C-7, C-8a

Table 3.21 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
8a	55.8	–	–
2-OMe	189.5	3.99 (*s*)	C-2
3-CHO	110.6	10.49 (*s*)	C-3
NH	–	8.29 (*brs*)	–

3.6.3.10 Compound **CE20** (Methyl-1,6-dihydroxy-9*H*-carbazole-3-carboxylate)



Compound **CE20** ($C_{14}H_{11}NO_4$) was isolated as light yellow solid. All ^1H and ^{13}C NMR spectral data (Table 3.22) were similar to those of **CE13** except that compound **CE20** showed ABX aromatic protons [δ_H 7.57 (*d*, *J* = 2.4 Hz, H-5), 7.44 (*d*, *J* = 8.8 Hz, H-8) and 7.02 (*dd*, *J* = 8.8, 2.4 Hz, H-7] instead of 1,2-disubstituent aromatic protons of ring A. Therefore, methyl 1,6-dihydroxy-9*H*-carbazole-3-carboxylate was characterized to be **CE20** (Borger & Knolker, 2008).

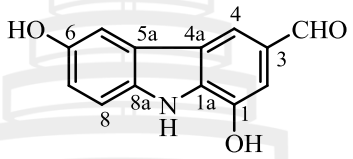
Table 3.22 ^1H NMR Spectroscopic Data of **CE20** in Acetone-d_6

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
2	7.53 (*d*, 1.2)	8	7.44 (*d*, 8.8)
4	8.28 (*d*, 1.2)	1-OH	8.99 (*s*)

Table 3.22 (continued)

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
5	7.57 (*d*, 2.4)	3-CO_2Me	3.87 (*s*)
7	7.02 (*dd*, 8.8, 2.4)	6-OH	10.63 (*s*)

3.6.3.11 Compound **CE21** (Clausine Z)



Compound **CE21** ($C_{13}H_9NO_3$) was isolated as light brown solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.23) were closely related to those of **CE20** except that compound **CE21** showed a formyl group (δ_H 9.96/ δ_C 191.2) instead of methyl ester at C-3. The structure of **CE21** was also confirmed by HMBC spectrum as shown in Table 3.23. Therefore, clausine Z was deduced to be **CE21** (Potterat et al., 2005).

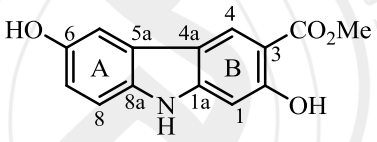
Table 3.23 NMR Spectroscopic Data of **CE21** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	143.6	–	–
1a	134.8	–	–
2	107.0	7.38 (*d*, 1.2)	C-1, C-1a, C-4, 3-CHO
3	129.6	–	–
4	118.7	8.56 (*d*, 1.2)	C-1a, C-2, C-5a, 3-CHO
4a	123.9	–	–

Table 3.23 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
5	105.1	7.60 (*d*, 2.0)	C-6, C-7, C-8a
5a	128.5	–	–
6	151.7	–	–
7	115.8	7.04 (*d*, 8.8, 2.0)	–
8	112.3	7.47 (*d*, 8.8)	–
8a	134.6	–	–
1-OH	–	10.60 (*br s*)	C-1a, C-4a
3-CHO	191.2	9.96 (*s*)	C-2, C-4
6-OH	–	8.44 (*br s*)	–

3.6.3.12 Compound **CE22** (Sansoakamine)

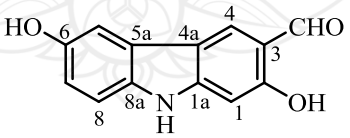


Compound **CE22** was isolated as light brown solid with the molecular ion peak at *m/z* 257.0683 $[M]^+$ in the HREIMS (calcd *m/z* 257.0688), corresponding to the molecular formula $C_{14}H_{11}NO_4$. The ^1H NMR spectral data (Table 3.24) was similar to those of **CE20** except that compound **CE22** showed *para*-coupling aromatic protons [δ_H 8.52 (*s*, H-4) and 6.85 (*s*, H-1)] instead of *meta*-coupling aromatic protons of ring B. The structure of **CE22** was also confirmed by HMBC correlations as shown in Table 3.24. Thus, sansoakamine was characterized to be **CE22**.

Table 3.24 NMR Spectroscopic Data of **CE22** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	96.5	6.85 (*s*)	C-2, C-3
1a	146.3	–	–
2	160.4	–	–
3	116.9	–	–
4	122.5	8.52 (*s*)	3-*C*O_2Me, C-4a, C-8a
4a	104.8	–	–
5	105.3	7.50 (*d*, 2.4)	C-6, C-8a
6	151.8	–	–
7	114.4	6.92 (*dd*, 8.8, 2.4)	C-6, C-8a
8	111.3	7.28 (*d*, 8.8)	C-5a, C-7, C-8a
8a	134.9	–	–
2-OH	–	11.03 (*s*)	C-1, C-2
3-CO_2*Me*	51.6	3.98 (*s*)	3-*C*O_2Me
3-*C*O_2Me	171.3	–	–
6-OH	–	10.26 (*s*)	–
NH	–	8.06 (*br s*)	–

3.6.3.13 Compound **CE23** (Lansine)



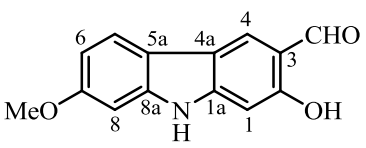
Compound **CE23** ($C_{13}H_9NO_3$) was isolated as white solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.25) were closely related to those of **CE22** except that compound **CE23** showed a formyl group (δ_H 9.92/ δ_C 195.1) instead of the methyl

ester group at C-3. The structure of **CE23** was also confirmed by HMBC spectrum as shown in Table 3.25. Therefore, lansine was deduced to be **CE23** (Wu et al., 1996).

Table 3.25 NMR Spectroscopic Data of **CE23** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
1	96.5	6.83 (*s*)	C-1a, C-2, C-3, C-4a
1a	146.3	–	–
2	160.4	–	–
3	115.3	–	–
4	127.4	8.14 (*s*)	C-1a, C-2, C-5a, 3-CHO
4a	117.8	–	–
5	103.3	7.48 (*d*, 2.8)	C-4a, C-6, C-7, C-8a
5a	123.9	–	–
6	154.9	–	–
7	114.4	7.02 (*dd*, 8.8, 2.8)	C-5, C-6, C-8a
8	111.4	7.29 (*d*, 8.8)	C-5a, C-6, C-8a
8a	134.7	–	–
2-OH	–	11.43 (*s*)	C-1, C-2, C-3
3-CHO	195.1	9.92 (*s*)	C-2, C-3, C-4
6-OMe	56.0	3.92 (*s*)	C-6
NH	–	8.14 (*br s*)	–

3.6.3.14 Compound **CE24** (2-Hydroxy-3-formyl-7-methoxycarbazole)

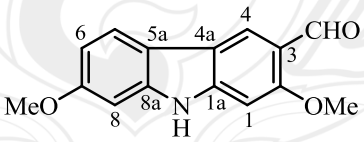


Compound **CE24** was ($C_{14}H_{11}NO_3$) was isolated as yellow solid. The ^1H NMR spectral data (Table 3.26) was similar to that of compound **CE23**. However, the main difference is that compound **CE24** showed a methoxyl group on C-7 whereas compound **CE23** showed a hydroxyl group on C-6. Therefore, 2-hydroxy-3-formyl-7-methoxycarbazole was characterized to be **CE24** (Ruangrungst & Ariyaprayoon, 1990).

Table 3.26 ^1H NMR Spectroscopic Data of **CE24** in Acetone-d_6

Position	δ_H (***mult.*, *J* in Hz**)	**Position**	δ_H (***mult.*, *J* in Hz**)
1	6.89 (*s*)	2-OH	11.43 (*s*)
4	8.05 (*s*)	3-CHO	9.92 (*s*)
5	7.85 (*d*, 8.0)	7-OMe	3.90 (*s*)
6	6.88 (*dd*, 8.0, 1.5)	NH	8.16 (*br s*)
8	6.84 (*d*, 1.5)		

3.6.3.15 Compound **CE25** (3-Formyl-2,7-dimethoxycarbazole)

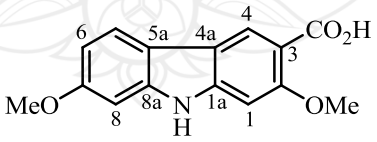


Compound **CE25** was ($C_{15}H_{13}NO_3$) was isolated as yellow solid. All ^1H and ^{13}C NMR spectral data (Table 3.27) were similar to those of compound **CE24** except that compound **CE25** displayed an additional methoxyl group (δ_H 3.99/ δ_C 55.3) instead of a hydroxyl group at C-2. The structure of **CE25** was also confirmed by HMBC correlation as shown in Table 3.27. Therefore, 3-formyl-2,7-dimethoxycarbazole was identified to be **CE25** (Ruangrungst & Ariyaprayoon, 1990).

Table 3.27 NMR Spectroscopic Data of **CE25** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	92.9	7.11 (*s*)	C-1a, C-2, C-3, C-4a
1a	145.7	–	–
2	160.8	–	–
3	117.7	–	–
4	119.2	8.37 (*s*)	C-1a, C-2, C-5a, 3-CHO
4a	117.0	–	–
5	120.7	7.99 (*d*, 8.4)	C-4a, C-7, C-8a
5a	117.5	–	–
6	108.6	6.84 (*dd*, 8.4, 1.5)	C-5a, C-8a
7	158.8	–	–
8	95.3	7.03 (*d*, 1.5)	C-5a, C-6, C-7, C-8a
8a	142.1	–	–
2-OMe	55.3	3.99 (*s*)	C-2
3-CHO	195.1	9.92 (*s*)	C-2, C-3, C-4
7-OMe	54.7	3.85 (*s*)	C-7
NH	–	10.44 (*br s*)	–

3.6.3.16 Compound **CE26** (Clauszoline J)



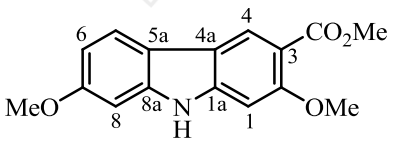
Compound **CE26** was ($C_{15}H_{13}NO_4$) was isolated as white solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.28) were similar to that of compound **CE25** except that compound **CE26** showed a carboxy group (3-CO_2H, δ_C 165.8) instead of the

formyl group. The structure of **CE26** was also confirmed by HMBC as shown in Table 3.28. Therefore, clauszoline J was deduced to be **CE26** (Ito et al., 1997).

Table 3.28 NMR Spectroscopic Data of **CE26** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
1	93.6	7.23 (*s*)	C-1a, C-2, C-3, C-4a
1a	144.0	–	–
2	157.1	–	–
3	110.4	–	–
4	122.9	8.63 (*s*)	C-1a, C-2, C-5a, 3-CO_2H
5	120.6	8.01 (*d*, 8.8)	C-4a, C-7, C-8a
5a	117.8	–	–
6	108.4	6.86 (*dd*, 8.8, 1.5)	C-5a, C-8a
7	159.0	–	–
8	95.2	7.05 (*d*, 1.5)	C-5a, C-6, C-7, C-8a
8a	142.4	–	–
2-OMe	56.1	4.12 (*s*)	C-2
3-CO_2H	165.8	–	–
7-OMe	54.8	3.87 (*s*)	C-7
NH	–	10.58 (*br s*)	–

3.6.3.17 Compound **CE27** (Clausine H)



Compound **CE27** was ($C_{16}H_{15}NO_4$) was isolated as yellow solid. All ^1H and ^{13}C NMR spectral data (Table 3.29) were closely related to those of compound

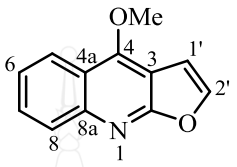
CE25 except that compound **CE27** showed a methyl ester group (δ_H 3.83/ δ_C 50.6) instead of the formyl group. The structure of **CE27** was also confirmed by HMBC correlation as shown in Table 3.29. Therefore, clausine H was characteried to be **CE27** (Wu et al, 1994).

Table 3.29 NMR Spectroscopic Data of **CE27** in Acetone-d_6

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
1	94.0	7.10 (*s*)	C-1a, C-2, C-3, C-4a
1a	143.7	–	–
2	158.6	–	–
3	112.4	–	–
4	122.9	8.41 (*s*)	C-1a, C-2, C-5a, 3-*C*O_2Me
5	120.2	7.95 (*d*, 8.8)	C-4a, C-7, C-8a
5a	116.6	–	–
6	108.3	6.82 (*dd*, 8.8, 2.8)	C-5a, C-8a
7	158.0	–	–
8	95.0	7.02 (*d*, 2.8)	C-5a, C-6, C-7, C-8a
8a	141.8	–	–
2-OMe	55.4	3.89 (*s*)	C-2
3-*C*O_2Me	166.8	–	–
3-CO_2*Me*	50.6	3.83 (*s*)	3-*C*O_2Me
7-OMe	54.7	3.85 (*s*)	C-7
NH	–	10.42 (*br s*)	–

3.6.4 Furanoquinoline Alkaloids

3.6.4.1 Compound **CE32** (Dictamine)



Compound **CE32** ($C_{12}H_9NO_2$) was isolated as colorless solid. The IR spectrum revealed the C–O stretching of furan (1087 cm^{-1}) and aromatic functionality (1625 and 1582 cm^{-1}), whereas the UV spectrum showed the maximum absorbance at 236, 242, 308, 314 and 329 nm. The ^1H NMR spectral data (Table 3.30) exhibited characteristic of linear furanoquinoline framework at δ_H 8.25 (*dd*, *J* = 8.4, 1.2, H-5), 8.00 (*dd*, *J* = 8.0, 0.8, H-8), 7.67 (*m*, H-7), 7.60 (*d*, *J* = 2.8, H-2′), 7.43 (*m*, H-6), 7.05 (*d*, *J* = 2.8, H-1′). Moreover, the methoxyl group at δ_H 4.42 (*s*, 4-OMe) was also observed in the spectrum. This methoxyl group was placed on C-4 due to the HMBC correlation between OMe (δ_H 4.42) and H-5 (δ_H 8.25) with C-4 (δ_H 156.5). Therefore compound **CE32** was deduced as dictamine (Terezan et al., 2010).

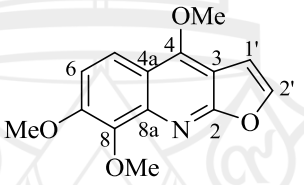
Table 3.30 NMR Spectroscopic Data of **CE32** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
2	163.8	–	–
3	103.4	–	–
4	156.5	–	–
4a	118.6	–	–
5	122.3	8.25 (*dd*, 8.4, 1.2)	C-4, C-7, C-8a
6	123.7	7.43 (*m*)	C-4a, C-5, C-7, C-8
7	129.6	7.67 (*m*)	C-5, C-6, C-8, C-8a
8	127.7	8.00 (*dd*, 8.0, 0.8)	C-4a, C-6

Table 3.30 (continued)

Position	δ_C	δ_H (*mult., J* in Hz)	HMBC
8a	145.6	–	–
1′	104.2	7.05 (*d*, 2.8)	C-2, C-2′, C-3
2′	143.5	7.60 (*d*, 2.8)	C-1′, C-2, C-3
4-OMe	59.0	4.42 (*s*)	C-4

3.6.4.2 Compound **GP8** (Skimmianine)



Compound **GP8** ($C_{14}H_{13}NO_4$) was isolated as light yellow solid. All ^1H and ^{13}C NMR spectral data (Table 3.31) of **GP8** were closely related to those of compound **CE32** except for the appearance of two methoxyl groups on C-7 (δ_H 3.98/ δ_C 57.0) and C-8 (δ_H 4.08/ δ_C 61.9). The structure of **GP8** was also confirmed by HMBC correlation as shown in Table 3.31. Therefore, **GP8** was assigned as skimmianine (Kamal et al., 2012).

Table 3.31 NMR Spectroscopic Data of **GP8** in $CDCl_3$

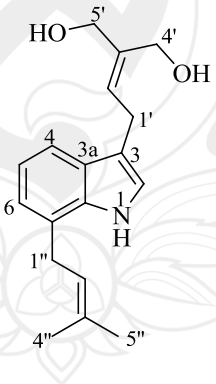
Position	δ_C	δ_H (*mult., J* in Hz)	HMBC
2	164.6	–	–
3	102.2	–	–
4	157.4	–	–
4a	115.1	–	–

Table 3.31 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
5	118.4	7.94 (*d*, 9.6)	C-4,C-6, C-7, C-8a
6	112.3	7.18 (*d*, 9.6)	C-4a, C-7, C-8
7	152.3	–	–
8	142.2	–	–
8a	141.7	–	–
1′	104.9	6.74 (*d*, 2.8)	C-2, C-2′, C-3
2′	143.2	7.51 (*d*, 2.8)	C-1′, C-2, C-3
4-OMe	59.2	4.36 (*s*)	C-4
7-OMe	57.0	3.98 (*s*)	C-7
8-OMe	61.9	4.08 (*s*)	C-8

3.6.5 Indole Alkaloid

3.6.5.1 Compound **GC10** (Glycosmisindole)



Compound **GC10** was obtained as colorless oil. The molecular formula, $C_{18}H_{23}NO_2$, was assigned from the ESI-TOF-MS ion at *m/z* 286.1800 $[M+H]^+$ (calcd 286.1807). The ^{1}H NMR spectrum (Table 3.32) exhibited a singlet proton at 6.86 (*s*, H-2), a NH proton at δ_H 8.03 (*br s*), and three mutually coupled aromatic protons at δ_H 7.41 (*d*, *J* = 8.0 Hz, H-4), 7.04 (*dd*, *J* = 8.0, 7.2 Hz, H-5), and 6.98 (*d*, *J* = 7.2 Hz, H-

6) which were characteristics of a 3,7-disubstituted indole nucleus (Wang *et al*., 2005). The ^{1}H and ^{13}C NMR spectra also showed the prenyl group [δ 5.36 (1H, *t, J* = 7.0 Hz, H-2″)/ 122.0 (C-2″), 3.50 (2H, *d, J* = 7.0 Hz, H-1″)/ 30.4 (C-1″), 1.77 (3H, s, Me-4″)/ 18.0 (C-4″), 1.75 (3H, s, Me-5″)/ 25.8 (C-5″) and 1.33.4 (C-3″)], which was placed at C-7 due to the ^{2}J and ^{3}J HMBC correlation of H-1″ (δ_H 3.50) with C-6 (δ_C 121.5), C-7 (δ_C 124.3) and C-7a (δ_C 137.3). In addition, a set of $CH_2CH=C(CH_2OH)_2$ moiety was also observed from the ^{1}H and ^{13}C NMR spectra [δ 5.81 (1H, *t, J* = 7.2 Hz, H-2′)/129.3 (C-2′), 4.39 (2H, *s*, H-4′)/59.5 (C-4′), 4.18 (2H, s, H-5′)/ 67.0 (C-5′), 3.50 (2H, *d, J* = 7.2 Hz, H-1′)/23.5 (C-1′) and δ 135.6 (C-3′)] which was placed at C-3 of indole skeleton based on the ^{2}J and ^{3}J correlations between H-1′ (δ 3.50) with C-2 (δ 121.6), C-3 (δ 114.7), and C-3a (δ 127.1) in the HMBC spectrum. The assignment of H-4′(δ 4.39) and H-5′ (δ 4.18) was done by the NOESY experiment in which H_2-1′ (δ 3.50) showed a cross peak with H_2-4′ (δ 4.39) while H-2′ (δ 5.81) showed cross peaks with H_2-1′ (δ 3.50) and H_2-5′ (δ 4.18). Detailed assignments of the protons and carbons as well as the HMBC correlations are shown in Table 3.32, allowing assignment of structure **GC10** to glycosmisindole.

Table 3.32 NMR Spectroscopic Data of **GC10** in $CDCl_3$

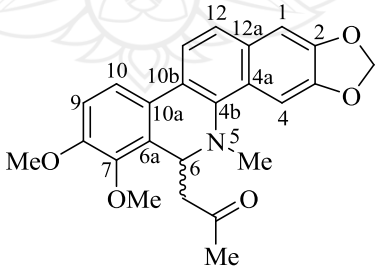
Position	δ_C	δ_H (*mult., J* in Hz)	HMBC
2	121.6	6.86 (*s*)	C-3, C-3a, C-7a
3	114.7	–	–
3a	127.1	–	–
4	116.7	7.41 (*d*, 8.0)	C-3, C-3a, C-5, C-7a
5	119.6	7.04 (*dd*, 8.0, 7.2)	C-4, C-6, C-7
6	121.5	6.98 (*d*, 7.2)	C-4, C-5, C-7, C-7a
2	121.6	6.86 (*s*)	C-3, C-3a, C-7a
3	114.7	–	–
3a	127.1	–	–
4	116.7	7.41 (*d*, 8.0)	C-3, C-3a, C-5, C-7a

Table 3.32 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
5	119.6	7.04 (*dd*, 8.0, 7.2)	C-4, C-6, C-7
6	121.5	6.98 (*d*, 7.2)	C-4, C-5, C-7, C-7a
7	124.3	–	–
7a	137.3	–	–
1′	23.5	3.50 (*d*, 7.2)	C-2, C-2′, C-3′, C-3, C-3a
2′	129.3	5.81 (*t*, 7.2)	C-1′, C-3, C-3′
3′	135.6	–	–
4′	59.5	4.39 (*s*)	C-2′, C-3′, C-5′
5′	67.0	4.18 (*s*)	C-2′, C-3′, C-4′
1″	30.4	3.50 (*d*, 7.0)	C-2″, C-3″, C-6, C-7a
2″	122.0	5.36 (*t*, 7.0)	C-1″, C-3″
3″	133.4	–	–
4″	18.0	1.77 (*s*)	C-2″, C-3″, C-5″
5″	25.8	1.75 (*s*)	C-2″, C-3″, C-4″
1-NH	–	8.03 (*s*)	C-3, C-3a, C-7a

3.6.6 Phenantridine Alkaloids

3.6.6.1 Compound **FL24** (6-Acetonyldihydrochelerythrine)



Compound **FL24** ($C_{24}H_{23}NO_5$) was isolated as white solid. The IR spectrum displayed carbonyl functionality (1715 cm^{-1}) while the UV spectrum showed the maximum absorbances at 229 and 282 nm. These results suggested that compound **FL24** was a dihydrobenzophenantridine skeleton (Deng & Qin, 2010). The ^{1}H NMR spectral data (Table 3.33) exhibited two sets of AB-type *ortho*-coupled aromatic protons at δ_H 7.72 (*d, J* = 8.4 Hz, H-11), 7.55 (*d, J* = 8.4 Hz, H-10), 7.48 (*d, J* = 8.4 Hz, H-12), 6.96 (*d, J* = 8.4 Hz, H-9) and a set of *para*-coupled aromatic proton at δ_H 7.52 (*s*, H-4) and 7.10 (*s*, H-1). Additionally, methylenedioxy group at δ_H 6.04/δ_C 101.0 was also observed in the ^{1}H and ^{13}C NMR spectral data which was located on C-2, 3 due to ^3J HMBC correlation of methylenedioxy (δ_H 6.04) with C-2 (148.1) and C-3 (147.5). Finally, the remaining NMR spectrum showed a methylene group at δ_H 2.25 (*dd, J* = 13.8, 4.0 Hz)/ δ_C 46.8, a methyl group at δ_H 2.06 (*s*)/ δ_C 31.1 and carbonyl group at δ_C 207.4. The HMBC correlations showed correlation from acetonide methylene protons (δ_H 2.25) to *N*-methine carbon (δ_C 54.9) at C-6. Futhermore, The ^{1}H NMR spectrum also showed two methoxy groups at δ_H 3.95 (*s*) and 3.92 (*s*), which were located on C-7 and C-8, respectively, because of ^3J correlations between 7-OMe (δ_H 3.95) with C-7 (δ_C 145.5) and 8-OMe (δ_H 3.92) with C-8 (δ_C 152.1) in the HMBC spectrum. Therefore, compound **FL24** was assigned as 6-acetonyldihydrochelerythrine (Julian & Delgado, 2001).

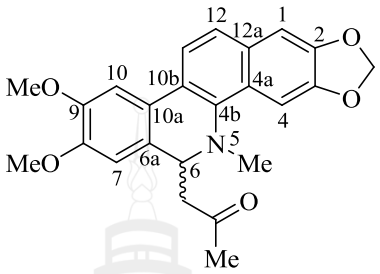
Table 3.33 NMR Spectroscopic Data of **FL24** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	104.3	7.10 (*s*)	C-3, C-4a, C-12
2	148.1	–	–
3	147.5	–	–
4	100.6	7.52 (*s*)	C-2, C-3
4a	127.3	–	–
4b	139.0	–	–
6	54.9	5.04 (*dd*, 10.8, 4.0)	C-4b, C-6a, C-7, C-10a

Table 3.33 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
6a	124.7	–	–
7	145.5	–	–
8	152.1	–	–
9	111.5	6.96 (*d*, 8.4)	C-7, C-8
10	118.8	7.55 (*d*, 8.4)	C-6a, C-8, C-10a, C-10b
10a	128.1	–	–
10b	123.7	–	–
11	119.7	7.72 (*d*, 8.4)	C-4b, C-10b, C-12, C-12a
12	123.9	7.48 (*d*, 8.4)	C-1, C-4a, C-10b
12a	131.0	–	–
5-NMe	42.8	2.62 (*s*)	C-6
6-*CH*$_2$C(=O)Me	46.8	2.25 (*dd*, 13.8, 4.0)	C-6, 6-CH$_2$*C*(=O)Me
6-CH$_2$*C*(=O)Me	207.4	–	–
6-CH$_2$C(=O)*Me*	31.1	2.06 (*s*)	6-*CH*$_2$C(=O)Me, 6-CH$_2$*C*(=O)Me
7-OMe	61.0	3.95 (*s*)	C-7
8-OMe	55.8	3.92 (*s*)	C-8
–OCH$_2$O–	101.0	6.04 (*d*, 0.8)	C-2, C-3

3.6.6.2 Compound **FL25** (8-Acetonyldihydronitidine)



Compound **FL25** ($C_{24}H_{23}NO_5$) was isolated as light yellow solid. The ^{1}H NMR spectral data (Table 3.34) was similar to those of **FL24** except that compound **FL25** showed *para*-coupled aromatic proton of ring A [δ_H 6.85 (*s*, H-7) and 7.32 (*s*, H-10)] instead of AB-type *ortho*-coupled aromatic proton. Therefore, 8-acetonyldihydronitidine was characterized to be **FL25** (Nissanka et al., 2001).

Table 3.34 NMR Spectroscopic Data of **FL25** in $CDCl_3$

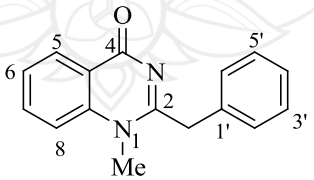
Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1	104.3	7.12(*s*)	C-3, C-4a, C-12
2	148.6	–	–
3	147.5	–	–
4	100.5	7.56 (*s*)	C-6a, C-8, C-10b
4a	127.3	–	–
4b	139.6	–	–
6	60	4.55 (*dd*, 8.4, 6.6)	C-4b, C-6a, C-7, C-10a
6a	127.0	–	–
7	110.3	6.85 (*s*)	C-6a, C-9, C-10a
8	149.0	–	–
9	148.2	–	–

Table 3.34 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
10	106.4	7.32 (*s*)	C-6a, C-8, C-10a, C-10b
10a	128.1	–	–
10b	123.4	–	–
11	119.6	7.71 (*d*, 8.4)	C-4b, C-10b, C-12, C-12a
12	123.8	7.51 (*d*, 8.4)	C-1, C-10b, C-4a
12a	130.9	–	–
5-NMe	42.4	2.61 (*s*)	C-6
6-*CH*$_2$C(=O)Me	48.4	2.69 (*dd*, 16.0, 8.4)	C-6, 6-CH$_2$*C*(=O)Me
		2.33 (*dd*, 16.0, 6.6)	
6-CH$_2$C(=O)*Me*	31.5	1.98 (*s*)	6-*CH*$_2$C(=O)Me,
			6-CH$_2$*C*(=O)Me
6-CH$_2$*C*(=O)Me	208.0	–	–
8-OMe	56.0	3.94 (*s*)	C-7
9-OMe	56.1	3.99 (*s*)	C-8
–OCH$_2$O–	101.0	6.05 (*d*, 0.8)	C-2, C-3

3.6.7 Quinazolinone Alkaloid

3.6.7.1 Compound **GP5** (Arborine)



Compound **GP5** ($C_{16}H_{14}N_2O$) was obtained as light yellow viscous oil. The IR spectrum revealed the carbonyl functionality at 1700 cm^{-1}. The UV spectrum showed the maxima absorbances at 204, 230, 276 and 305 nm, supporting that this

compound contained quinazolinone moiety (Chakravarti et al., 1961). The ^{1}H NMR spectral data of **GP5** (Table 3.35) exhibited a set of 1,2-disubstituted benzene ring at δ_H 8.33 (*dd*, *J* = 8.0, 1.2, H-5), 7.69 (*m*, H-7), 7.44 (*m*, H-6) and 7.34 (*d*, *J* = 8.8, H-8). Additionally, benzyl methylene protons [δ_H 4.27 (*s*)] and phenyl ring [δ_H (7.32 (*dd*, *J* = 8.4, H-2′/H-6′), 7.31 (*m*, H-3′/H-5′), 7.27 (*m*, H-4′)] were also observed in ^{1}H NMR spectrum. On the basis of HMBC correlation (Table 3.35), methylene carbon of benzyl group was connected to the quinazolinone at C-2 due to methylene protons (δ_H 4.27) correlation with C-2 (δ_C 162.3), C-1′ (δ_C 134.5) and C-2′/C-6′ (δ_C 129.1). Futhermore, the spectrum also showed methyl group at δ_H 3.63 (*s*)/ δ_C 34.9 which connected located to the 1-NMe because of ^{3}J correlations between N*Me* (δ_H 3.63) and C-2 (δ_C 162.3) and C-9 (δ_C 141.5) in the HMBC spectrum. Thus, compound **GP5** was identified as arborine (Bowen et al., 1978).

Table 3.35 NMR Spectroscopic Data of **GP5** in $CDCl_3$

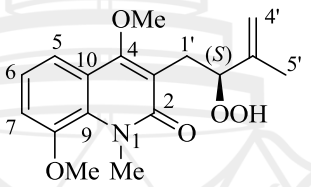
Position	**δ_C**	**δ_H (*mult.*, *J* in Hz)**	**HMBC**
2	162.3	–	–
4	169.1	–	–
5	128.4	8.33 (*dd*, 8.0, 1.2)	C-4, C-7, C-9
6	125.9	7.44 (*m*)	C-7, C-8, C-10
7	133.8	7.69 (*m*)	C-5, C-9
8	114.6	7.34 (*d*, 8.8)	C-6, C-10
9	141.5	–	–
10	120.0	–	–
1′	134.5	–	–
2′/6′	129.1	7.32 (*dd*, 8.4, 1.2)	C-1′, C-3′/5′, C-6′, -CH_2-
3′/5′	128.2	7.31 (*m*)	C-2′/ C-6′, C-4′, C-5′
4′	127.4	7.27 (*m*)	C-2′, C-3′, C-5′

Table 3.35 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1-NMe	34.9	3.63 (*s*)	C-2, C-9
-CH_2-	43.4	4.27 (*s*)	C-1′, C-2, C-2′

3.6.8 Quinolone Alkaloids

3.6.8.1 Compound **GP1** (Glycopentaphyllone)



Compound **GP1** was isolated as yellowish gum, showed a pseudomolecular ion peak at *m/z* 320.1495 ($[M+H]^+$, calcd 320.1498) in the ESI-TOF-MS spectral data corresponding to the molecular formula of $C_{17}H_{21}NO_5$. The IR spectrum displayed the hydroxy and carbonyl functionalities at 3409 and 1729 cm^{-1}, respectively. The UV spectrum showed the maximum absorbances at λ_{max} 215, 231, 256, 283, 295 and 330 nm, suggesting that compound **GP1** contained quinolone skeleton (Arruda et al., 1992). The ^{1}H NMR spectral data of **GP1** (Table 3.36) showed a set of ABC-type aromatic protons at δ_H 7.43 (*dd*, *J* = 8.0, 1.2 Hz, H-5), 7.22 (*t*, *J* = 8.0 Hz, H-6), and 7.09 (*dd*, *J* = 8.0, 1.2 Hz, H-7). The signals at δ_H 5.02 (*br s*, H-4′a), 5.00 (*br s*, H-4′b)/ δ_C 112.6 (C-4′), δ_H 4.38 (*dd*, *J* = 9.2, 3.6 Hz, H-2′)/ δ_C 86.0 (C-2′), δ_H 3.25 (*dd*, *J* = 13.6, 9.2 Hz, H-1′a), 3.11 (*dd*, *J* = 13.6, 3.6 Hz, H-1′b)/ δ_C 25.4 (C-1′), and 1.92 (*s*, H-5′)/ δ_C 20.4 (C-5′) were recognized as the resonances of a 2-oxygenated-3-methylbut-3-enyl unit. In addition, two methoxyl groups at δ_H 3.90 (*s*, 4-OMe) and 3.92 (*s*, 8-OMe), and a *N*–methyl group (δ_H 4.01) along with a singlet D_2O exchangeable signal at δ_H 11.2 were also observed in the ^{1}H NMR spectral data. These results suggested that the structure of **GP1** was closely related to those of

acutifolin (**GP2**) (Table 3.37). The secondary OH group at C-2′ in compound **GP2** was replaced by a hydroperoxy group in compound **GP1** of which the C-2′ in **GP1** resonated at about 10 ppm lower field than **GP2** [**GP1**: δ_H 4.38/δ_C 86.0 (Table 3.36); **GP2**: δ_H 4.32/δ_C 76.2 (Table 3.37)]. Moreover, the ^{1}H NMR signals of a labile OH proton (**GP1**: δ_H 11.2; **GP2**: δ_H 4.96 (observed from our experiment)) and H-4′b (**GP1**: δ_H 5.00; **GP2**: δ_H 4.83 (Table 3.36)) were also shifted to the downfield. The above information were also supported with the ESI-TOF-MS spectral data which showed the pseudomolecular ion peak at *m/z* 320.1495 ($[M+H]^+$) indicating **GP1** had one atom of oxygen higher than **GP2**. Compound **GP1** was, therefore, identified to be glycopentaphyllone.

The reduction of hydroperoxide **GP1** with PPh_3 gave the corresponding alcohol **GP2** which also supported the above information (Figure 3.1). This compound was further used as a starting material for C-2′ absolute configuration determination by applied Mosher's method. It was treated separately with (*R*)- and (*S*)-*α*-methoxy-*α*-trifluoromethyl-phenylacetyl chloride (MTPA-Cl) in the presence of pyridine, yielding the (*S*)- and (*R*)-bis-MTPA esters. The observed chemical shift differences $\Delta\delta_{SR}$ (Figure 3.2) revealed that the absolute configuration is 2′S configuration. Hence, this allowed assignment of the absolute stereochemistry of **GP1** with 2′S configuration. Compound **GP1** was, therefore, identified to be glycopentaphyllone, a hydroperoxy derivative of **GP2** at C-2′. The complete assignments of ^{1}H, ^{13}C NMR and HMBC of **GP1** were shown in Table 3.36.

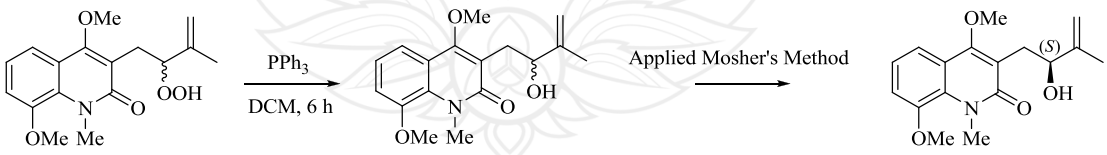


Figure 3.1 Reduction of **GP1** by PPh_3/DCM and Applied Mosher's Method of **GP2**

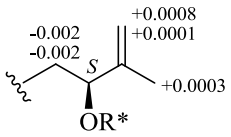
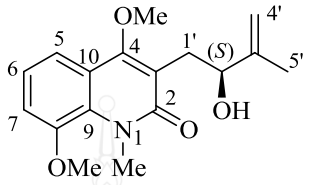


Figure 3.2 $\Delta\delta_{SR}$ Sign Distribution of bis-MTPA esters **GP2**

Table 3.36 NMR Spectroscopic Data of **GP1** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
2	166.9	–	–
3	120.0	–	–
4	161.9	–	–
5	115.9	7.43 (*d*, 8.0, 1.2)	C-4, C-7
6	123.0	7.22 (*t*, 8.0)	C-5, C-8
7	113.7	7.09 (*dd*, 8.0, 1.2)	C-5, C-6, C-8, C-9
8	149.1	–	–
9	130.7	–	–
10	119.8	–	–
1′	25.4	3.25 (*dd*, 13.6, 9.2)	C-2, C-2′, C-3, C-3′, C-4
		3.11 (*dd*, 13.6, 3.6)	
2′	86.0	4.38 (*dd*, 9.2, 3.6)	C-3′, C-4′
3′	144.3	–	–
4′	112.6	5.02 (*br s*), 5.00 (*br s*)	C-2′, C-3′, C-5′
5′	20.4	1.92 (*s*)	C-2′, C-3′, C-4′
4-OMe	61.7	3.90 (*s*)	C-4
8-OMe	56.6	3.92 (*s*)	C-8
2′-OOH	–	11.2 (*s*)	–
N-Me	36.2	4.01 (*s*)	C-2, C-9

3.6.8.2 Compound **GP2** (Acutifolin)



Compound **GP2** ($C_{17}H_{21}NO_4$) was isolated as yellow viscous oil. All ^{1}H and ^{13}C NMR spectral data (Table 3.37) of compound **GP2** were closely related to those of **GP1** except compound **GP2** appeared the hydroxyl group on C-2′ (δ_H 4.96/ δ_C 76.2) instead of hydroperoxy group as appeared in compound **GP1**. The structure of **GP2** was also confirmed by HMBC spectrum as shown in Table 3.37. The absolute configuration was assigned as *S*-configuration by applied Mosher's method as shown in Figures 3.10 and 3.11. Therefore, **GP2** was assigned as acutifolin (Arruda et al., 1992).

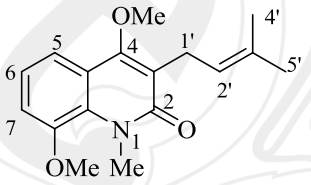
Table 3.37 NMR Spectroscopic Data of **GP2** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
2	167.0	–	–
3	120.9	–	–
4	161.6	–	–
5	115.9	7.45 (*d*, 8.0, 1.6)	C-4, C-7, C-9
6	122.8	7.18 (*t*, 8.0)	C-5, C-8, C-10
7	113.6	7.07 (*dd*, 8.0, 1.6)	C-5, C-6, C-8, C-9
8	148.8	–	–
9	130.5	–	–
10	119.9	–	–

Table 3.37 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
1′	32.1	3.06 (*dd*, 14.4, 3.2)	C-2, C-2′, C-3, C-3′
		2.94 (*dd*, 14.4, 9.2)	
2′	76.2	4.32 (*dd*, 9.2, 3.6)	C-3′, C-4′
3′	147.9	–	–
4′	110.1	5.06 (*br d*, 1.2)	C-2′, C-3′, C-5′
		4.83 (*br d*, 1.2)	
5′	17.8	1.94 (*s*)	C-2′, C-3′, C-4′
4-OMe	62.1	3.91 (*s*)	C-4
8-OMe	56.5	3.91 (*s*)	C-8
2′-OH	–	4.96 (*s*)	–
N-Me	35.8	3.98 (*s*)	C-2, C-9

3.6.8.3 Compound **GP3** (3-(3′,3′-Dimethyl-allyl)-4,8- dimethoxy-*N*-methyl quinolin-2-one)

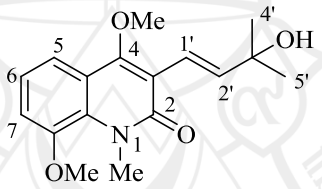


Compound **GP3** ($C_{17}H_{21}NO_3$) was isolated as colorless viscous oil. The ^1H spectral data (Table 3.38) of **GP3** was similar to that of **GP2** except compound **GP3** was not observed the hydroxyl group on C-2′ of the prenyl unit. Therefore, **GP3** was identified as 3-(3′,3′-dimethyl-allyl)-4,8-dimethoxy-*N*-methyl quinolin-2-one (Chakravarty et al., 1999).

Table 3.38 ^{1}H NMR Spectroscopic Data of **GP3** in $CDCl_3$

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
5	7.44 (*br d*, 8.0)	4′	1.80 (*s*)
6	7.16 (*t*, 8.0)	5′	1.68 (*s*)
7	7.04 (*br d*, 8.0)	4-OMe	3.89 (*s*)
1′	3.39 (*br d*, 6.0)	8-OMe	3.87 (*s*)
2′	5.25 (*m*)	N-Me	3.96 (*s*)

3.6.8.4 Compound **GP4** (Glycocitlone C)



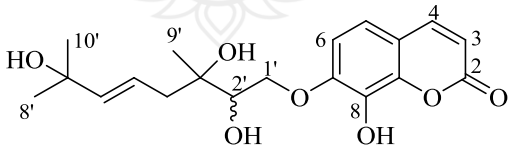
Compound **GP4** ($C_{17}H_{21}NO_4$) was isolated as colorless viscous oil. All ^{1}H and ^{13}C NMR spectral data of **GP4** (Table 3.39) were similar to those of **GP2** except compound **GP4** exhibited a 2-methylbut-3-en-2-ol unit [δ_H 7.24 (*d*, *J* = 16.4 Hz, H-2′), 6.82 (*d*, *J* = 16.4 Hz, H-1′), 1.45 (*s*, Me-4′ and Me-5′)] instead of 1-hydroxy -3-methylbut-3-enyl unit. The geometry of double bond at C-1′/C-2′ was identified to be *E*-geometry due to the large *J* value of H-1′ and H-2′ (16.4 Hz). The structure of **GP4** was also confirmed by HMBC correlation as shown in Table 3.39. Therefore, compound **GP4** was deduced as glycocitlone C (Kobayashi & Harayama, 2009).

Table 3.39 NMR Spectroscopic Data of **GP4** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
2	164.0	–	–
3	120.6	–	–
4	160.4	–	–
5	116.1	7.52 (*br d*, 8.0)	C-4, C-7, C-9
6	122.3	7.18 (*t*, 8.0)	C-8, C-10
7	114.0	7.06 (*dd*, 8.0, 1.2)	C-5, C-8, C-9
8	148.5	–	–
9	130.2	–	–
10	120.0	–	–
1′	116.4	6.82 (*d*, 16.4)	C-2, C-2′, C-3′, C-4
2′	144.3	7.24 (*d*, 16.4)	C-1′, C-3′, C-4′/C5′
3′	71.4	–	–
4′/5′	29.7	1.45 (*s*)	C-2′, C-3′, C-5′/C-4′
4-OMe	60.8	3.90 (*s*)	C-4
8-OMe	56.6	3.87 (*s*)	C-8
N-Me	35.3	3.94 (*s*)	C-2, C-9

3.6.9 Coumarins

3.6.9.1 Compound **CE1** (Clausenaexcavin)



Compound **CE1** was isolated as colorless viscous oil with a molecular formula $C_{19}H_{24}O_7$ on the basis of the $[M\text{-}H_2O]^+$ ion at *m/z* 346.1422 in the HREIMS (calcd *m/z* 346.1416). The UV spectrum showed maximum absorption bands at 207,

230, 258 and 318 nm indicating conjugated system in the molecule whereas the IR spectrum showed the hydroxyl and carbonyl functionalities at 3408 and 1718 cm^{-1} respectively. The ^1H NMR signals (Table 3.40) at δ_H 6.25 (H-3) and 7.60 (H-4) (each *d*, *J* = 9.5 Hz) and 6.93 (H-5) and 6.80 (H-6) (each *d*, *J* = 8.5 Hz) indicated the presence of 7,8-dioxygenated coumarin nucleus (Rahmani et al., 2003). In addition the existence of 2,3,7-trihydroxy-3,7-dimethyloct-5-enyloxy group was also observed in the ^1H NMR spectrum at δ_H 5.77 (*d*, *J* = 16.0 Hz, H-6′), 5.73 (*m*, H-5′), 4.99 (*dd*, *J* = 11.5, 3.0 Hz, H-1′a), 4.09 (*dd*, *J* = 11.5, 9.0 Hz, H-1′b), 3.98 (*dd*, *J* = 9.0, 3.0 Hz, H-2′), 2.44 (*dd*, *J* = 14.0, 6.0 Hz, H-4′a), 2.29 (*dd*, *J* = 14.0, 7.5 Hz, H-4′b), 1.34 (*s*, H-9′), 1.30 (*s*, H-8′) and 1.29 (*s*, H-10′). The COSY and HMBC correlations (Table 3.40) were also supported this moiety. The HMBC correlations between H-1′, H-5 and H-6 and C-7 (146.4) indicated that the side chain moiety was located at C-7 of coumarin framework. The geometry of double bond at C-5′/C-6′ was identified to be *E*-geometry due to the large *J* value of H-6′ (16.0 Hz). Therefore, clausenaexcavin was identified to be **CE1**.

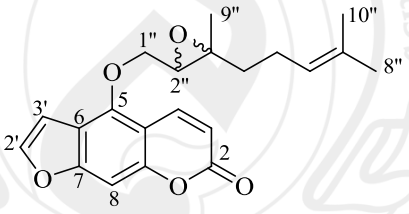
Table 3.40 NMR Spectroscopic Data of **CE1** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
2	160.7	–	–
3	113.5	6.25 (*d*, 9.5)	C-2, C-4a
4	143.9	7.60 (*d*, 9.5)	C-2
4a	113.4	–	–
5	119.5	6.93 (*d*, 8.5)	C-4, C-6, C-7
6	113.3	6.80 (*d*, 8.5)	C-4a, C-8
7	146.4	–	–
8	131.8	–	–
8a	143.7	–	–
1′	65.1	4.09 (*dd*, 11.5,9.0)	C-7
		4.99 (*dd*, 11.5,3.0)	

Table 3.40 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
2′	77.9	3.98 (*dd*, 9.0, 3.0)	C-1′, C-3′
3′	72.9	–	–
4′a	41.5	2.29 (*dd*, 14.0, 7.5)	C-5, C-6
4′b		2.44 (*dd*, 14.0, 6.0)	
5′	140.3	5.73 (*m*)	C-3, C-4
6′	120.3	5.77 (*d*, 16.0)	C-7
7′	72.3	–	–
8′	29.9	1.30 (*s*)	C-7
9′	22.8	1.34 (*s*)	C-4
10′	29.9	1.29 (*s*)	C-7

3.6.9.2 Compound **FL8** (Lucidafuranocoumarin A)



Compound **FL8** was isolated as colorless viscous oil. The molecular formula, $C_{21}H_{22}O_5$, was established by ESI-TOF-MS, which showed its pseudo-molecular ion peak $[M+H]^+$ at *m/z* 355.1531 (calcd for $C_{21}H_{23}O_5$, 355.1545). The UV spectrum showed absorption maxima of a conjugated furanocoumarin at 202, 219, 249, 259, 266, and 306 nm (Ito et al., 1998), whereas the IR spectrum displayed an absorption band of carbonyl functionality at 1732 cm^{-1}. The ^1H NMR spectral data (Table 3.41) of **FL8** showed the characteristic of furanocoumarin framework at δ_H 8.20 (*d*, *J* = 9.6 Hz, H-4), 7.61 (*d*, *J* = 2.4 Hz, H-2′), 6.96 (*d*, *J* = 2.4 Hz, H-3′), and 6.29 (*d*, *J* = 9.6 Hz, H-3). In addition, the presence of a singlet signal of an aromatic proton

was also observed at δ_H 7.17 (*s*), which identified to be H-8 due to the ^2J and ^3J HMBC correlations (Table 3.41) with C-4a (δ_C 107.3), C-6 (δ_C 114.0), C-7 (δ_C 158.0), and C-8a (δ_C 152.5). Furthermore, the ^{1}H NMR spectrum also displayed 3-methyl-3-(4-methylpent-3- enyl)oxiran-2-yl)methoxyl group (2″,3″- epoxygeranyloxy group) at δ_H 5.10 (*br t*, J = 7.2 Hz, H-6″), 4.61 (*dd*, J = 10.8, 4.0 Hz, H-1″a), 4.44 (*dd*, J = 10.8, 6.8 Hz, H-1″b), 3.24 (*dd*, J = 6.8, 4.0 Hz, H-2″), 2.10 (*m*, H-5″), 1.75 (*m*, H-4″a), 1.69 (*s*, H-10″), 1.62 (*s*, H-8″), 1.50 (*m*, H-4″b), and 1.33 (*s*, H-9″). This finding was supported by HMBC correlations (Table 3.41). The ^3J HMBC correlations from H-1″ and H-4 to C-5 (δ_C 148.3) indicated that the side chain moiety was located at C-5 of furanocoumarin framework. Therefore, the structure of **FL8** was characterized as lucidafuranocoumarin A.

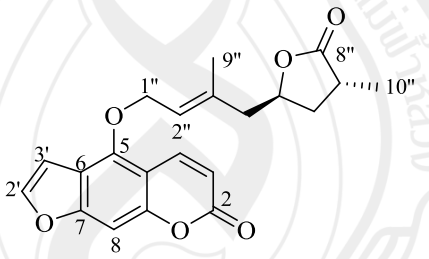
Table 3.41 NMR Spectroscopic Data of **FL8** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, J in Hz)	HMBC
2	161.0	–	–
3	113.0	6.29 (*d*, 9.6)	C-2, C-4a
4	139.0	8.20 (*d*, 9.6)	C-2, C-5, C-8
4a	107.3	–	–
5	148.3	–	–
6	114.0	–	–
7	158.0	–	–
8	94.7	7.17 (*s*)	C-4a, C-6, C-7, C-8a
8a	152.5	–	–
2′	145.2	7.61 (*d*, 2.4)	C-6, C-7
3′	104.5	6.96 (*d*, 2.4)	C-6, C-7
1″	72.2	4.61 (*dd*, 10.8, 4.0)	C-2″, C-3″, C-5
		4.44 (*dd*, 10.8, 6.8)	
2″	60.3	3.24 (*dd*, 6.8, 4.0)	C-1″

Table 3.41 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
3″	60.7	–	–
4″	38.2	1.75 (*m*), 1.50 (*m*)	C-2″, C-3″, C-5″, C-6″
5″	23.6	2.10 (*m*)	C-3″, C-4″, C-6″, C-7″
6″	123.0	5.10 (*br t*, 7.2)	C-4″, C-5″, C-7″, C-8″
7″	132.4	–	–
8″	17.6	1.62 (*s*)	C-6″, C-7″, C-10″
9″	16.9	1.33 (*s*)	C-3″, C-4″
10″	25.6	1.69 (*s*)	C-6″, C-7″, C-8″

3.6.9.3 Compound **FL9** (Lucidafuranocoumarin B)



Compound **FL9** was obtained as light yellow gum and its molecular formula was determined as $C_{21}H_{20}O_6$ ($[M]^+$ *m/z* 368.1256, calcd. for $C_{21}H_{20}O_6$, 368.1260) based on HR-EI-MS. The IR spectrum displayed the carbonyl lactone functionalities at 1735 and 1765 cm^{-1}, and the UV spectrum showed the typical absorbances at λ_{max} 267 and 282 nm. The ^1H NMR spectral data (Table 3.42) of **FL9** showed the characteristic of furanocoumarin framework (Girennavar et al., 2006) at δ_H 8.16 (*d*, *J* = 9.6 Hz, H-4), 7.61 (*d*, *J* = 2.4 Hz, H-2′), 7.17 (*s*, H-8), 6.95 (*d*, *J* = 2.4 Hz, H-3′), and 6.29 (*d*, *J* = 9.6 Hz, H-3) indicative of a substituent at C-5. This finding was supported by the ^2J and ^3J HMBC correlations (Table 3.42) of H-8 to C-4a (δ_C 107.4), C-6 (δ_C 114.1), C-7 (δ_C 158.1) and C-8a (δ_C 152.6). In addition, the units of

–OCH_2CH=C(Me)–CH_2– [δ_H 5.64 (*br t*, *J* = 9.6 Hz, H-20″), 4.97 (*d*, *J* = 9.6 Hz, H_2-1″), 2.46 (*m*, H-4″a), 2.33 (*m*, H-4″b) and 1.77 (*s*, Me-9″)] and *α*-methyl-*γ*-lactone ring [δ_H 4.66 (*m*, H-5″), 2.70 (*m*, H-7″), 2.12 (*m*, H-6″a), 2.00 (*m*, H-6″b) and 1.29 (*d*, *J* = 7.2 Hz, Me-10″)] were also observed in the ^{1}H NMR spectrum. On the basis of COSY and HMBC spectra (Table 3.42), both units were linked to each other at C-4″ and C-5″. The relative stereochemistry of **FL9** was established by NOE difference spectra. The methyl protons Me-10″ (δ_H 1.29) were enhanced when irradiated at H-5″ (δ_H 4.66). This result implied that H-5″ and Me-10″ had the *syn* relative orientation. Additionally, the geometry of a double bond at C-2″ and C-3″ was assigned as *E*-configuration according to the enhancement of H_2-4″ (δ_H 2.46 and 2.33) upon the irradiation of H-2″ (δ_H 5.64). Therefore, the structure of **FL9** was identified to be lucidafuranocoumarin B.

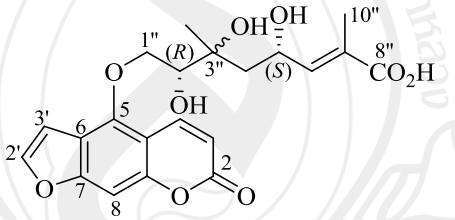
Table 3.42 NMR Spectroscopic Data of **FL9** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC	COSY
2	161.0	–	–	–
3	112.8	6.29 (*d*, 9.6)	C-2, C-4a	C-4
4	139.4	8.16 (*d*, 9.6)	C-2, C-4a, C-5, C-8	C-3
4a	107.4	–	–	–
5	148.6	–	–	–
6	114.1	–	–	–
7	158.1	–	–	–
8	94.4	7.17 (*s*)	C-4a, C-6, C-7, C-8a	–
8a	152.6	–	–	–
2′	145.1	7.61 (*d*, 2.4)	C-3′, C-6, C-7	C-3′
3′	104.9	6.95 (*d*, 2.4)	C-2′, C-6, C-7	C-2′
1″	69.3	4.97 (*d*, 9.6)	C-2″, C-3″, C-5	C-2″
2″	122.8	5.64 (*br t*, 9.6)	C-4″, C-9″	C-1″
3″	137.6	–	–	–

Table 3.42 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC	COSY
4″	45.0	2.46 (*m*)	C-2″, C-3″, C-5″, C-6″	C-5″
		2.33 (*m*)		
5″	76.1	4.66 (*m*)	C-3″, C-6″, C-8″	C-4″, C-6″
6″	35.1	2.12 (*m*)	C-4″, C-5″, C-7″, C-8″,	C-5″, C-7″
		2.00 (*m*)	C-10″	
7″	33.7	2.70 (*m*)	C-6″ C-8″, C-10″	C-6″, C-10″
8″	179.6	–	–	–
9″	17.1	1.77 (*s*)	C-2″, C-3″, C-4″	–
10″	15.8	1.29 (*d*, 7.2)	C-6″, C-7″, C-8″	–

3.6.9.4 Compound **FL10** (Lucidafuranocoumarin C)



Compound **FL10** was isolated as a light yellow gum and its molecular formula, $C_{21}H_{22}O_9$, was determined by the pseudo ion peak at *m/z* 423.1052 ($C_{21}H_{20}O_8Na$ $[M\text{-}H_2O+Na]^+$, calcd for 423.1050) in the ESI-TOF-MS. The IR spectrum showed two carbonyl (1700 and 1734 cm^{-1}) and hydroxyl (3426 cm^{-1}) functionalities. The ^1H and ^{13}C NMR spectral data of **FL10** (Table 3.43) displayed C_{10} terpenoidal furanocoumarin skeleton similar to those of **FL9**, except the double bond at C-2″,C-3″ and Me-10″ were oxidized to diol and carboxylic acid, respectively. The ^1H and ^{13}C NMR chemical shifts were very similar to those of feroniellic acid A, isolated from the same plant by Phuwapraisirisan et al. (2008). However, some of ^1H NMR signals of these compounds, **FL10** and feroniellic acid A,

showed significant chemical shift differences. For example, the ^{1}H NMR spectrum at H-2″, H-4a″, H-4b″ and H-9″of **FL10** resonated at δ_H 4.10, 2.21, 1.61 and 1.41, respectively, whereas feroniellic acid A appeared at δ_H 4.43, 2.36, 1.94 and 1.25. In addition, the ^{13}C NMR signal of C-9″ of both compounds also showed significant difference (δ 29.9 for feroniellic acid A and δ 23.3 for **FL10**). From the above information, **FL10** is an isomer of feroniellic acid A.

To determine the absolute configurations of **FL10**, it was treated separately with (*R*)- and (*S*)-α-methoxy-α-trifluoromethyl-phenylacetyl chloride (MTPA-Cl) in the presence of pyridine, yielding the (*S*)- and (*R*)-bis-MTPA esters. Based on the ^{1}H-NMR of (*S*)- and (*R*)-bis-MTPA esters, the differences between the chemical shifts, $\Delta\delta_{SR}$, were demonstrated in Figure 3.3. The negative signs around C-2″ and C-5″ led to the assignments of 1,4-*syn* diols with the *R*- and *S*-configurations at C-2″and C-5″, respectively, when directly compared with Mosher's model (Freire et al., 2005; Ohtani et al., 1991). Therefore, compound **FL10** was identified to be lucidafuranocoumarin C.

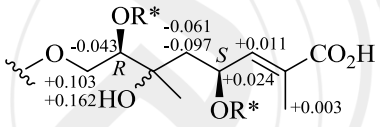


Figure 3.3 $\Delta\delta_{SR}$ Sign Distribution of *syn*-1,4 of bis-MTPA Esters **FL10**

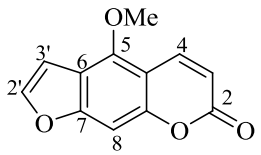
Table 3.43 NMR Spectroscopic Data of **FL10** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC	COSY
2	161.5	–	–	–
3	112.4	6.17 (*d*, 10.0)	C-2, C-4a	H-4
4	139.5	8.14 (*d*, 10.0)	C-2, C-4a, C-5, C-8	H-3
4a	106.9	–	–	–
5	148.4	–	–	–

Table 3.43 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC	COSY
6	113.9	–	–	–
7	158.0	–	–	–
8	94.3	6.99 (*s*)	C-4a, C-6, C-7, C-8a	–
8a	152.1	–	–	–
2′	145.3	7.59 (*d*, 2.4)	C-3′, C-6, C-7	H-3′
3′	104.8	6.98 (*d*, 2.4)	C-2′, C-6, C-7	H-2′
1″	74.0	4.64 (*dd*, 10.0, 2.4)	C-2″, C-3″, C-5	H-2″
		4.39 (*dd*, 10.0, 8.4)		
2 ″	76.0	4.10 (*br d*, 8.4)	C-1″	H-1″
3 ″	72.5	–	–	
4 ″	41.2	2.21 (*m*)	C-2″, C-3″, C-5″, C-6″	H-5″
		1.61 (*m*)		
5 ″	78.1	5.30 (*m*)	–	H-6″
6 ″	150.1	7.15 (*br s*)	C-5″, C-7″, C-8″	H-5″
7 ″	129.3	–	–	–
8 ″	174.1	–	–	–
9 ″	23.3	1.41 (*s*)	C-2″, C-3″, C-4″	–
10 ″	10.5	1.91 (*s*)	C-6″, C-7″, C-8″	–

3.6.9.5 Compound **FL5** (Bergapten)

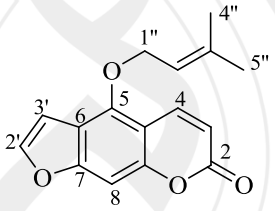


Compound **FL5** ($C_{12}H_8O_4$) was isolated as white solid. The ^{1}H NMR spectral data (Table 3.44) was closely related to that of **FL8** except that compound **FL5** showed a methoxy group (δ_H 4.27) instead of 2″,3″- epoxygeranyloxy group at C-5. Therefore, bergapten was deduced to be **FL5** (Masuda et al., 1997).

Table 3.44 ^{1}H NMR Spectroscopic Data of **FL5** in $CDCl_3$

Position	**δ_H (*mult.*, *J* in Hz)**	**Position**	**δ_H (*mult.*, *J* in Hz)**
3	6.27 (*d*, 10.0)	2′	7.59 (*d*, 2.4)
4	8.15 (*d*, 10.0)	3′	7.02 (*d*, 2.4)
8	7.12 (*s*)	5-OMe	4.27 (*s*)

3.6.9.6 Compound **FL6** (Isoimperatorin)

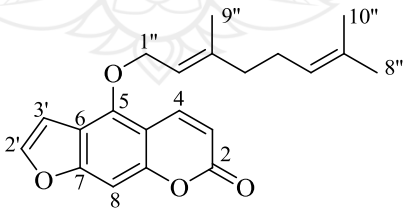


Compound **FL6** ($C_{16}H_{14}O_4$) was isolated as white solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.45) were similar to those of **FL8** except that compound **FL6** showed a prenyl group [δ_H/δ_C 5.53 (*d*, *J* = 7.2 Hz, H-2″)/119.0, 4.92 (*d*, *J* = 7.2 Hz, H_2-1″)/69.7, 1.90 (*s*, Me-4″)/25.8 and 1.70 (*s*, Me-5″)/18.2) instead of 2″,3″-epoxygeranyloxy group at C-5. The structure of **FL6** was also confirmed by HMBC as shown in Table 3.45. Therefore, isoimperatorin was identified to be **FL6** (Masuda et al., 1997).

Table 3.45 NMR Spectroscopic Data of **FL6** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
2	161.3	–	–
3	112.5	6.26 (*d*, 9.6)	C-2, C-4a
4	139.6	8.15 (*d*, 9.6)	C-2, C-5, C-8
4a	107.4	–	–
5	148.9	–	–
6	114.1	–	–
7	158.1	–	–
8	94.1	7.14 (*s*)	C-4a, C-6, C-7, C-8a
8a	152.6	–	–
2′	144.8	7.59 (*d*, 2.4)	C-3′, C-6, C-7
3′	105.0	6.96 (*d*, 2.4)	C-2′, C-6, C-7
1″	69.7	4.92 (*d*, 7.2)	C-2″, C-3″, C-5
2″	119.0	5.53 (*d*, 7.2)	C-4″, C-5″
3″	139.8	–	–
4″	25.8	1.90 (*s*)	C-2″, C-3″, C-5″
5″	18.2	1.70 (*s*)	C-2″, C-3″, C-4″

3.6.9.7 Compound **FL7** (Bergamottin)



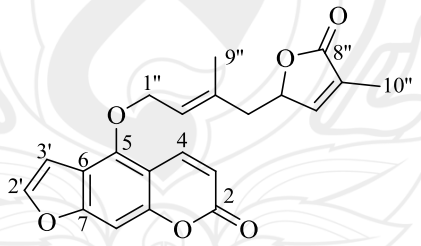
Compound **FL7** ($C_{21}H_{22}O_4$) was isolated as yellow solid. The ^1H NMR spectral data (Table 3.46) was similar to that of **FL6** except that compound **FL7**

showed geranyl unit [δ_H 5.53 (*br t*, *J* = 6.8 Hz, H-2″), 5.06 (*m*, H-6″), 4.95 (*d*, *J* = 6.8 Hz, H_2-1″), 2.10 (*m*, Me-4″ and Me-5″), 1.69 (*s*, Me-10″), 1.68 (*s*, Me-8″), 1.60 (*s*, Me-9″)] instead a prenyl group at C-2″. Therefore, bergamottin was identified to be **FL7** (Girennavar et al., 2006).

Table 3.46 ^{1}H NMR Spectroscopic Data of **FL7** in $CDCl_3$

Position	δ_H (*mult.*, *J* in Hz)	Position	δ_H (*mult.*, *J* in Hz)
3	6.27 (*d*, 9.6)	2″	5.53 (*br t*, 6.8)
4	8.15 (*d*, 9.6)	4″/5″	2.10 (*m*)
8	7.15 (*s*)	6″	5.06 (*m*)
2′	7.60 (*d*, 2.4)	8″	1.68 (*s*)
3′	6.96 (*d*, 2.4)	9″	1.60 (*s*)
1″	4.95 (*d*, 6.8)	10″	1.69 (*s*)

3.6.9.8 Compound **FL11** (Anisolactone)

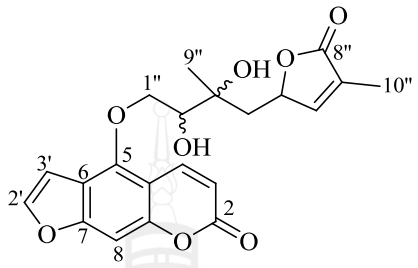


Compound **FL11** ($C_{21}H_{18}O_6$) was isolated as white solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.47) were closely related to those of compound **FL9** except that compound **FL11** showed a double bond at C-6″/C-7″ [δ_H 7.00 (*br s*, H-6″)/ δ_C 148.0 (C-6″)] instead the single bond as appeared in compound **FL9**. The structure of compound **FL11** was also confirmed by HMBC correlation as shown in Table 3.47. Thus, compound **FL11** was identified as anisolactone (Lakshmi et al., 1984).

Table 3.47 NMR Spectroscopic Data of **FL11** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
2	161.1	–	–
3	112.7	6.28 (*d*, 9.6)	C-2, C-4a
4	139.3	8.16 (*d*, 9.6)	C-2, C-5, C-8a
4a	107.4	–	–
5	148.6	–	–
6	114.0	–	–
7	158.0	–	–
8	94.3	7.14 (*s*)	C-4a, C-6, C-7, C-8a
8a	152.0	–	–
2′	145.1	7.61 (*d*, 2.0)	C-3′, C-6, C-7
3′	104.9	6.95 (*br s*)	C-2′, C-6, C-7
1″	69.2	4.97 (*m*)	C-2″, C-3″, C-5
2″	123.2	5.68 (*br t*, 6.0)	C-4″, C-9″
3″	136.8	–	–
4″	43.2	2.47, 2.35 (*m*)	C-2″, C-3″, C-5″, C-9″
5″	78.0	5.01 (*m*)	C-2″, C-3″, C-4″
6″	148.0	7.00 (*br s*)	C-3″, C-6″
7″	130.4	–	–
8″	171.8	–	–
9″	17.3	1.79 (*s*)	C-2″, C-3″, C-4″
10″	10.6	1.92 (*s*)	C-6″, C-7″, C-8″

3.6.9.9 Compound **FL12** (2″,3″-Dihydroxyanisolactone)



Compound **FL12** ($C_{21}H_{20}O_8$) was isolated as light yellow solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.48) were similar to those of compound **FL11** except that the double bond of compound **FL12** at C-2″/C-3″ was oxidized to diol [δ_H 3.29 (*dd*, *J* = 6.8, 4.4, H-2″)/ δ_C 61.4 (C-2″) and δ_C 58.4 (C-3″)]. The structure of **FL12** was also confirmed by HMBC as shown in Table 3.48. Therefore, compound **FL12** was deduced as 2″,3″-dihydroxyanisolactone (Phuwapraisirisan et al., 2007).

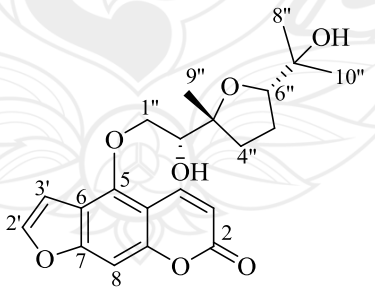
Table 3.48 NMR Spectroscopic Data of **FL12** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
2	161.1	–	–
3	113.2	6.34 (*d*, 9.6)	C-2, C-4a
4	139.1	8.28 (*d*, 9.6)	C-2, C-5, C-8a
4a	107.3	–	–
5	148.2	–	–
6	113.9	–	–
7	158.0	–	–
8	94.8	7.21 (*s*)	C-4a, C-6, C-7, C-8a
8a	153.3	–	–
2′	145.4	7.63 (*d*, 2.4)	C-3′, C-6, C-7

Table 3.48 (continued)

Position	δ_C	δ_H (*mult.*, *J* in Hz)	HMBC
3′	104.4	6.97 (*d*, 2.4)	C-2′, C-6, C-7
1″	71.6	4.68 (*dd*, 10.8, 4.4)	C-2″, C-3″, C-5
		4.44 (*dd*, 10.8, 6.8)	
2″	61.4	3.29 (*dd*, 6.8, 4.4)	C-1″, C-3″
3″	58.4	-	–
4″	43.0	2.06 (*dd*, 14.4, 4.4)	C-2″, C-3″, C-5″
		1.66 (*dd*, 14.4, 10.4)	
5″	77.9	5.09 (*m*)	C-6″
6″	148.1	7.08 (*m*)	C-5″, C-6″, C-7″
7″	130.3	-	–
8″	173.6	-	–
9″	10.6	1.49 (*s*)	C-2″, C-3″, C-4″
10″	16.8	1.94 (*s*)	C-6″, C-7″, C-8″

3.6.9.10 Compound **FL13** (Feroniellin A)



Compound **FL13** ($C_{21}H_{24}O_7$) was isolated as white solid. All ^1H and ^{13}C NMR spectral data (Table 3.49) also exhibited C_{10} terpenoidal furanocoumarin skeleton similar to those of **FL7**. However, compound **FL13** showed a unit of CH_2-CH-O [δ_H 4.59 (*dd*, 10.0, 3.5, H-1″a) and 4.38 (*dd*, 10.0, 8.0, H-1″b)/ δ_C 75.0 (C-1″),

and 4.04 (*dd*, *J* = 8.0, 3.5 Hz, H-2″)/ δ_C 75.3 (C-2″)] and a unit of C-CH_2-CH_2-CH-O unit [δ_H 3.84 (*m*, H-6″)/ δ_C 86.9, 2.20 (*m*, H-4″a) and 1.77 (*m*, H-4″b)/ δ_C 35.6, 1.91 (*m*, H_2-5″)/ δ_C 25.0] in ^1H and ^{13}C NMR spectrum. The C_{10} terpenoid formed the furan ring on C-3″/C-6″ due to the cross peak of H-6″ (δ_H 3.84) with δ_C 83.9 (C-3″) in HMBC spectrum. A singlet methyl at δ_H 1.15 (*s*, Me-9″) was placed at C-3″ on the basic of HMBC correlation between this methyl with C-2″ (δ_C 75.3), C-3″ (δ_C 83.9) and C-4″ (δ_C 35.6). The remaining singlet methyls, [δ_H 1.27 (Me-8″) and 1.24 (Me-10″)] were located on C-7″ because of ^2J and ^3J correlations with C-6″ (δ_C 86.9) and C-7″ (δ_C 69.7) in the HMBC spectrum. Thus, compound **FL13** was assigned as feroniellin A (Phuwapraisirisan et al., 2006).

Table 3.49 NMR Spectroscopic Data of **FL13** in $CDCl_3$

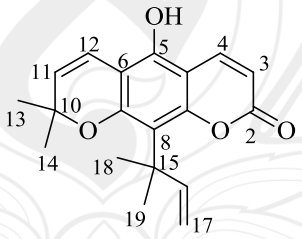
Position	δ_C[a]	δ_H (*mult.*, *J* in Hz)	HMBC
2	160.0	–	–
3	112.2	6.27 (*d*, 9.6)	C-2, C-4a
4	139.6	8.22 (*d*, 9.6)	C-2, C-5, C-8a
4a	106.8	–	–
5	149.4	–	–
6	113.5	–	–
7	158.2	–	–
8	93.2	7.14 (*s*)	C-4a, C-6, C-7, C-8a
8a	152.8	–	–
2′	145.4	7.60 (*d*, 2.4)	C-3′, C-6, C-7
3′	105.4	7.01 (*d*, 2.4)	C-2′, C-6, C-7
1″	75.0	4.59 (*dd*, 10.0, 3.5)	C-2″, C-5
		4.38 (*dd*, 10.0, 8.0)	
2″	75.3	4.04 (*dd*, 8.0, 3.5)	C-3″

Table 3.49 (continued)

Position	δ_C[a]	δ_H (*mult.*, *J* in Hz)	HMBC
3″	83.9	-	–
4″	35.6	1.77 (*m*)	C-3″, C-5″, Me-9″
		2.20 (*m*)	
5″	25.0	1.91 (*m*)	C-3″, C-4″, C-6″, C-7″
6″	86.9	3.84 (*m*)	C-3″, C-7″
7″	69.7	-	–
8″	25.9	1.27 (*s*)	C-6″, C-7″, C-10″
9″	24.9	1.15 (*s*)	C-2″, C-3″, C-4″
10″	21.4	1.24 (*s*)	C-6″, C-7″, C-8″

Note. [a]Recorded in acetone-d_6

3.6.9.11 Compound **CE8** (Nordentatin)



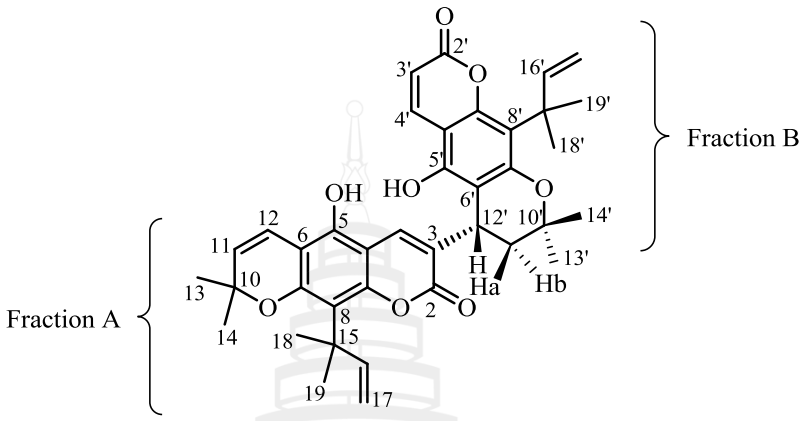
Compound **CE8** ($C_{19}H_{20}O_4$) was isolated as white solid. All ^{1}H and ^{13}C NMR spectral data (Table 3.50) were similar to those of **FL5** except that compound **CE8** showed a 2,2-dimethylpyran ring [δ_H 6.47(*d*, *J* = 10.0 Hz, H-17)/ δ_C 114.7, 5.70 (*d*, *J* = 10.0 Hz, H-17)/ δ_C 130.1 and 1.44 (*s*)/ δ_C 27.2] instead of a furan ring at C-6/C-7. The ^{1}H NMR spectral data also showed a dimethylallyl group at δ_H 6.28 (*dd*, *J* = 17.2, 10.4 Hz, H-16), 4.92 (*dd*, *J* = 17.2, 1.2 Hz, H-17a), 4.86 (*dd*, *J* = 10.4, 1.2 Hz, H-17b) and 1.64 (*s*, Me-18 and Me-19) which located on C-8, due to ^2J and ^3J HMBC

correlation of H-16 (δ_H 6.28) with δ_C 116.2 (C-8). Therefore, compound **CE8** was deduced as nordentatin (Huang et al 1997).

Table 3.50 NMR Spectroscopic Data of **CE8** in $CDCl_3$

Position	δ_C	δ_H (*mult.*, *J* in Hz)	**HMBC**
2	160.9	–	–
3	110.5	6.15 (*d*, 9.6)	C-2, C-4a
4	139.9	7.99 (*d*, 9.6)	C-2, C-5, C-8a
4a	107.0	–	–
5	146.3	–	–
6	105.8	–	–
7	156.0	–	–
8	116.2	–	–
8a	153.0	–	–
10	77.0	–	–
11	130.1	5.70 (*d*, 10.0)	C-6 C-13/C-14
12	114.7	6.47 (*d*, 10.0)	C-5, C-6, C-7, C-10
13/14	27.2	1.44 (*s*)	C-10, C-14/C-13
15	41.0	–	–
16	150.0	6.28 (*dd*, 17.2, 10.4)	C-15, C-18/C-19
17	108.0	4.92 (*dd*, 17.2, 1.2)	C-15, C-16
		4.86 (*dd*, 10.4, 1.2)	
18/19	29.5	1.64 (*s*)	C-8, C-15, C-16, C-18/C-19

3.6.9.12 Compound **CE10** (Binorpocitrin)



Compound **CE10** ($C_{38}H_{38}O_8$) was isolated as white solid. The ^{1}H and ^{13}C NMR spectral data (Table 3.51) displayed a dimeric coumarin which consists of two fragments, A and B. All ^{1}H and ^{13}C NMR spectral data of fragment A were similar to that of nordentatin (**CE8**) except that the H-3 of fragment A was missing from the ^{1}H NMR spectrum which implied that this compound contained a substituent group on C-3 of nordentatin. The ^{1}H and ^{13}C NMR spectral data of fragment B were also similar to nordentatin as well. However, the main difference was found that the double bond of pyran ring was missing. Fragment B showed a unit of -CH_2-CH- unit [δ_H 4.38 (*dd*, *J* = 8.8, 7.6 Hz / δ_C 31.7, 2.33 (*dd*, *J* = 13.6, 7.6 Hz) and 1.94 (*dd*, *J* = 13.6, 8.8 Hz/ δ_C 40.3] instead of a double bond at C-11′ and C-12′. The connectivity of fragments A and B was linked together at C-3 and C-12′ due to the ^{2}J and ^{3}J HMBC correlations of H-4 (δ_H 6.61) with δ_C 31.7 (C-12′) and of H-11′a, H-11′b and H-12′ with δ_C 126.2 (C-3). Thus, compound **CE10** was identified as binorpocitrin (Huang et al., 1997).

Table 3.51 NMR Spectroscopic Data of **CE10** in Acetone-d_6

Position	δ_C[a]	δ_H (*mult.*, *J* in Hz)	HMBC
2	161.2	–	–
3	126.2	–	–
4	139.6	6.61 (*s*)	C-2, C-3, C-5, C-8a, C-12′
4a	107.6	–	–
5	151.1	–	–
6	108.1	–	–
7	159.9	–	–
8	115.7	–	–
8a	156.3	–	–
10	76.6	–	–
11	129.7	5.71 (*d*, 10.0)	C-6, C-10, C-13, C-14
12	117.0	6.68 (*d*, 10.0)	C-5, C-6, C-7, C-10
13/14	27.4	1.42 (*s*)	C-10, C-11, C-14/C-13
15	41.8	–	–
16	153.1	6.29 (*dd*, 16.8, 10.0)	C-15, C-18/C-19
17	69.7	4.91 (*dd*, 16.8, 1.2)	C-15, C-16
		4.82 (*dd*, 10.0, 1.2)	
18/19	30.3	1.64 (*s*)	C-8, C-15, C-16, C-18, C-19
2′	160.7	–	–
3′	110.4	6.05 (*d*, 9.6)	C-2′, C-4′a
4′	140.1	8.08 (*d*, 9.6)	C-2′, C-4′a, C-5′, C-8′a
4′a	107.5	–	–
5′	151.2	–	–
6′	107.8	–	–
7′	159.0	–	–
8′	115.7	–	–
8′a	155.1	–	–

Table 3.51 (continued)

Position	δ_C[a]	δ_H (*mult.*, *J* in Hz)	HMBC
10′	77.1	–	–
11′a	40.3	2.33 (*dd*, 13.6, 7.6)	C-3, C-6′, C-12′, C-10′, C-
11′b		1.94 (*dd*, 13.6, 8.8)	13′, C-14′
12′	31.7	4.38 (*dd*, 8.8, 7.6)	C-2, C-3, C-4, C-6′, C-7′, C-11'
13′	30.1	1.40 (*s*)	C-10′, C-11′, C-14′
14′	24.9	1.33 (*s*)	C-10′, C-11′, C-13′
15′	41.5	–	-
16′	151.6	6.29 (*dd*, 16.8, 10.0)	C-15′, C-18′/C-19′
17′	108.3	4.91 (*dd*, 16.8, 1.2)	C-15′, C-16′
		4.82 (*dd*, 10.0, 1.2)	
18′/19′	27.6	1.67 (*s*)	C-8′, C-15′, C-16′, C-18′/C-19′
5-OH	–	8.49 (*br s*)	–
5′-OH	–	8.76 (*br s*)	–

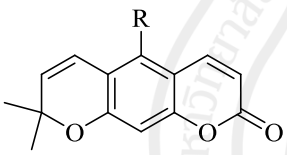
Note. [a]Recorded at 500 MHz

3.7 Biological Assay

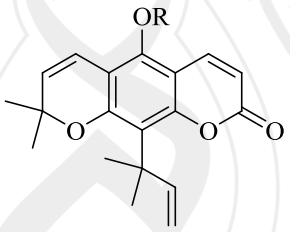
Some isolated compounds were selected for the evaluation of cytotoxic against three human cancer cell lines (KB, MCF-7 and NCI-H187), antimalarial activity against *P. falciparum*, antituberculosis against *M. tuberculosis* and antibacterial against *E. coli* TISTR 780, *S. typhimurium* TISTR 292, *Staph aureus* TISTR 1466 and MRSA SK1.

3.7.1 Cytotoxic activity

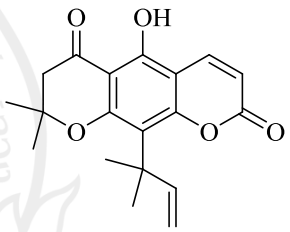
As summarized in Table 3.52, four different classes of compounds consisting of pyranocoumarins, furanocoumarins and carbazole alkaloids were evaluated for their against KB, MCF-7 and NCI-H187 cell lines. For cytotoxic activities of pyranocoumarins (**CE5-CE9**), compound **CE8** exhibited the highest cytotoxicity against KB, MCF-7 and NCI-H187 cell lines with the IC_{50} values of 5.95, 15.28 and 7.10 µg/mL, respectively. Compound **CE9** was selective activity against NCI-H187 cell line with the IC_{50} value of 8.63 µg/mL whereas the remaining compounds were weakly active or inactive with all cell lines. It should be noted that the pyranocoumarin (**CE7**) with substituent at C-8 exhibited strong activity than that of non-substituent group (**CE6**). The cytotoxicity is increased when the OMe group at C-5 in **CE7** was replaced by the OH group in **CE8**. Furthermore, a double bond at C-11 and C-12 in **CE8** also plays an important role for cytotoxicity comparing with compound **CE9**.



CE5: R = H
CE6: R = OMe



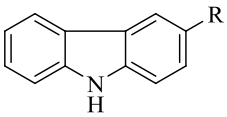
CE7: R = Me
CE8: R = H



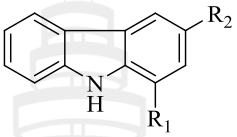
CE9

In case of cytotoxicity of carbazole alkaloids (**CE11-CE16**, **CE19-CE27** and **CE30**, Table 3.52) we found that compounds **CE12** and **CE20** exhibited strong cytotoxicity against KB cell line with the IC_{50} values of 4.68 and 4.63 µg/mL, respectively. Three carbazole alkaloids, **CE16** (IC_{50} 3.76 µg/mL), **CE21** (IC_{50} 1.61 µg/mL) and **CE23** (IC_{50} 0.78 µg/mL) also showed strong cytotoxicity against MCF-7 cell line and all of them also showed higher activity than standard drug doxorubicin (IC_{50} 7.62 µg/mL). **CE19-CE22** as well as **CE30** showed strong cytotoxicity against NCI-H187 cell line with the IC_{50} values of 4.11, 1.45, 1.07, 2.82 and 5.65 µg/mL, respectively, whereas compound **CE21** exhibited cytotoxicity equivalence to that of a

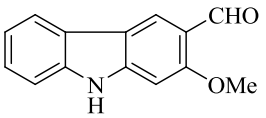
standard drug, ellipticine (IC_{50} 1.06 µg/mL). Only two compounds, **CE25** and **CE27**, were inactive with three cancer cell lines. The remaining compounds exhibited cytotoxicity against all three human cancer cell lines with the IC_{50} values ranging from 6.84-50 µg/mL for KB, 15.28-50 µg/mL for MCF-7 and 7.10-50 µg/mL for NCI-H187 cell lines.



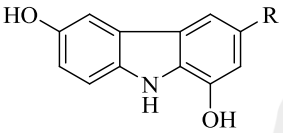
CE11: R = CO_2Me
CE12: R = CHO



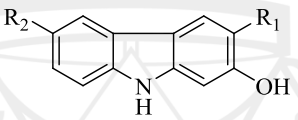
CE13: R_1 = OH , R_2 = CO_2Me
CE14: R_1 = OH, R_2 = CHO
CE15: R_1 = OMe, R_2 = CO_2Me
CE16: R_1 = OMe, R_2 = CHO



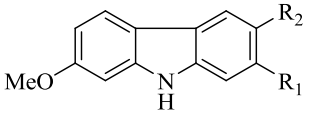
CE19



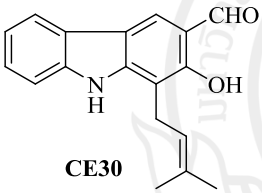
CE20: R = CO_2Me
CE21: R = CHO



CE22: R_1 = CO_2Me , R_2 = OH
CE23: R_1 = CHO, R_2 = OMe



CE24: R_1 = OH, R_2 = CHO
CE25: R_1 = OMe, R_2 = CHO
CE26: R_1 = OMe, R_2 = CO_2H
CE27: R_1 = OMe, R_2 = CO_2Me



CE30

Table 3.52 Cytotoxicity of Compounds **CE2**, **CE3**, **CE5-CE9**, **CE11-CE16**, **CE19-CE27**, **CE30** and **CE32**

Compounds	Cytotoxicity (IC_{50}, µg/mL)		
	KB[a]	**MCF-7**[b]	**NCI-H187**[c]
CE2	25.74	26.62	13.03
CE3	>50	17.09	>50
CE2	25.74	26.62	13.03
CE3	>50	17.09	>50

Table 3.52 (continued)

Compounds	Cytotoxicity (IC_{50}, µg/mL)		
	KB[a]	**MCF-7**[b]	**NCI-H187**[c]
CE5	17.97	44.05	18.57
CE6	>50	>50	35.54
CE7	33.16	26.72	15.92
CE8	5.95	15.28	7.10
CE9	>50	>50	8.63
CE11	13.44	38.23	21.57
CE12	4.68	>50	13.03
CE13	17.76	15.43	9.38
CE14	13.54	15.43	9.38
CE15	>50	25.26	>50
CE16	19.34	3.76	10.72
CE19	23.21	25.00	4.11
CE20	4.63	25.00	1.45
CE21	12.50	1.61	1.07
CE22	14.29	15.28	2.82
CE23	6.84	0.78	7.74
CE27	>50	>50	>50
CE30	26.31	47.75	5.65
CE32	36.60	5.68	21.66
Doxorubicin	NT[d]	7.62	NT[d]
Ellipticine	1.76	NT[d]	1.06

Note. [a]KB = Oral cavity cancer; [b]MCF7 = Breast cancer; [c]NCI-H187 = Small cell lung cancer; [d]NT = not tested

The cytotoxicity against KB, MCF-7 and NCI-H187 cell lines of furanocoumarins (**FL1-FL13**) was summarized in Table 3.53. The results showed that only two compounds **FL7** and **FL8** showed moderate cytotoxicity against NCI-H187

cell line with the IC_{50} values of 8.40 and 10.06 µg/mL, respectively. All remaining compounds were weakly active or inactive cytotoxicity against all three cancer cell lines.

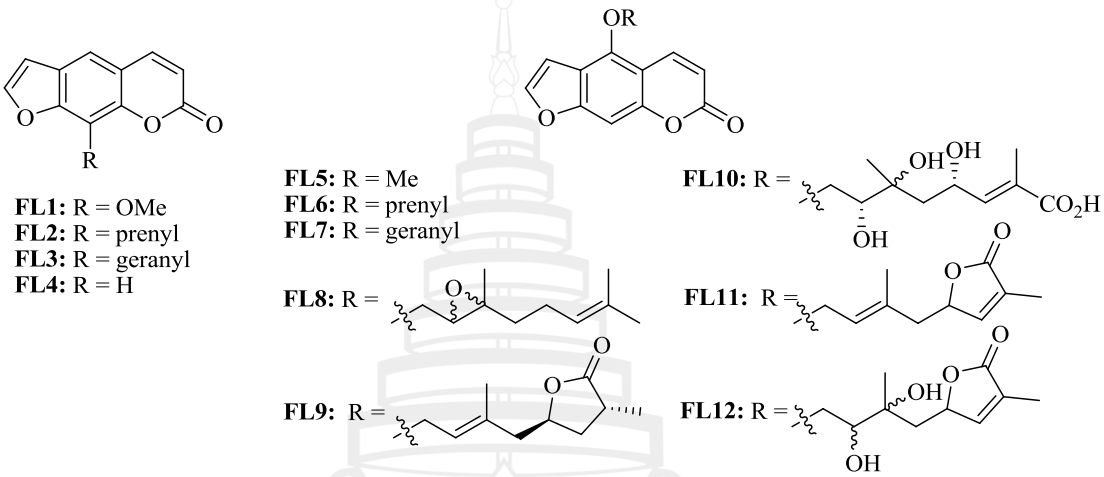


Table 3.53 Cytotoxicity of Compounds **FL1**, **FL2**, **FL4- FL13**, **FL15-FL17**, **FL20**, **FL22**, **FL24** and **FL25**

Compounds	Cytotoxicity (IC_{50}, µg/mL)		
	KB[a]	**MCF-7**[b]	**NCI-H187**[c]
FL1	>50	>50	>50
FL2	>50	>50	>50
FL4	17.97	44.05	18.57
FL5	>50	>50	>50
FL6	>50	>50	>50
FL7	27.35	>50	8.40
FL8	25.58	>50	10.06
FL9	>50	>50	>50
FL10	>50	>50	>50
FL11	>50	>50	29.30
FL12	>50	>50	>50

Table 3.53 (continued)

Compounds	Cytotoxicity (IC_{50}, µg/mL)		
	KB[a]	**MCF-7**[b]	**NCI-H187**[c]
FL13	>50	>50	>50
FL15	17.97	44.05	18.57
FL16	>50	>50	>50
FL17	>50	17.09	>50
Doxorubicin[d]	NT[e]	7.62	NT[e]
Ellipticine[d]	1.76	NT[e]	1.06

Note. [a]KB = Oral cavity cancer; [b]MCF7 = Breast cancer; [c]NCI-H187 = Small cell lung cancer; [d]NT = not tested

3.7.2 Antimalarial Activity

Compounds **CE8**, **CE13-CE15**, **CE19**, **CE21**, **CE22**, **CE32** and **FL1** were also evaluated for their antimalarial activity against *P. falciparum*. The results showed that only compound **CE8** exhibited strong antimalarial activity with the IC_{50} value of 0.533 µg/mL whereas compound **CE19** showed moderate activity (IC_{50} = 6.74 µg/mL). The remaining compounds were inactive.

Table 3.54 Antimalarial Activity of Compounds **CE8**, **CE13-CE15**, **CE19**, **CE21**, **CE22**, **CE32** and **FL1**

Compounds	IC_{50} (µg/mL)	Compounds	IC_{50} (µg/mL)
CE8	0.533	**CE21**	>50
CE13	>50	**CE22**	>50
CE14	>50	**CE32**	>50

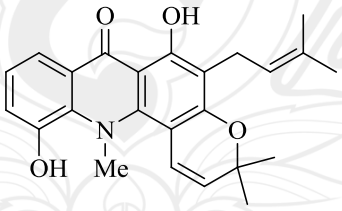
Table 3.54 (continued)

Compounds	IC_{50} (µg/mL)	Compounds	IC_{50} (µg/mL)
CE15	>50	**FL1**	>50
CE19	6.74	Dihydroartemisinin[a]	0.004

Note. [a]Positive control

3.7.3 Antibacterial Activity

The antibacterial activity against Gram positive (*Staph aureus* TISTR 1466 and MRSA SK1) and Gram negative bacteria (*E. coli* TISTR 780, and *S. typhimurium* TISTR 292) of compounds **AM1-AM5**, **AM7**, **AM9**, **AM10**, **AM12-AM15**, **GP1-GP10**, **GC2**, **GC3**, **GC8**, **GC11** and **GC14** were summarized in Table 3.55. Only compound **AM2** exhibited strong activity against MRSA SK1 and *S. aureus* TISTR 1466 with MIC values of 2 and 4 µg/mL, respectively, whereas all remaining compounds showed weakly active or inactive antibacterial activity against Gram positive and Gram negative bacteria.



AM2

Table 3.55 Antibacterial Activity of Compounds **AM1-AM5**, **AM7**, **AM9**, **AM10**, **AM12-AM15**, **GP1-GP10**, **GC2**, **GC3**, **GC8**, **GC11** and **GC14**

Compounds	MIC (µg/mL)			
	Gram-positive		Gram-negative	
	MRSA-SK1	***S. aureus***	***E. coli***	***S. typhimurium***
AM1	>128	>128	128	>128
AM2	2	4	128	128
AM3	>128	>128	>128	>128
AM4	>128	>128	>128	128
AM5	>128	>128	>128	128
AM7	64	128	>128	128
AM9	>128	>128	>128	128
AM10	>128	>128	>128	128
AM12	128	128	128	128
AM13	128	>128	128	128
AM14	>128	>128	>128	>128
AM15	>128	>128	>128	128
GP1	>128	>128	>128	128
GP2	128	>128	128	128
GP5	>128	>128	128	128
GP6	>128	>128	>128	128
GP7	>128	>128	128	128
GP8	128	>128	128	128
GP9	128	>128	128	128
GP10	>128	>128	128	128
GC2	>128	>128	>128	>128
GC3	>128	>128	>128	128
GC8	16	>128	>128	128
GC11	>128	>128	128	128
GC14	128	>128	>128	128

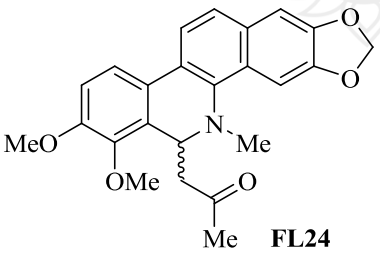
Table 3.55 (continued)

Compounds	MIC (µg/mL)			
	Gram-positive		Gram-negative	
	MRSA-SK1	***S. aureus***	***E. coli***	***S. typhimurium***
Vancomycin[a]	1	0.25	>128	>128
Gentamycin[a]	>128	>128	0.25	0.25

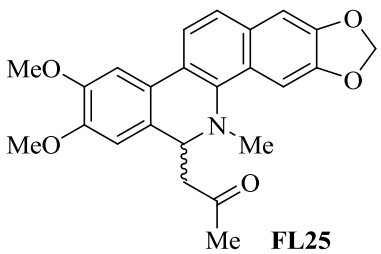
Note. [a]Positive control

3.7.3 Biological Activities for Phenantridine Alkaloids

Two phenantridine alkaloids (**FL24** and **FL25**) were tested for their biological activities including cytotoxicity against KB, MCF7 and NCI-H187 cell lines, antimalarial and antimycobacterial activities. The results were summarized in Table 3.56. Compound **FL25** showed strong cytotoxic acitivity against all three cancer cell lines KB (IC_{50} 0.637 µg/mL), MCF7 (IC_{50} 4.48 µg/mL) and NCI-H187 (IC_{50} 0.094 µg/mL) cell lines which are more potent than those of standard drugs (Table 3.56). Compound **FL24** was selective cytotoxicity against MCF7 with IC_{50} value of 5.10 µg/mL. Additionally, compounds **FL24** and **FL25** were also showed good antimalarial activity against *P. falciparum* with IC_{50} values of 2.46 and 0.336 µg/mL, respectively. Only compound **FL25** showed moderate anti-TB activity against *M. tuberculosis* with MIC value of 6.25 µg/mL.



FL24



FL25

Table 3.56 Biological Activities of **FL24** and **FL25**

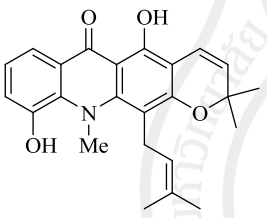
Compounds	Cytotoxicity (IC_{50}, µg/mL)			Antimalaria (IC_{50}, µg/mL)	Anti-TB (MIC, µg/mL)
	KB[a]	MCF7[b]	NCI-H187[c]		
FL24	>50	5.10	29.14	2.46	NT[d]
FL25	0.637	4.48	0.094	0.336	6.25
Doxorubicin[e]	NT[d]	7.62	NT[d]	NT[d]	NT[d]
Ellipticine[e]	1.76	NT[d]	1.06	NT[d]	NT[d]
Dihydroartemisinie[e]	NT[d]	NT[d]	NT[d]	0.004	NT[d]
Isoniazid[e]	NT[d]	NT[d]	NT[d]	NT[d]	0.023

Note. [a]KB = Oral cavity cancer; [b]MCF7 = Breast cancer; [c]NCI-H187 = Small cell lung cancer; [d]NT = Not tested; [e]Positive control: doxorubicin and ellipticine for cytotoxicity; dihydroartemisinie for antimalaria; isoniazid for anti-TB

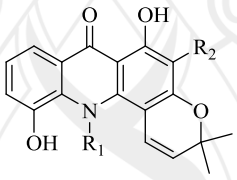
CHAPTER 4

CONCLUSION

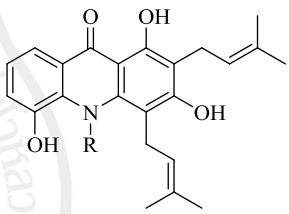
In conclusion, the chemical investigation of the acetone extract of *A. monophylla* roots led to the isolation and identification of 15 known compounds (**AM1**-**AM15**). All compounds except for compounds **AM6** and **AM11** were evaluated for their antibacterial activity. Compound **AM2** exhibited strong antibacterial activity against methicillin-resistant *S. aureus* SK1 (MRSA) and *S. aureus* with MIC values of 2 and 4 µg/mL, respectively.



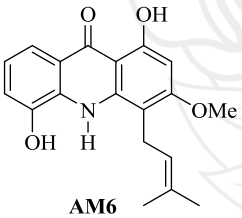
AM1



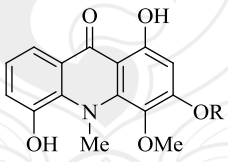
AM2: R_1 = Me, R_2 = prenyl
AM5: R_1 = R_2 = H



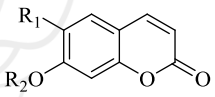
AM3: R = Me
AM4: R = H



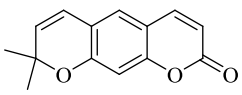
AM6



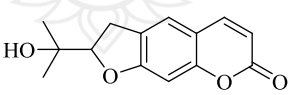
AM7: R = Me
AM8: R = H



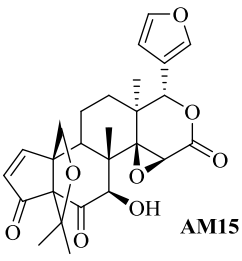
AM9 : R_1 = R_2 = H
AM10: R_1 = H, R_2 = geranyl
AM11: R_1 = OMe, R_2 = geranyl
AM12: R_1 = prenyl, R_2 = H



AM13

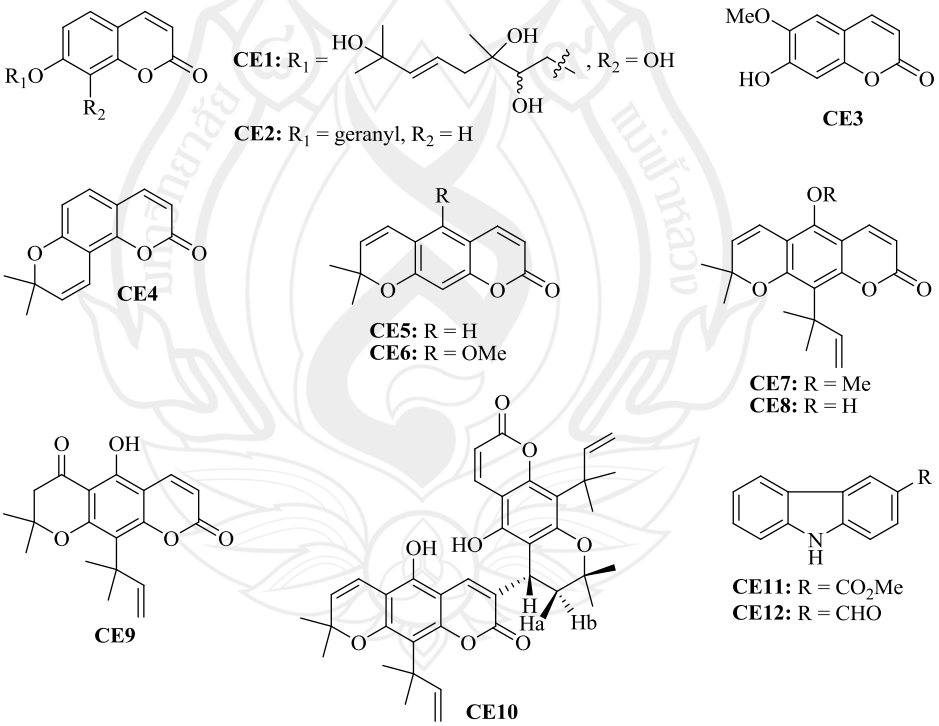


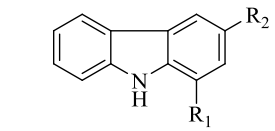
AM14



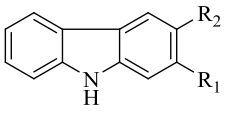
AM15

The investigation of chemical constituents from *C. excavata* led to isolation and identification of 43 compounds. A new coumarin (**CE1**) together with five known compounds (**CE3**, **CE4**, **CE34**, **CE36** and **CE38**) were isolated from the hexanes-CH_2Cl_2 extract of fruits whereas a new carbazole alkaloid (**CE22**) along with 18 compounds (**CE2**, **CE5**, **CE8**, **CE11-CE16**, **CE18-CE22**, **CE23**, **CE32**, **CE33**, **CE35** and **CE37**) were isolated from the EtOAc extract of stems. The remaining 18 known compounds (**CE3**, **CE6-CE10**, **CE13**, **CE16**, **CE17** and **CE24-CE32**) were isolated from the acetone extract of roots. Some of isolated compounds were further evaluated for their cytotoxicity against KB, MCF7 and NCI-H187 human cell lines. Compounds **CE20**, **CE21** and **CE23** showed the highest cytotoxicity against KB, NCI-H187 and MCF7 human cell lines with IC_{50} value of 4.63, 1.07 and 0.78 µg/mL, respectively.

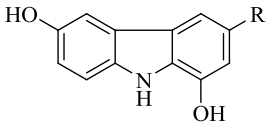




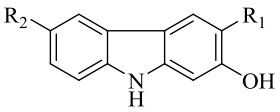
CE13: R_1 = OH , R_2 = CO_2Me
CE14: R_1 = OH, R_2 = CHO
CE15: R_1 = OMe, R_2 = CO_2Me
CE16: R_1 = OMe, R_2 = CHO
CE17: R_1 = OMe, R_2 = Me



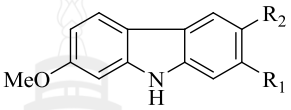
CE18: R_1 = OH , R_2 = CO_2Me
CE19: R_1 = OMe, R_2 = CHO



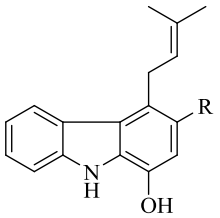
CE20: R = CO_2Me
CE21: R = CHO



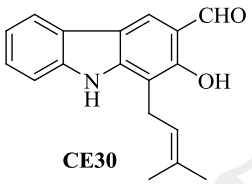
CE22: R_1 = CO_2Me , R_2 = OH
CE23: R_1 = CHO, R_2 = OMe



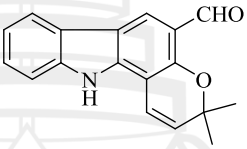
CE24: R_1 = OH, R_2 = CHO
CE25: R_1 = OMe, R_2 = CHO
CE26: R_1 = OMe, R_2 = CO_2H
CE27: R_1 = OMe, R_2 = CO_2Me



CE28: R = CO_2Me
CE29: R = CHO



CE30



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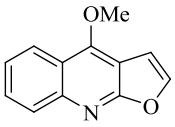

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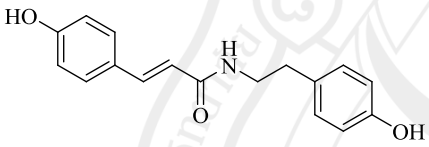

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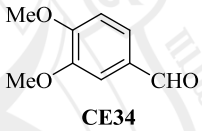

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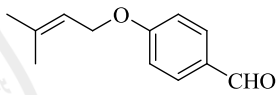

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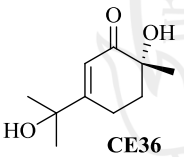

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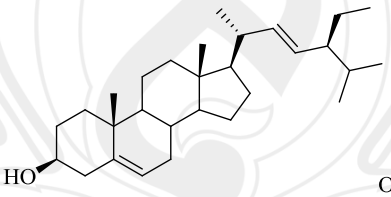

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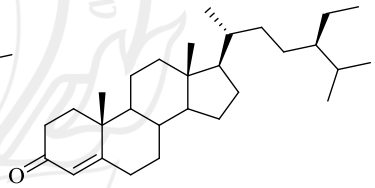
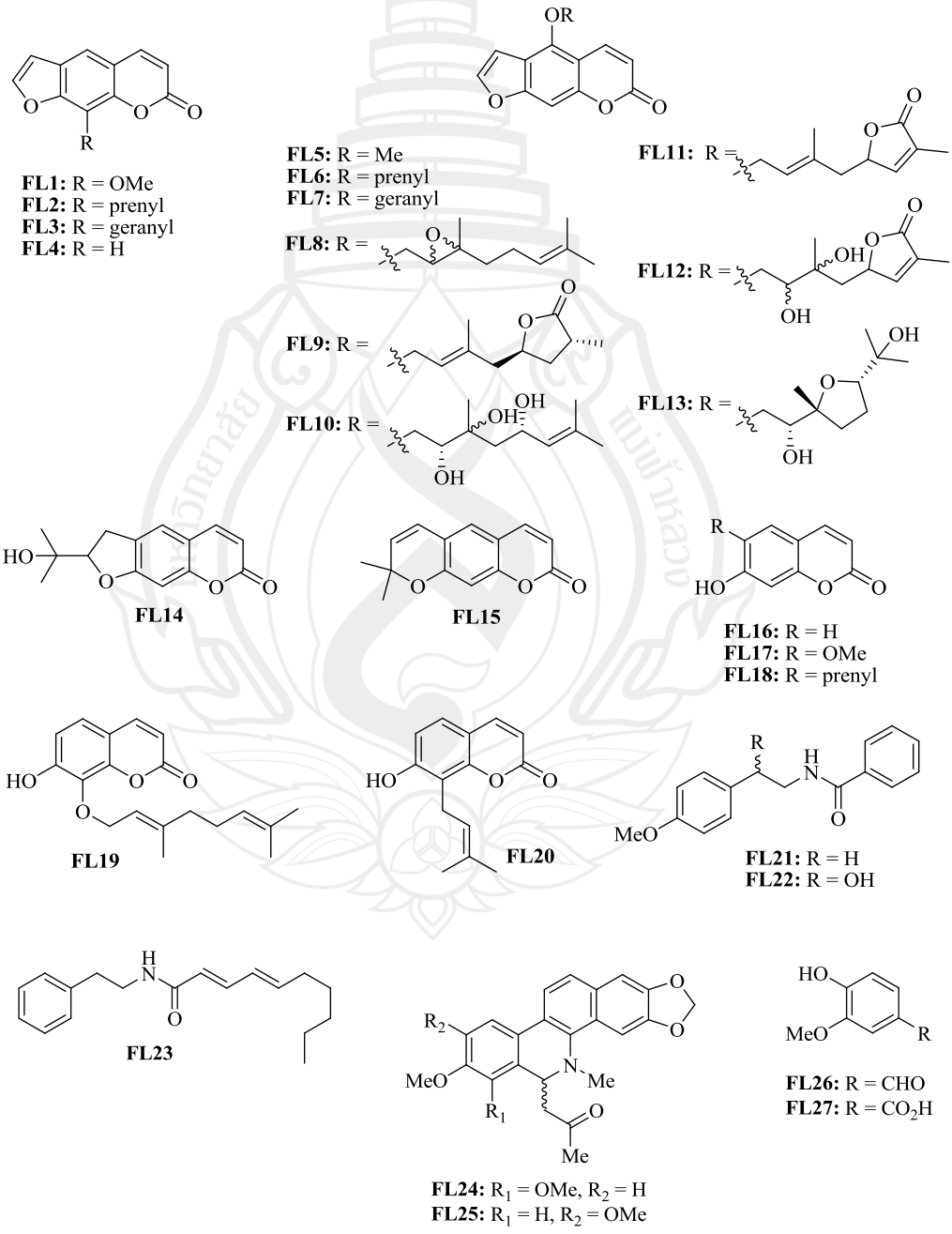
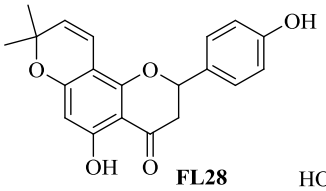


CE38

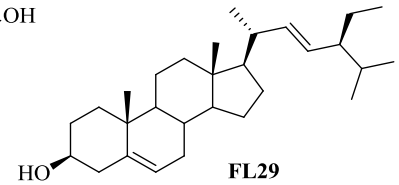
The isolation and identification of *F. lucida* yielded 36 compounds. A new furanocoumarin (**FL8**) together with 17 compounds (**FL1**, **FL3-FL7**, **FL11**, **FL12, FL14**, **FL15**, **FL18-FL22**, **FL24** and **FL25**) were isolated from the acetone extract of roots while two new furanocoumarins (**FL9** and **FL10**) along with 9 compounds (**FL2**, **FL7**, **FL11-FL13**, **FL16** and **FL26-FL28**) were isolated from the acetone extract of twigs. The remaining seven known compounds (**FL14**, **FL16**, **FL17**, **FL21**, **FL23**, **FL29** and **FL30**) isolated from the acetone extract of fruits. Some of the

isolates were evaluated for their biological activities including cytotoxicity against KB, MCF-7 and NCI-H187 human cancer cell lines, antimalarial and antituberculosis activities. Compound **FL25** showed strong cytotoxicity against KB (IC_{50} = 0.637 µg/mL) and NCI-H187 (IC_{50} = 0.094 µg/mL) human cancer cell lines, antimalarial activity against *P. falciparum* (IC_{50} = 0.336 µg/mL), and antituberculosis activity against *M. tuberculosis* (MIC = 6.25 µg/mL).

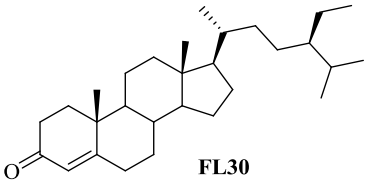




FL28

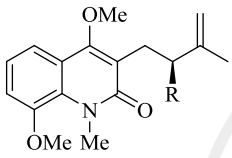


FL29

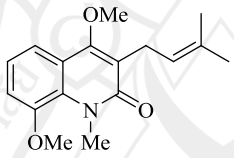


FL30

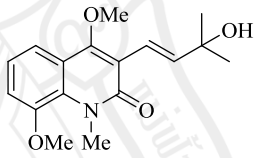
A new hydroperoxyquinolone alkaloid (**GP1**) along with nine compounds (**GP2–GP10**) were isolated from the CH_2Cl_2-MeOH extract of *G. pentaphylla* fruits. All isolates were evaluated for their antibacterial activity. All compounds except for compounds **GP1** and **GP6** exhibited weak antibacterial activity against Gram-positive bacteria (*E. coli* and *S. typhimurium*) with MIC value of 128 µg/mL. For antibacterial activity against Gram-negative bacteria (*S. aureus* and MRSA), all of them except for **GP2**, **GP8** and **GP9** exhibited weak activity with the same MIC value of 128 µg/mL.



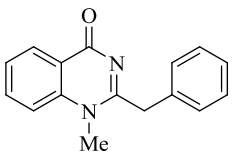
GP1: R = OOH
GP2: R = OH



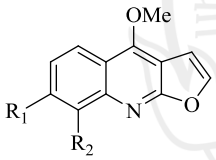
GP3



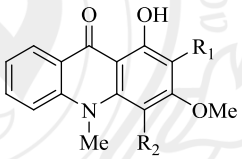
GP4



GP5

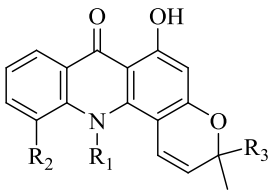


GP6: $R_1 = R_2 = H$
GP7: $R_1 = H$, $R_2 = OMe$
GP8: $R_1 = R_2 = OMe$

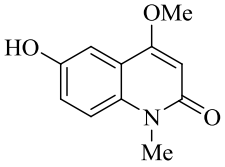


GP9: $R_1 = H$, $R_2 = OMe$
GP10: $R_1 = OMe$, $R_2 = H$

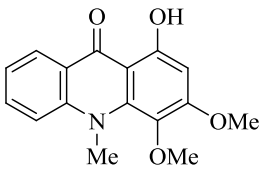
A phytochemical investigation of the acetone extract of *G. cochinchinensis* twigs led to the isolation and identification of a new acridone alkaloid (**GC1**) and a new indole alkaloid (**GC10**), together with 13 known compounds (**GC2-GC9** and **GC11-GC15**). Some of the isolates were evaluated for their biological activities. Compound **GC8** exhibited moderate antibacterial activity against MRSA with a MIC value of 16 µg/mL.



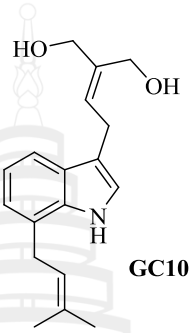
GC1: R_1 = H, R_2= H, R_3 = CH_2OH
GC2: R_1 = H, R_2 = H, R_3 = Me
GC3: R_1 = Me, R_2 = H, R_3 = Me
GC4: R_1 = H, R_2 = OH, R_3 = Me



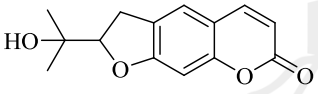
GC9

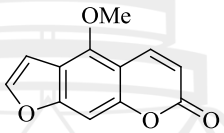


GC5

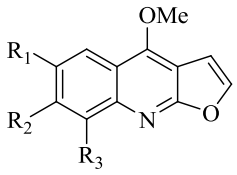


GC10

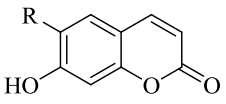




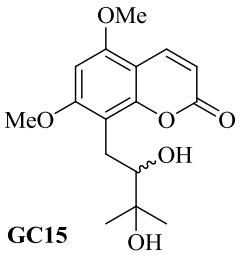
GC13 **GC14**



GC6: R_1 = R_2 = H, R_3 = OMe
GC7: R_1 = H, R_2 = R_3 = OMe
GC8: R_1 = R_2 = OMe, R_3 = H



GC11: R = OMe
GC12: R = prenyl



GC15

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REFERENCES

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APPENDIX

APPENDIX

NMR spectra of some isolated compounds from *A. monophylla, C. excavata, F. lucida, G. pentaphylla* and *G. cochinchinensis*

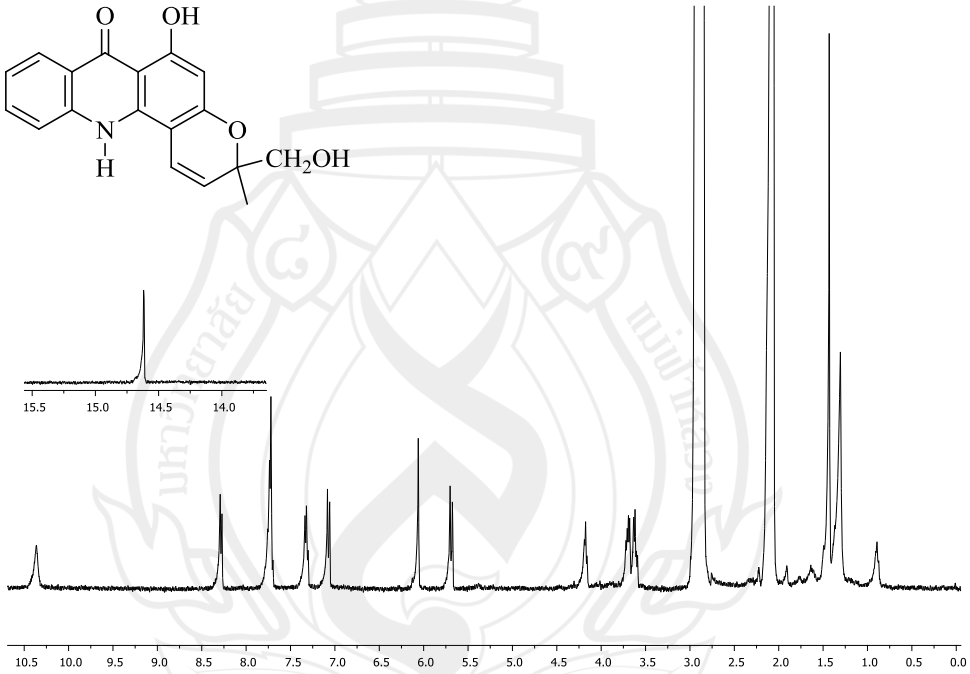

Figure A1 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **GC1**

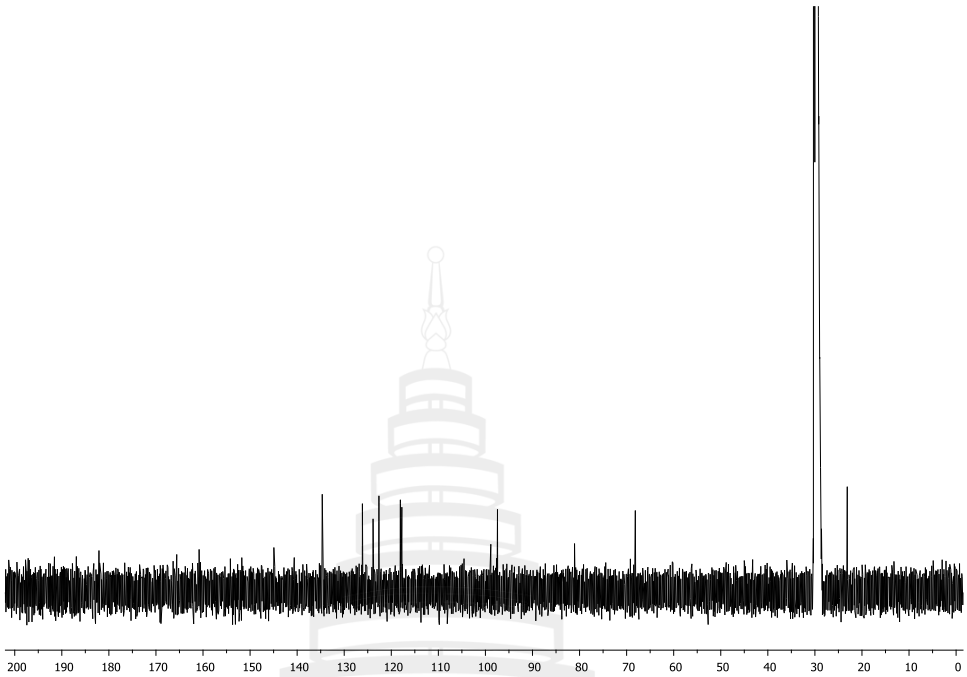

Figure A2 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **GC1**

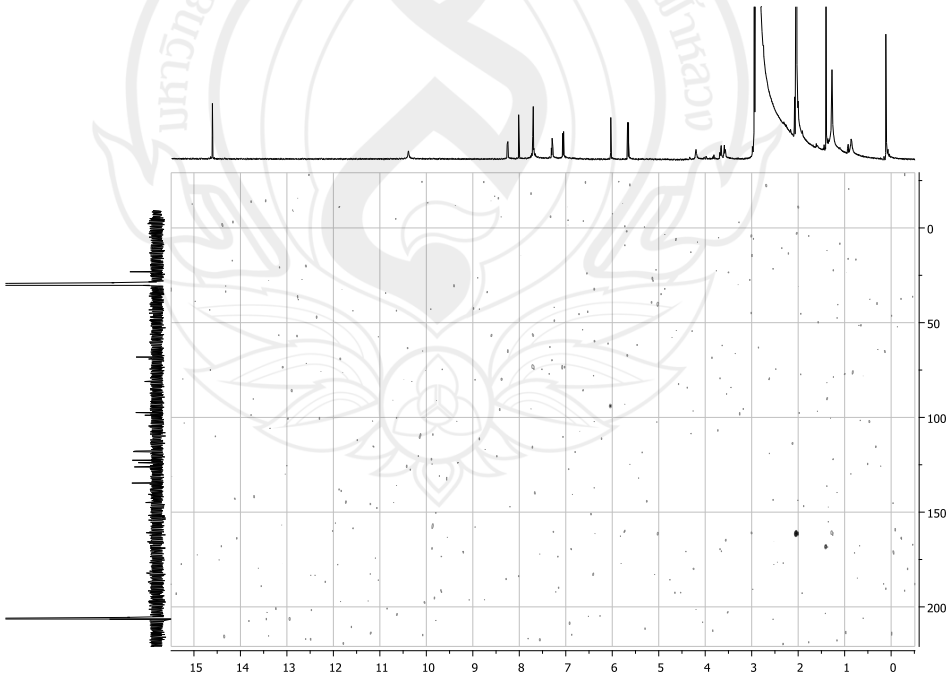

Figure A3 HMQC (Acetone-d_6) Spectrum of **GC1**

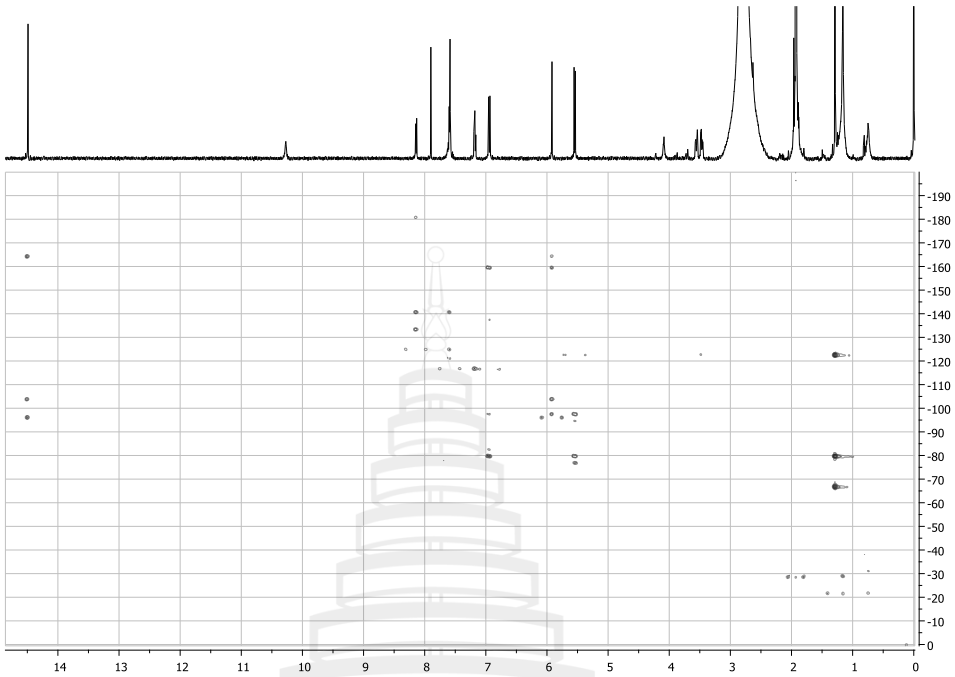

Figure A4 HMBC (Acetone-d_6) Spectrum of **GC1**

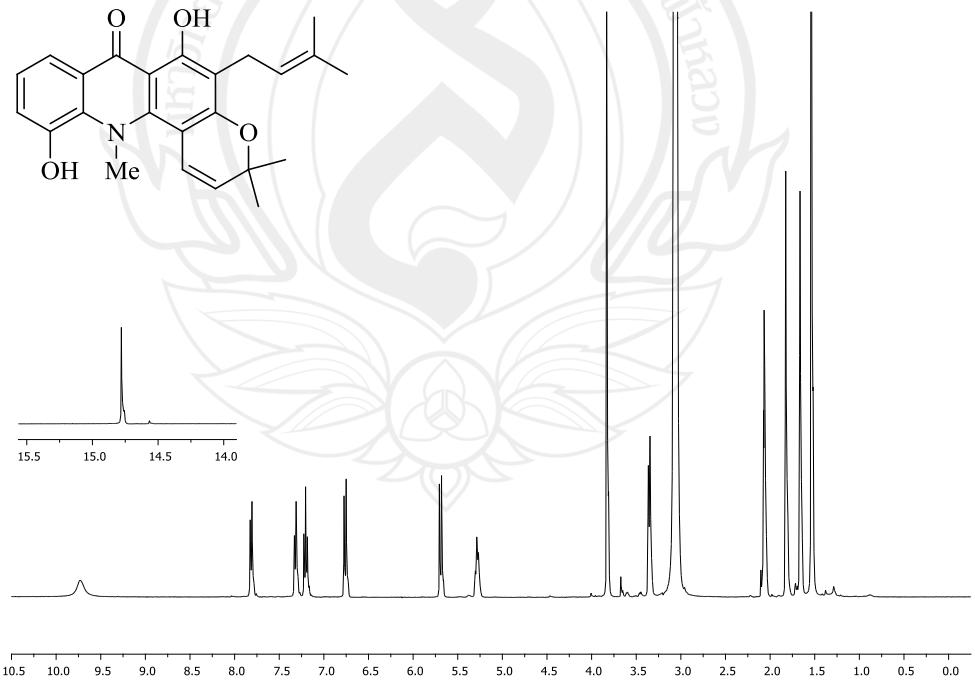

Figure A5 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **AM2**

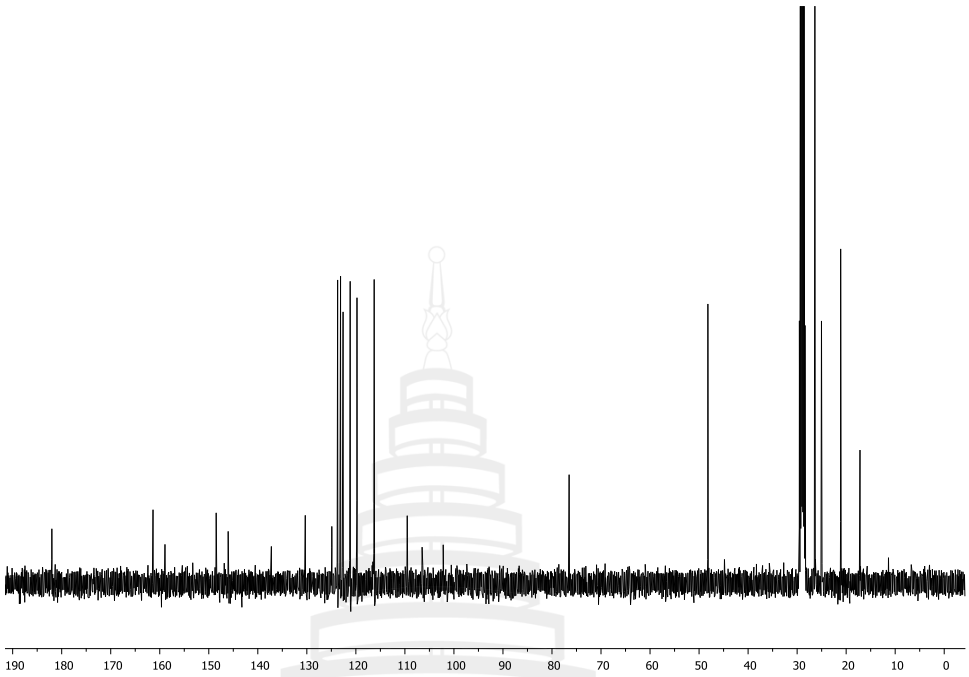

Figure A6 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **AM2**

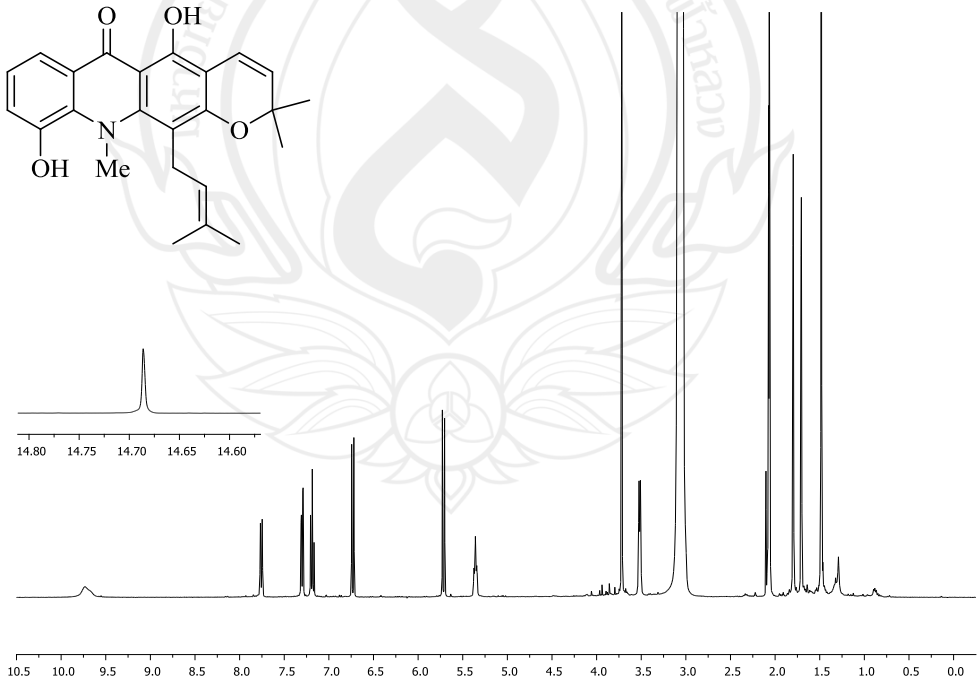

Figure A7 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **AM1**

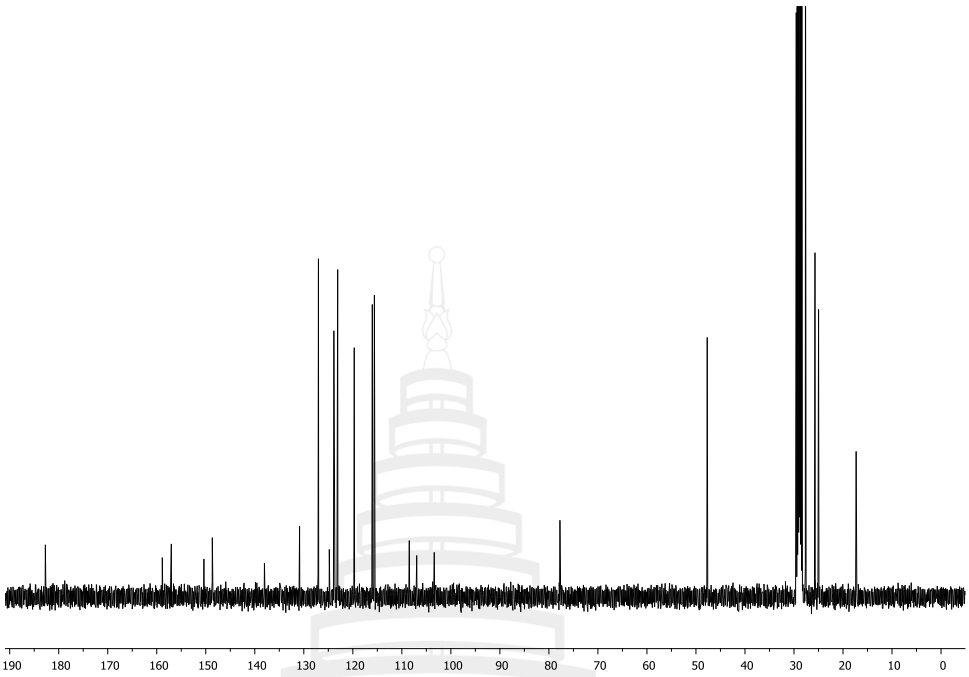

Figure A8 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **AM1**

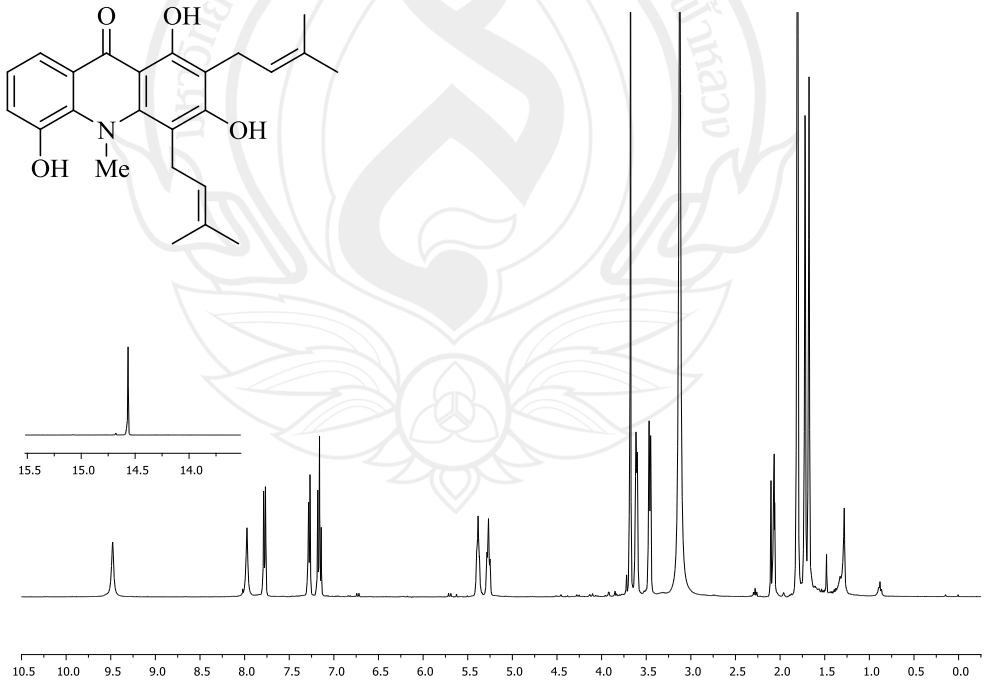

Figure A9 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **AM3**

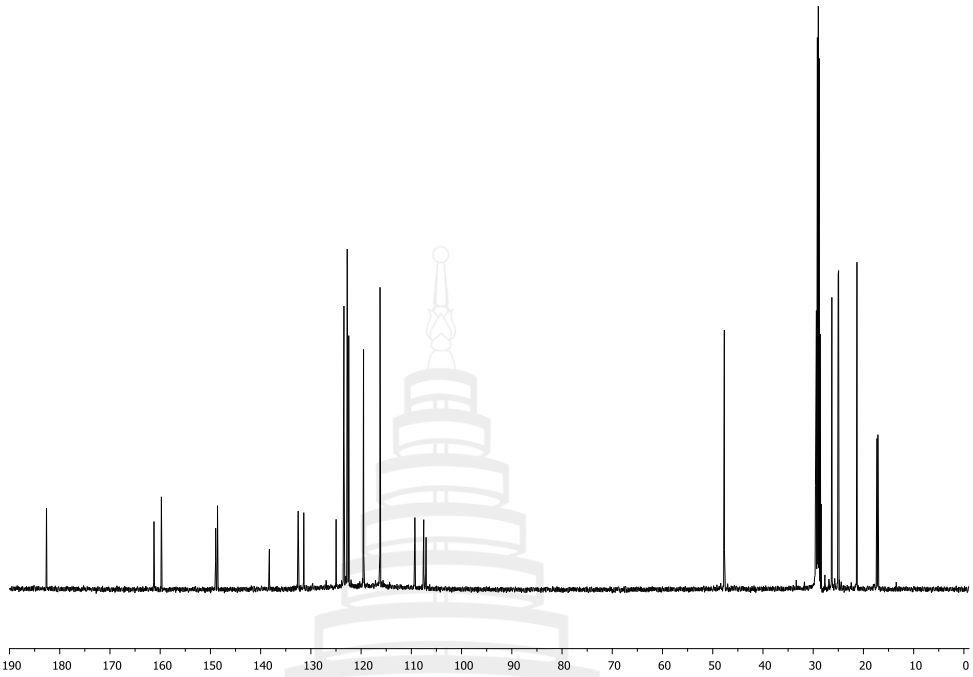

Figure A10 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **AM3**

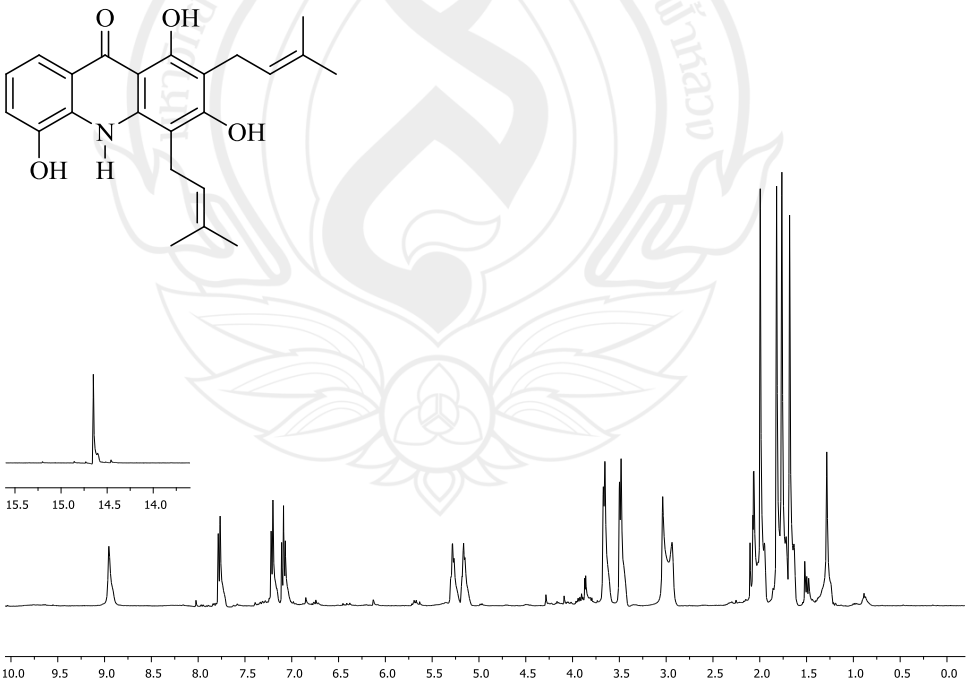

Figure A11 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **AM4**

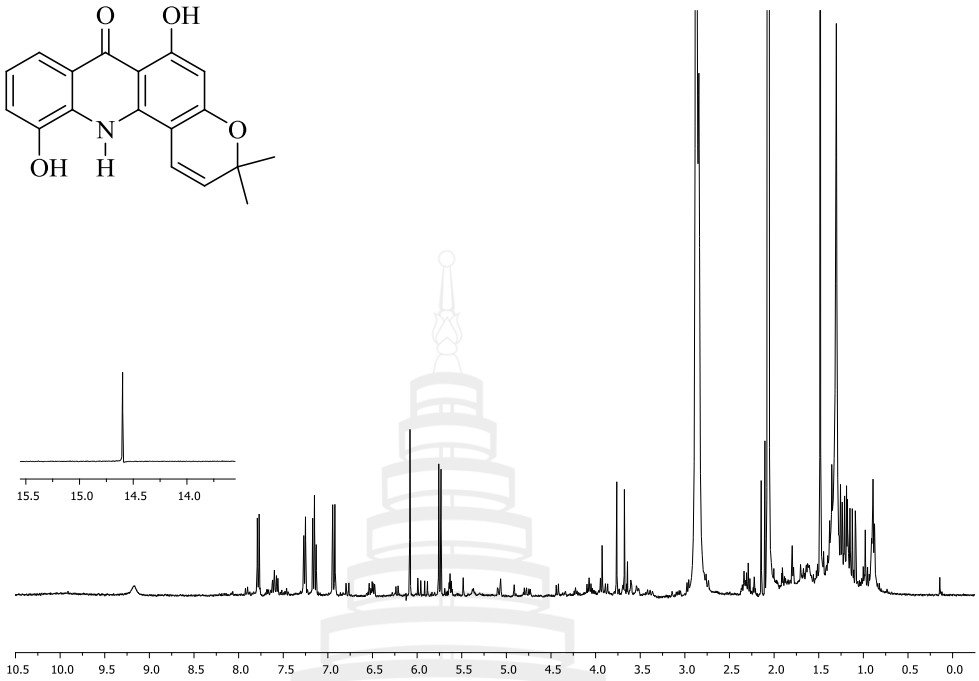

Figure A12 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **AM5**

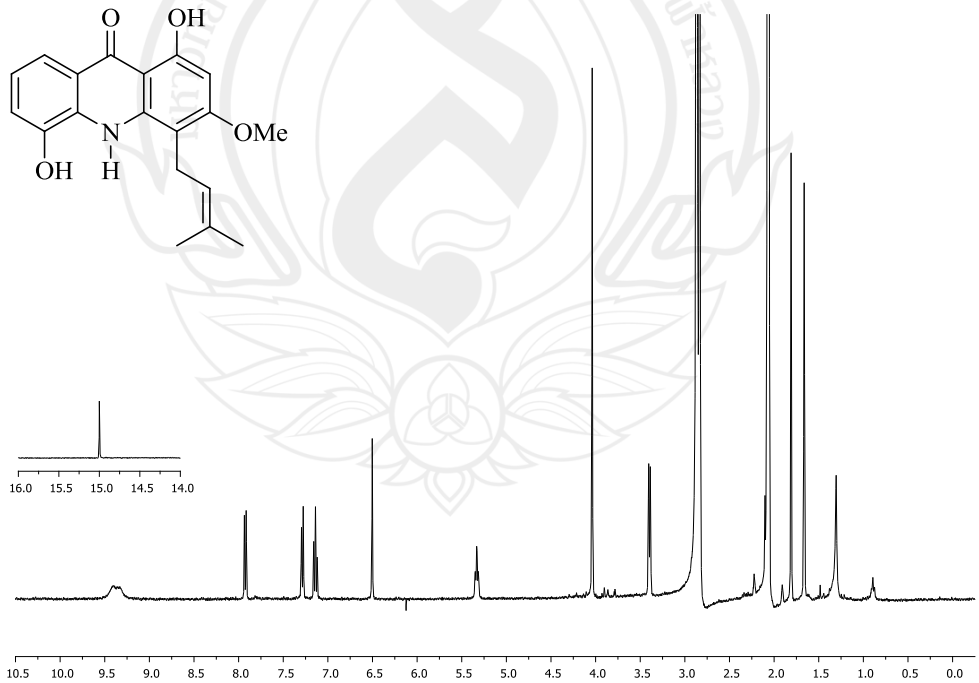

Figure A13 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **AM6**

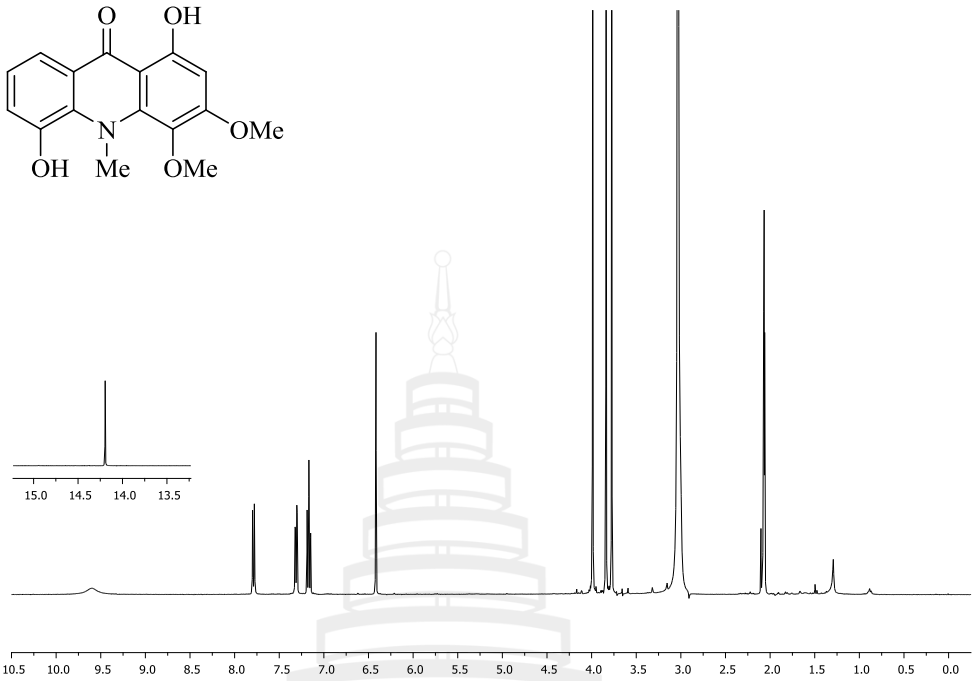

Figure A14 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **AM7**

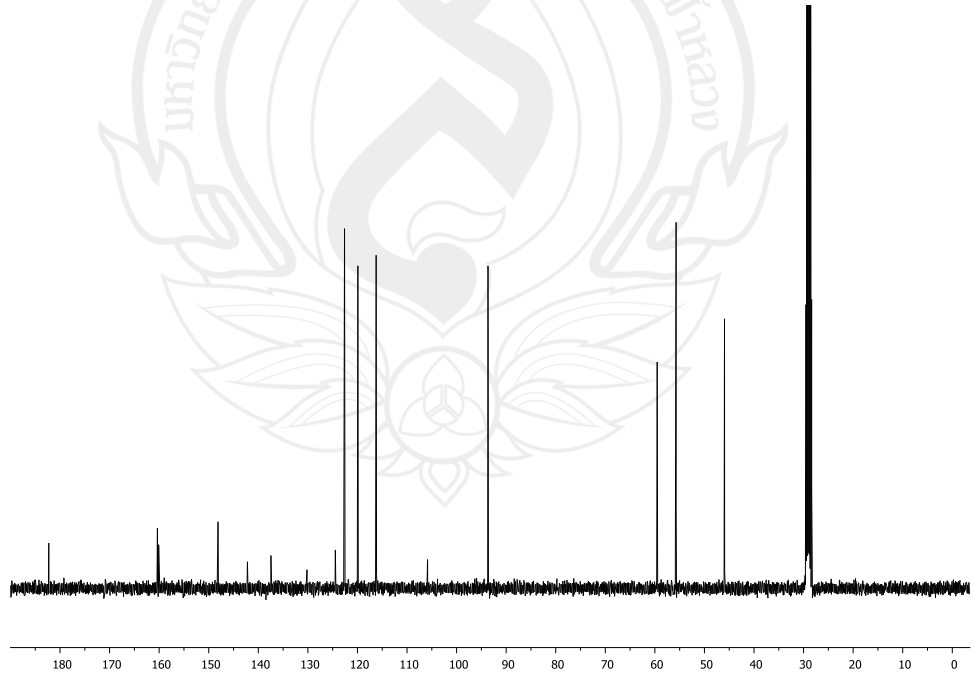

Figure A15 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **AM7**

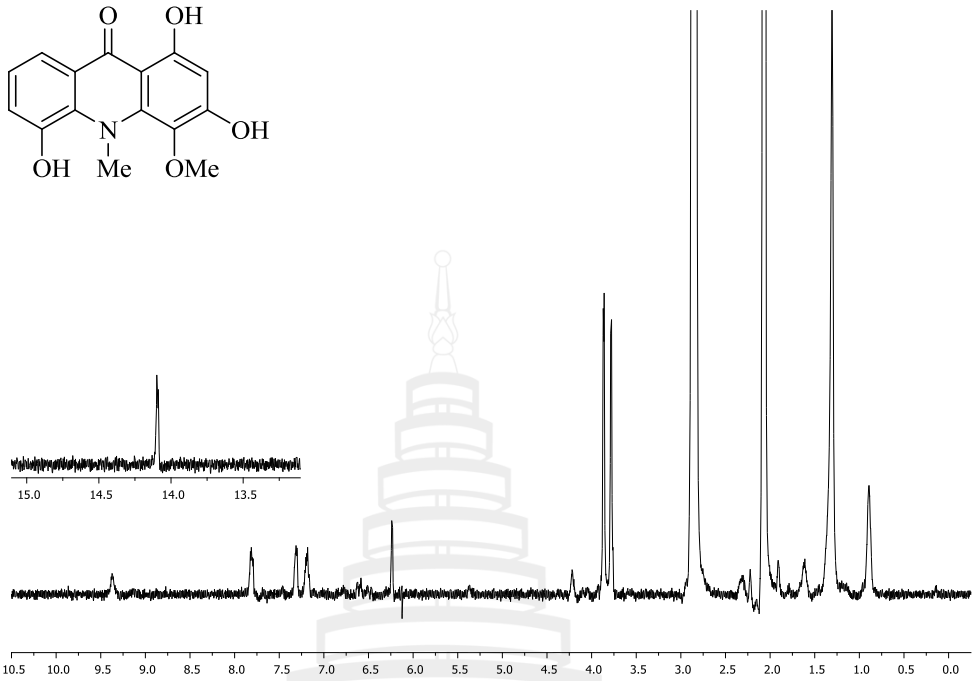

Figure A16 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **AM8**

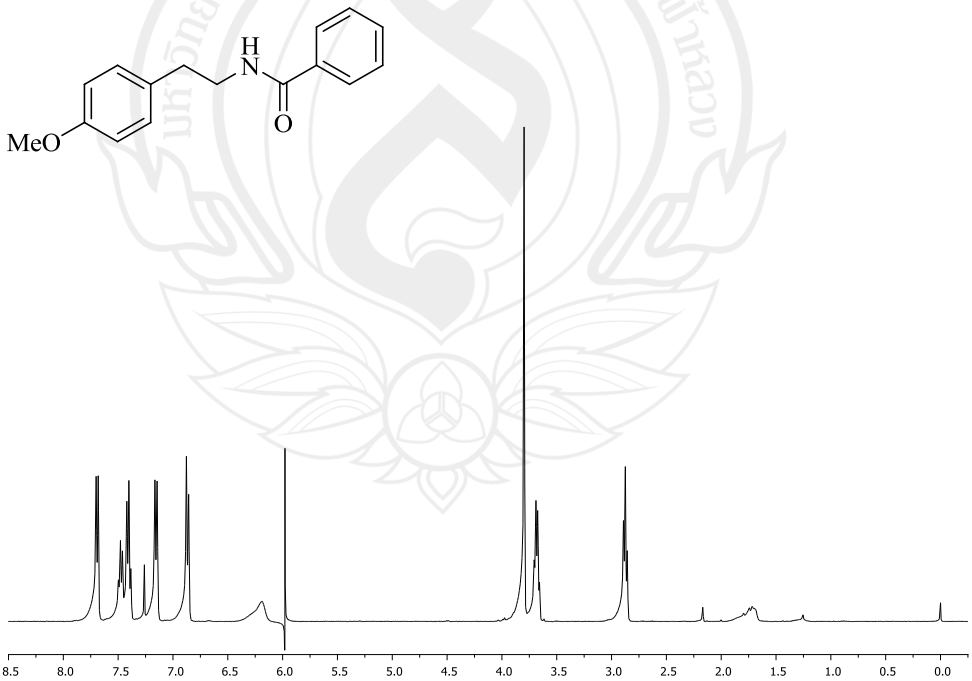

Figure A17 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL21**

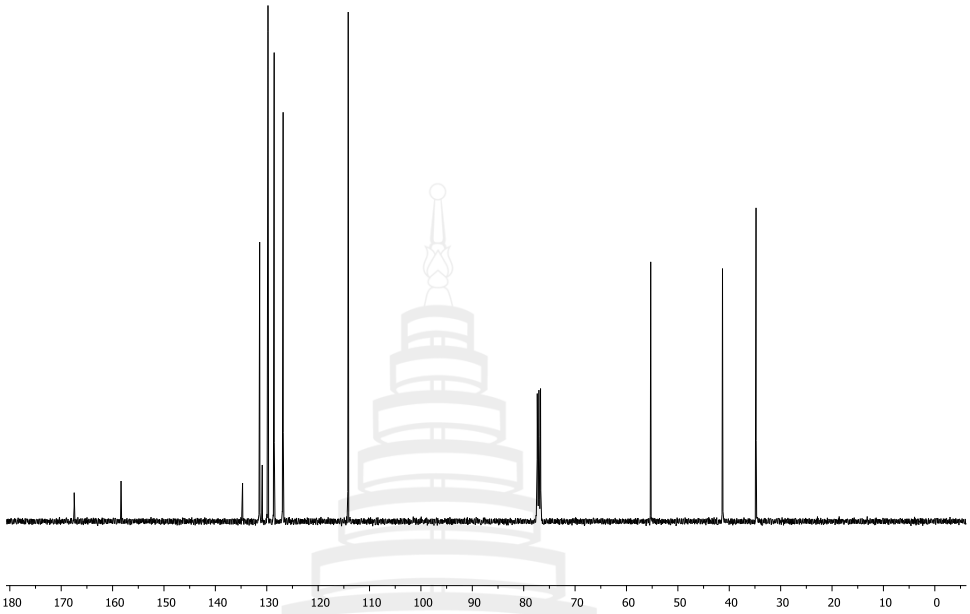

Figure A18 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL21**

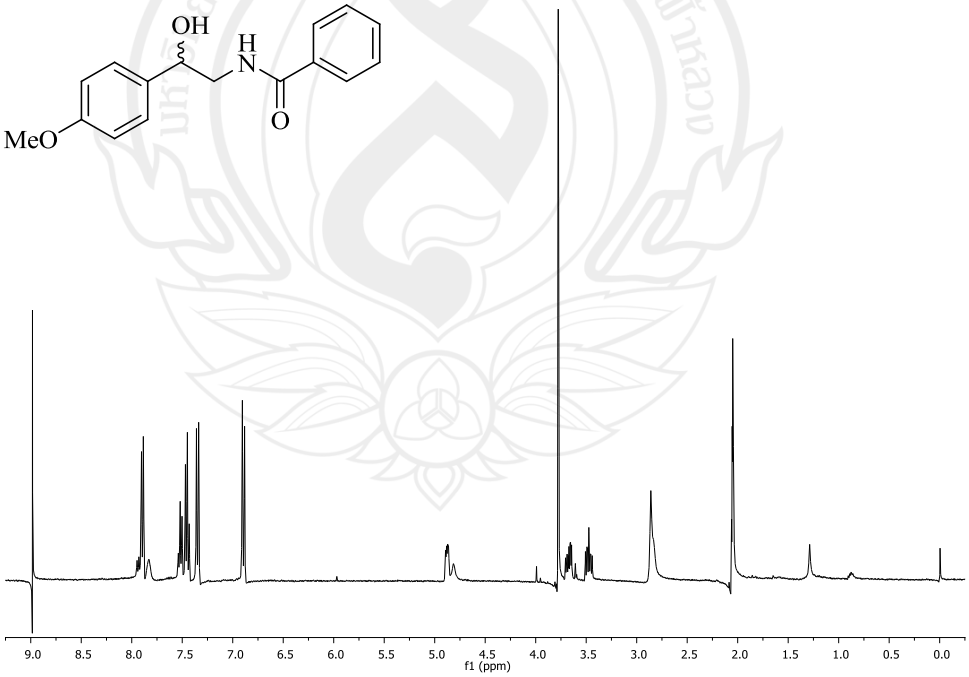

Figure A19 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **FL22**

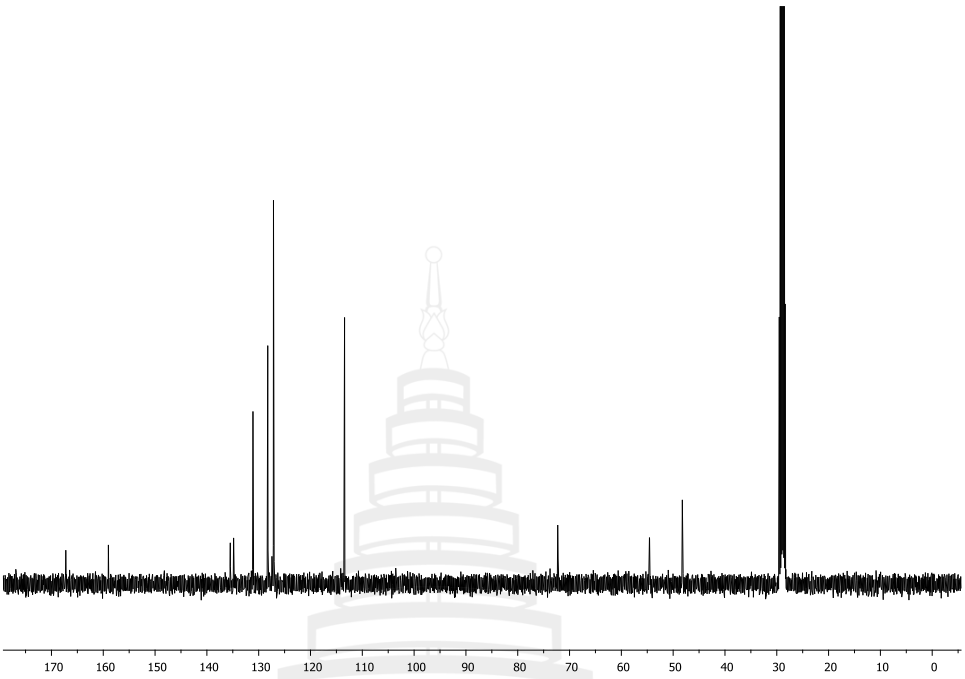

Figure A20 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **FL22**

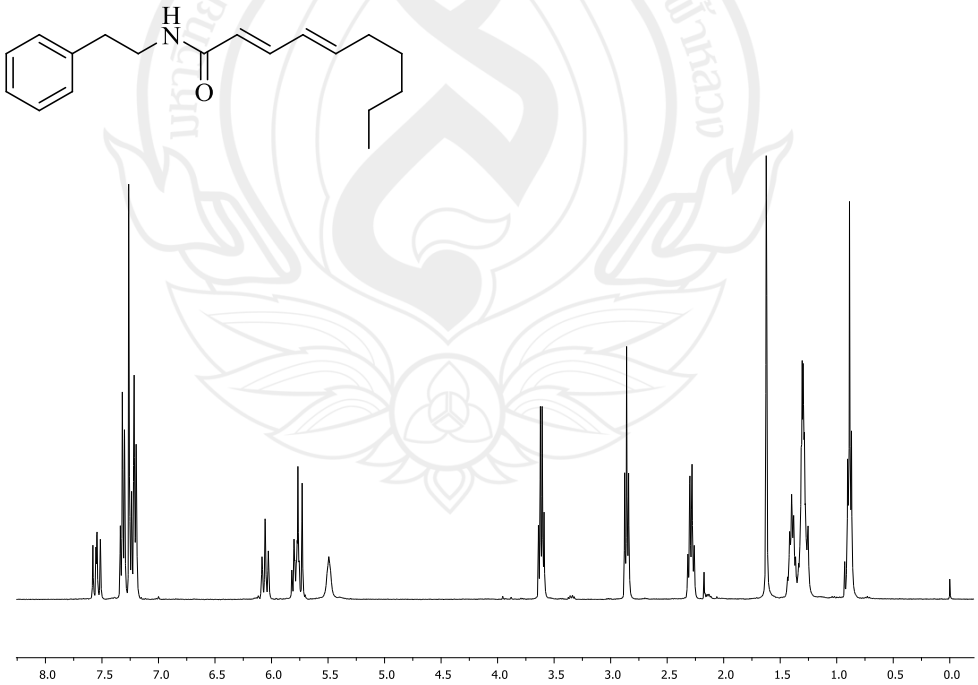

Figure A21 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL23**

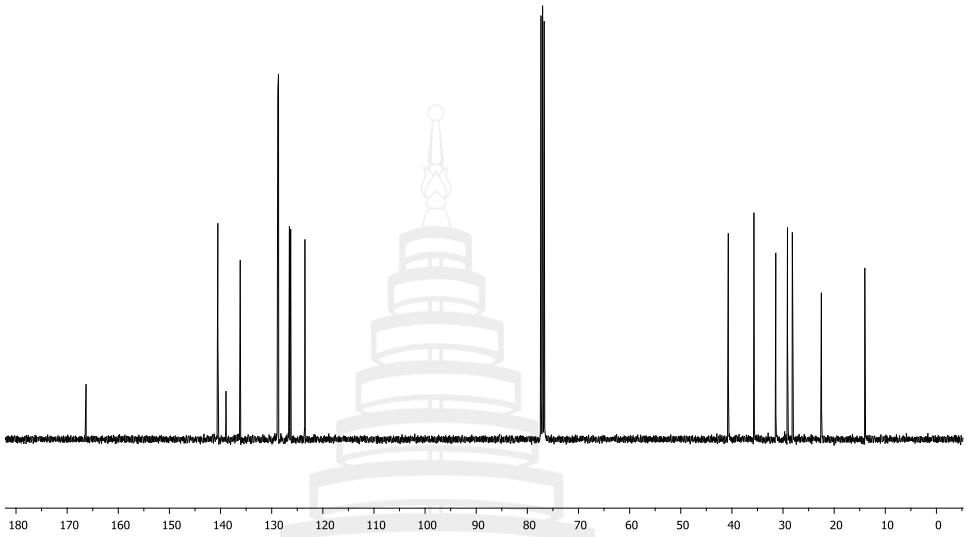

Figure A22 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL23**

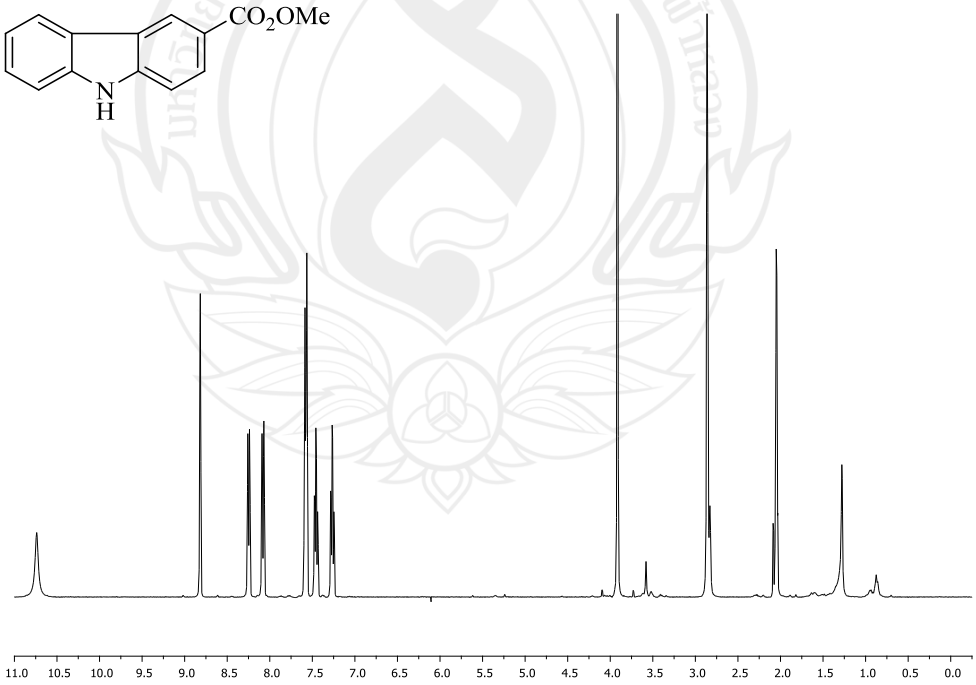

Figure A23 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **CE11**

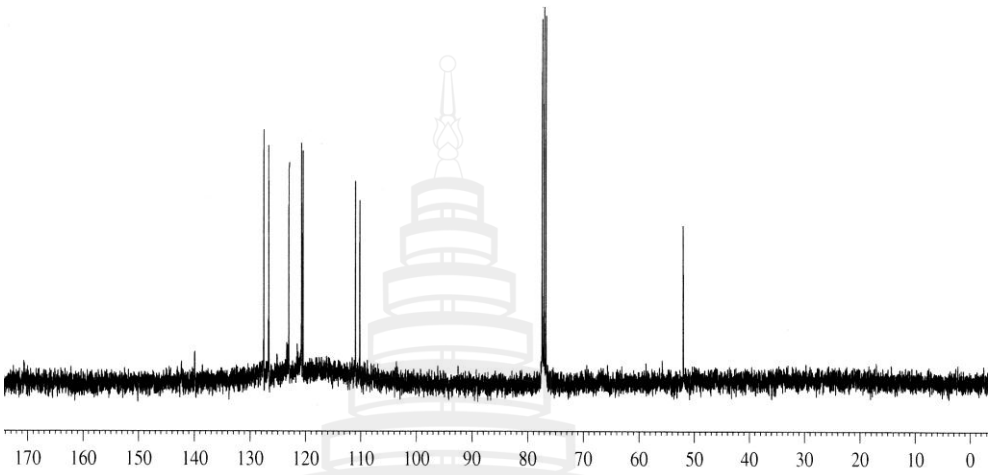

Figure A24 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **CE11**

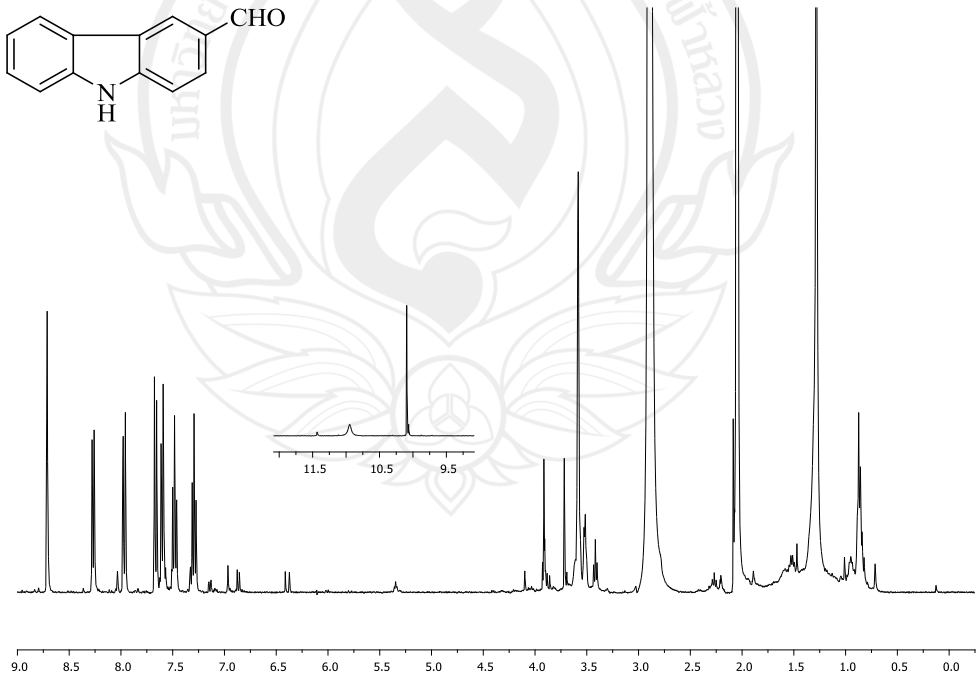

Figure A25 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **CE12**

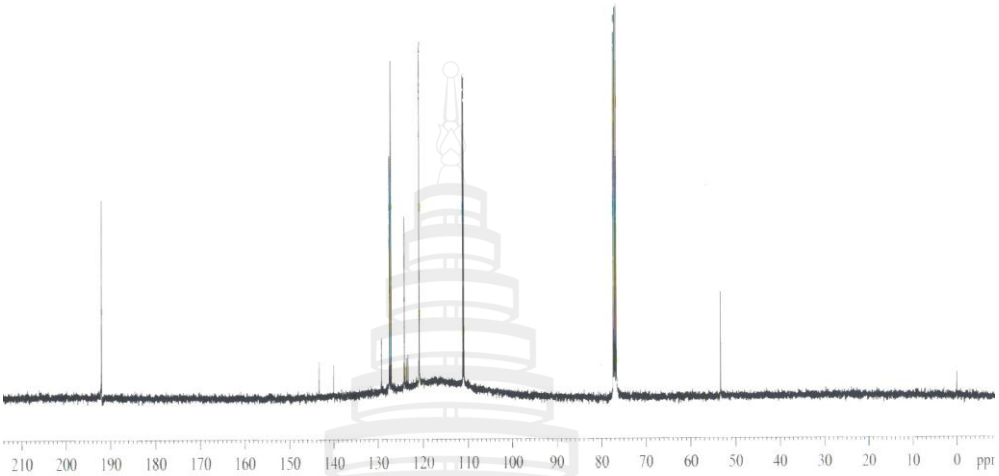

Figure A26 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **CE12**

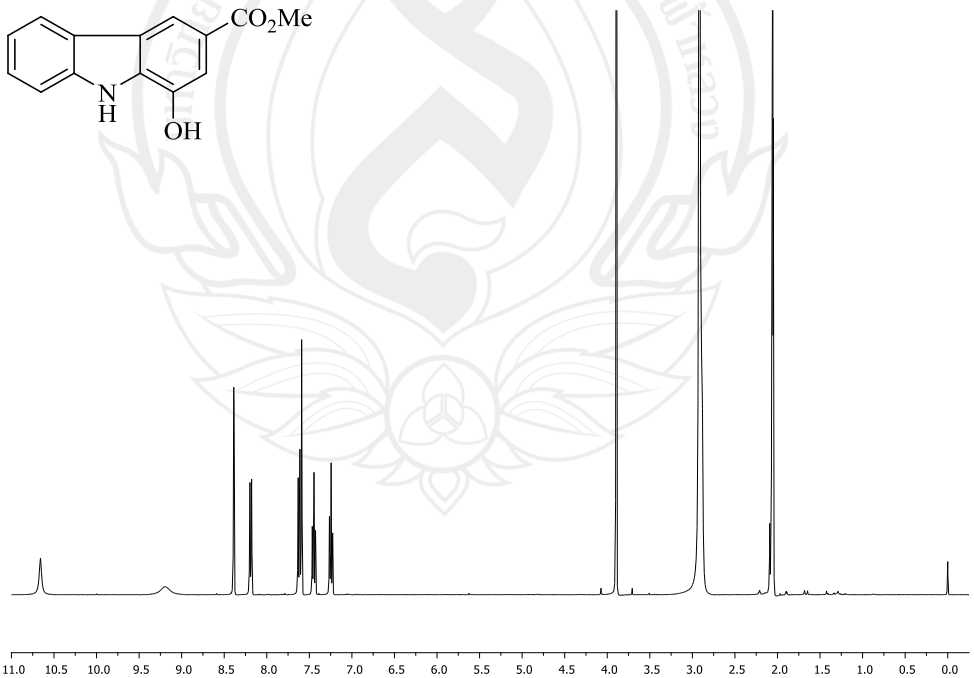

Figure A27 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE13**

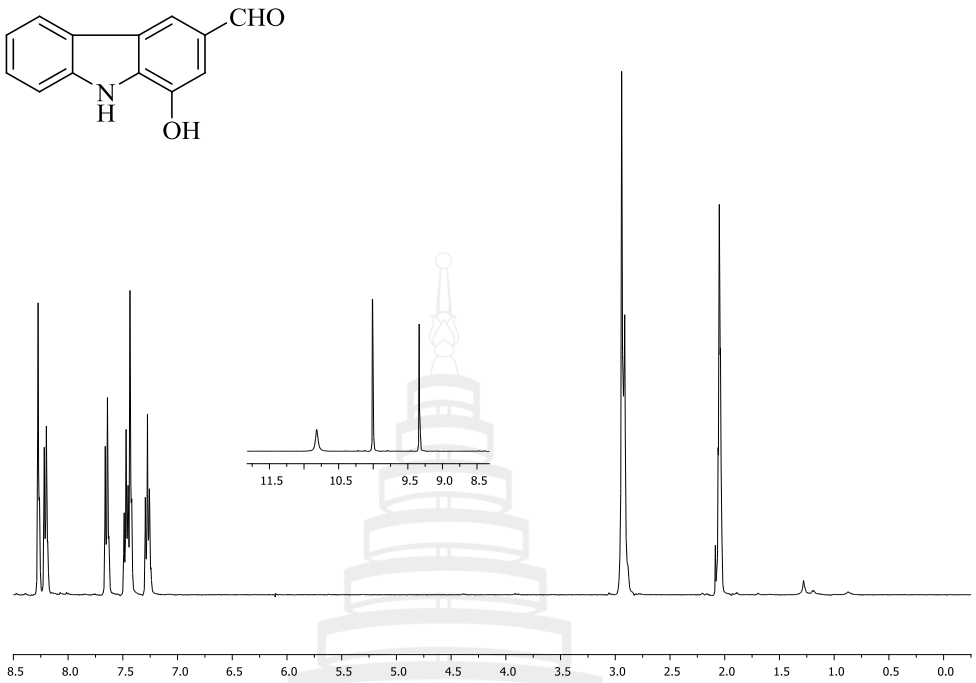

Figure A28 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE14**

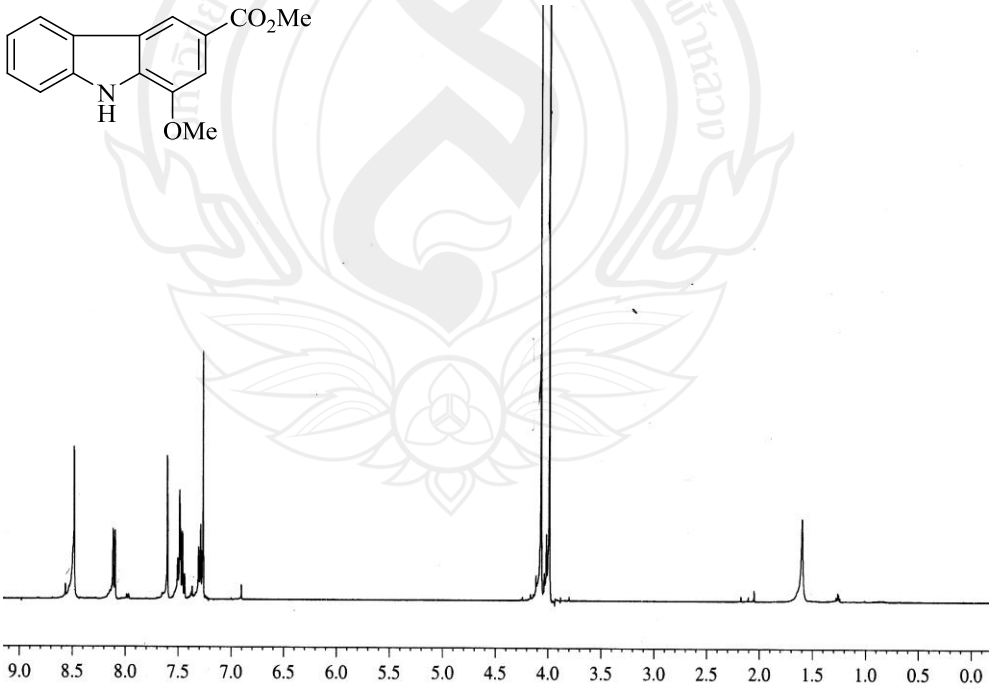

Figure A29 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **CE15**

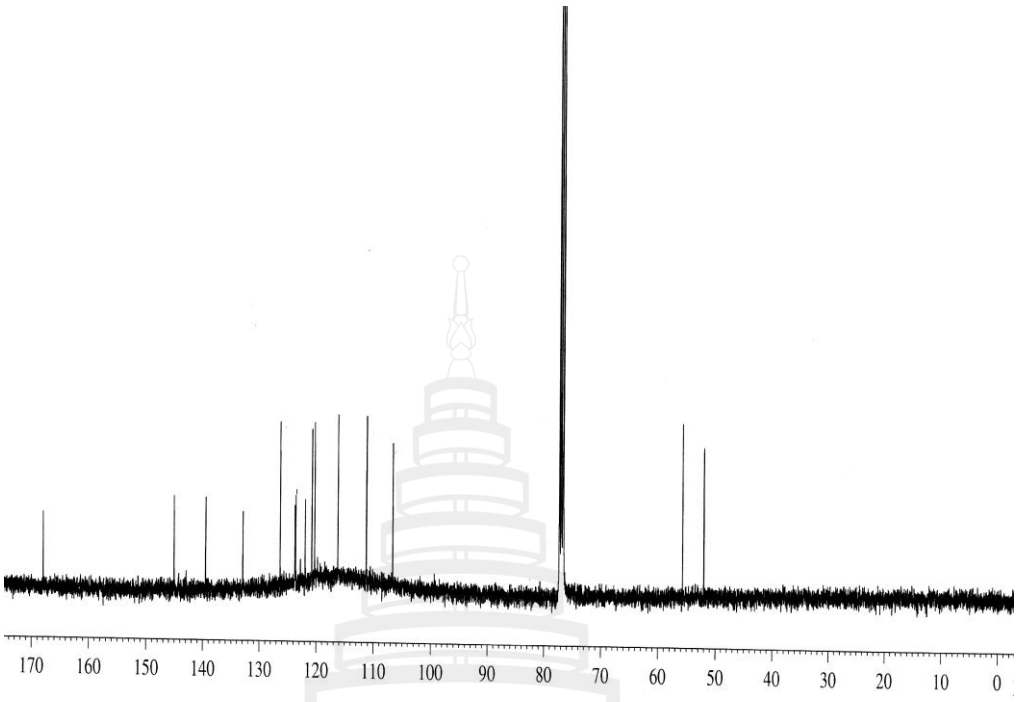

Figure A30 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **CE15**

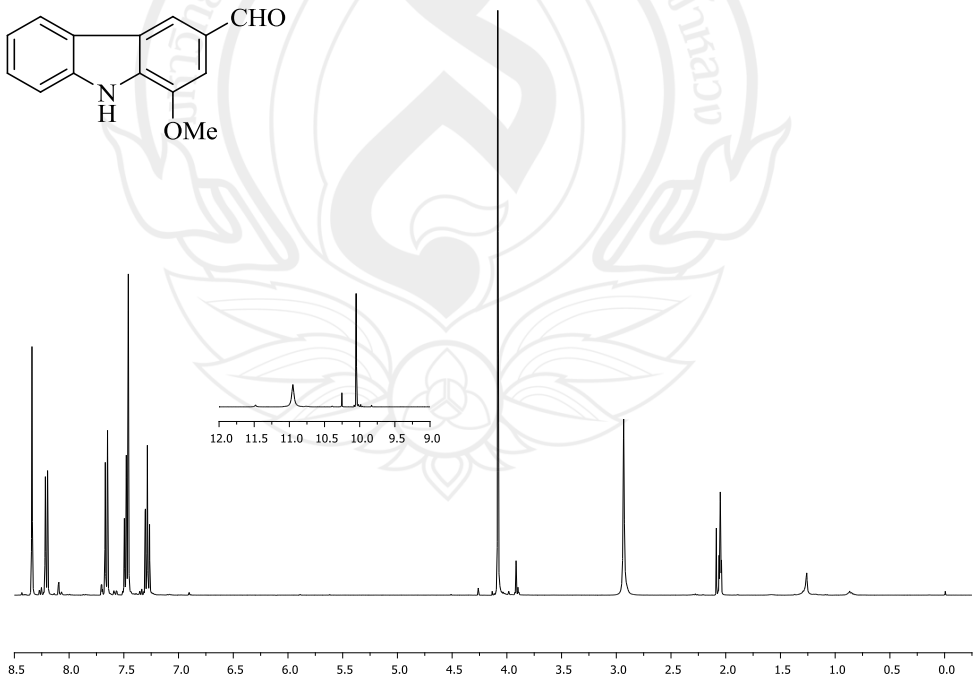

Figure A31 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **CE16**

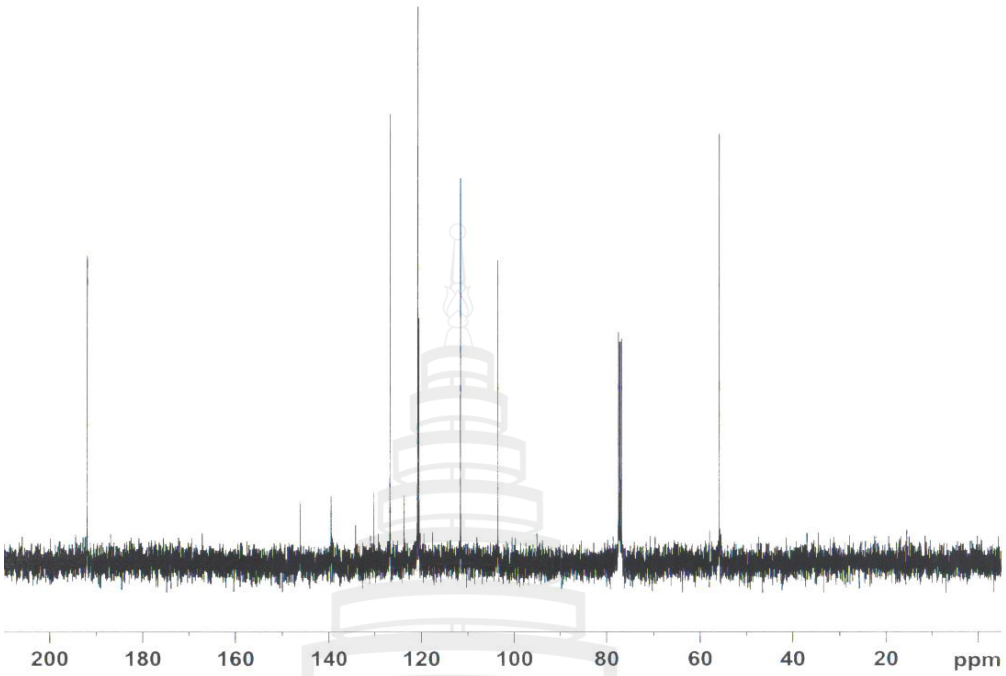

Figure A32 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **CE16**

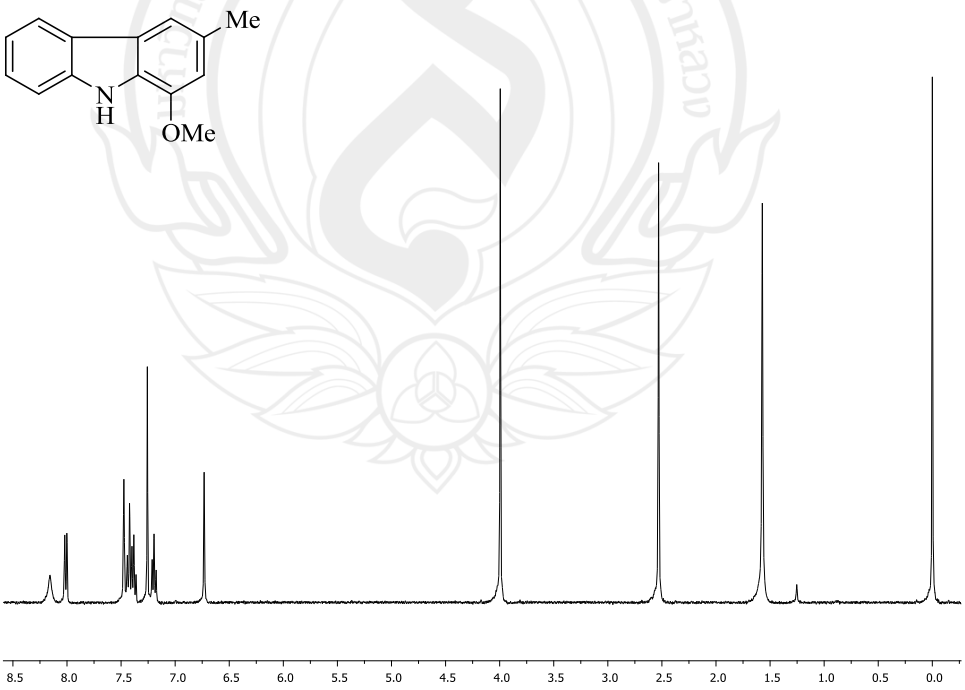

Figure A33 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **CE17**

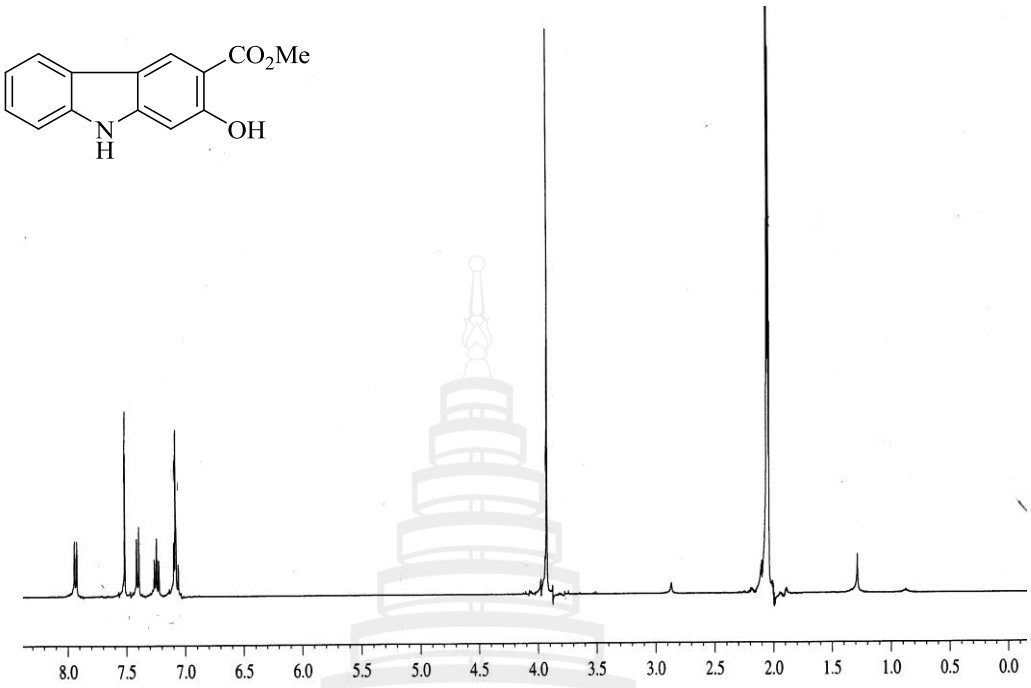

Figure A34 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE18**

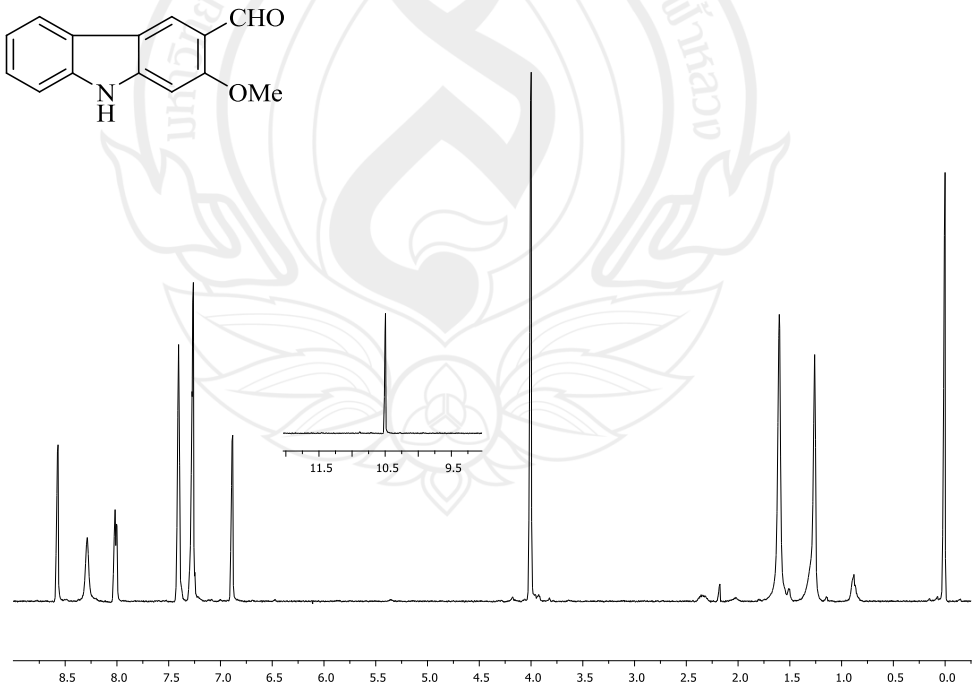

Figure A35 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **CE19**

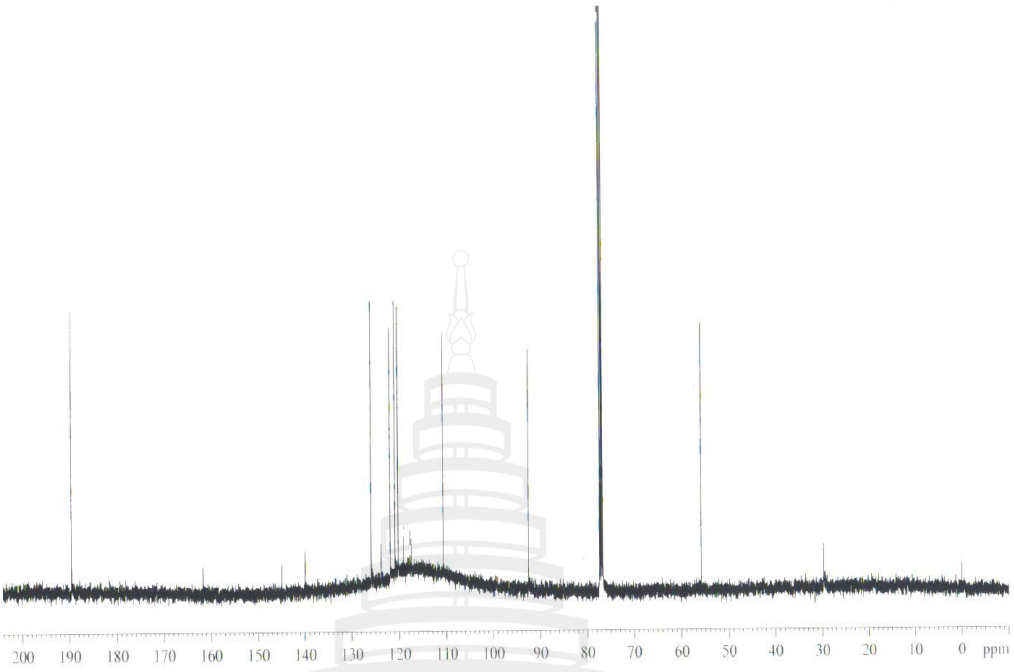

Figure A36 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **CE19**

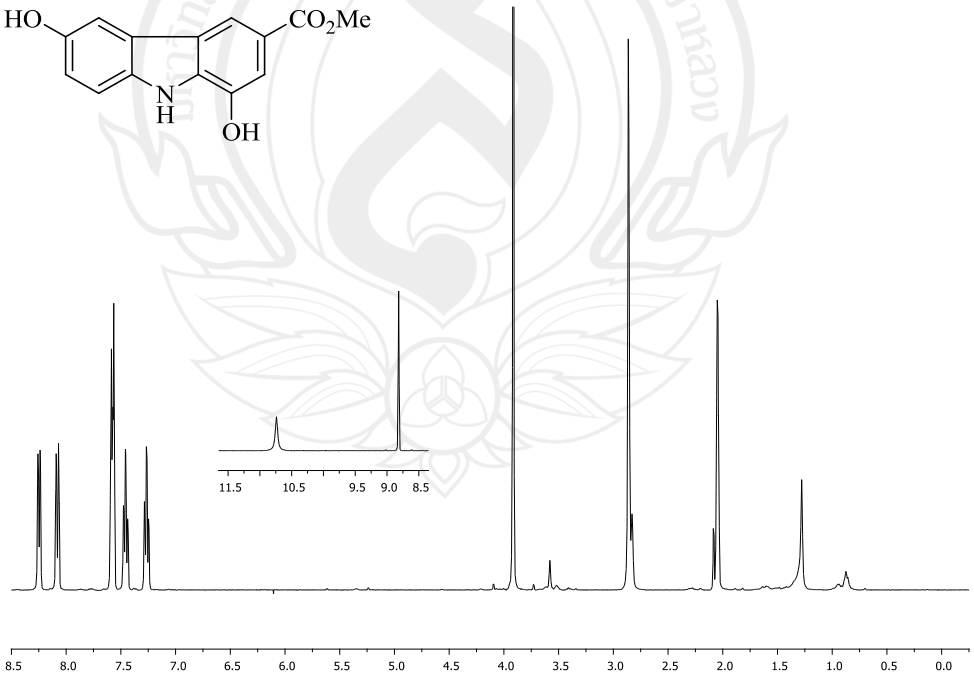

Figure A37 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE20**

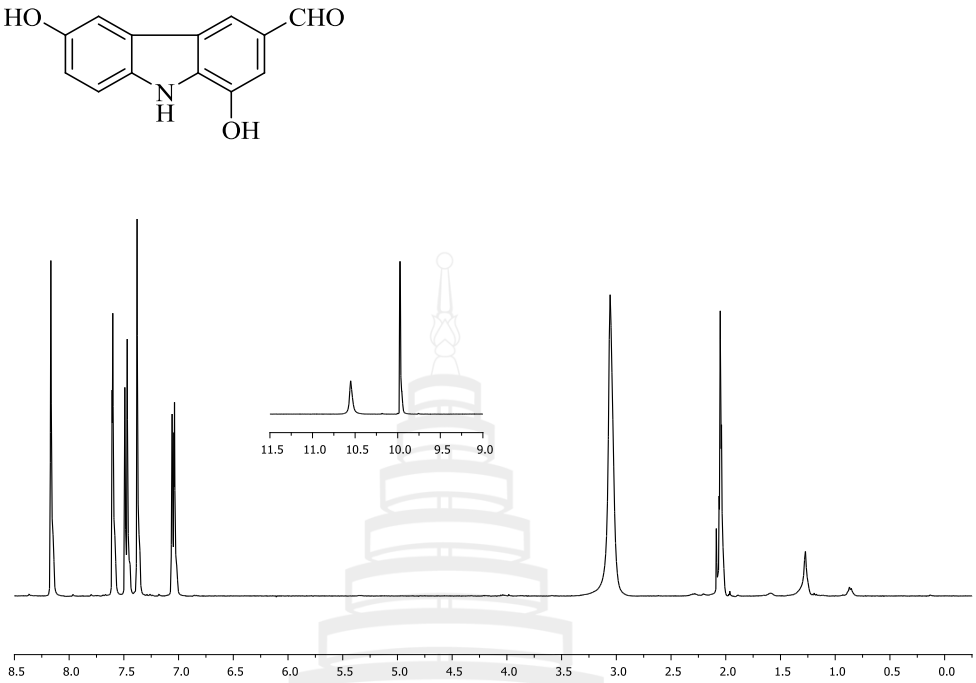

Figure A38 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE21**

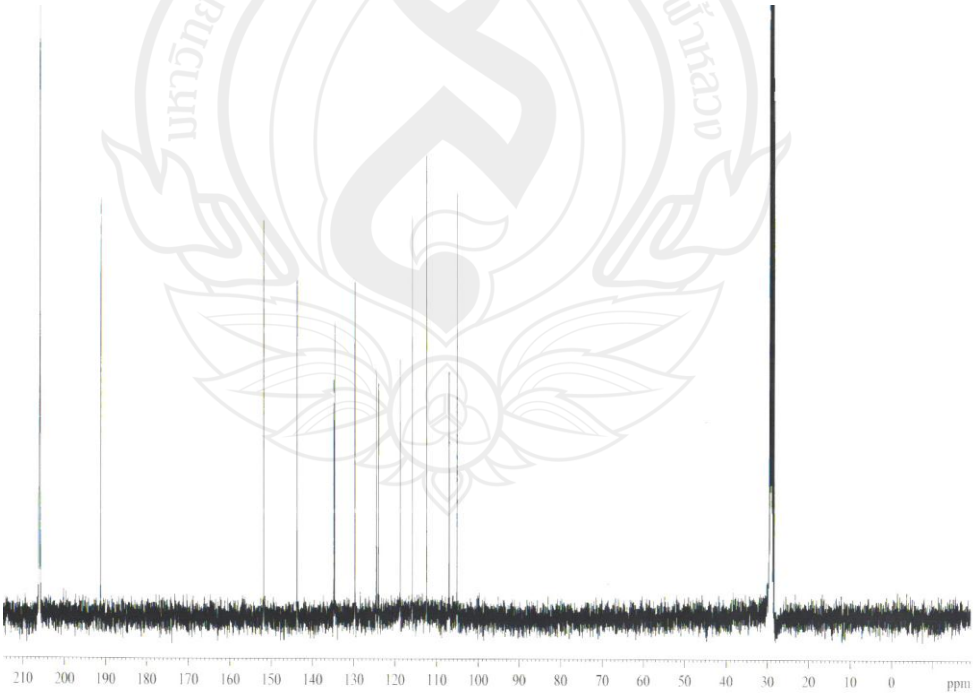

Figure A39 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **CE21**

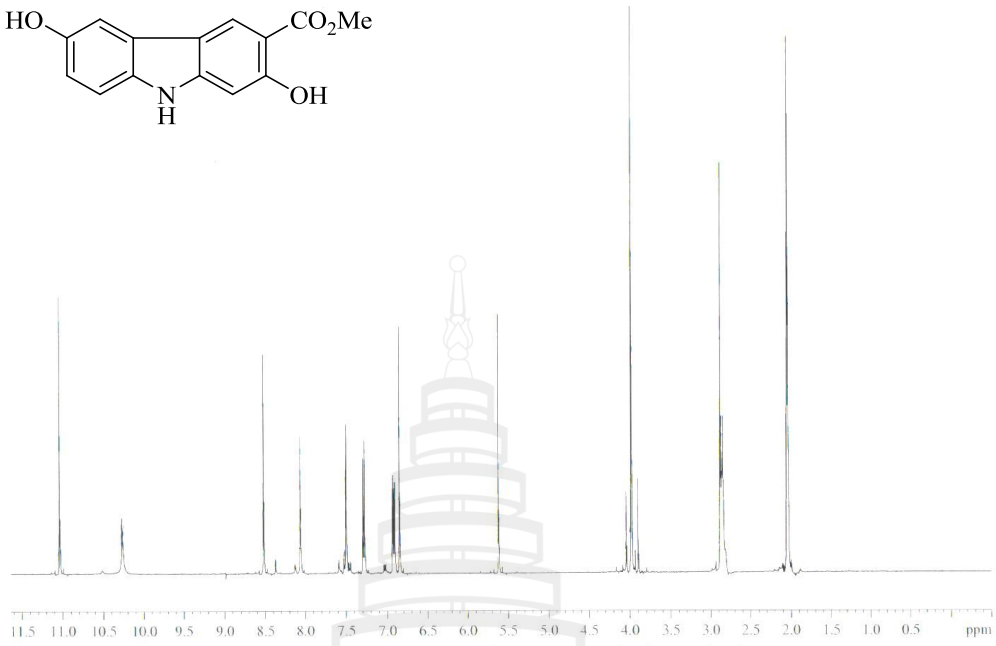

Figure A40 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE22**

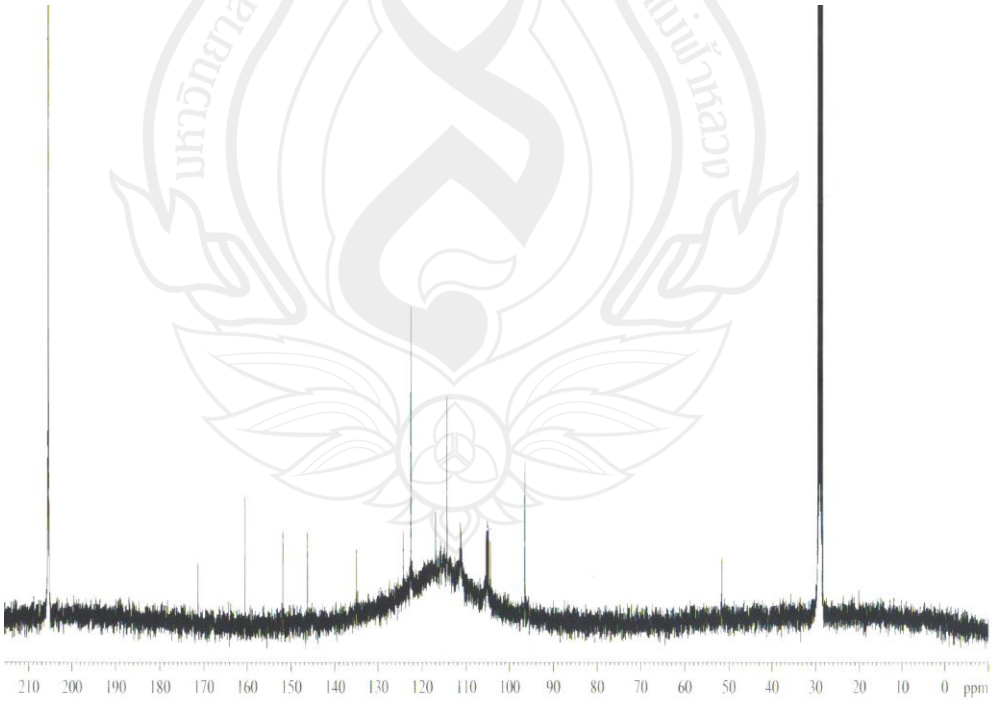

Figure A41 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **CE22**

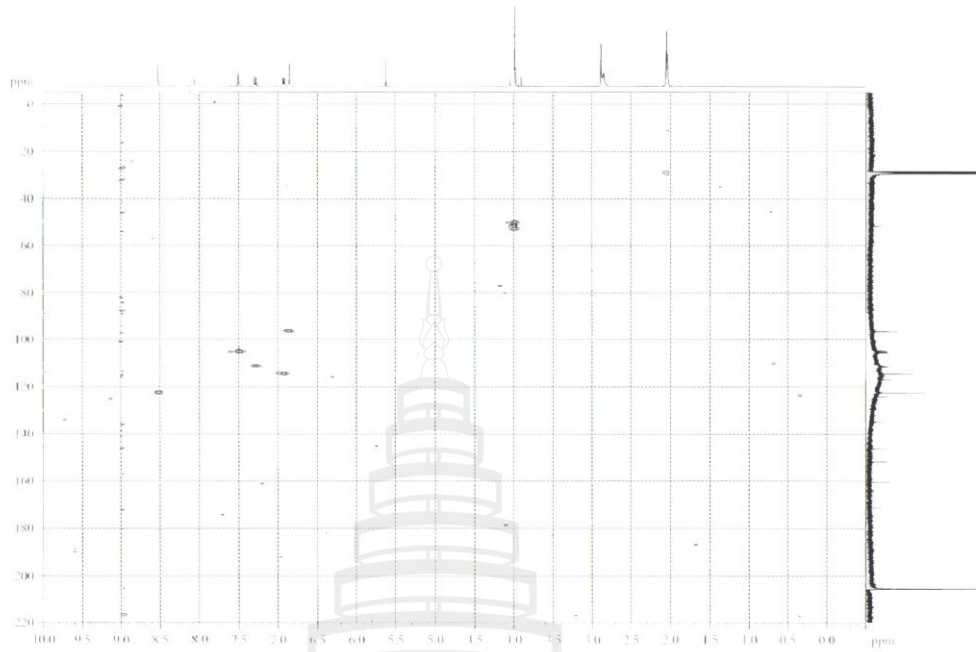

Figure A42 HMQC (Acetone-d_6) Spectrum of **CE22**

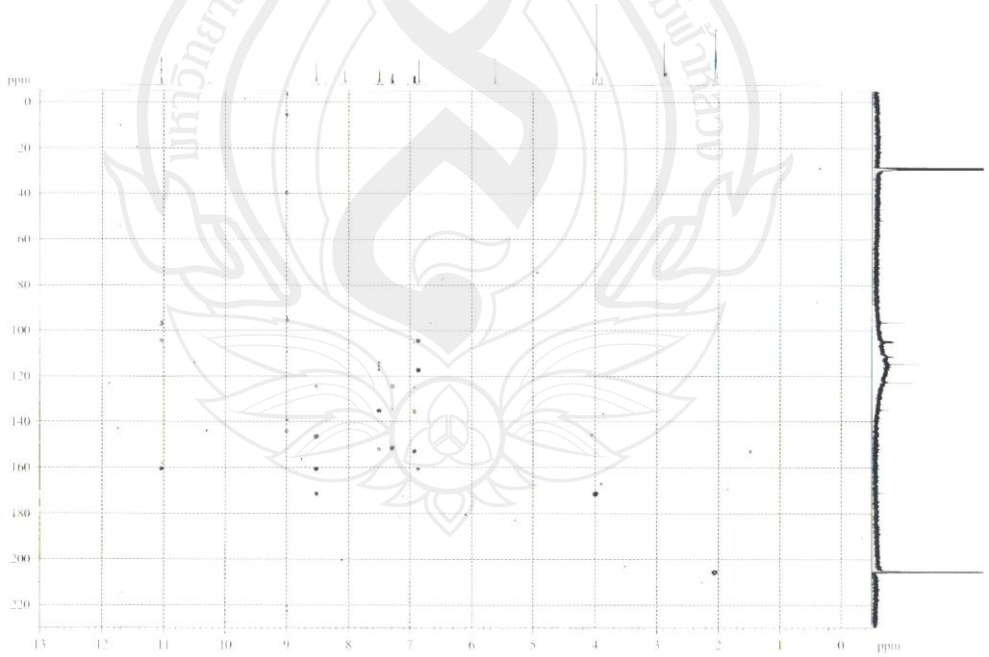

Figure A43 HMBC (Acetone-d_6) Spectrum of **CE22**

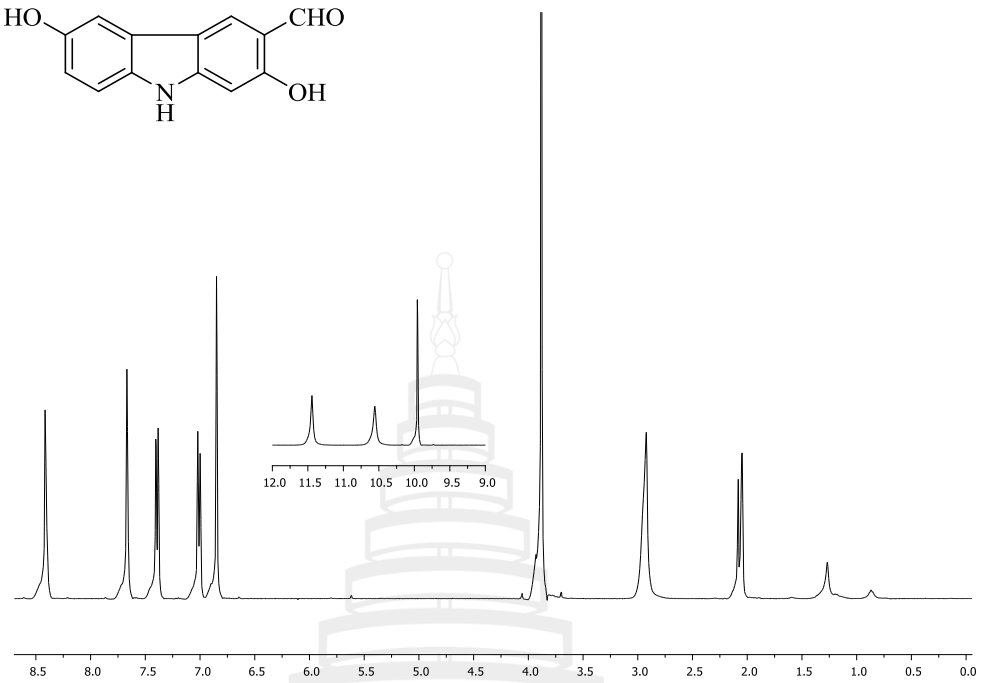

Figure A44 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE23**

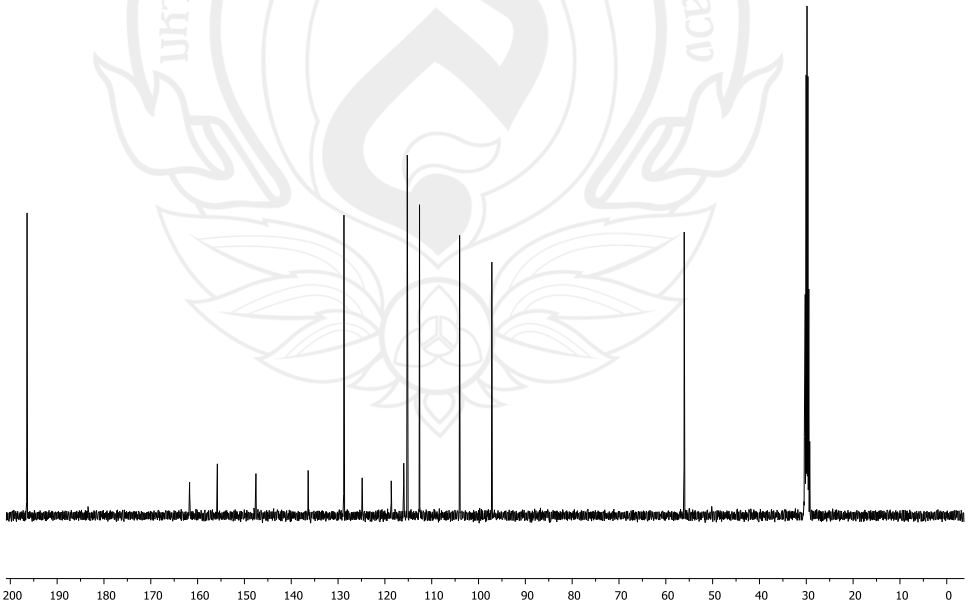

Figure A45 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **CE23**

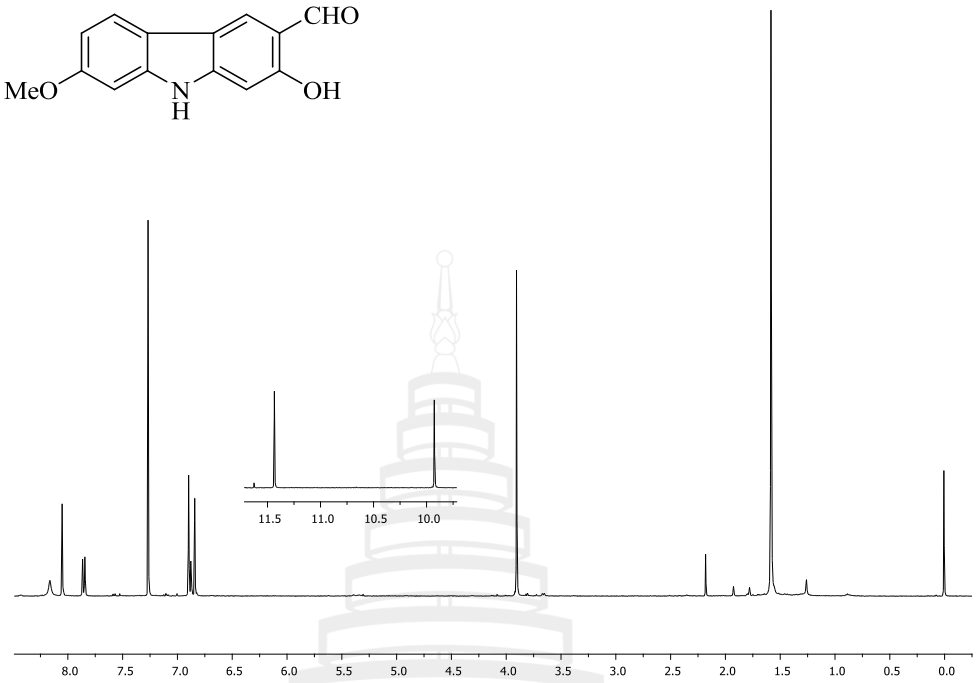

Figure A46 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE24**

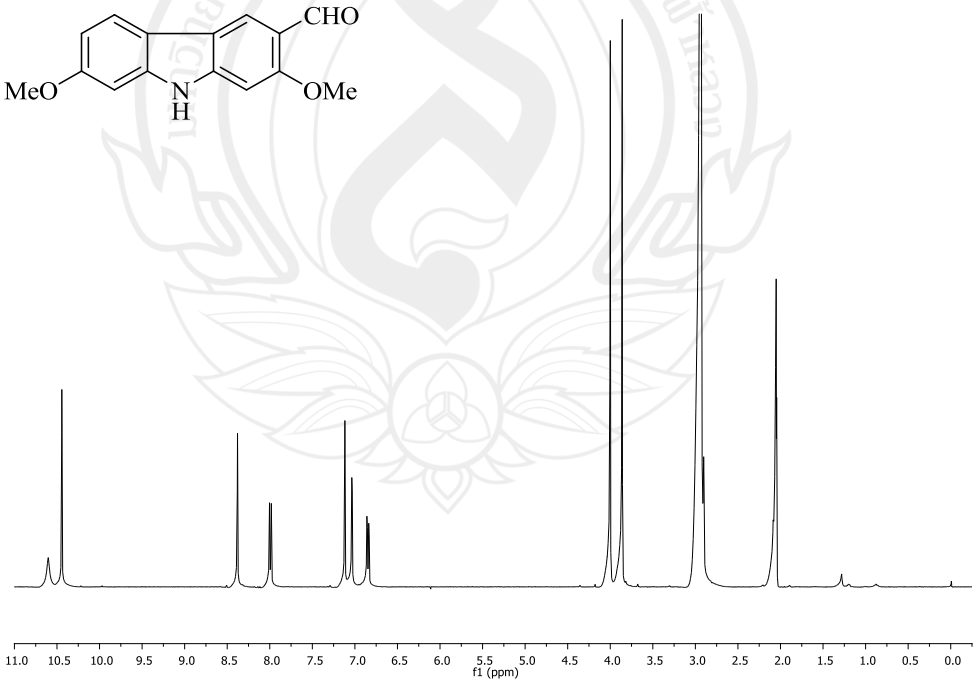

Figure A47 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE25**

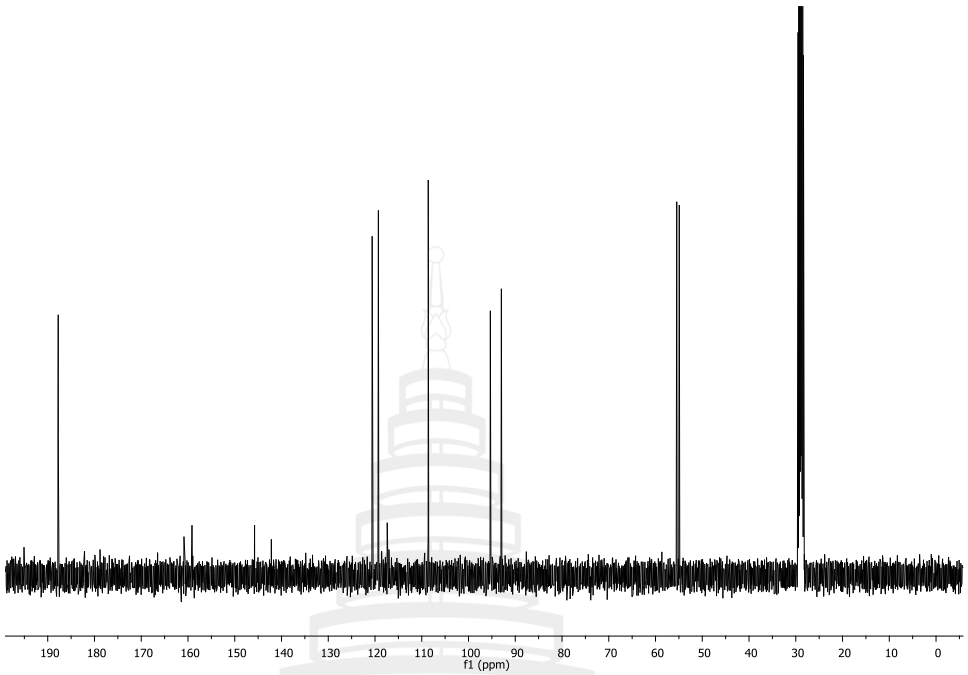

Figure A48 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **CE25**

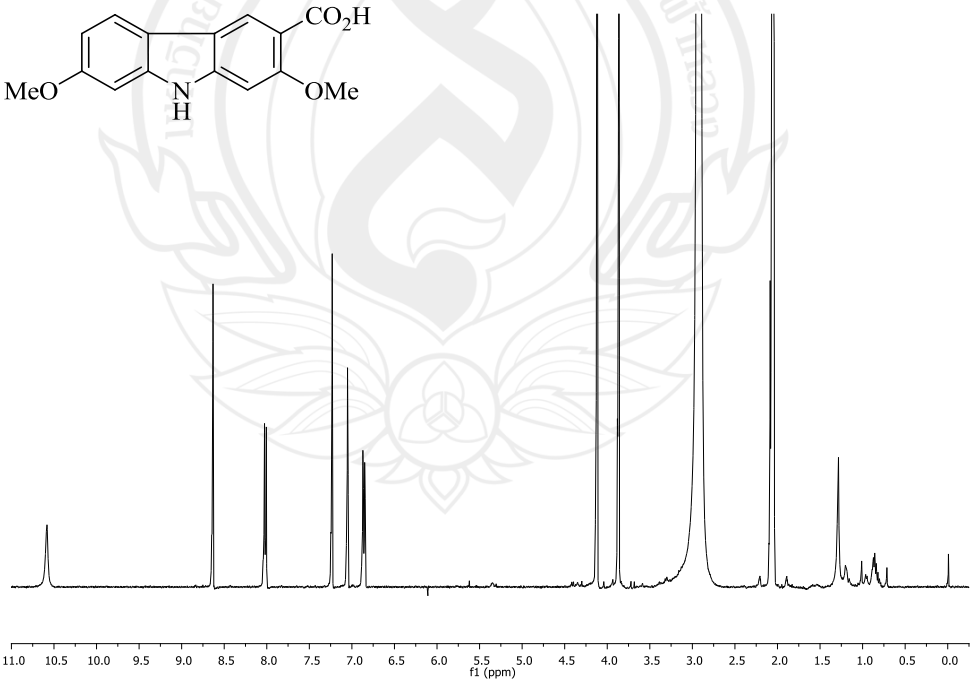

Figure A49 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE26**

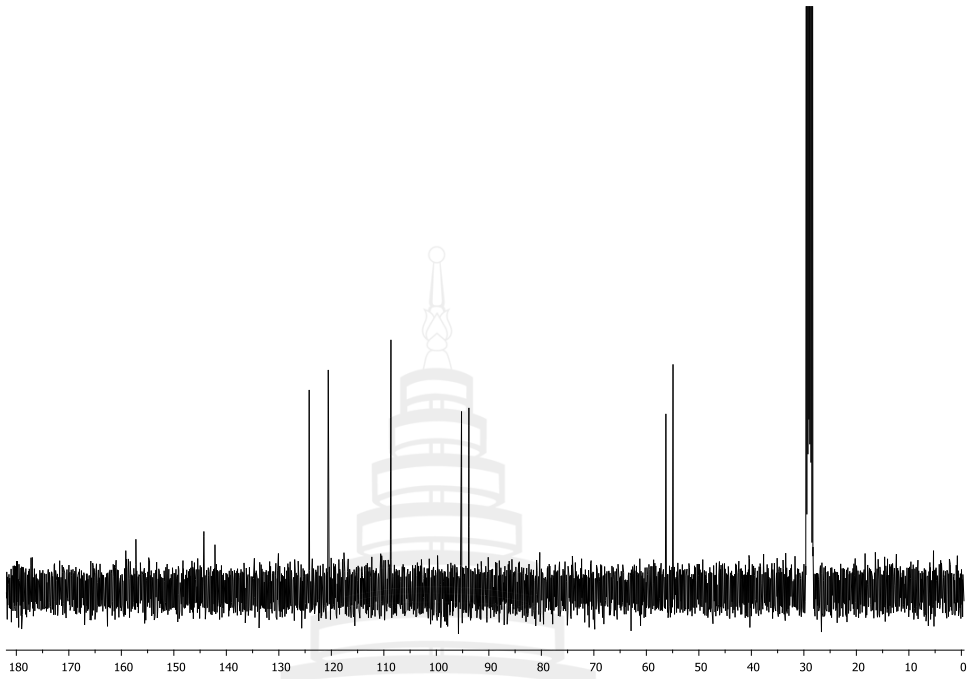

Figure A50 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **CE26**

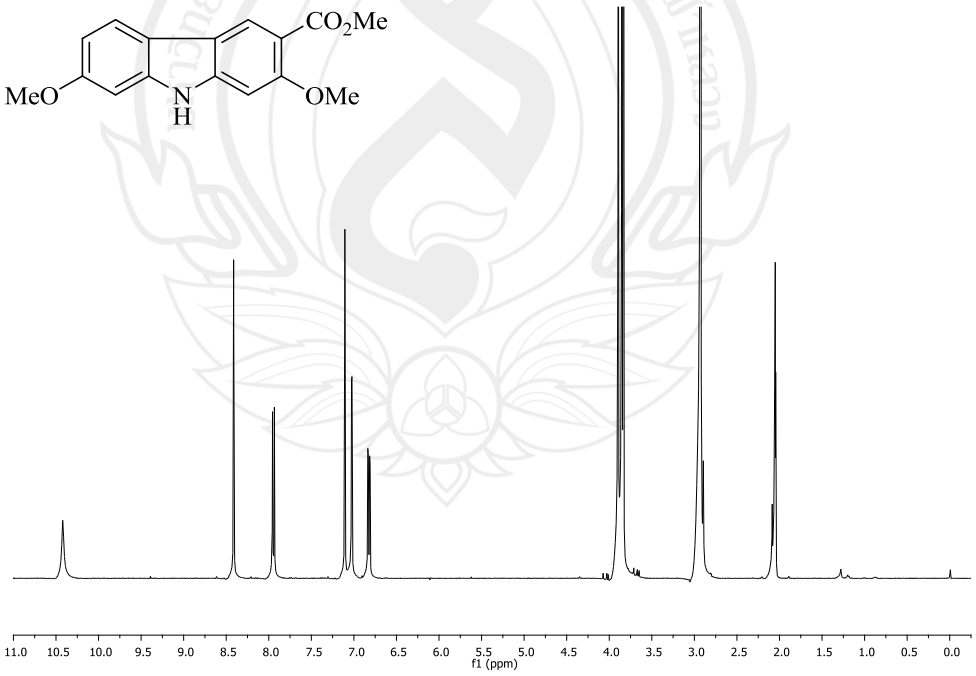

Figure A51 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE27**

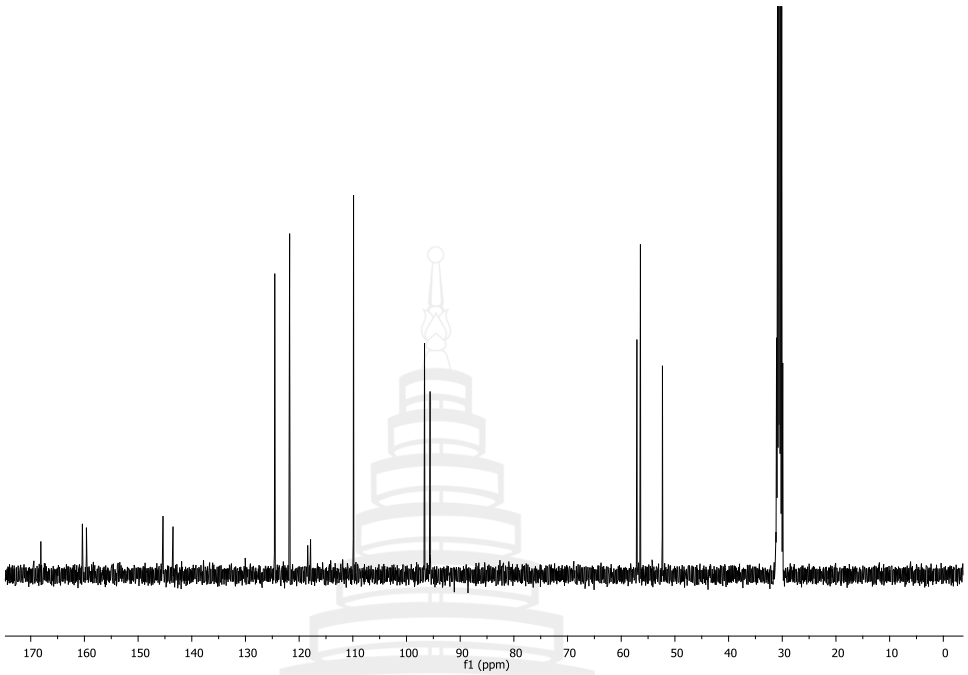

Figure A52 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **CE27**

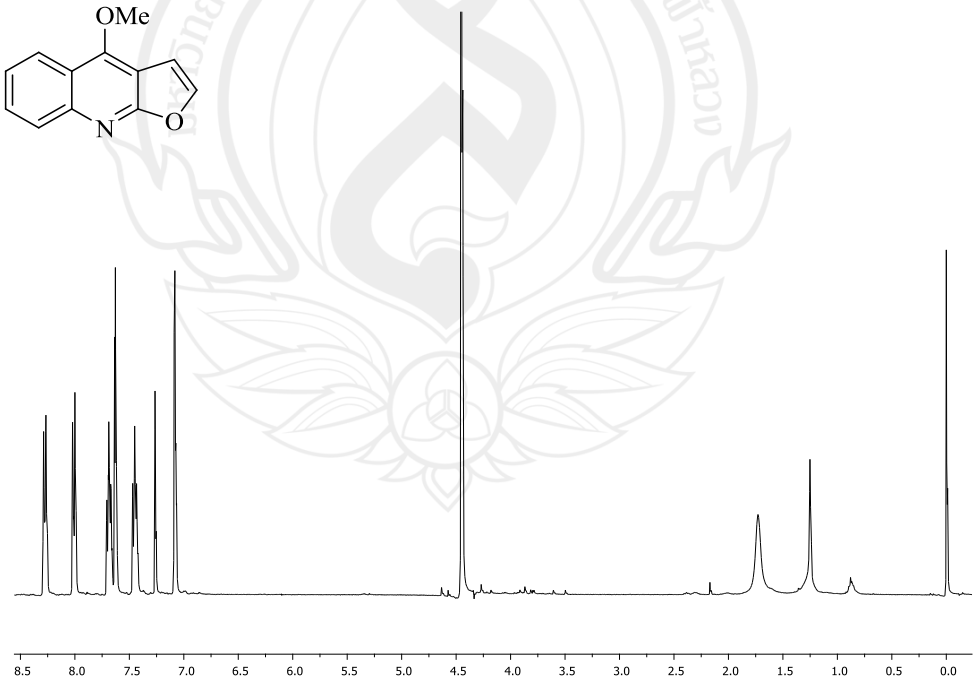

Figure A53 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **CE32**

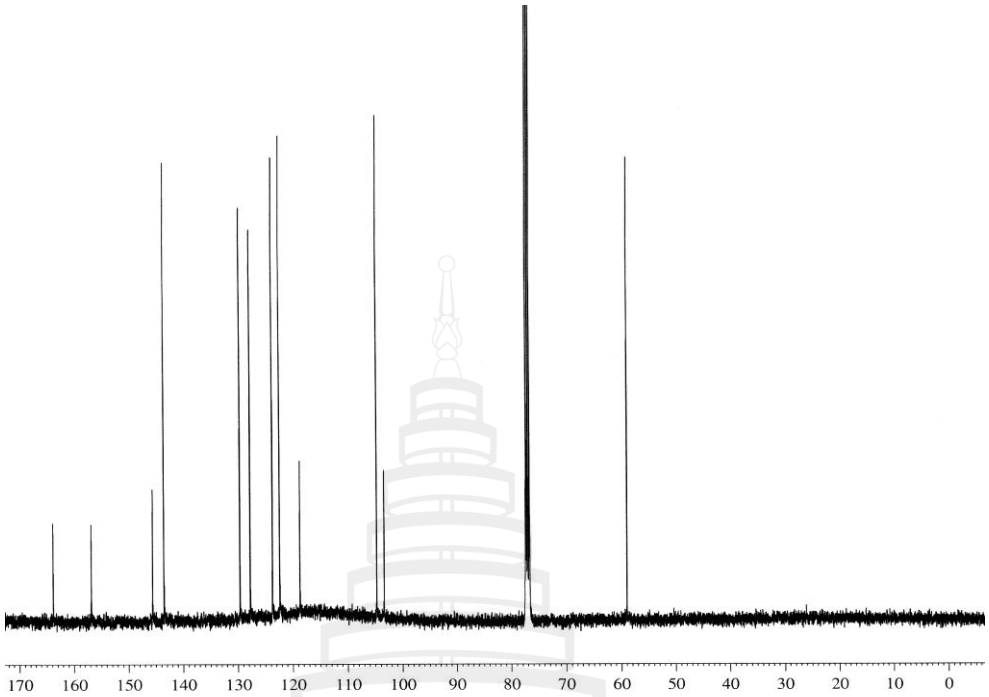

Figure A54 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **CE32**

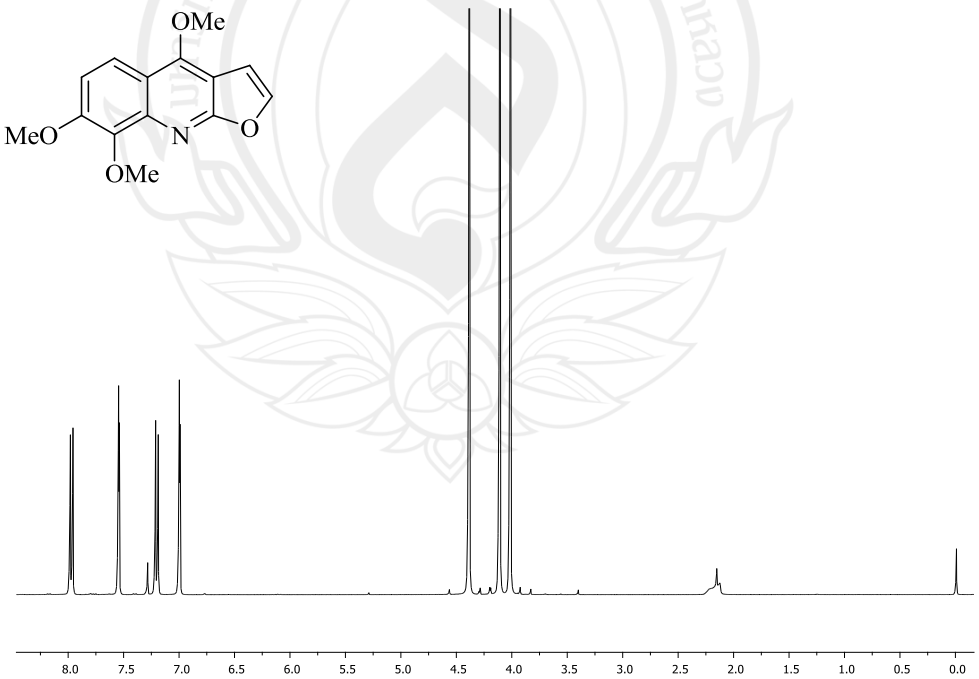

Figure A55 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **GP8**

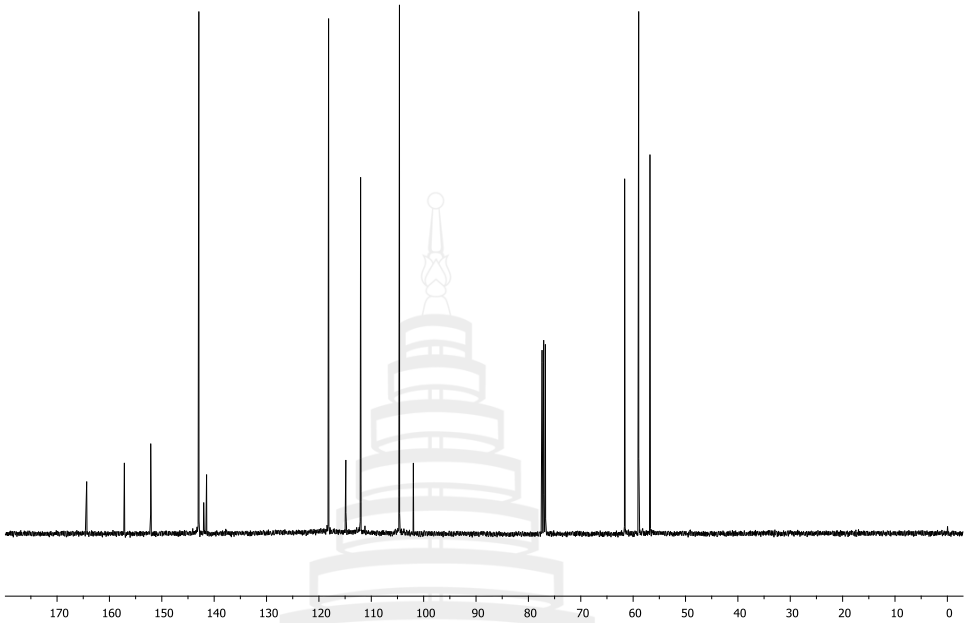

Figure A56 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **GP8**

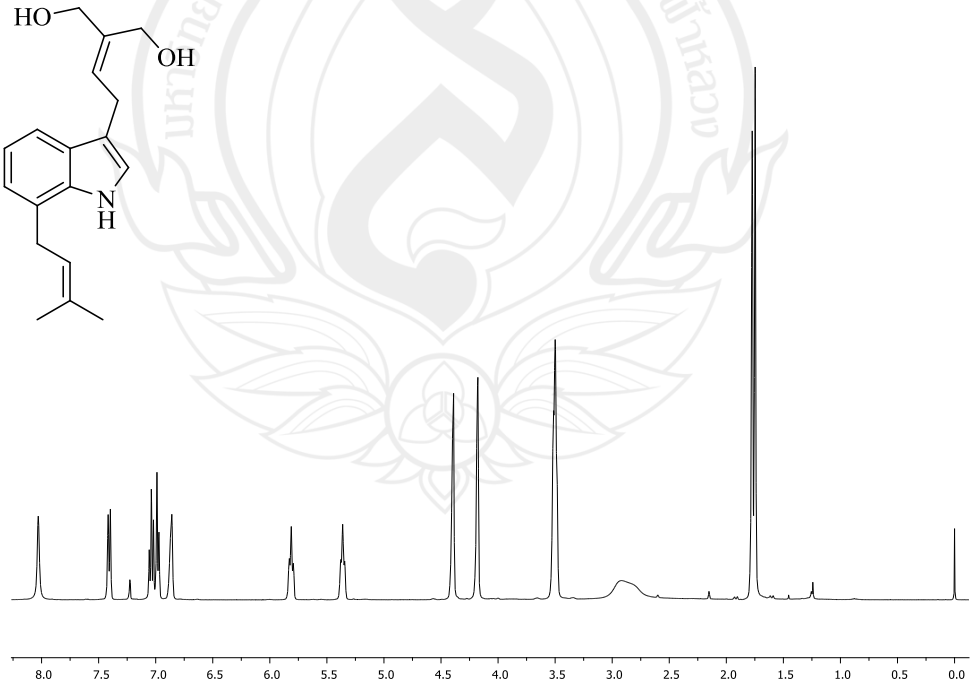

Figure A57 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **GC10**

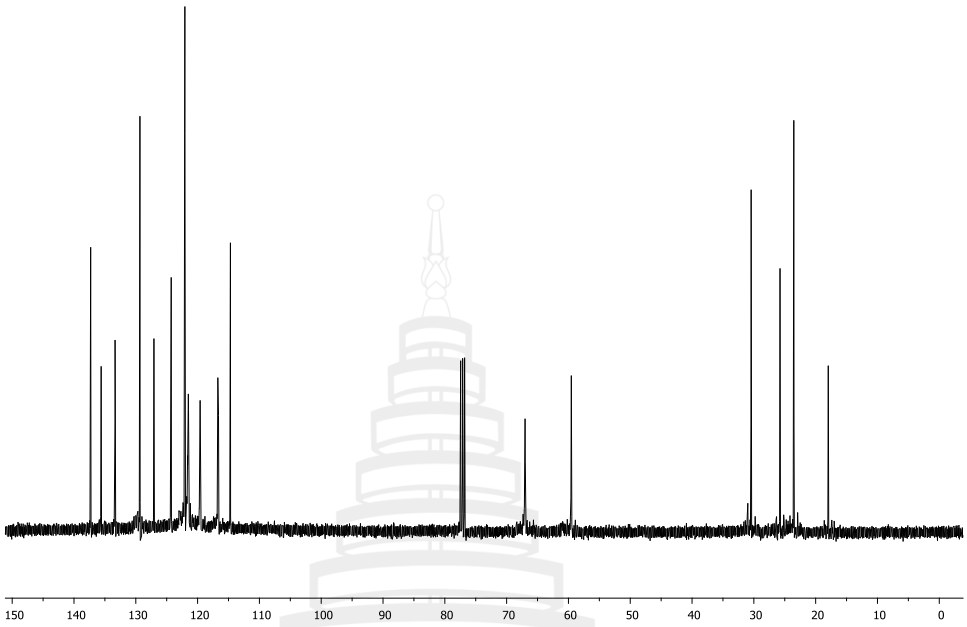

Figure A58 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **GC10**

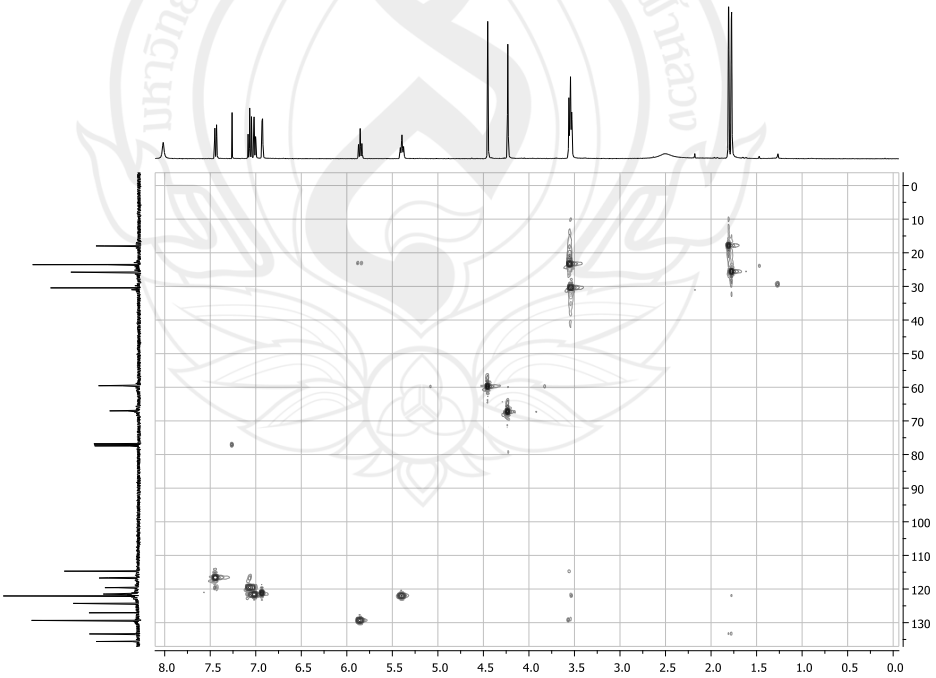

Figure A59 HMQC ($CDCl_3$) Spectrum of **GC10**

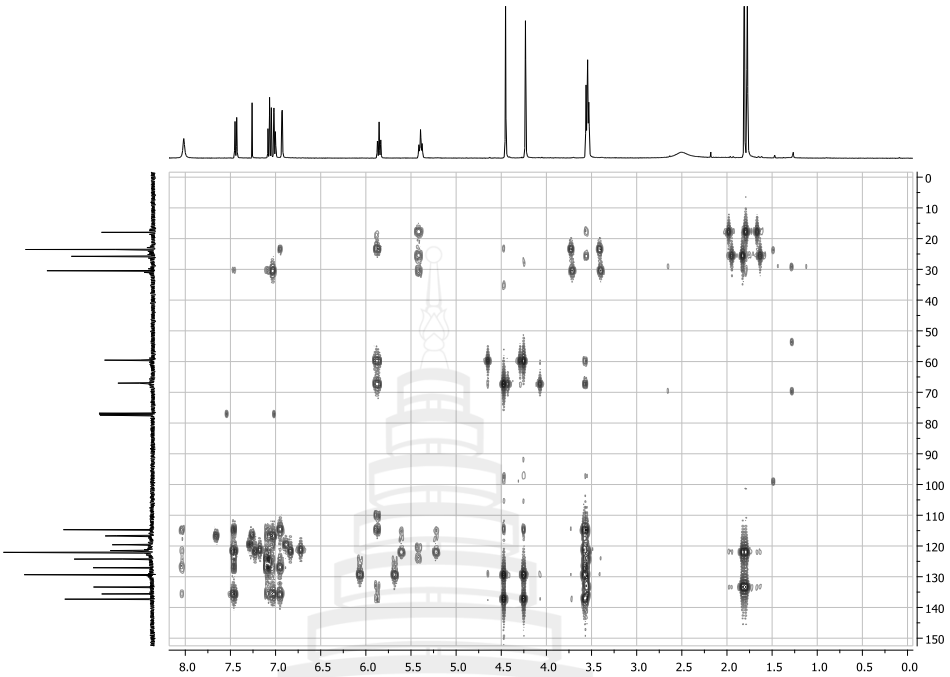

Figure A60 HMBC ($CDCl_3$) Spectrum of **GC10**

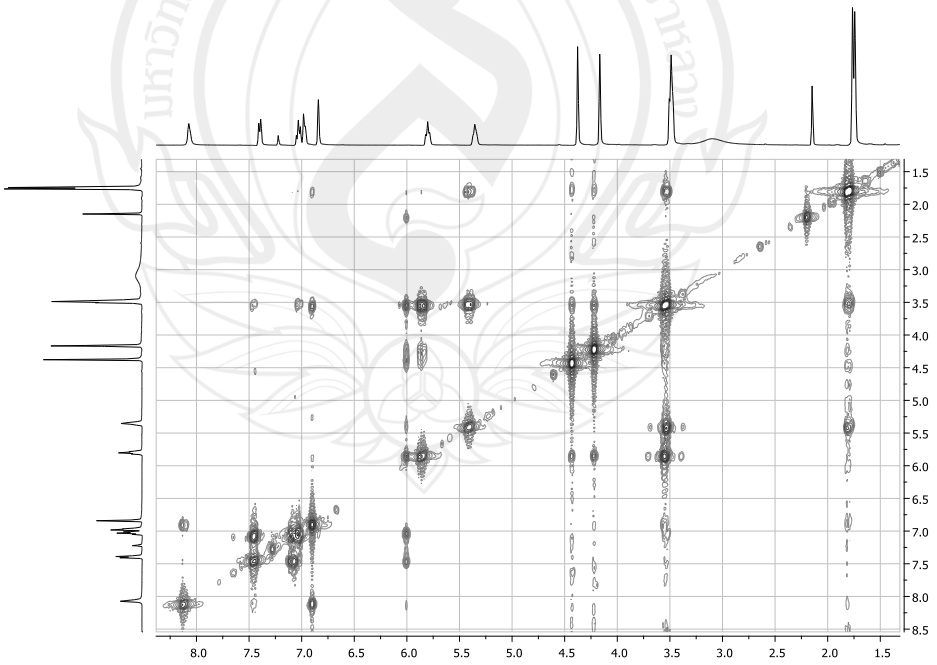

Figure A61 COSY ($CDCl_3$) Spectrum of **GC10**

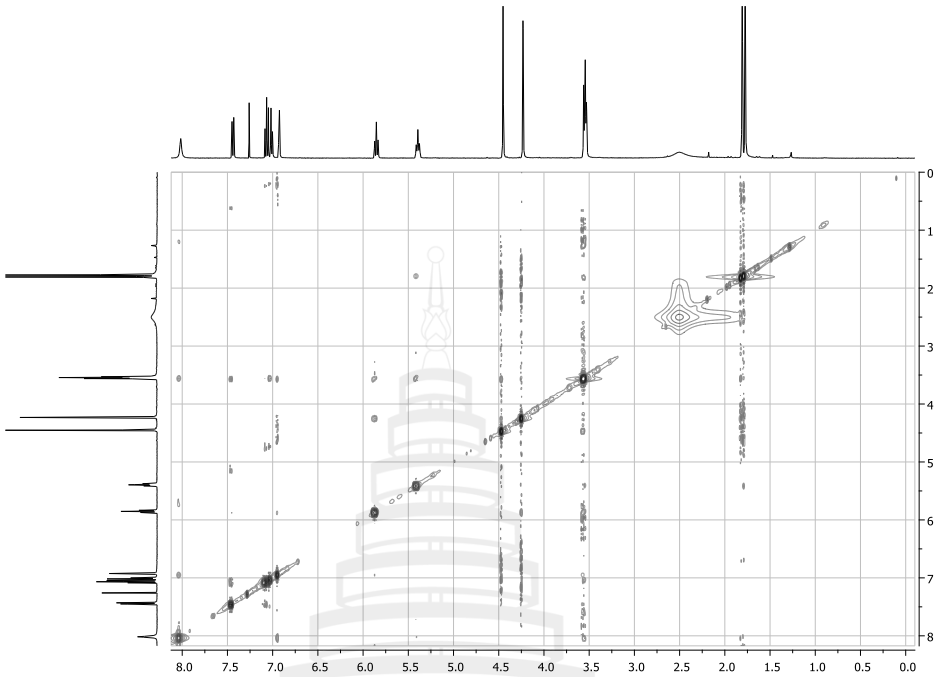

Figure A62 NOESY ($CDCl_3$) Spectrum of **GC10**

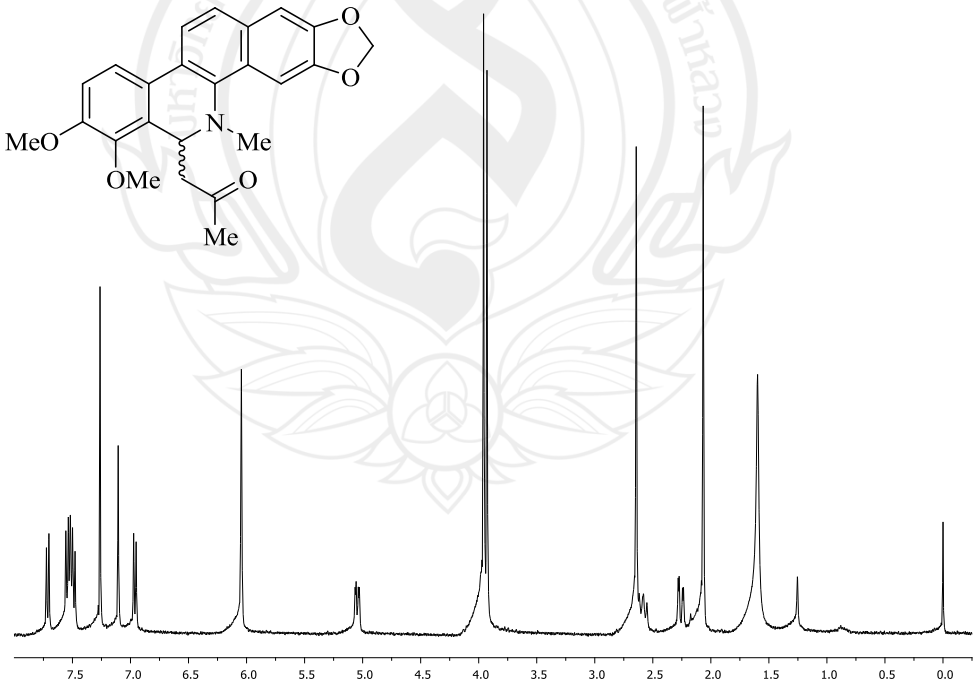

Figure A63 ^1H NMR (400 MHz, $CDCl_3$) Spectrum of **FL24**

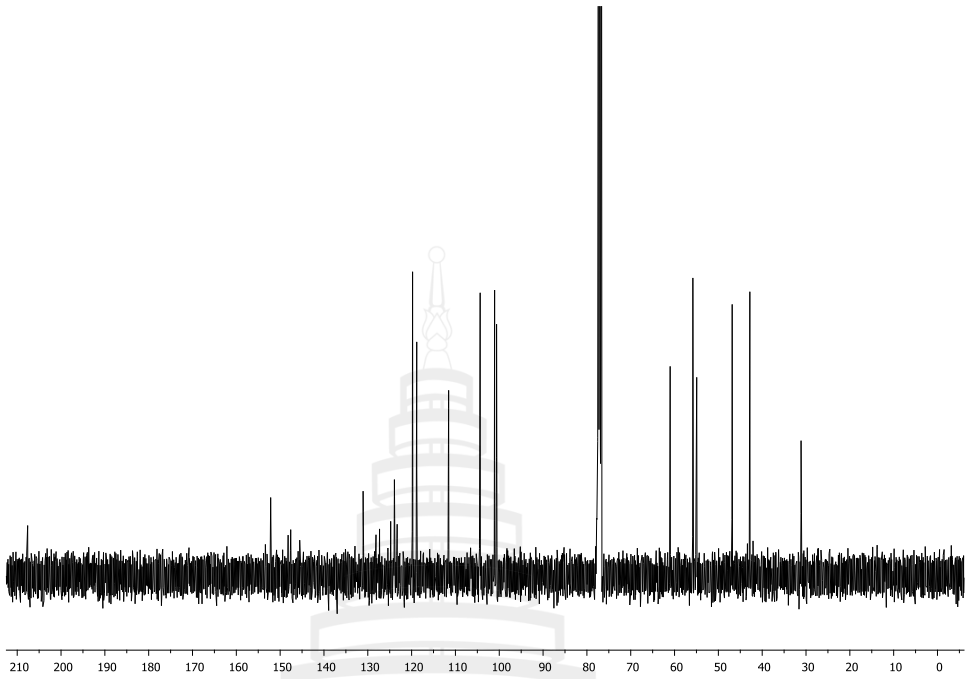

Figure A64 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL24**

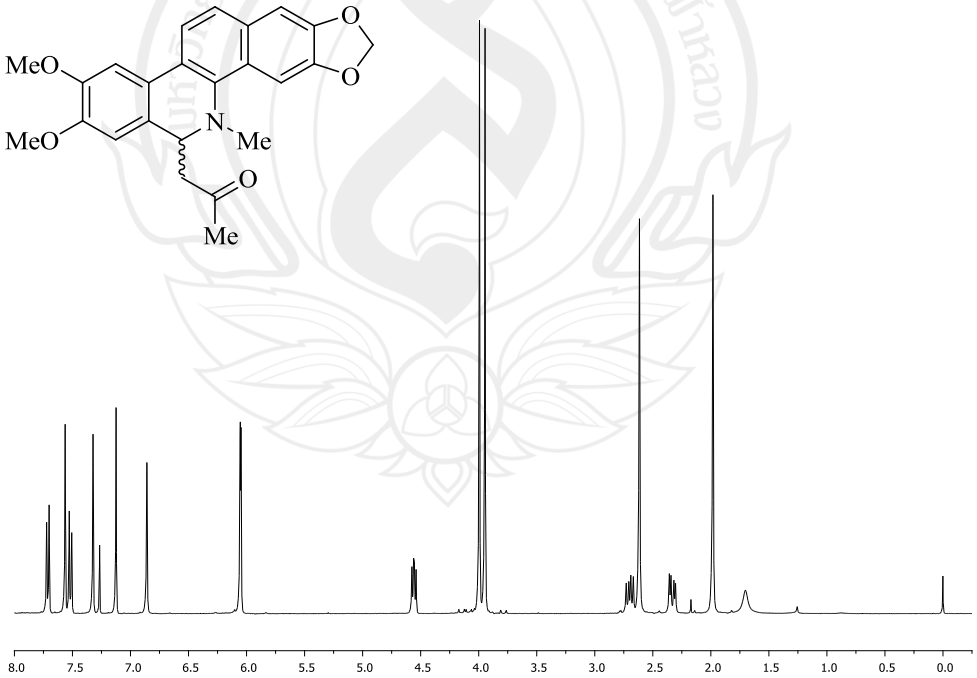

Figure A65 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL25**

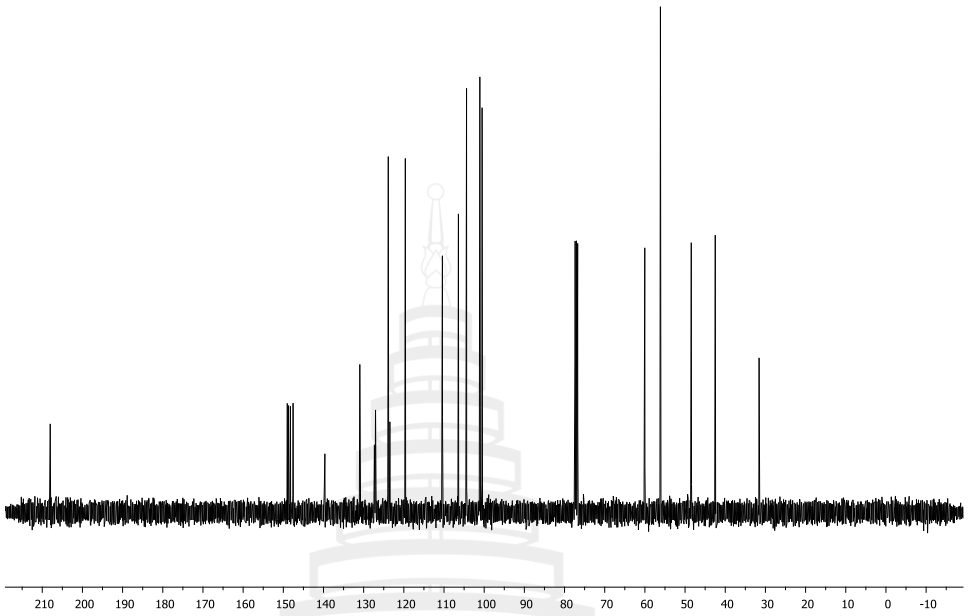

Figure A66 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL25**

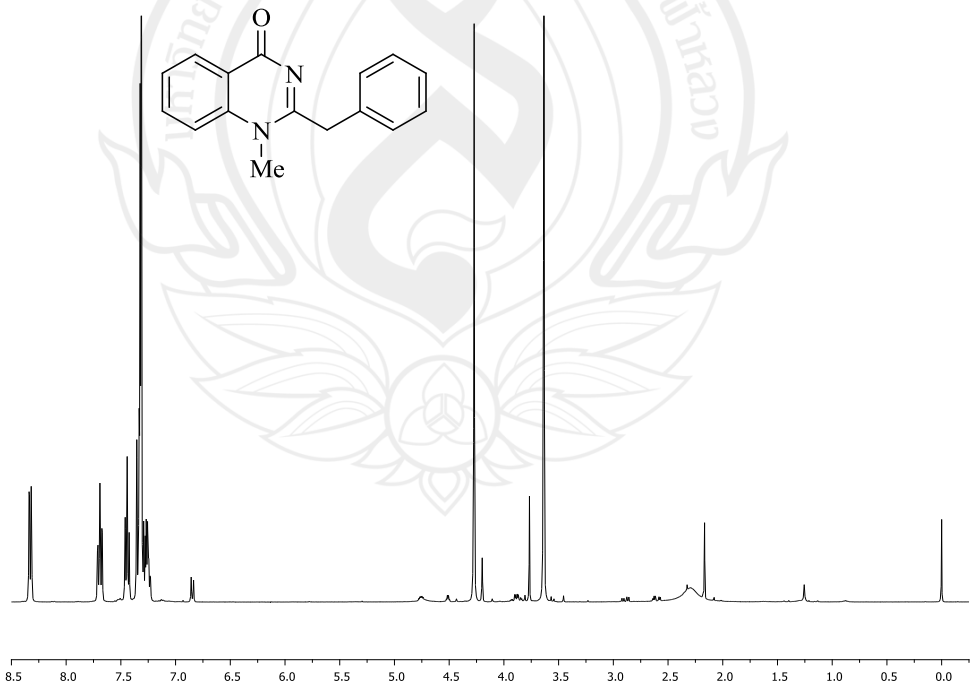

Figure A67 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **GP5**

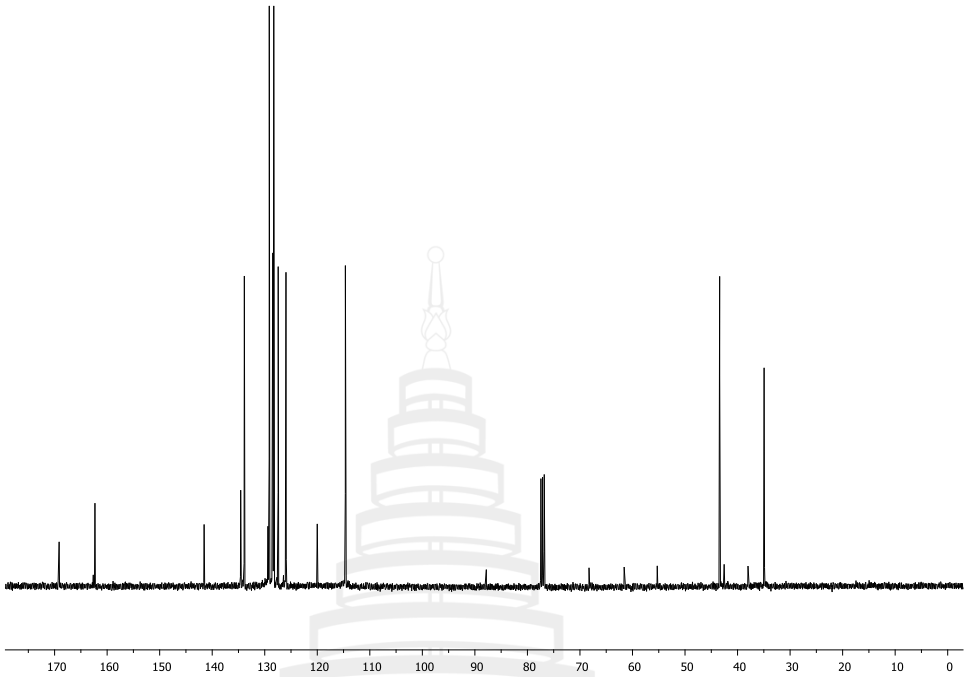

Figure A68 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **GP5**

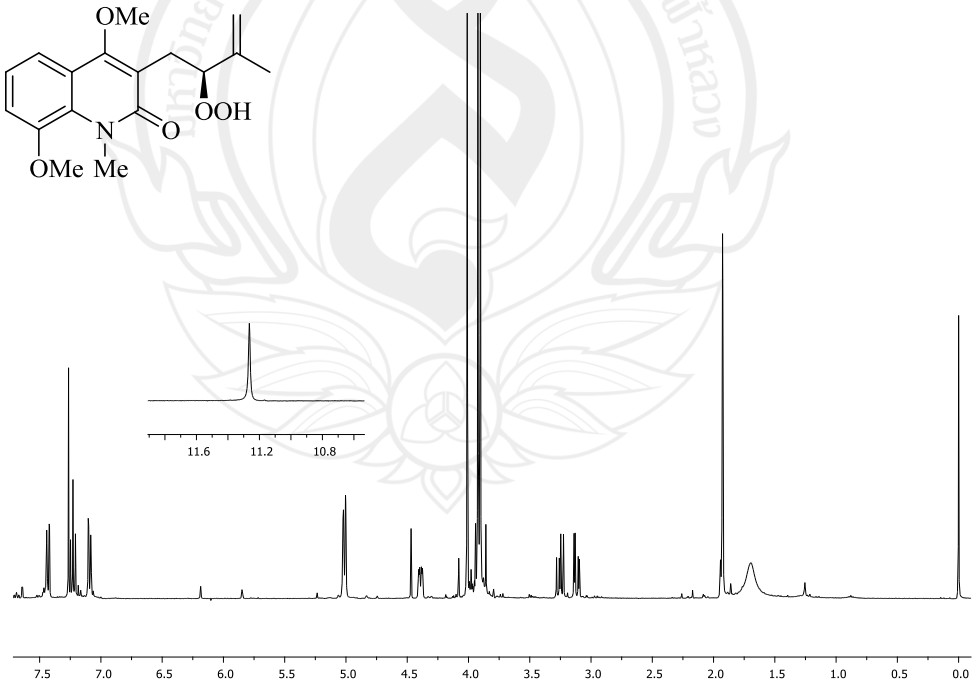

Figure A69 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **GP1**

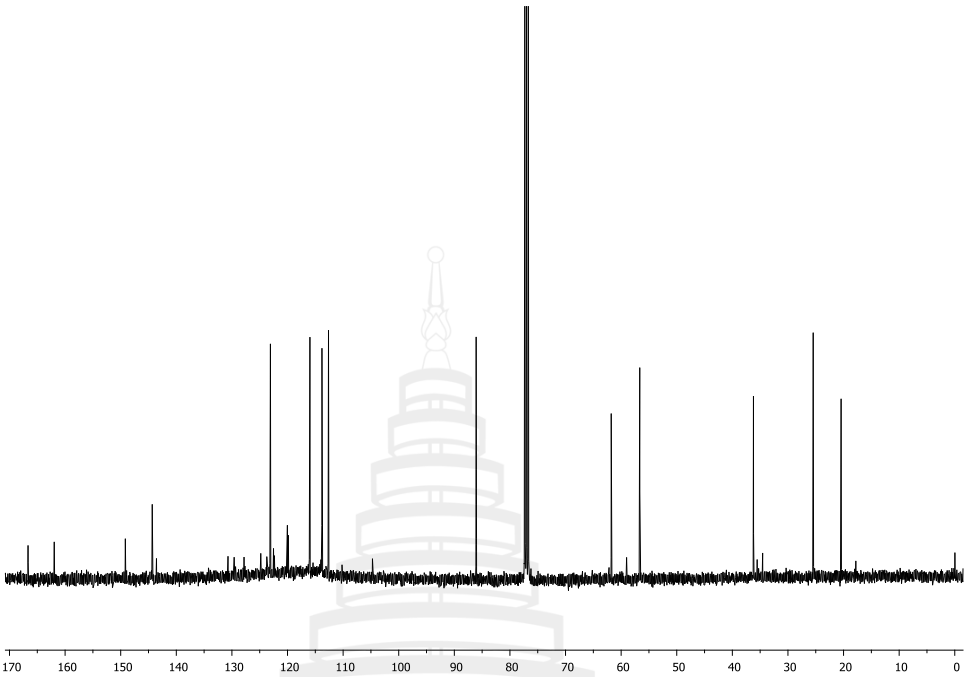

Figure A70 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **GP1**

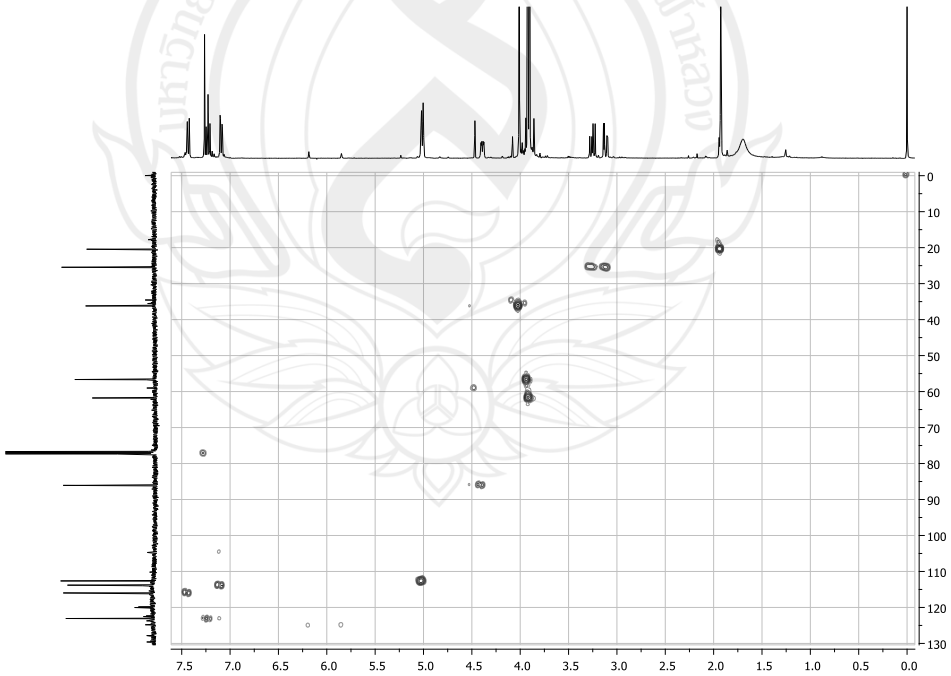

Figure A71 HMQC ($CDCl_3$) Spectrum of **GP1**

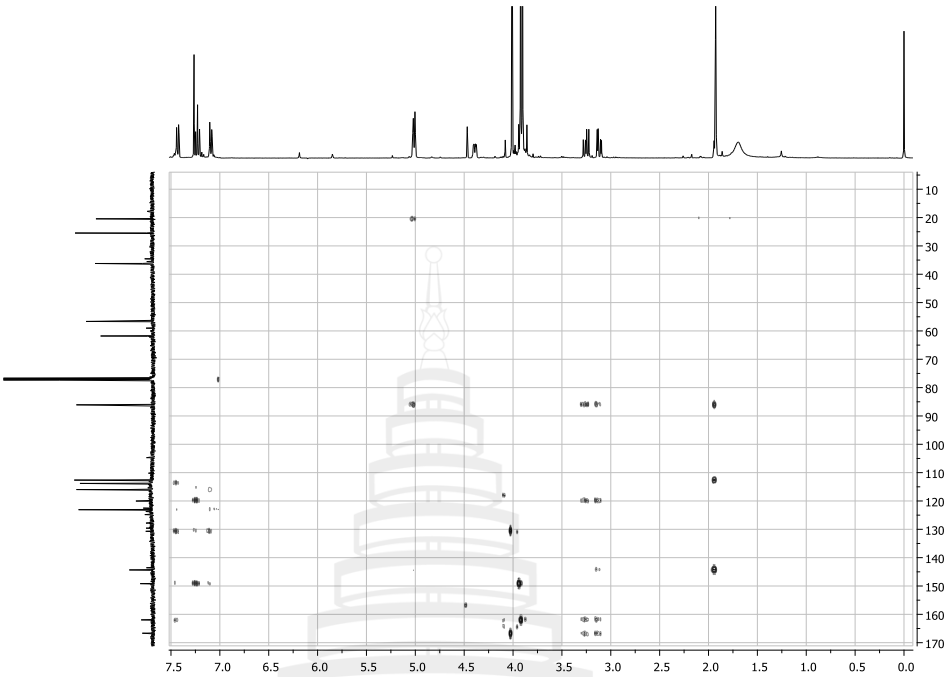

Figure A72 HMBC ($CDCl_3$) Spectrum of **GP1**

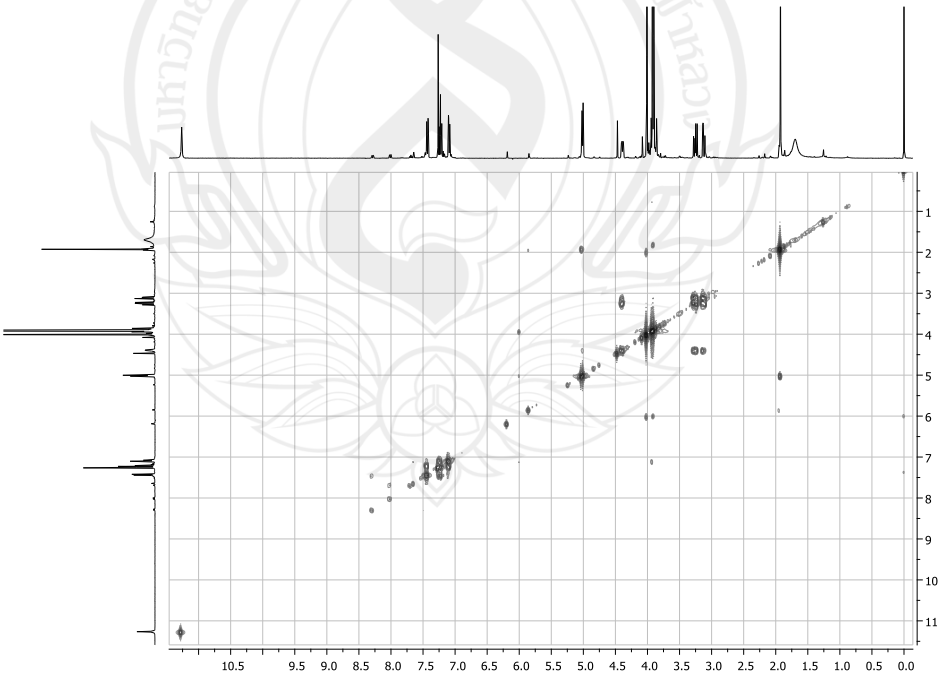

Figure A73 COSY ($CDCl_3$) Spectrum of **GP1**

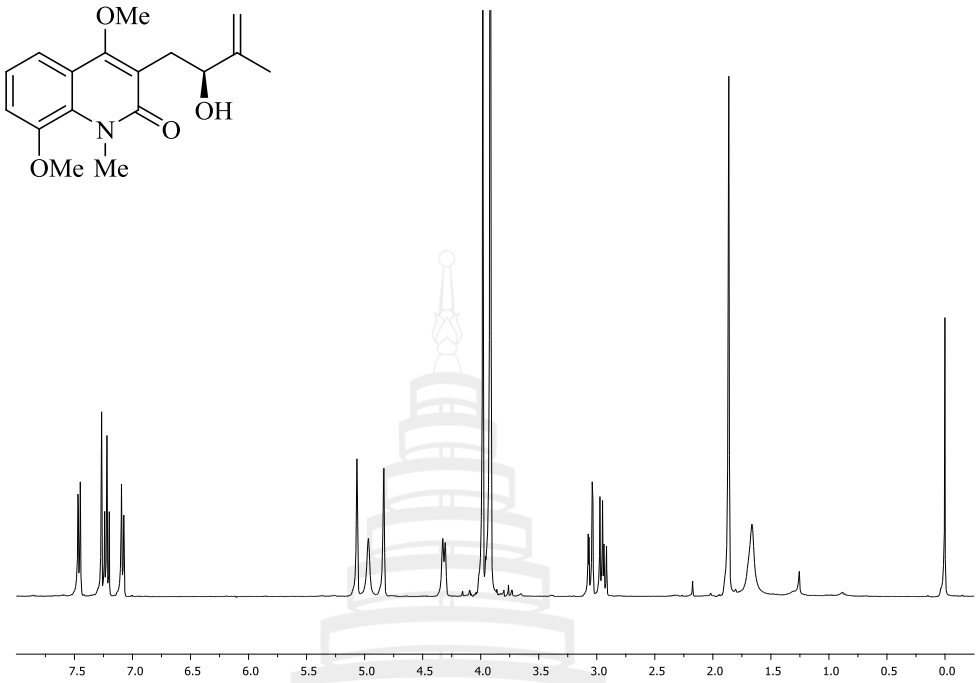

Figure A74 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **GP2**

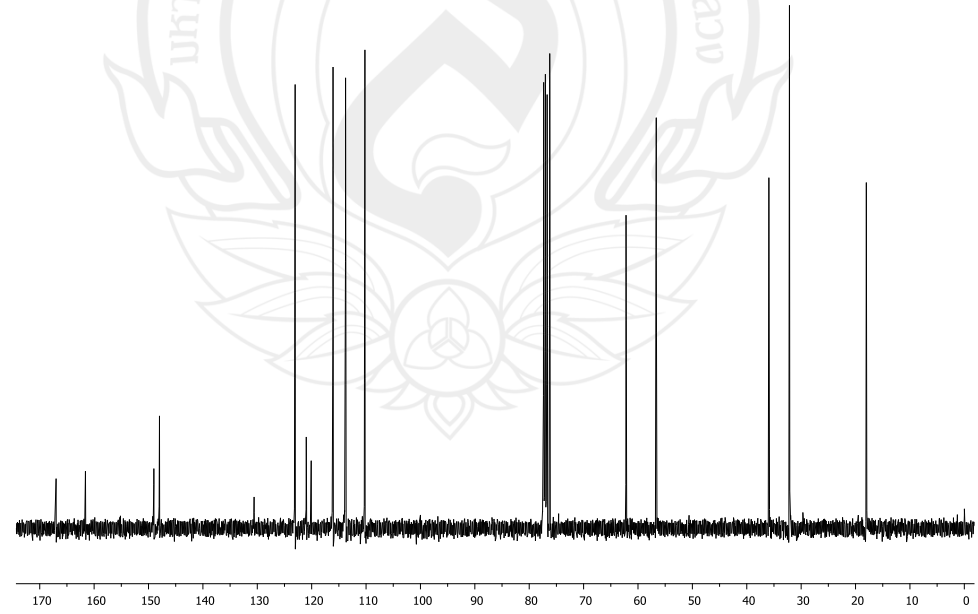

Figure A75 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **GP2**

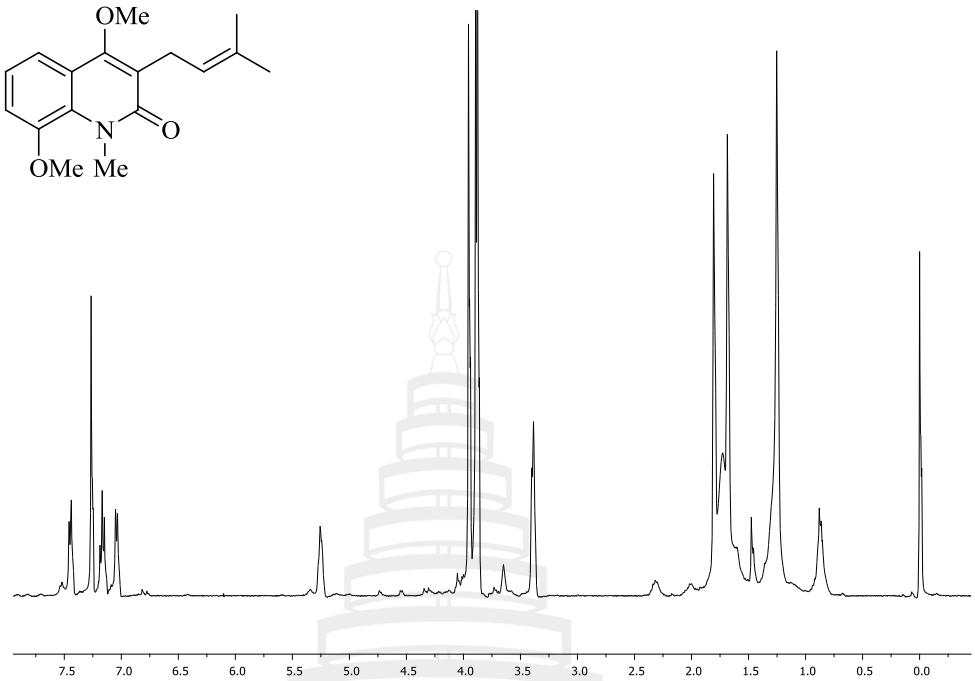

Figure A76 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **GP3**

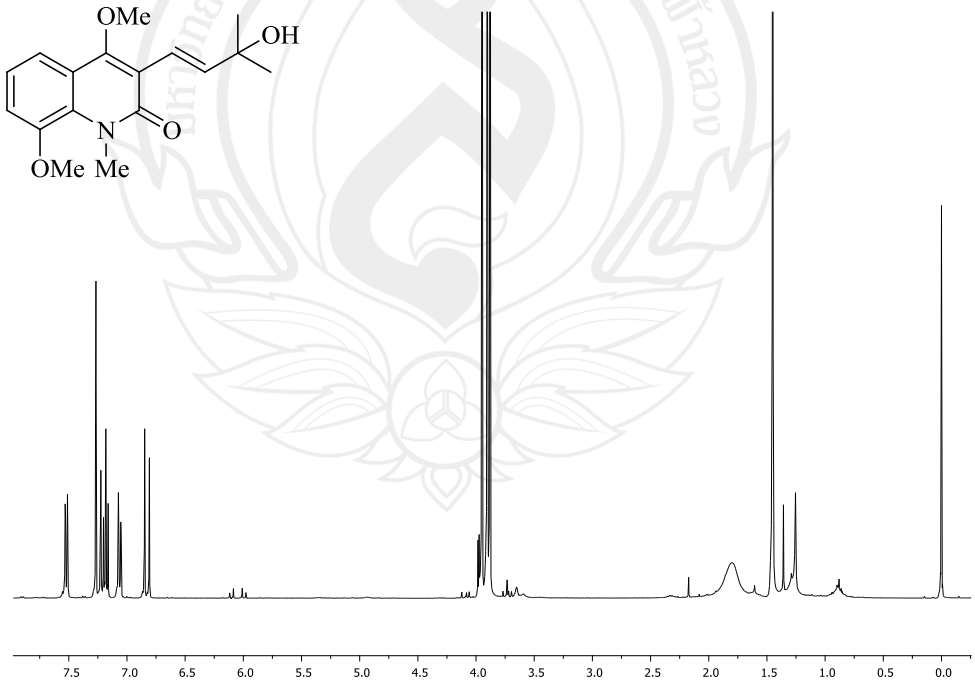

Figure A77 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **GP4**

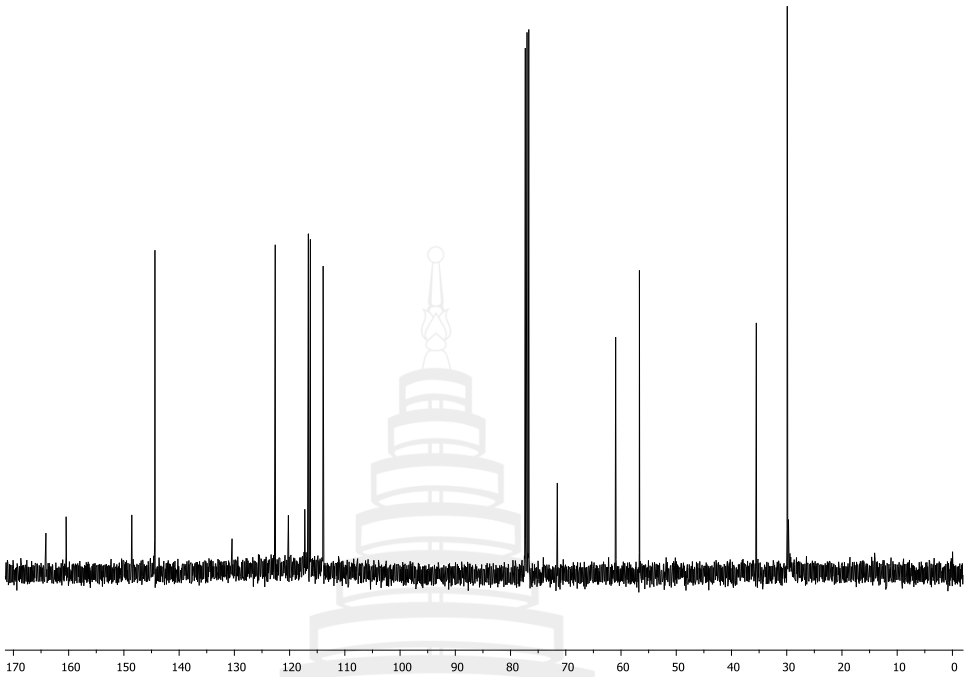

Figure A78 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **GP4**

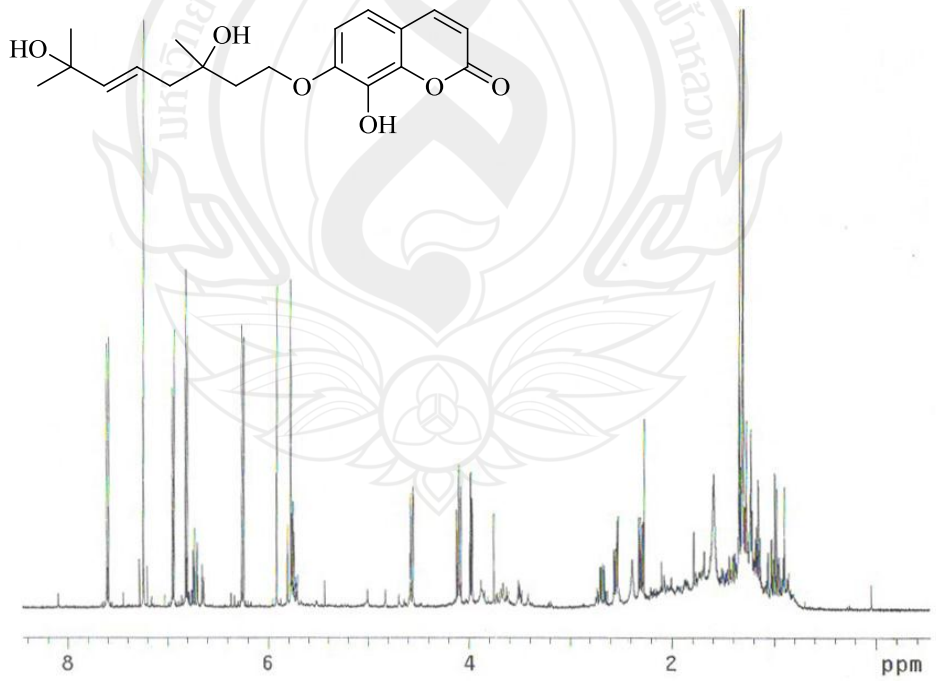

Figure A79 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **CE1**

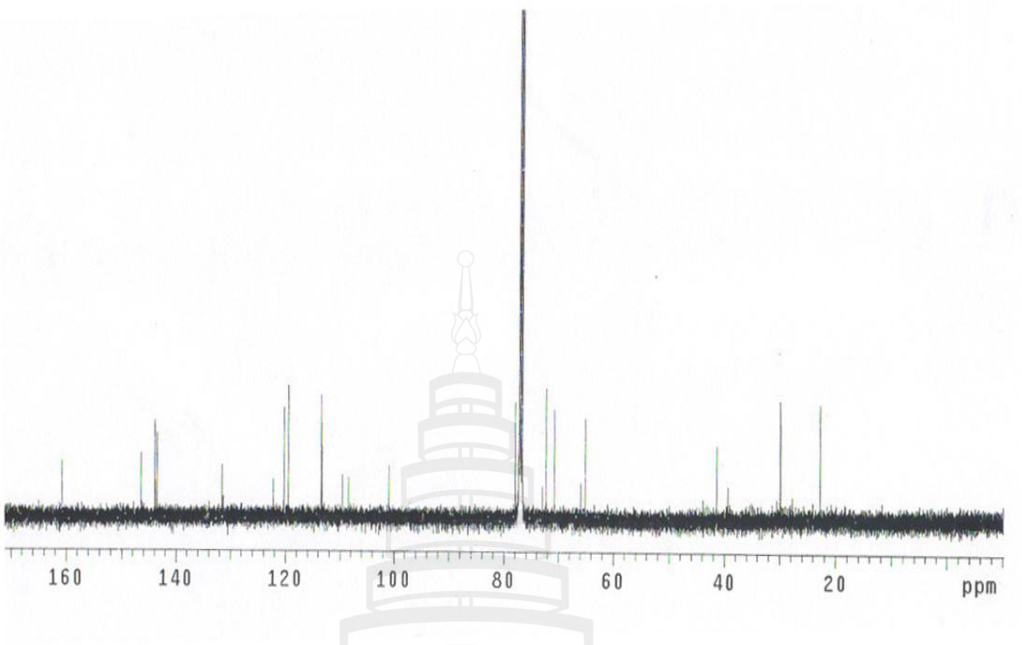

Figure A80 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **CE1**

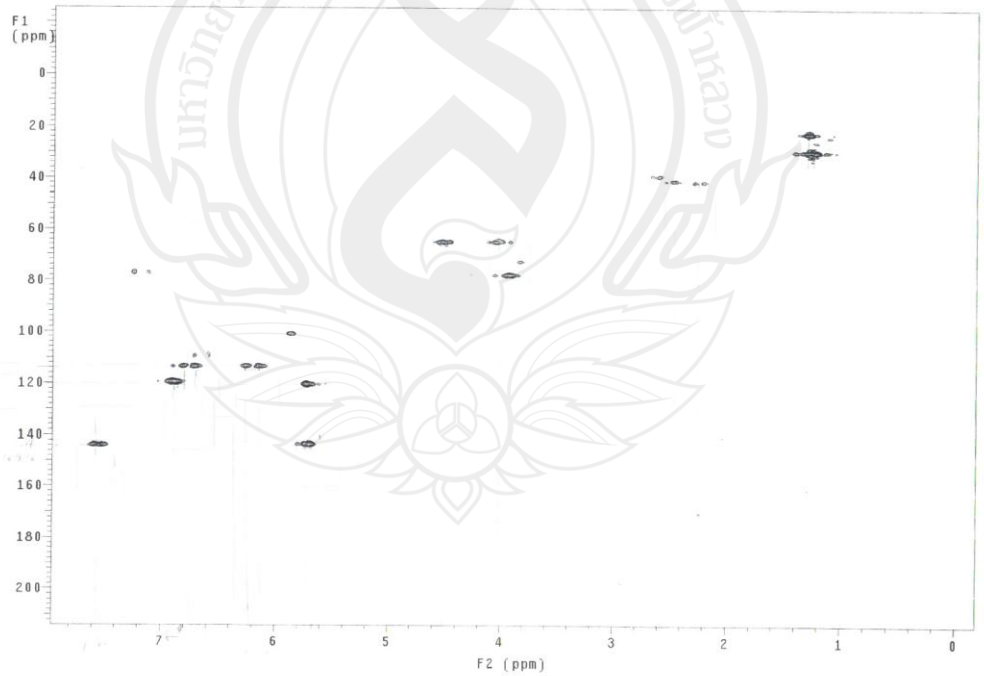

Figure A81 HMQC ($CDCl_3$) Spectrum of **CE1**

Figure A82 HMBC ($CDCl_3$) Spectrum of **CE1**

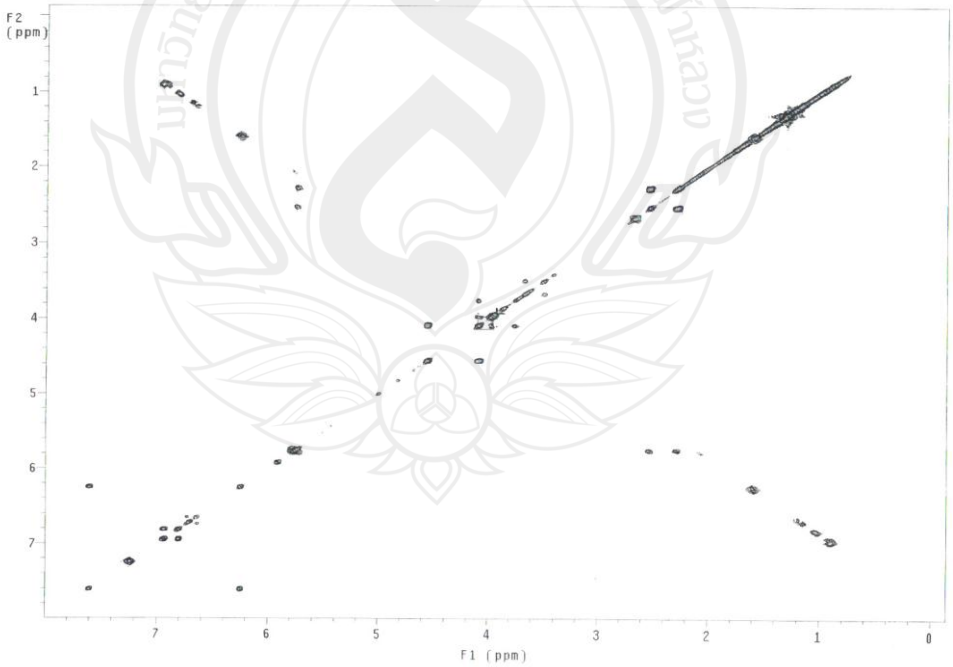

Figure A83 COSY ($CDCl_3$) Spectrum of **CE1**

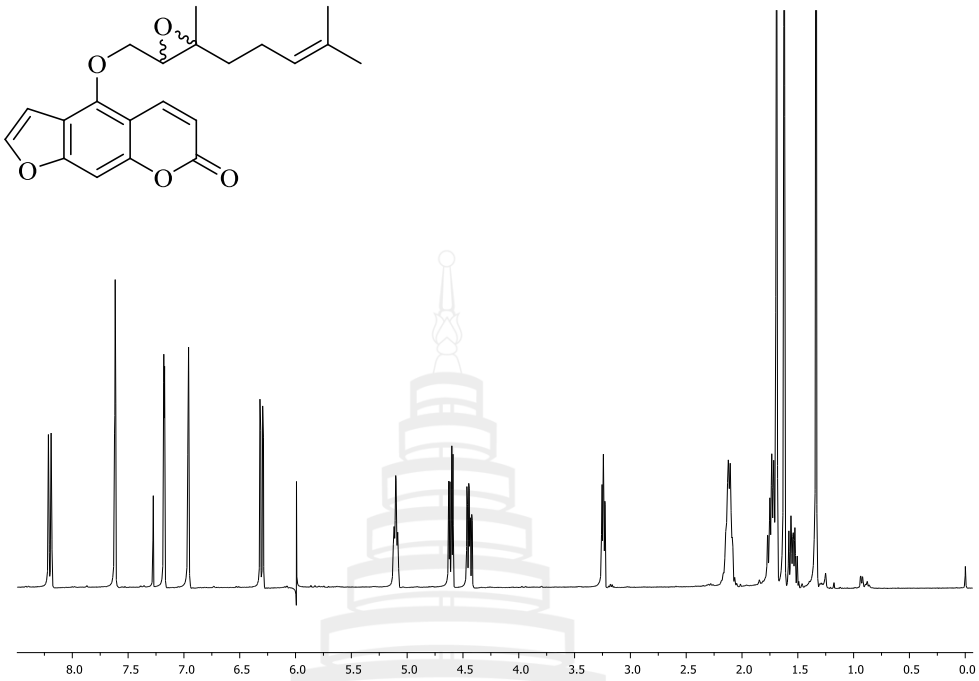

Figure A84 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL8**

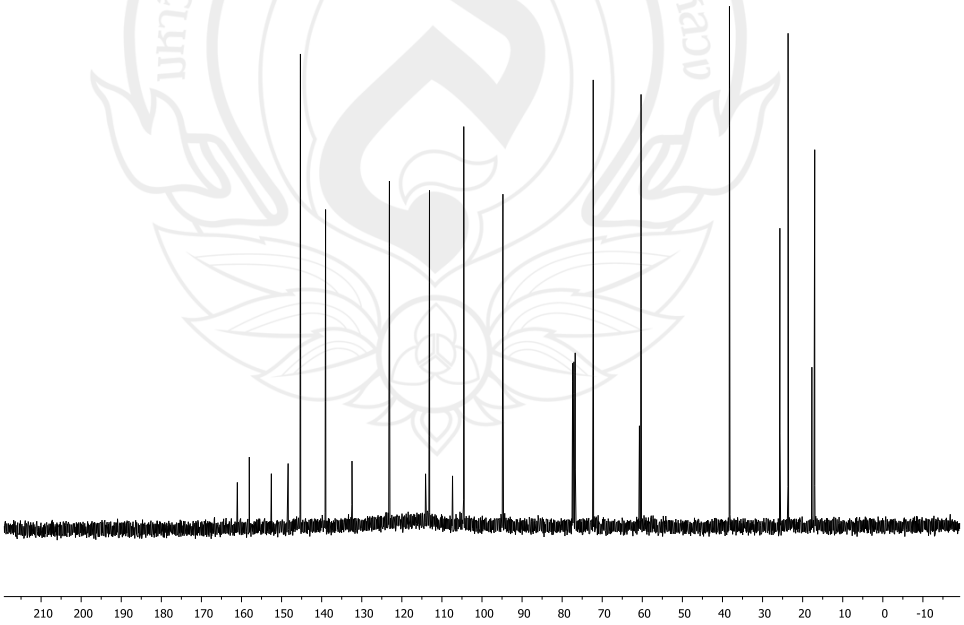

Figure A85 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL8**

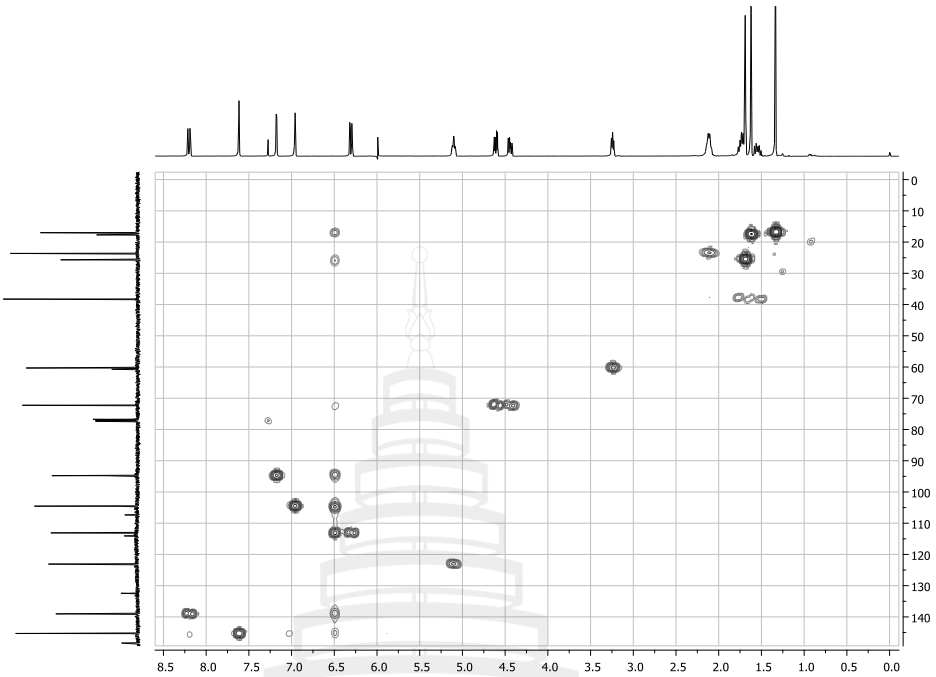

Figure A86 HMQC ($CDCl_3$) Spectrum of **FL8**

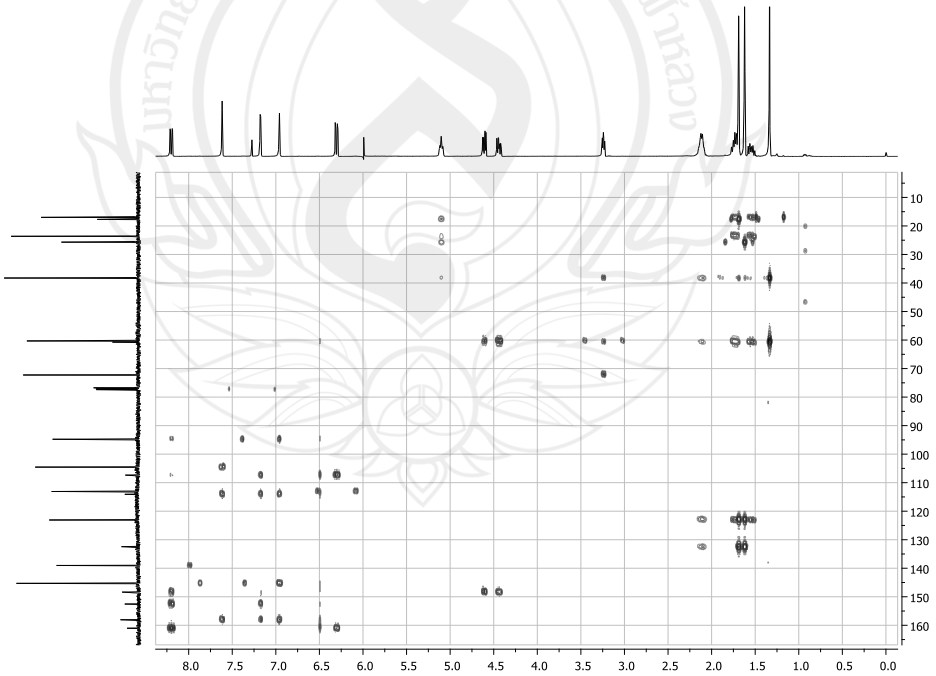

Figure A87 HMBC ($CDCl_3$) Spectrum of **FL8**

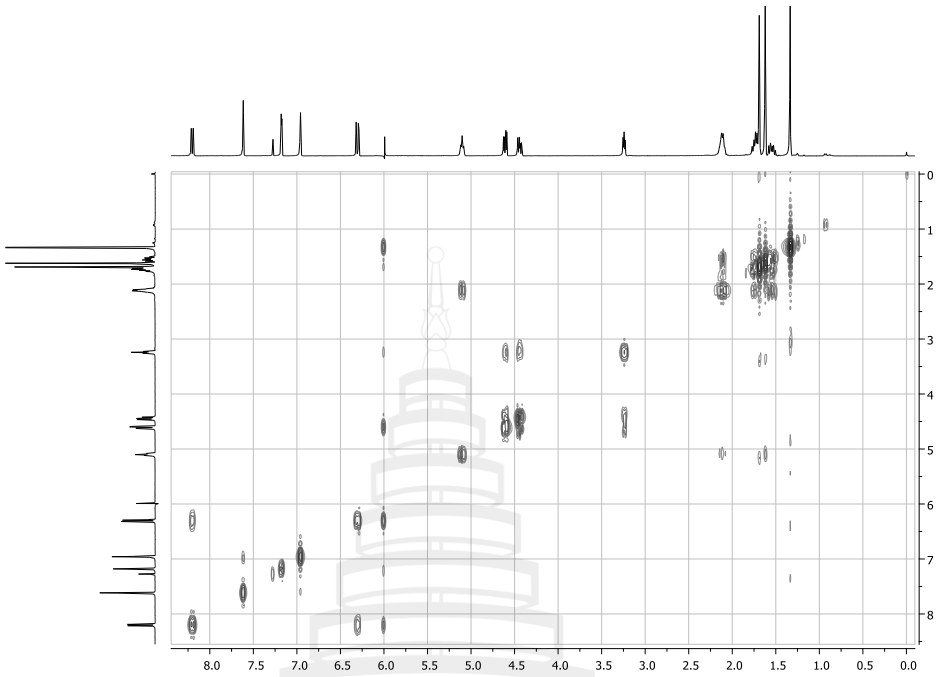

Figure A88 COSY ($CDCl_3$) Spectrum of **FL8**

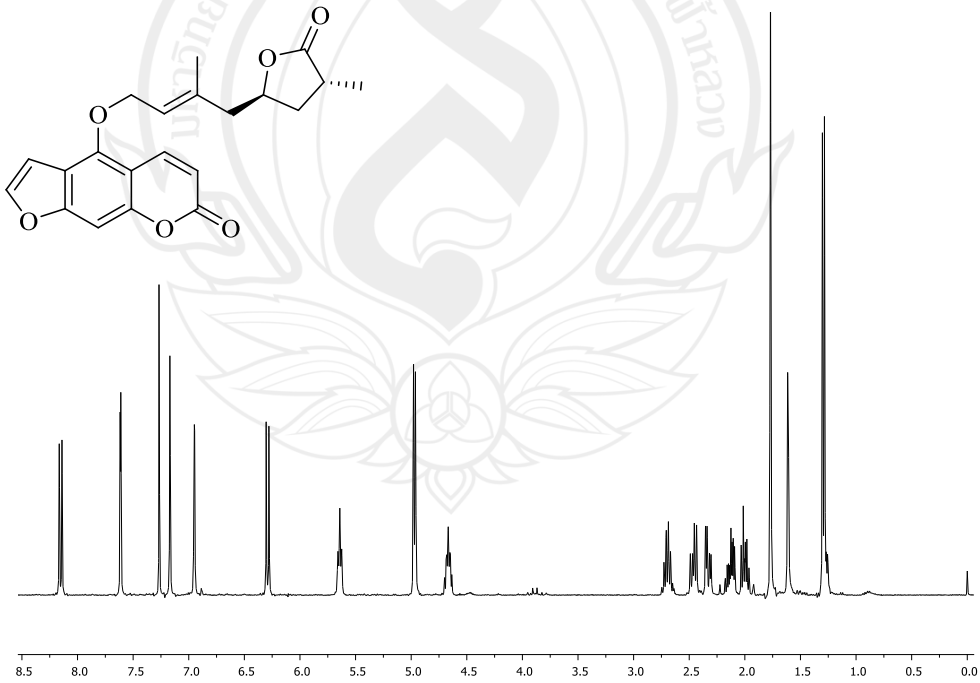

Figure A89 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL9**

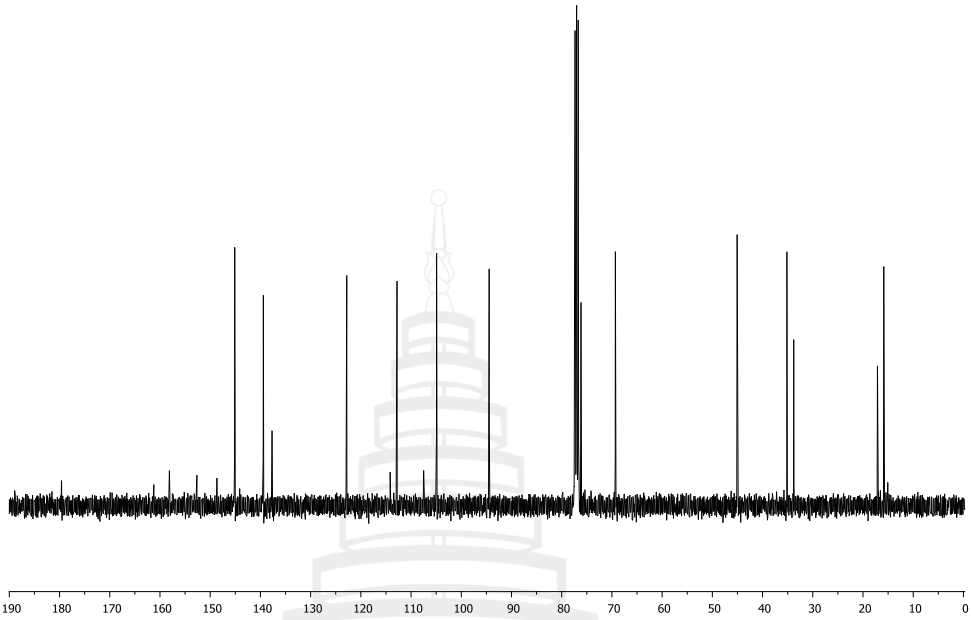

Figure A90 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL9**

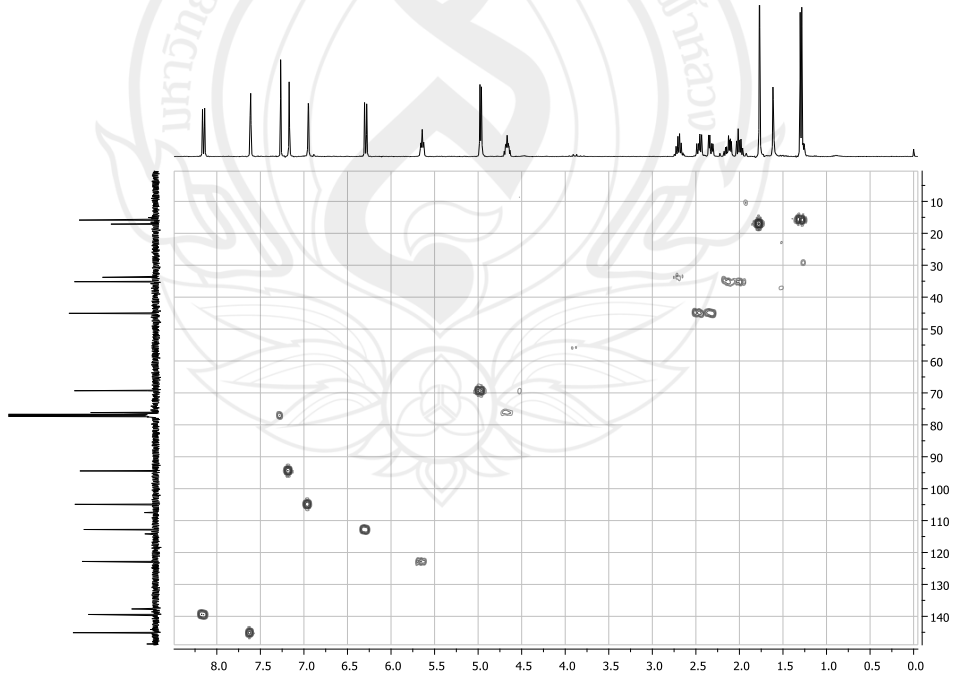

Figure A91 HMQC ($CDCl_3$) Spectrum of **FL9**

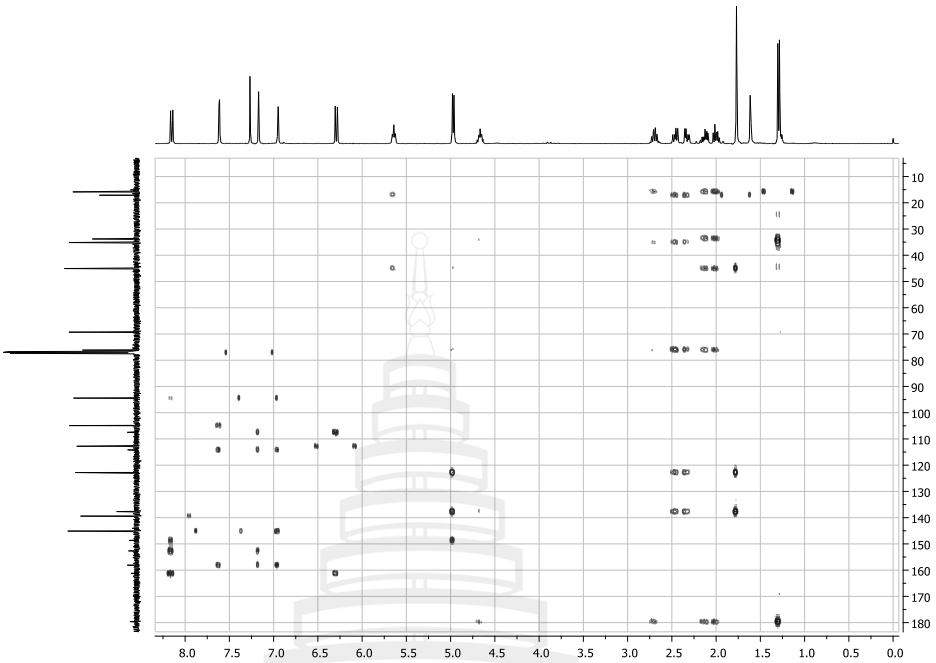

Figure A92 HMBC ($CDCl_3$) Spectrum of **FL9**

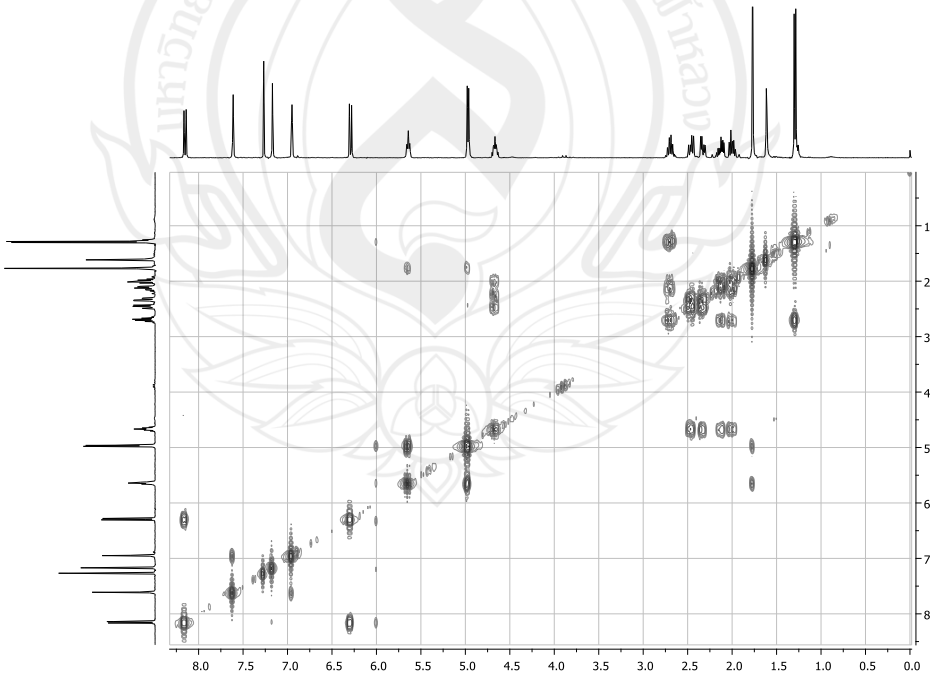

Figure A93 COSY ($CDCl_3$) Spectrum of **FL9**

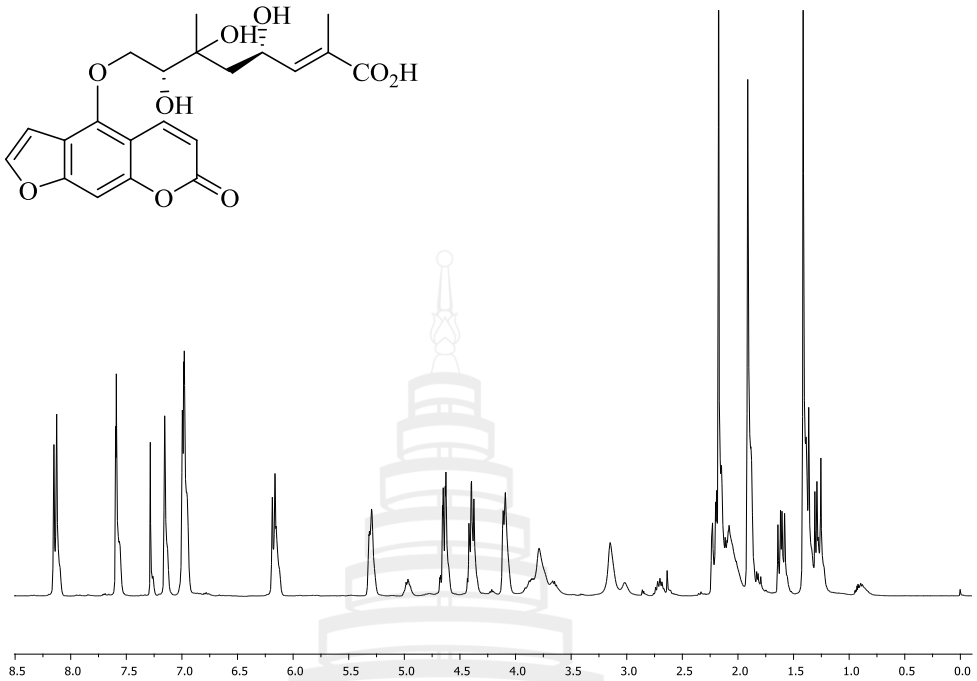

Figure A94 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL10**

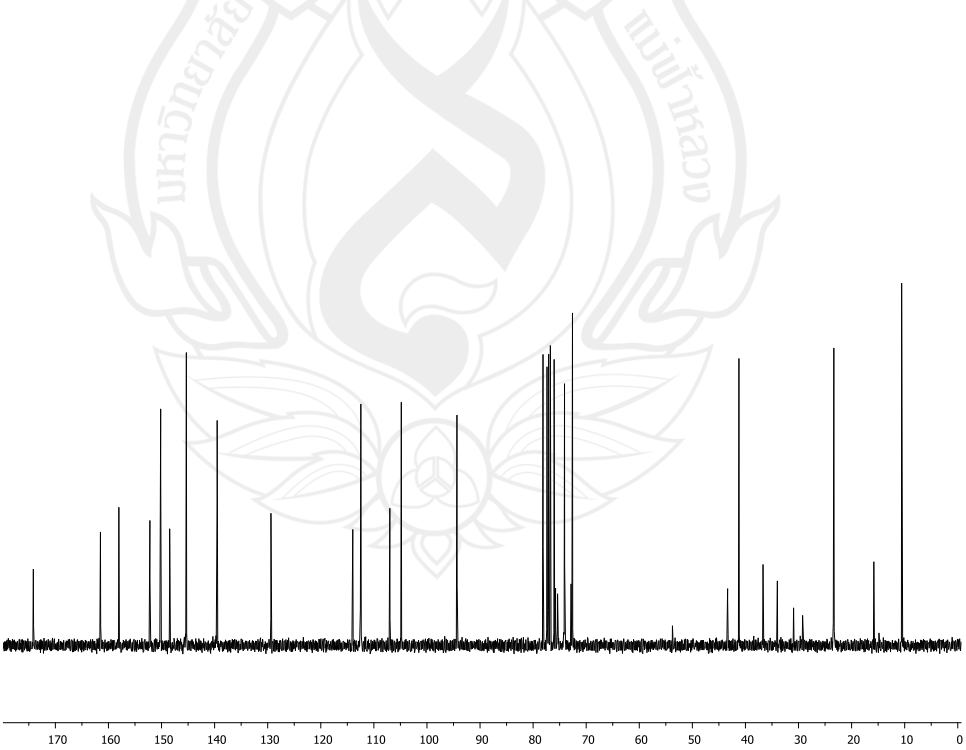

Figure A95 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL10**

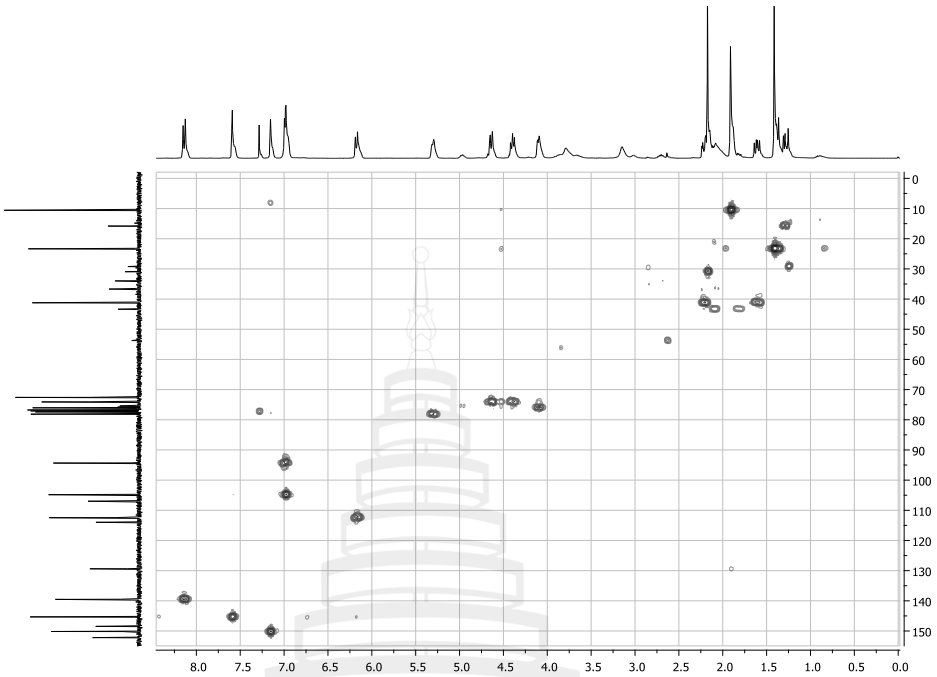

Figure A96 HMQC ($CDCl_3$) Spectrum of **FL10**

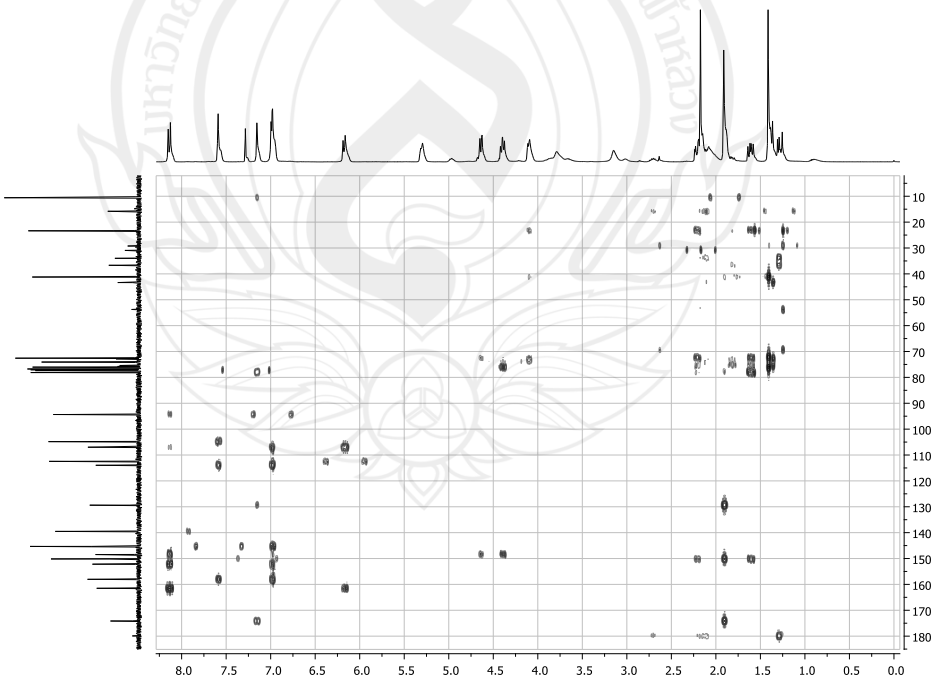

Figure A97 HMBC ($CDCl_3$) Spectrum of **FL10**

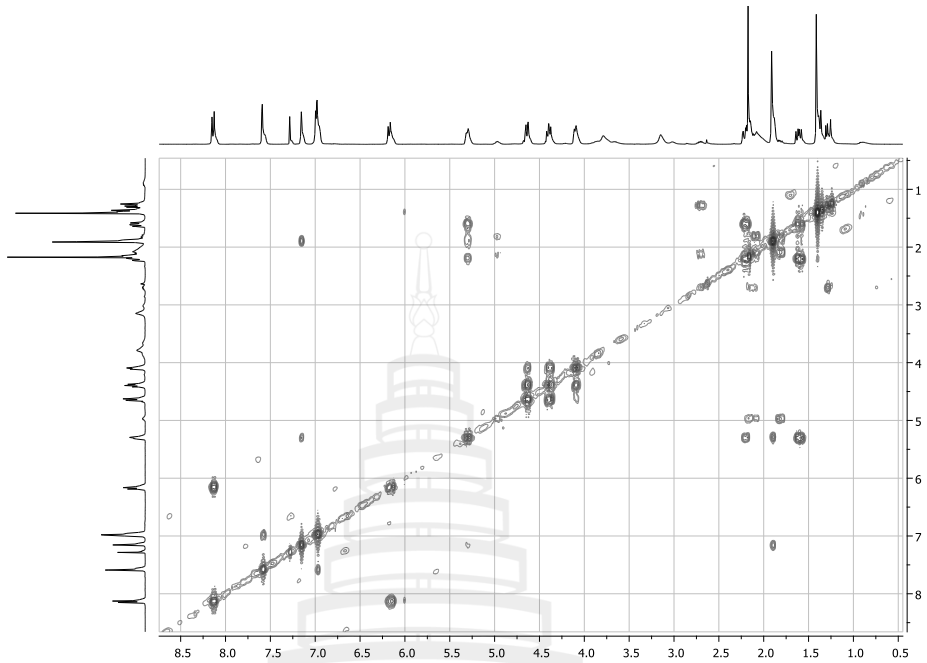

Figure A98 COSY ($CDCl_3$) Spectrum of **FL10**

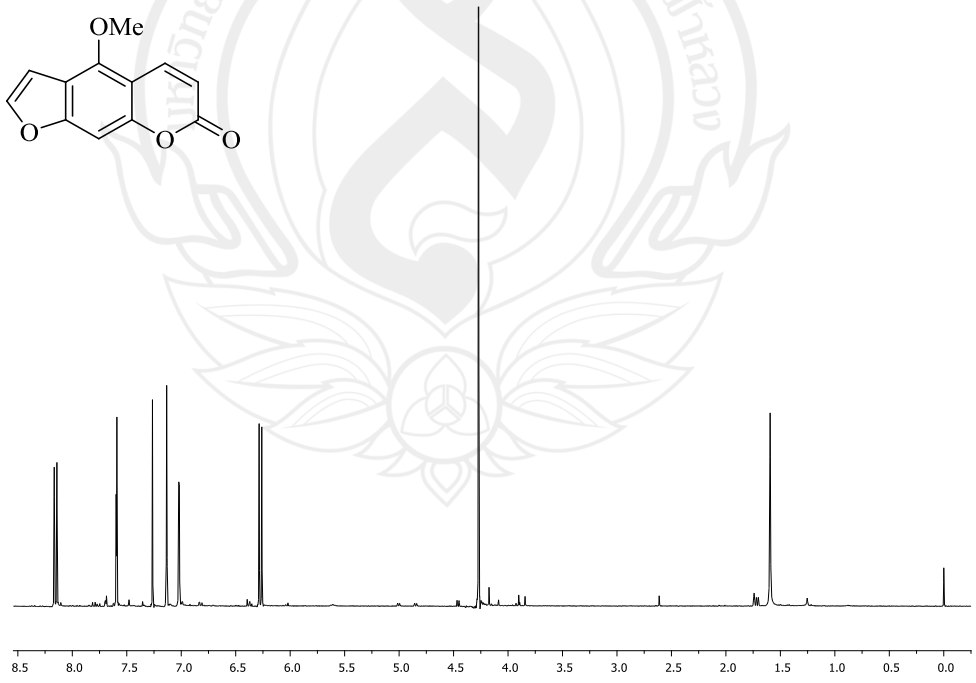

Figure A99 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL5**

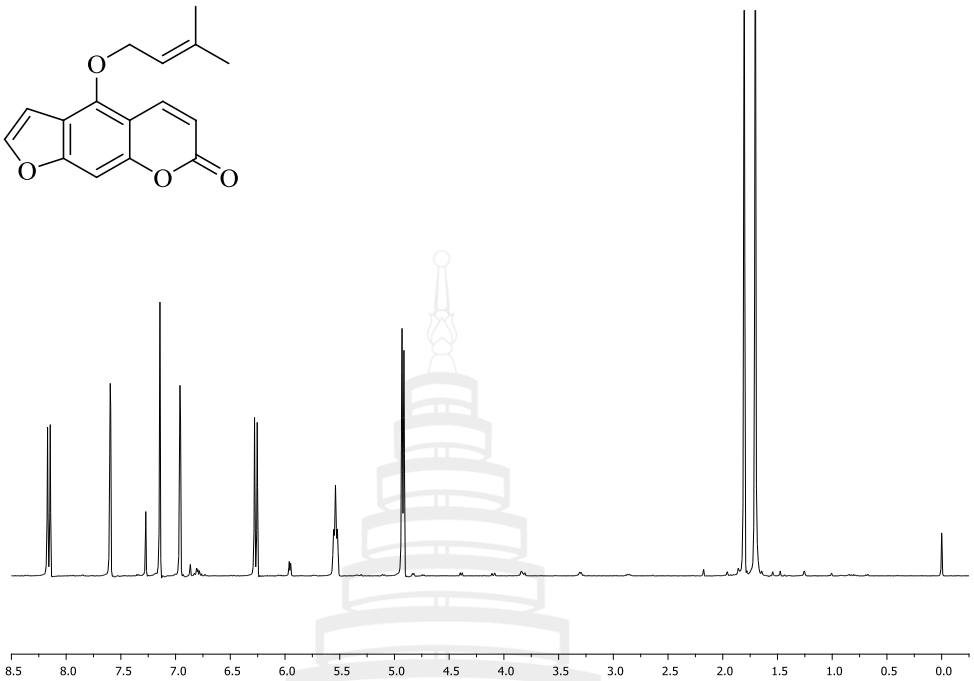

Figure A100 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL6**

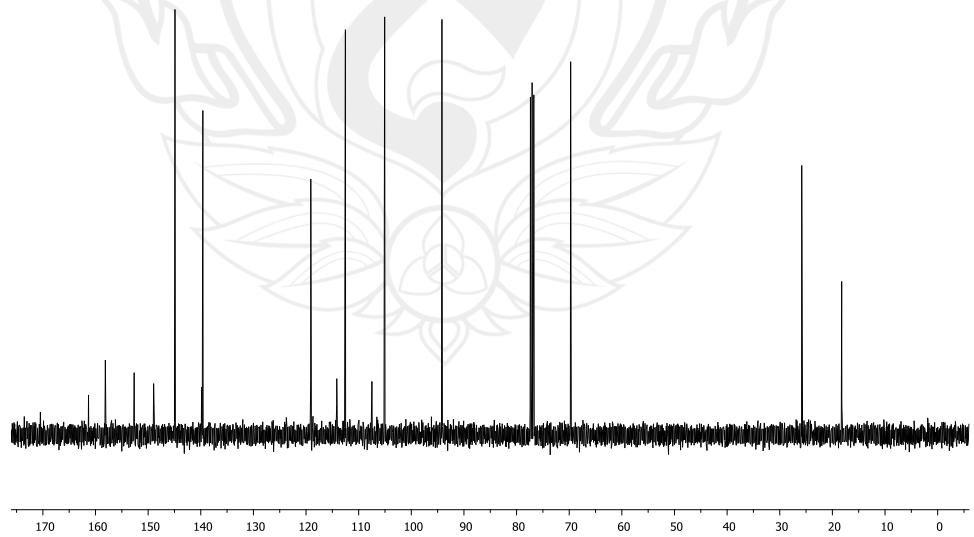

Figure A101 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL6**

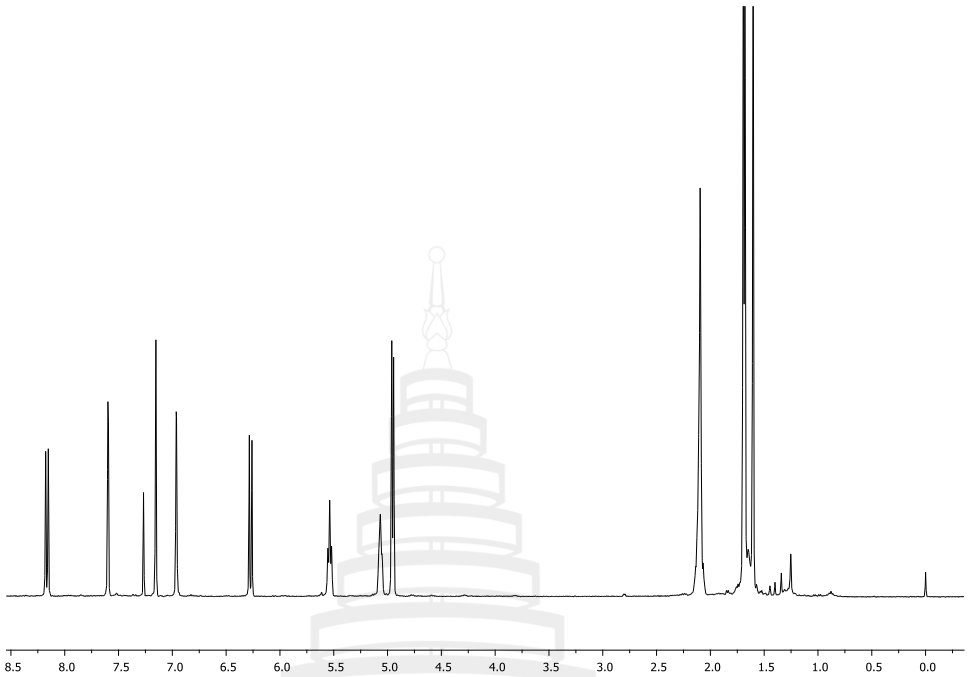

Figure A102 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL7**

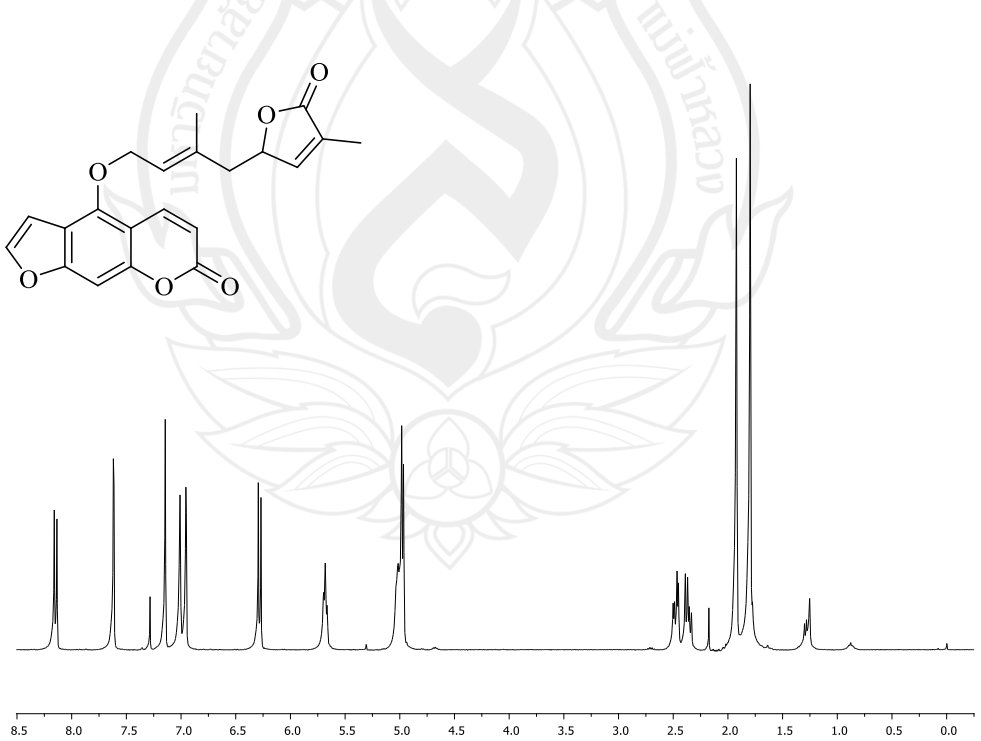

Figure A103 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL11**

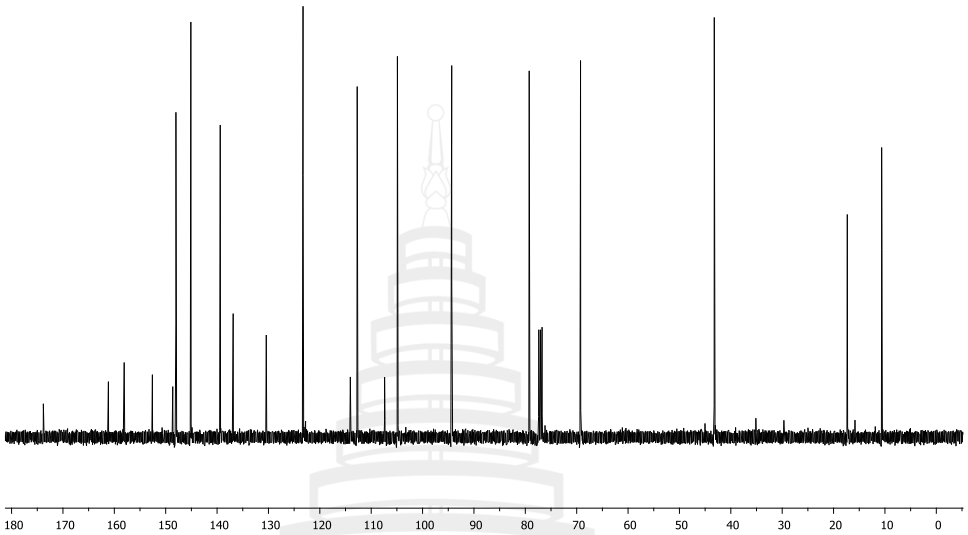

Figure A104 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL11**

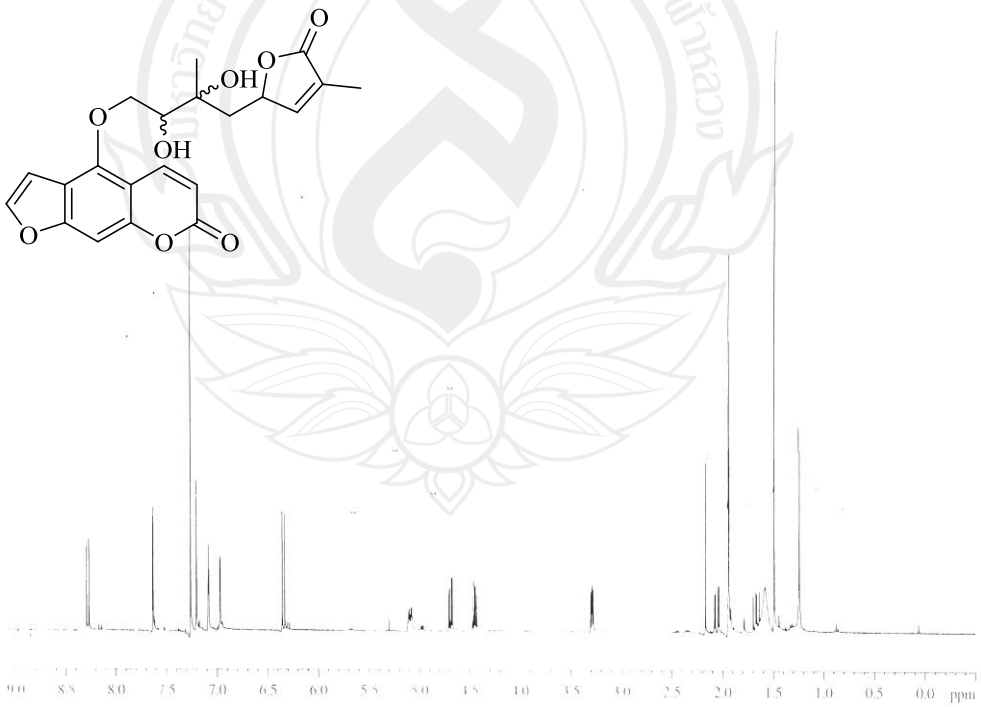

Figure A105 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **FL12**

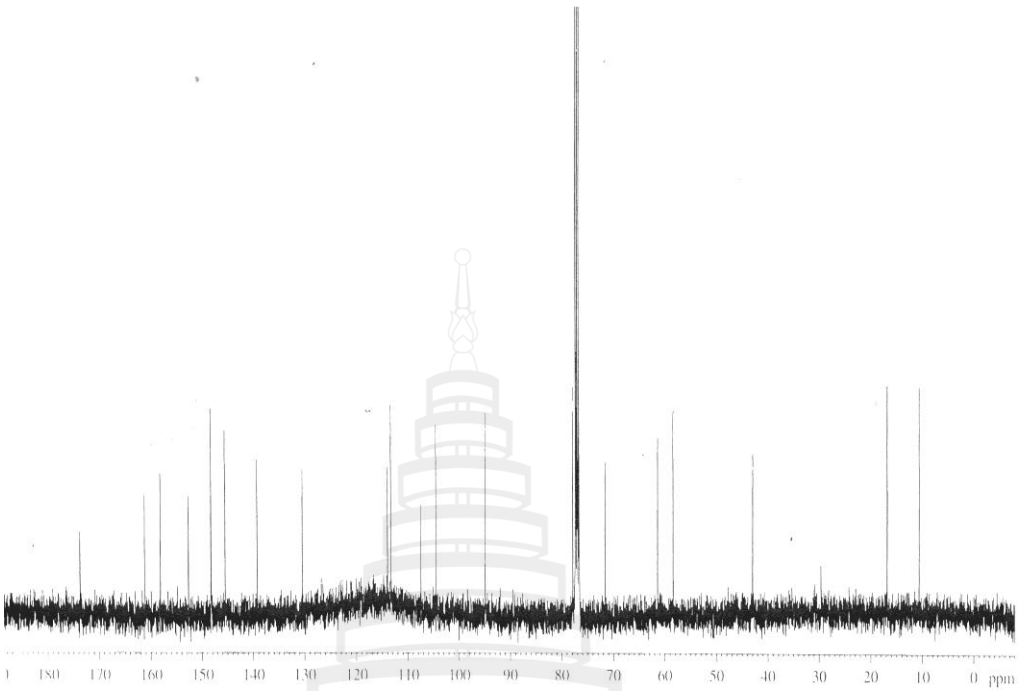

Figure A106 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **FL12**

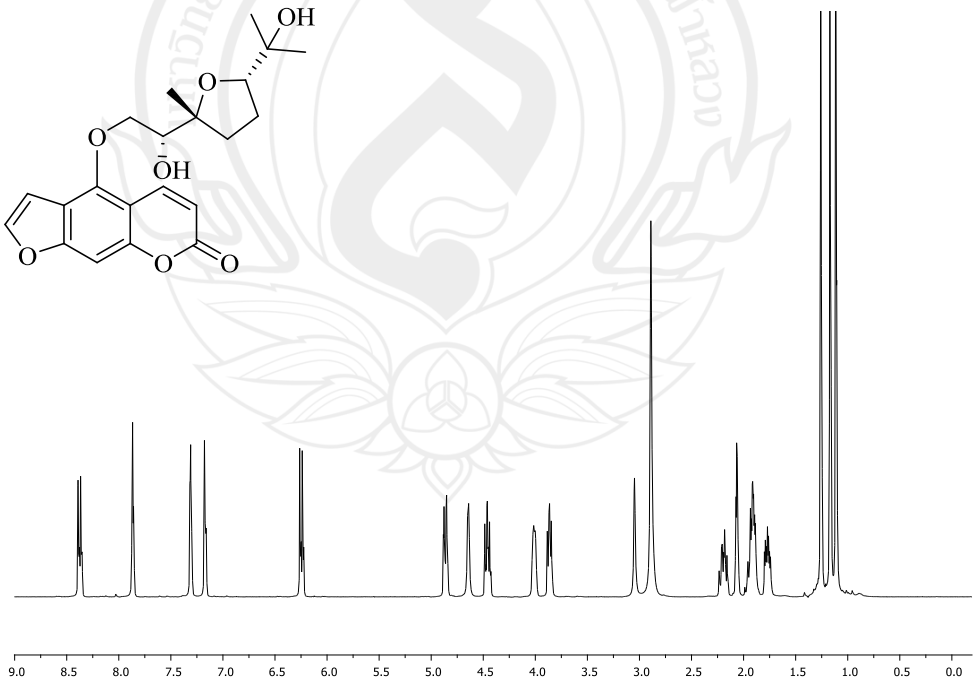

Figure A107 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **FL13**

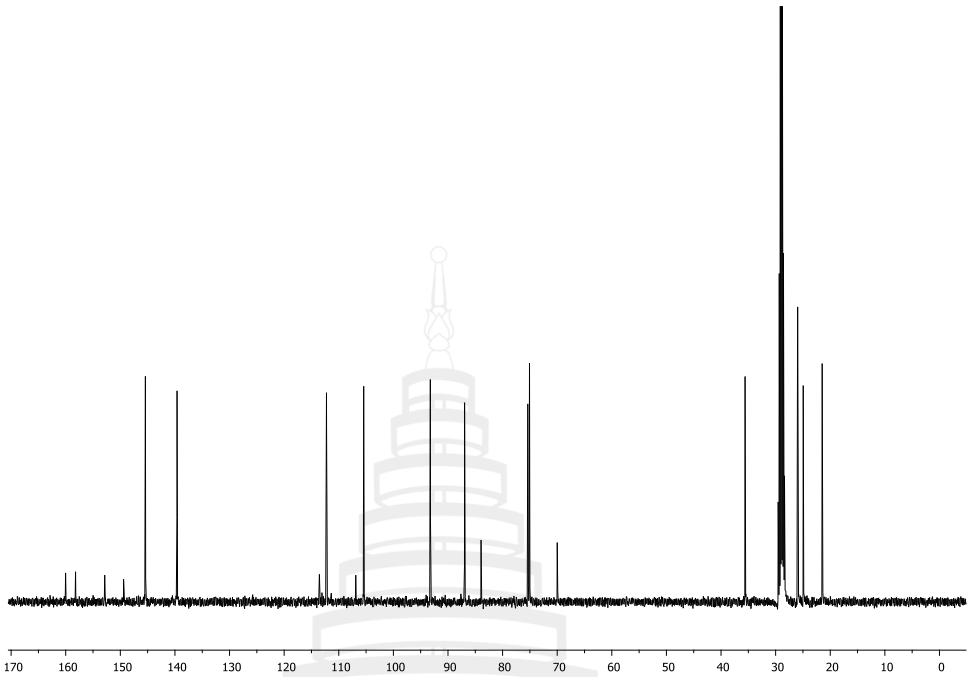

Figure A108 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **FL13**

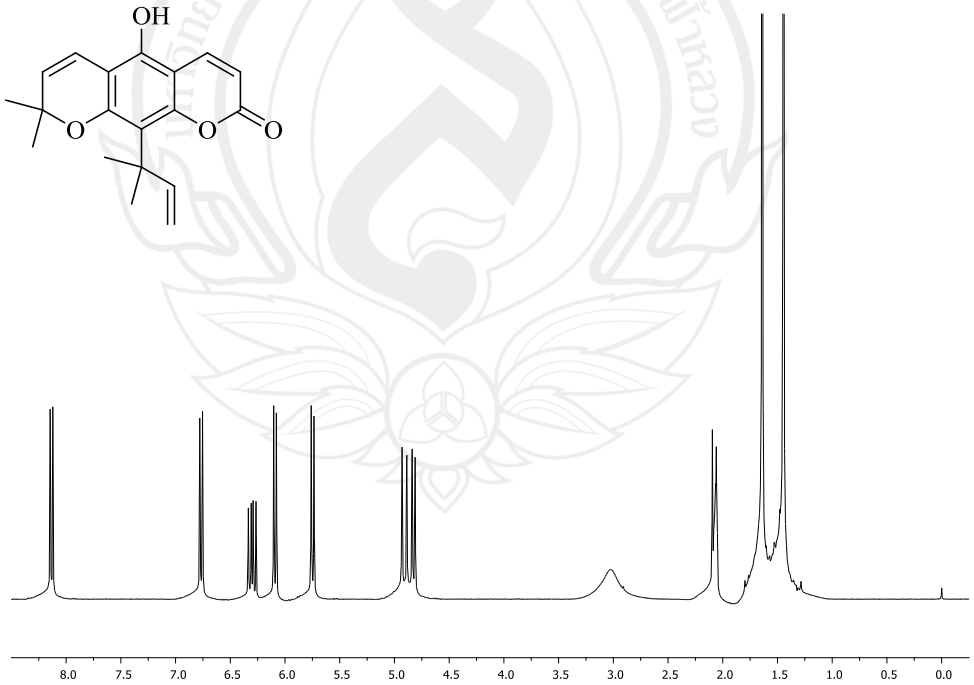

Figure A109 ^{1}H NMR (400 MHz, $CDCl_3$) Spectrum of **CE8**

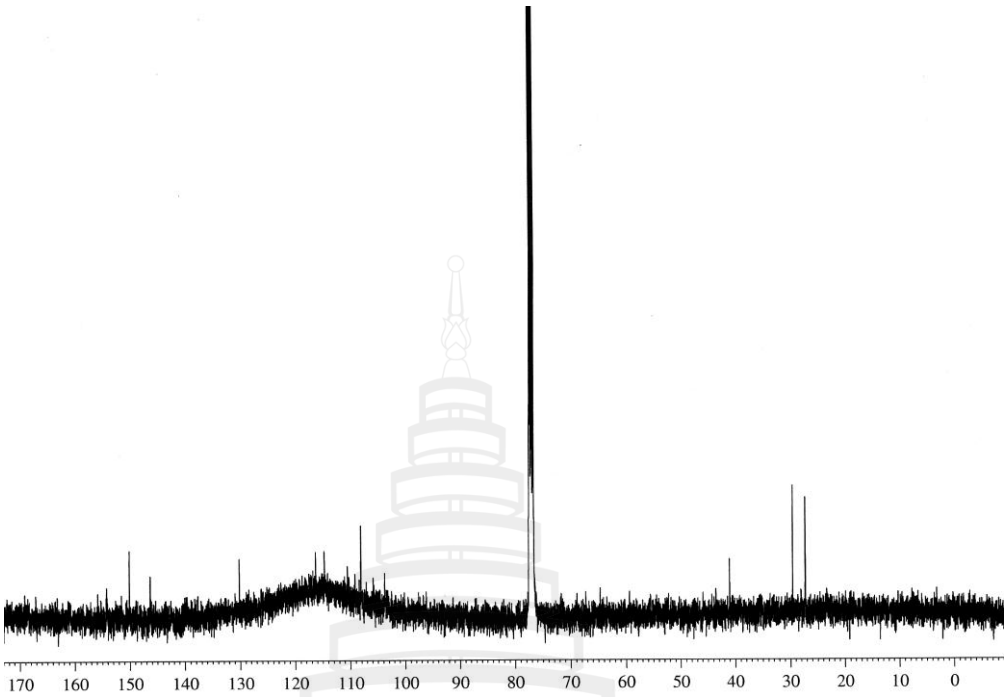

Figure A110 ^{13}C NMR (100 MHz, $CDCl_3$) Spectrum of **CE8**

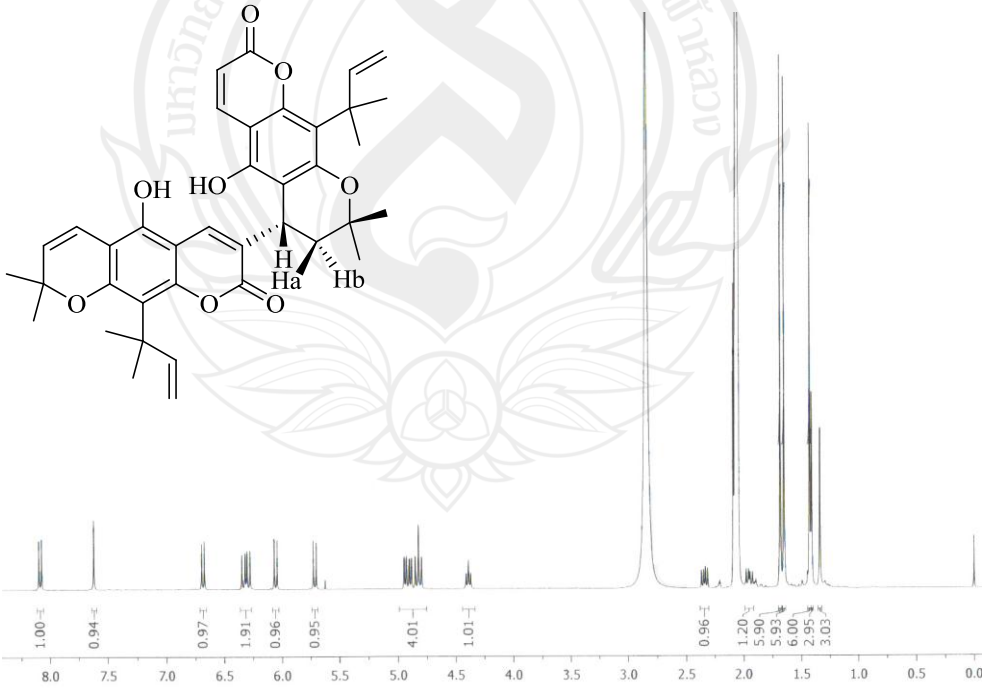

Figure A111 ^{1}H NMR (400 MHz, Acetone-d_6) Spectrum of **CE10**

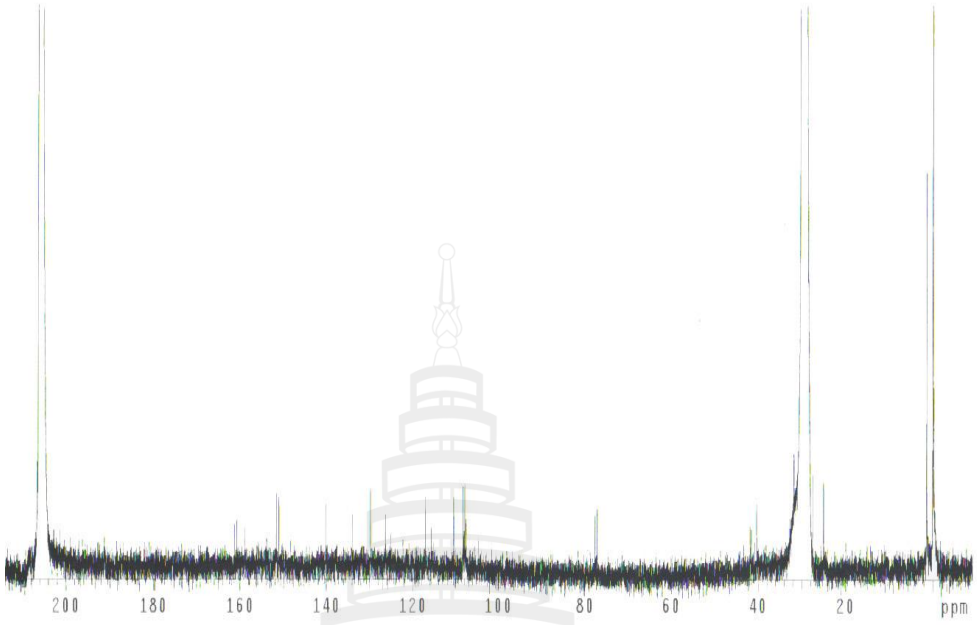

Figure A112 ^{13}C NMR (100 MHz, Acetone-d_6) Spectrum of **CE10**