

องค์ประกอบทางเคมีและฤทธิ์ทางชีวภาพของเนื้อไม้ชิงชัน *Dalbergia oliveri*
และการสังเคราะห์ไอโซฟลาโวนอยด์ที่คัดเฉพาะ



นางสาวสุจิตตรา ดีเสมอ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต

สาขาวิชาเคมี ภาควิชาเคมี

คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2548

ISBN 974-14-3377-8

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

CHEMICAL CONSTITUENTS AND BIOLOGICAL ACTIVITIES OF THE
HEARTWOODS OF *Dalbergia oliveri* AND THE SYNTHESIS
OF SELECTED ISOFLAVONOIDS

Miss Sujitra Deesamer

A Dissertation Submitted in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy Program in Chemistry

Department of Chemistry

Faculty of Science

Chulalongkorn University


Academic Year 2005

ISBN 974-14-3377-8

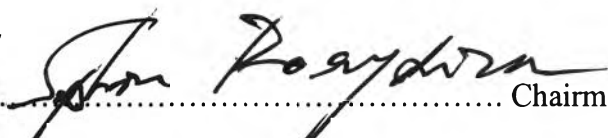

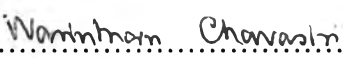



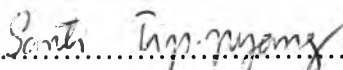
481988

Thesis Title Chemical Constituents and Biological Activities of the Heartwoods
 of *Dalbergia oliveri* and the Synthesis of Selected Isoflavonoids
By Miss Sujittra Deesamer
Field of Study Chemistry
Thesis Advisor Professor Udom Kokpol, Ph.D.
Thesis Co-advisor Assistant Professor Warinthorn Chavasiri, Ph.D.

Accepted by the faculty of Science, Chulalongkorn University in Partial Fulfillment
of the Requirements for the Doctor's Degree

 Deputy Dean for Administrative Affairs,
..... Acting Dean, The Faculty of Science
(Associate Professor Tharapong Vitidsant, Ph.D.)

THESIS COMMITTEE

 Chairman
(Professor Sopon Roengsumran, Ph.D.)
 Thesis Advisor
(Professor Udom Kokpol, Ph.D.)
 Thesis Co-advisor
(Assistant Professor Warinthorn Chavasiri, Ph.D.)
 Member
(Professor Padet Sidisunthorn, Ph.D.)
 Member
(Professor Somsak Ruchirawat, Ph.D.)
 Member
(Associate Professor Nijisiri Ruangrunsi, Ph.D.)
 Member
(Associate Professor Santi Tipayang, Ph.D.)

สุจิตตรา ดีเสมอ : องค์ประกอบทางเคมีและฤทธิ์ทางชีวภาพของเนื้อไม้ชิงชัน *Dalbergia oliveri* และการสังเคราะห์ไอโซฟลาโวนอยด์ที่คัดเฉพาะ (CHEMICAL CONSTITUENTS AND BIOLOGICAL ACTIVITIES OF THE HEARTWOODS OF *Dalbergia oliveri* AND THE SYNTHESIS OF SELECTED ISOFLAVONOIDS) อ. ที่ปรึกษา: ศ. ดร. อุดม ก๊กผล, อ. ที่ปรึกษาร่วม: ผศ. ดร. วรินทร์ ชวศิริ, 198 หน้า. ISBN 974-14-3377-8.

ผลการศึกษาฤทธิ์ทางชีวภาพเบื้องต้นแสดงให้เห็นว่าสิ่งสกัดของเนื้อไม้ชิงชันแสดงฤทธิ์ต้านอนุมูลอิสระ DPPH การศึกษาองค์ประกอบทางเคมีของสิ่งสกัดดังกล่าว แยกสารได้ 3 ชนิดจากสิ่งสกัดเฮกเซน ได้แก่ คีโตนโซ่ตรงชนิดอิมิตัว ของผสมของ triterpenoid ester และ stigmasterol และสารบริสุทธิ์ 8 ชนิดจากสิ่งสกัดไดคลอโรมีเทน ในขณะที่องค์ประกอบส่วนใหญ่ในสิ่งสกัดเอทิลแอลกอฮอล์ที่ได้เหมือนกับที่พบในสิ่งสกัดไดคลอโรมีเทน โดยอาศัยสมบัติทางกายภาพและสเปกโทรสโกปีพบว่าโครงสร้างของสารที่แยกได้คือ *trans*-cinnamic acid, (+)-pterocarpin, (+)-medicarpin, (+)-3,4-*trans*-[3-hydroxy-9-methoxypterocarpan-8-yl]-2',7-dihydroxy-4'-methoxyisoflavan, (\pm)-mucronulatol, formononetin, (\pm)-violanone และ calycosin (+)-medicarpin ซึ่งเป็นองค์ประกอบหลักแสดงฤทธิ์ยับยั้งเชื้อรา *Fusarium oxysporum* และ *Alternaria brassicicola* และแสดงฤทธิ์ความเป็นพิษต่อเซลล์มะเร็งตับ (+)-pterocarpin แสดงฤทธิ์ความเป็นพิษต่อเซลล์มะเร็งตับด้วยค่า IC_{50} เท่ากับ 2.3 $\mu\text{g}/\text{mL}$ นอกจากนี้ (\pm)-mucronulatol แสดงฤทธิ์ต้านอนุมูลอิสระ DPPH ในระดับสูงเช่นเดียวกับฤทธิ์ยับยั้งเชื้อรา *F. oxysporum* นอกจากนี้ (\pm)-violanone ยังแสดงความเป็นพิษต่อหนอนใยผักและลูกน้ำยุงลายด้วยค่า LC_{50} เท่ากับ 92 and 121 ppm ตามลำดับ

ได้สังเคราะห์ไอโซฟลาโวนอยด์เป้าหมาย 3 ชนิดใน 8 ขั้นตอนเป็นครั้งแรก โดยใช้ปฏิกิริยา arylation ของ α -phenylthiochroman-4-one กับ aryllead (IV) triacetate รีเอเจนต์ผลิตภัณฑ์รวมของปฏิกิริยาเมื่อเทียบกับสารตั้งต้นของ 3',7-dihydroxy-2',4'-dimethoxy-isoflavone, -isoflavanone และ -isoflavan คือ 9%, 13% และ 8-13% ตามลำดับ นอกจากนี้ การสังเคราะห์ไอโซฟลาโวนเป้าหมายโดยการเติมคาร์บอน 1 ยูนิท เข้าไปที่ deoxybenzoin (ผ่าน deoxybenzoin) สามารถทำได้สำเร็จใน 10 ขั้นตอนจาก 2,6-dimethoxyphenol ซึ่งให้ผลิตภัณฑ์รวมของปฏิกิริยา 6% 3',7-dihydroxy-2',4'-dimethoxyisoflavan แสดงฤทธิ์ความเป็นพิษต่อเซลล์ HBL100 ด้วยค่า IC_{50} เท่ากับ 5.21 μM

ภาควิชา.....เคมี.....	ลายมือชื่อนิสิต..... สุจิตตรา ดีเสมอ
สาขาวิชา.....เคมี.....	ลายมือชื่ออาจารย์ที่ปรึกษา..... อุดม ก๊กผล
ปีการศึกษา.....2548.....	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม..... วรินทร์ ชวศิริ

4473844923: MAJOR CHEMISTRY

KEY WORDS: *Dalbergia oliveri*/ ISOFLAVONOIDS/ BIOLOGICAL ACTIVITIES/ TOTAL SYNTHESIS OF BIOACTIVES ISOFLAVONOIDS

SUJITTRA DEESAMER: CHEMICAL CONSTITUENTS AND BIOLOGICAL ACTIVITIES OF THE HEARTWOODS OF *Dalbergia oliveri* AND THE SYNTHESIS OF SELECTED ISOFLAVONOIDS. THESIS ADVISOR: PROF. UDOM KOKPOL, Ph.D., THESIS CO-ADVISOR: ASST. PROF. WARINTHORN CHAVASIRI, Ph.D., 198 pp. ISBN 974-14-3377-8.

The preliminary biological activity results pointed out that the extract of *Dalbergia oliveri* G. heartwoods exhibited significant scavenging effect on DPPH radical. The chemical constituent investigation led to the isolation of three substances, long chain saturated ketone, a mixture of triterpenoid ester and stigmaterol from the hexane extract and eight pure compounds from CH₂Cl₂ extract. Most chemical constituents in EtOAc extract were similar to those found in CH₂Cl₂ extract. By means of physical properties and spectroscopic evidences, the structures of isolated compounds could be determined as *trans*-cinnamic acid, (+)-pterocarpin, (+)-medicarpin, (+)-3,4-*trans*-[3-hydroxy-9-methoxypterocarpan-8-yl]-2',7-dihydroxy-4'-methoxyisoflavan, (±)-mucronulatol, formononetin, (±)-violanone and calycosin. Among the isolated substances, (+)-medicarpin, the major component, displayed significant antifungal activity against both *Fusarium oxysporum* and *Alternaria brassicicola* and cytotoxicity toward HepG2 cells. (+)-Pterocarpin presented high cytotoxicity against HepG2 cells with IC₅₀ value of 2.3 µg/mL. In addition, (±)-mucronulatol exhibited the highest scavenging activity toward DPPH radical as well as the highest antifungal activity against *F. oxysporum*. Moreover, (±)-violanone showed significant cytotoxicity against diamondback moth and mosquito larvae with LC₅₀ values of 92 and 121 ppm, respectively.

Three target isoflavonoids were accomplishly synthesized for the first time in eight steps using arylation of common α-phenylthiochroman-4-one with aryllead (IV) triacetate reagent as a key step. The total yield of 3',7-dihydroxy-2',4'-dimethoxy-isoflavone, -isoflavanone and -isoflavan over eight steps reaction sequence was 9%, 13% and 8-13%, respectively based on the starting material. In addition, the synthesis of desired isoflavone using the addition of a one carbon unit to a deoxybenzoin (*via* deoxybenzoin) was accomplished in ten steps from 2,6-dimethoxyphenol as starting material, giving total yield of 6%. 3',7-Dihydroxy-2',4'-dimethoxyisoflavan displayed high cytotoxicity against HBL100 cells with IC₅₀ value of 5.21 µM.

Department.....Chemistry.....

Student's signature.....

Sujittra Deesamer

Field of study.....Chemistry.....

Advisor's signature.....

Udom Kokpol

Academic year.....2005.....

Co-advisor's signature.....

Warinthorn Chavasiri

ACKNOWLEDGEMENTS

The author would like to express her deep appreciation to her advisor and co-advisor, Professor Dr. Udom Kokpol and Assistant Professor Dr. Warinthorn Chavasiri for their very kind assistance, generous guidance, and encouragement through out the course of this research. Sincere thanks are extend to Natural Products Research Unit, Department of Chemistry, Faculty of Science, Chulalongkorn University for the support of chemicals and laboratory facilities and the Thailand Research Fund for the 2002 Royal Golden Jubilee Ph.D. research assistant fellowship. In addition, the author also wishes to express gratitude to Professor Dr. Sophon Roengsumran, Professor Dr. Padet Sidisunthorn, Professor Dr. Somsak Ruchiirawat, Associate Professor Dr. Nijisiri Ruangrunsi and Associate Professor Dr. Santi Tippayang serving as the chairman and members of this thesis committee, respectively, for their valuable discussion and suggestion.

The author also acknowledged Professor Dr. Jean-Pierre Finet and Dr. Sebastien Combes, Laboratoire SREP, “Radiocaux Libres et Syntheses”, Universite de Provence, Centre St Jerome, Marseille, France, for providing the knowledge and practical skill on synthesis of isoflavonoids, looking after when the author got down with an accident and accommodation for the author to stay during a keeping fit in France. In addition, she would like to thank Nicolas Vidal, Laboratoire Synthese et Etude de Substances Naturelles a Activities Biologiques (SESNAB), Faculte des Sciences et Techniques de St Jerome, Universite Paul Cezanne, Marseille, France, for antimicrobial test. Furthermore, she would like to thank Assistant Professor Nongnuj Muangsin for proceeding X-ray experiments.

The author would also like to express her special thanks to gratitude to her parents, family members, Miss Angkana Ruttanasuksakul and Mr. Wanchai Pluempanupat for their inspiration, understanding, great support and encouragement throughout the entire course of study. Finally her great thanks are expanded to all her friends and members in Natural Products Research Unit for their friendship, helps and limitless effort during her graduate studies. Without them, the author would never have been able to achieve this goal.

CONTENTS

	Pages
Abstract in Thai	iv
Abstract in English	v
Acknowledgements	vi
Contents	vii
List of Figures.....	x
List of Tables.....	xiii
List of Schemes	xv
List of Abbreviations.....	xvi
CHAPTER I: INTRODUCTION.....	1
1.1 Preliminary Screening Study	2
1.1.1 Extraction of Selected Plants	2
1.1.2 Biological Screening Assay	5
1.1.2.1 Insecticidal Activity (Contact toxicity: topical application)	5
1.1.2.2 Scavenging Effect on DPPH Radical	5
1.1.3 Results of Biological Activity Screening Test.....	6
1.2 The Goal of This Research	9
CHAPTER II: CHEMICAL CONSTITUENTS AND BIOLOGICAL	
 ACTIVITIES OF THE HEARTWOODS OF	
 <i>Dalbergia oliveri</i>	10
2.1 INTRODUCTION	10
2.1.1 Botanical Characteristics of <i>Dalbergia oliveri</i> Gamble.....	10
2.1.2 Chemical Constituents and Literature Reviews on	
<i>Dalbergia</i> Genus	11
2.1.3 Chemical Constituents and Literature Reviews on	
<i>Dalbergia oliveri</i> Gamble	14
2.1.4 The Goal of This Research.....	16
2.2 EXPERIMENTAL.....	16
2.2.1 Plant Material.....	16
2.2.2 Instruments and Equipment	16
2.2.3 Chemical Test	17

	Pages
3.2.2 Chemicals.....	128
3.2.3 Synthesis of Isoflavonoids using the Arylation of Chromanone Moiety	129
3.2.3.1 Preparation of Activated Chromanone.....	129
3.2.3.2 Preparation of Aryllead (IV) Triacetate Derivatives.....	132
3.2.3.3 Preparation of 3-Aryl-3-phenylthio-2,3-dihydro-4 <i>H</i> -1- benzopyran-4-one.....	134
3.2.3.4 Preparation of 3-Aryl-4 <i>H</i> -1-benzopyran-4-one <i>via</i> Desulphurization of 3-Aryl-3-phenylthio-4 <i>H</i> -1-benzopyran- 4-one using <i>m</i> -CPBA	135
3.2.3.5 Preparation of Isoflavone	136
3.2.3.6 Preparation of 3-Aryl-2,3-dihydro-4 <i>H</i> -1-benzopyran-4-one <i>via</i> Desulphurisation of 3-Aryl-3-phenylthio-4 <i>H</i> -1- benzopyran-4-one using Nickel Boride.....	137
3.2.3.7 Preparation of Isoflavanone	138
3.2.3.8 Preparation of Isofavan	139
3.2.4 Synthesis of Isoflavone <i>via</i> Deoxybenzoin.....	140
3.2.5 Biological Activity.....	147
3.2.5.1 Cytotoxicity Test.....	147
3.3 RESULTS AND DISCUSSION.....	148
3.3.1 Synthesis of Isoflavonoids using Arylation Reaction.....	148
3.3.2 Synthesis of Isoflavone using Deoxybenzoin	162
3.3.3 Cytotoxicity Test of Three Synthetic Compounds.....	167
3.4 CONCLUSION.....	167
CHAPTER IV: CONCLUSION.....	169
4.1 Biological Constituents from the Heartwoods of <i>Dalbergia oliveri</i>	170
4.2 Synthesis of Selected Isoflavonoids	172
4.3 Proposal for the Future Work	177
REFERENCES.....	178
APPENDICES.....	192
APPENDICES A	193
APPENDICES B.....	197
VITA.....	198

LIST OF FIGURES

Figures	Pages
1.1 TLC autographic assay for radical scavenger	6
2.1 (a) Tree, (b) leaves, (c) flowers and (d) fruit and seeds of <i>Dalbergia oliveri</i>	11
2.2 Chemical constituents of the heartwoods of <i>Dalbergia</i> genus	13
2.3 Chemical constituents of <i>Dalbergia oliveri</i>	15
2.4 TLC autographic assay for DPPH radical scavenger for the extracts of the heartwoods of <i>D. oliveri</i>	24
2.5 The IR spectrum of D1	28
2.6 The ¹ H-NMR spectrum of D1	28
2.7 The ¹³ C-NMR spectrum of D1	29
2.8 The mass spectrum of D2	33
2.9 The IR spectrum of D2	34
2.10 The ¹ H-NMR spectrum of D2	34
2.11 The ¹³ C-NMR spectrum of D2	35
2.12 NOE DIFF of D2 (irradiated at δ 5.52)	35
2.13 NOE DIFF of D2 (irradiated at δ 3.49-3.54)	36
2.14 NOE DIFF of D2 (irradiated at δ 3.83)	36
2.15 The mass spectrum of D3	41
2.16 The IR spectrum of D3	42
2.17 The ¹ H-NMR spectrum of D3	42
2.18 The ¹³ C-NMR spectrum of D3	43
2.19 NOE DIFF of D3 (irradiated at δ 5.53)	43
2.20 NOE DIFF of D3 (irradiated at δ 3.52-3.58)	44
2.21 NOE DIFF of D3 (irradiated at δ 3.80)	44
2.22 Computer-generated ORTEP drawing of D3	45
2.23 The IR spectrum of D4	52
2.24 The ¹ H-NMR spectrum of D4	52
2.25 The ¹³ C-NMR spectrum of D4	53
2.26 The HMBC spectrum of D4	53
2.27 The HSQC spectrum of D4	54

Figures	Pages
2.28 The COSY spectrum of D4	54
2.29 NOE DIFF of D4 (irradiated at δ 3.49-3.51)	55
2.30 NOE DIFF of D4 (irradiated at δ 5.46).....	55
2.31 NOE DIFF of D4 (irradiated at δ 4.78).....	56
2.32 NOE DIFF of D4 (irradiated at δ 3.70).....	56
2.33 NOE DIFF of D4 (irradiated at δ 3.79).....	57
2.34 NOE DIFF of D4 (irradiated at δ 8.33).....	57
2.35 NOE DIFF of D4 (irradiated at δ 8.53).....	58
2.36 NOE DIFF of D4 (irradiated at δ 8.75).....	58
2.37 The ^1H -NMR spectrum of fraction II.....	59
2.38 The mass spectrum of D5	63
2.39 The IR spectrum of D5	65
2.40 The ^1H -NMR spectrum of D5	65
2.41 The ^{13}C -NMR spectrum of D5	66
2.42 The mass spectrum of D6	69
2.43 The IR spectrum of D6	71
2.44 The ^1H -NMR spectrum of D6	71
2.45 The ^{13}C -NMR spectrum of D6	72
2.46 NOE DIFF of D6 (irradiated at δ 3.80 ppm).....	72
2.47 The mass spectrum of D7	76
2.48 The IR spectrum of D7	77
2.49 The ^1H -NMR spectrum of D7	77
2.50 The ^{13}C -NMR spectrum of D7	78
2.51 The IR spectrum of D8	81
2.52 The ^1H -NMR spectrum of D8	81
2.53 The ^{13}C -NMR spectrum of D8	82
2.54 NOE DIFF of D8 (irradiated at δ 3.91).....	82
2.55 The IR spectrum of HC1	87
2.56 The ^1H -NMR spectrum of HC1	88
2.57 The ^{13}C -NMR spectrum of HC1	88
2.58 The IR spectrum of HC2	90
2.59 The ^1H -NMR spectrum of HC2	90
2.60 The ^{13}C -NMR spectrum of HC2	91

Figures	Pages
2.61 The IR spectrum of HC3	92
2.62 The ^1H -NMR spectrum of HC3	93
2.63 The ^{13}C -NMR spectrum of HC3	93
2.64 DPPH radical scavenging effect of D5	98
3.1 The ^1H -NMR spectrum of P9	152
3.2 The ^{13}C -NMR spectrum of P9	152
3.3 The ^1H -NMR spectrum of P5	154
3.4 The ^{13}C -NMR spectrum of P5	155
3.5 The ^1H -NMR spectrum of P10	156
3.6 The ^{13}C -NMR spectrum of P10	156
3.7 The ^1H -NMR spectrum of P12	158
3.8 The ^{13}C -NMR spectrum of P12	159
3.9 The ^1H -NMR spectrum of P14	160
3.10 The ^{13}C -NMR spectrum of P14	160
3.11 The ^1H -NMR spectrum of P15	161
3.12 The ^{13}C -NMR spectrum of P15	162
4.1 Structures of isolated substances.....	170

LIST OF TABLES

Tables	Pages
1.1 The results of extraction of selected four plants in Leguminosae family ..	4
1.2 Biological activity screening test results of crude extract.....	7
2.1 Compounds from the heartwoods of <i>Dalbergia</i> Genus	12
2.2 The results of the extraction of the heartwoods of <i>D. oliveri</i>	23
2.3 The separation of CH ₂ Cl ₂ extract.....	25
2.4 The ¹ H-, ¹³ C-NMR chemical shift assignment of D1 compared with <i>trans</i> -cinnamic acid.....	27
2.5 The ¹ H-, ¹³ C-NMR chemical shift assignments of D2 compared with (-)(6 <i>aR</i> ,11 <i>aR</i>)-pterocarpin.....	32
2.6 The ¹ H-, ¹³ C-NMR chemical shift assignments of D3 compared with medicarpin.....	40
2.7 The ¹ H-, ¹³ C-NMR chemical shift assignments and 2D correlation of D4	49
2.8 The ¹ H-NMR chemical shift assignments of D4 compared with 44	51
2.9 The ¹ H-, ¹³ C-NMR chemical shift assignments of D5 compared with (<i>R</i>)-mucronulatol.....	62
2.10 The ¹ H-, ¹³ C-NMR chemical shift assignment of D6 compared with formononetin.....	68
2.11 The ¹ H-, ¹³ C-NMR chemical shift assignment of D7 compared with secundiflorol H.....	75
2.12 The ¹ H-, ¹³ C-NMR chemical shift assignment of D8 compared with calycosin.....	80
2.13 The separation of hexane extract.....	85
2.14 The separation of EtOAc extract	95
2.15 TLC autography assay for DPPH radical scavenger.....	97
2.16 IC ₅₀ values of radical scavenging effect on DPPH radical	99
2.17 The antifungal activity of isolated substances	100
2.18 The minimum amount required for the inhibition of fungal growth on TLC plates.....	101
2.19 Antimicrobial activity of isolated compounds	103

Tables	Pages
2.20 Cytotoxicity of isolated compounds against HepG2.....	104
2.21 Cytotoxicity of isolated compounds against diamondback moth	105
2.22 Cytotoxicity of isolated compounds against mosquito larvae	106
2.23 Isolated substances from the CH ₂ Cl ₂ extract of <i>D. oliveri</i> heartwoods	110
3.1 Cytotoxicity test activity of synthetic compounds.....	167
4.1 Results of biological activity of isolated substances from CH ₂ Cl ₂ extract from <i>D. oliveri</i> heartwoods	171
A1 Crystallographic data and structure refinement for D3	193
A2 Atomic coordinates (x 10 ⁴) and equivalent isotropic displacement parameters (A ² x 10 ³) for D3	194
A3 Bond distances of D3	195
A4 Bond angles of D3	196
B1 Radical scavenging effect on DPPH radical	197

LIST OF SCHEMES

Schemes	Pages
1.1 Extraction procedures for preliminary screening test	3
2.1 The extraction procedure of the heartwoods of <i>D. oliveri</i>	18
2.2 The separation of CH ₂ Cl ₂ extract.....	25
2.3 The significant ions observed in the mass spectrum of D2	33
2.4 The significant ions observed in the mass spectrum of D3	41
2.5 Possible mass fragmentation pattern of D5	64
2.6 Possible mass fragmentation pattern of D6	70
2.7 Possible mass fragmentation pattern of D7	76
2.8 Isolation diagram of the CH ₂ Cl ₂ extract from the heartwoods of <i>D. oliveri</i>	84
2.9 The separation of hexane extract	86
2.10 The separation of EtOAc extract.....	94
2.11 Isolation diagram of the EtOAc extract from the heartwoods of <i>D. oliveri</i>	96
2.12 The biosynthesis of flavonoid derivatives	107
3.1 Retrosynthesis of three selected isoflavonoids using arylation	149
3.2 Synthesis of aryllead (IV) triacetate.....	151
3.3 Synthesis of intermediate P10	153
3.4 Synthesis of three target isoflavonoids	157
3.5 Retrosynthesis of P12 via deoxybenzoin	163
3.6 Total synthesis of 3',7-dihydroxy-2',4'-dimethoxyisoflavone via deoxybenzoin	165
4.1 Total synthesis of three target molecule using arylation of chromanone moiety	174
4.2 Total synthesis of 3',7-dihydroxy-2',4'-dimethoxyisoflavone via deoxybenzoin	176

LIST OF ABBREVIATIONS

BHA	butylated hydroxyanisole
CDCl_3	deuterated chloroform
CH_2Cl_2	dichloromethane
CHCl_3	chloroform
cm	centimeter
cm^{-1}	unit of wavelength
COSY	correlated spectroscopy
d	doublet (NMR)
dd	doublet of doublet (NMR)
ddd	doublet of doublet of doublet (NMR)
DMSO	dimethylsulfoxide
DPPH	2,2-diphenyl-1-picrylhydrazine
EtOAc	ethyl acetate
EtOH	ethanol
FT	fourier transform
g	gram (s)
h	hour
HMBC	heteronuclear multiple bond correlation experiment
HSQC	heteronuclear multiple quantum coherence experiment
Hz	hertz
IR	infrared
J	coupling constant
m	multiplet (NMR)
mg	milligram (s)
mL	milliliter
mm	millimeter
m.p.	melting point
m/z	mass to charge ratio
M^+	molecular ion
MeOH	methanol
MS	mass spectrometry

MW	molecular weight
nm	nanometer (s)
NOE DIFF	nuclear overhauser effect difference
NMR	nuclear magnetic resonance
ppm	part per million
R _f	retardation factor
s	singlet (NMR)
t	triplet (NMR)
TLC	thin layer chromatography
UV	ultraviolet
wt	weight
λ	wavelength
δ	chemical shift
μg	microgram (s)
μM	micromolar
%	percent
°C	degree Celsius