

ผลกึ่งเจียบพลันของสารสกัดหญ้าหนวดแมวด้วยน้ำต่อเอนไซม์ไซโตโครม พี450 ในตับ
และค่าเคมีคลินิกในเลือดของหนูขาว



นางสาวธรรัตน์ ไชโย

ศูนย์วิทยทรัพยากร

จุฬาลงกรณ์มหาวิทยาลัย
วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาเภสัชศาสตรมหาบัณฑิต

สาขาวิชาเภสัชวิทยา ภาควิชาเภสัชวิทยา


คณะเภสัชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2547

ISBN 974-17-6909-1

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

SUBACUTE EFFECTS OF *ORTHOSIPHON GRANDIFLORUS* AQUEOUS EXTRACT ON
HEPATIC CYTOCHROME P450 AND CLINICAL BLOOD CHEMISTRY IN RATS



Miss Tanarat Chaiyo

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Pharmacy in Pharmacology

Department of Pharmacology

Faculty of Pharmaceutical Sciences


Chulalongkorn University

Academic Year 2004

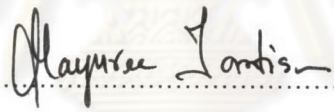
ISBN 974-17-6909-1

Thesis Title Subacute effects of *Orthosiphon grandiflorus* aqueous extract on
 hepatic cytochrome P450 and clinical blood chemistry in rats
By Tanarat Chaiyo
Field of study Pharmacology
Thesis Advisor Associate Professor Pol. Lt. Col. Somsong Lawanprasert, Ph.D.
Thesis Co-advisor Associate Professor Nuansri Niwattisaiwong, M.Sc.


Accepted by the Faculty of Pharmaceutical Sciences, Chulalongkorn University in
Partial Fulfillment of the Requirements for the Master's Degree



..... Dean of the Faculty of Pharmaceutical Sciences
(Associate Professor Boonyong Tantisira, Ph.D.)

THESIS COMMITTEE


..... Chairman
(Associate Professor Mayuree Tantisira, Ph.D.)


..... Thesis Advisor
(Associate Professor Pol. Lt. Col. Somsong Lawanprasert, Ph.D.)


..... Thesis Co-advisor
(Associate Professor Nuansri Niwattisaiwong, M.Sc.)


..... Member
(Assistant Professor Laddawal Phivthong-ngam, Ph.D.)


..... Member
(Associate Professor Chaiyo Chaichantipyuth, Ph.D.)

ธนารัตน์ ไชยโย : ผลกึ่งเฉียบพลันของสารสกัดหญ้าหนวดแมวด้วยน้ำต่อเอนไซม์ไซโตโครม ที450 ในตับ และค่าเคมีคลินิกในเลือดของหนูขาว. (SUBACUTE EFFECTS OF *ORTHOSIPHON GRANDIFLORUS* AQUEOUS EXTRACT ON HEPATIC CYTOCHROME P450 AND CLINICAL BLOOD CHEMISTRY IN RATS)
 อ. ที่ปรึกษา : รศ. ดร. พ.ต.ท.หญิง สมทรง ลาวัณย์ประเสริฐ, อ. ที่ปรึกษาร่วม : รศ. นवलศรี นวัตกรรมวงศ์, 160 หน้า
 ISBN 974-17-6909-1

หญ้าหนวดแมว มีชื่อทางพฤกษศาสตร์ว่า *Orthosiphon grandiflorus* Bold. เป็นสมุนไพรพื้นบ้านที่นิยมใช้เพื่อขับปัสสาวะและรักษาโรคนี้ในทางเดินปัสสาวะ การศึกษานี้มุ่งศึกษาผลกึ่งเฉียบพลันของสารสกัดหญ้าหนวดแมวด้วยน้ำต่อการทำงานของเอนไซม์ในตับหนึ่ง คือ เอนไซม์ไซโตโครม ที 450 (cytochrome P450, CYP) ในตับ นอกจากนี้ยังศึกษาผลของสารสกัดสมุนไพรนี้ต่อค่าเคมีคลินิกและโลหิตวิทยาในเลือดของหนูขาวด้วย โดยใช้หนูขาวเพศผู้พันธุ์สตาร์จำนวน 30 ตัว แบ่งหนูขาวแบบสุ่มเป็น 3 กลุ่ม กลุ่มละ 10 ตัว กลุ่มที่หนึ่งเป็นกลุ่มควบคุมได้รับน้ำกลั่นในขนาด 1 มิลลิลิตร/กิโลกรัม/วัน กลุ่มที่สองและสามได้รับสารสกัดหญ้าหนวดแมวด้วยน้ำขนาด 0.96 และ 4.8 กรัม/กิโลกรัม/วัน ตามลำดับ โดยการป้อนทางปากเป็นเวลา 30 วัน ในระหว่างทำการทดลองบันทึกน้ำหนักตัวทุก 7 วัน เมื่อครบระยะเวลา ทำให้หนูหมดความรู้จัก เก็บตัวอย่างเลือดจากหัวใจเพื่อตรวจค่าโลหิตวิทยาและแยกซีรัมเพื่อตรวจค่าเคมีคลินิก นำตับมาเตรียมไมโครโซม เพื่อตรวจวิเคราะห์ความเข้มข้นของ total CYP และสมรรถนะของ CYP1A1, 1A2, 2B1/2, 2E1 และ 3A ผลการทดลองพบว่าสารสกัดหญ้าหนวดแมวด้วยน้ำในขนาด 4.8 กรัม/กิโลกรัม/วัน ทำให้การเพิ่มของน้ำหนักหนูขาวต่ำกว่ากลุ่มควบคุม แต่ไม่มีผลต่อน้ำหนักสัมพัทธ์ของตับรวมทั้งค่าโลหิตวิทยาและค่าเคมีคลินิกดังต่อไปนี้ hematocrit, hemoglobin, platelet count, white blood cell count, red blood cell count, RBC indices (MCV, MCH and MCHC), RBC morphology, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, total bilirubin, direct bilirubin, serum creatinine, total cholesterol, triglyceride, low density lipoprotein-cholesterol, high density lipoprotein-cholesterol, glucose, uric acid, sodium, chloride และ calcium สารสกัดหญ้าหนวดแมวด้วยน้ำในขนาด 4.8 กรัม/กิโลกรัม/วันมีผลทำให้ค่า blood urea nitrogen และ potassium ในซีรัมเพิ่มขึ้นอย่างมีนัยสำคัญ สารสกัดหญ้าหนวดแมวด้วยน้ำทั้ง 2 ขนาดไม่มีผลต่อสมรรถนะของ CYP1A1, 1A2, 2B1/2, 2E1 และ 3A อย่างไรก็ตามสารสกัดหญ้าหนวดแมวด้วยน้ำในขนาด 4.8 กรัม/กิโลกรัม/วันมีผลทำให้ความเข้มข้นของ total CYP ลดลงอย่างมีนัยสำคัญ การที่ความเข้มข้นของ total CYP ลดลงนี้ควรมีการศึกษาต่อไปว่า CYP isoforms ใดที่ถูกยับยั้งจากการได้รับสารสกัดหญ้าหนวดแมวด้วยน้ำ ผลจากการทดลองนี้ทำให้ได้ข้อมูลเบื้องต้นว่าสารสกัดหญ้าหนวดแมวด้วยน้ำไม่มีอันตรกิริยาระหว่างยา รวมทั้งไม่มีผลเพิ่ม/ลดความเสี่ยงจากความเป็นพิษ การก่อกลายพันธุ์ และ/หรือการก่อมะเร็งจากสารแปลกปลอมใดๆที่มีเมแทบอลิซึม/ปฏิกิริยากระตุ้นการเกิดพิษที่ถูกเร่งโดยเอนไซม์ CYP isoforms ต่างๆ ที่ทำการศึกษาในงานวิจัยนี้

ภาควิชาเภสัชวิทยา

สาขาวิชาเภสัชวิทยา

ปีการศึกษา 2547

ลายมือชื่อนิสิต.....

ลายมือชื่ออาจารย์ที่ปรึกษา.....

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม.....

4676567833 : MAJOR PHARMACOLOGY

KEY WORD : *ORTHOSIPHON GRANDIFLORUS* / HEPATIC CYTOCHROME P450 / CLINICAL BLOOD CHEMISTRY / SUBACUTE TOXICITY

TANARAT CHAIYO : SUBACUTE EFFECTS OF *ORTHOSIPHON GRANDIFLORUS* AQUEOUS EXTRACT ON HEPATIC CYTOCHROME P450 AND CLINICAL BLOOD CHEMISTRY IN RATS. THESIS ADVISOR : ASSOC. PROF. POL. LT. COL. SOMSONG LAWANPRASERT, THESIS CO-ADVISOR : ASSOC. PROF. NUANSRI NIWATTISAIWONG, 160 pp. ISBN : 974-17-6909-1

Orthosiphon grandiflorus Bold. is commonly called in Thai as "Yaa nuat maeo". *O. grandiflorus* has been used traditionally as a diuretic and treatment of urinary stone disease. This study examined subacute effects of *O. grandiflorus* aqueous extract on phase I hepatic cytochrome P450 (CYP) in rats. In addition, effects of this plant extract on clinical blood chemistry and hematology were also determined. Thirty male Wistar rats were randomly divided into three treatment groups, of ten rats in each group. Rats in the first group were given distilled water 1 ml/kg/day serving as a control group. The other two groups of rats were given *O. grandiflorus* aqueous extract at dosages of 0.96 and 4.8 g/kg/day. Test compounds were administered orally for 30 consecutive days. During the treatment period, body weight was recorded every week. At the end of the treatment period, rats were anesthetized. Blood samples were collected by heart puncture and serum samples were prepared for measuring hematology and clinical blood chemistry, respectively. Microsomes were prepared from livers and used for determining of total CYP contents as well as activities of CYP1A1, 1A2, 2B1/2, 2E1 and 3A. The results showed that body weight gain of rats given *O. grandiflorus* aqueous extract at 4.8 g/kg/day was significantly lower than those in the control group. No significant effects of *O. grandiflorus* were shown on relative liver weight as well as these following clinical blood chemistry and hematology: hematocrit, hemoglobin, platelet count, white blood cell count, red blood cell count, RBC indices (MCV, MCH and MCHC), RBC morphology, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, total bilirubin, direct bilirubin, serum creatinine, total cholesterol, triglyceride, low density lipoprotein-cholesterol, high density lipoprotein-cholesterol, glucose, uric acid and electrolytes (such as sodium, chloride and calcium). *O. grandiflorus* aqueous extract at the dose of 4.8 g/kg/day caused a significant increase of blood urea nitrogen and serum potassium. Both dosages of *O. grandiflorus* aqueous extract did not affect the activities of CYP1A1, 1A2, 2B1/2, 2E1 and 3A. However, a significant decrease of total CYP content was found in rats receiving *O. grandiflorus* at 4.8 g/kg/day. Further study was suggested to find out which individual CYP isoform was affected by *O. grandiflorus* administration. In conclusion, results from this study provided a preliminary information that drug-drug interaction and potential of increase/decrease of xenobiotic-induced toxicity, mutagenesis and/or carcinogenesis would not be expected by *O. grandiflorus* administration if this plant aqueous extract was given concomitantly with drugs or with an exposure of xenobiotics that were metabolized/bioactivated by the CYP isoforms investigated in this study.

Department Pharmacology

Field of study Pharmacology

Academic year 2004

Student's signature..... *Tanarat Chaiyo*

Advisor's signature..... *Pol. Lt. Col. Somsong Lawanprasert*

Co-advisor's signature..... *N. Niwattisaiwong*

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my advisor, Associate Professor Pol. Lt. Col. Dr. Somsong Lawanprasert and my thesis co-advisor, Associate Professor Nuansri Niwattisaiwong for their helpful advise, guidance, encouragement and constructive criticism throughout my research study which enable me to accomplish this thesis.

I also wish to thank Assistant Professor Dr. Laddawal Phivthong-ngam, Associate Professor Chaiyo Chaichantipyuth and Associate Professor Dr. Mayuree Tantisira, the committee members, for their useful comments.

This study was supported in part by the Graduate School, Chulalongkorn University.

I wish to thank all staff members of the Department of Pharmacology, Faculty of Pharmaceutical Sciences, Chulalongkorn University as well as all staff members of the Department of Pharmacology, Faculty of Medicine, Srinakharinwirot University for their helps.

Finally, I would like to express my deepest appreciation to my family and my friends for their helps and encouragement.



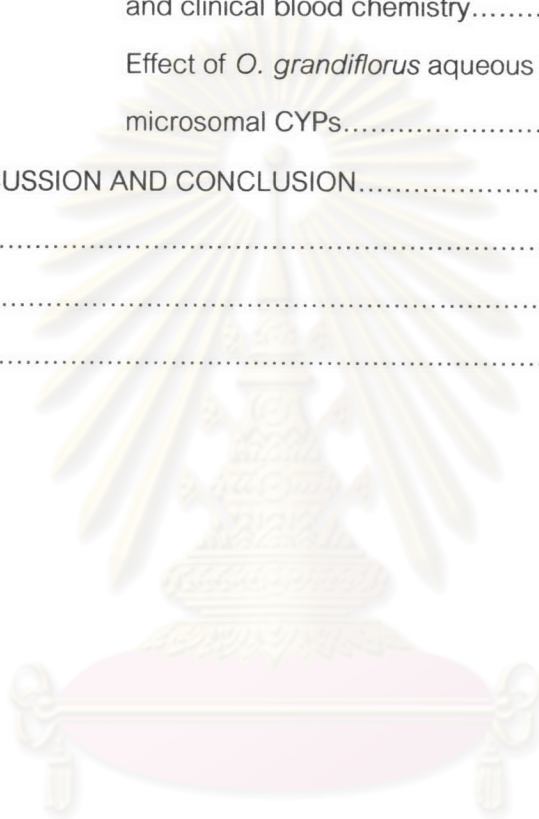
ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

CONTENTS

	page
ABSTRACT (THAI).....	iv
ABSTRACT (ENGLISH).....	v
ACKNOWLEDGEMENTS.....	vi
CONTENTS.....	vii
LIST OF TABLES.....	x
LIST OF FIGURES.....	xiii
LIST OF ABBREVIATIONS.....	xv
CHAPTER	
I INTRODUCTION.....	1
Hypothesis.....	4
Anticipated benefit from the study.....	4
Study design and process.....	4
II LITERATURE REVIEWS.....	5
<i>Orthosiphon grandiflorus</i>	5
Morphological characteristic of <i>O. grandiflorus</i>	5
Chemical constituents found in <i>O. grandiflorus</i>	6
Pharmacological effects.....	13
Toxicological effects.....	17
Acute toxicity.....	17
Subacute toxicity.....	17
Chronic toxicity.....	18
Xenobiotics metabolism.....	19
Cytochrome P450 (CYP).....	20
CYP1A subfamily.....	21
CYP2B subfamily.....	21
CYP2E subfamily.....	21
CYP3A subfamily.....	22

CHAPTER	page
	Mechanism of induction of CYPs.....31
	Mechanism of inhibition of CYPs.....32
III	MATERIALS AND METHODS.....34
	Materials.....34
	Experimental animals..... 34
	Instruments..... 34
	Chemicals.....35
	Methods.....36
	Preparation of <i>O. grandiflorus</i> aqueous extract.....36
	Chemical identifications.....36
	Effects of <i>O. grandiflorus</i> aqueous extract on hepatic CYP and clinical blood chemistry..... 38
	Animal treatment.....38
	Blood sampling for determination of hematology and clinical blood chemistry..... 39
	Liver microsome preparation..... 40
	Determination of protein concentrations..... 41
	Spectral determination of total CYP contents.....42
	Determination of CYP activities.....43
	Alkoxyresorufin O-dealkylation assays.....43
	Aniline 4-hydroxylation assay.....46
	Erythromycin N-demethylation assay.....48
	Data analysis..... 50
IV	RESULTS.....51
	Preparation of <i>O. grandiflorus</i> aqueous extract.....51
	Chemical identification of <i>O. grandiflorus</i> aqueous extract..... 51
	An ex vivo study.....53

CHAPTER	page
Effect of <i>O. grandiflorus</i> aqueous extract on body weight, relative liver weight and relative food & water consumptions.....	53
Effect of <i>O. grandiflorus</i> aqueous extract on hematology and clinical blood chemistry.....	58
Effect of <i>O. grandiflorus</i> aqueous extract on hepatic microsomal CYPs.....	79
V DISCUSSION AND CONCLUSION.....	86
REFERENCES.....	91
APPENDICES.....	97
VITAE.....	160



ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

LIST OF TABLES

Table	page
1. Reactions classed as phase I or phase II metabolism.....	19
2. Sequential homology between rat and human P450 forms.....	23
3. Carcinogens and toxins metabolized by human P450s.....	25
4. Regulation of P450 gene expression.....	27
5. Mechanisms of induction known to date for difference P450s.....	32
6. Effects of <i>O. grandiflorus</i> aqueous extract on body weight, liver weight and %relative liver weight.....	54
7. Seven-day body weight of individual control rat.....	98
8. Seven-day body weight of individual rat in <i>O. grandiflorus</i> group I	99
9. Seven-day body weight of individual rat in <i>O. grandiflorus</i> group II.....	100
10. Food consumption of individual control rat.....	101
11. Food consumption of individual rat in <i>O. grandiflorus</i> group I	102
12. Food consumption of individual rat in <i>O. grandiflorus</i> group II	103
13. Water consumption of individual control rat.....	104
14. Water consumption of individual rat in <i>O. grandiflorus</i> group I	105
15. Water consumption of individual rat in <i>O. grandiflorus</i> group II	106
16. Relative food consumption of individual control rat.....	107
17. Relative food consumption of individual rat in <i>O. grandiflorus</i> group I.....	108
18. Relative food consumption of individual rat in <i>O. grandiflorus</i> group II.....	109
19. Relative water consumption of individual control rat.....	110
20. Relative water consumption of individual rat in <i>O. grandiflorus</i> group I.....	111
21. Relative water consumption of individual rat in <i>O. grandiflorus</i> group II.....	112
22. Terminal body weight of individual rat.....	113
23. Liver weight of individual rat.....	114
24. Serum AST concentration of individual rat.....	115
25. Serum ALT concentration of individual rat.....	116

Table	page
26. Serum ALP concentration of individual rat.....	117
27. Serum total bilirubin concentration of individual rat.....	118
28. Serum direct bilirubin concentration of individual rat.....	119
29. Total protein of individual rat.....	120
30. Albumin of individual rat.....	121
31. Globulin of individual rat.....	122
32. BUN concentration of individual rat.....	123
33. Serum creatinine concentration of individual rat.....	124
34. Serum sodium concentration of individual rat.....	125
35. Serum potassium concentration of individual rat.....	126
36. Serum chloride concentration of individual rat.....	127
37. Serum calcium concentration of individual rat.....	128
38. Serum uric acid concentration of individual rat.....	129
39. Serum total cholesterol concentration of individual rat.....	130
40. Serum triglyceride concentration of individual rat.....	131
41. Serum LDL-C concentration of individual rat.....	132
42. Serum HDL-C concentration of individual rat.....	133
43. Serum glucose concentration of individual rat.....	134
44. Hematocrit of individual rat.....	135
45. Hemoglobin of individual rat.....	136
46. Platelet count of individual rat.....	137
47. WBC count of individual rat.....	138
48. RBC count of individual rat.....	139
49. RBC indices (MCV, MCH and MCHC) of individual control rat.....	140
50. RBC indices (MCV, MCH and MCHC) of individual rat in <i>O. grandiflorus</i> group I.....	141
51. RBC indices (MCV, MCH and MCHC) of individual rat in <i>O. grandiflorus</i> group II.....	142

Table	page
52. RBC morphology of individual rat.....	143
53. Percent differential WBCs of individual control rat.....	144
54. Percent differential WBCs of individual rat in <i>O. grandiflorus</i> group I.....	145
55. Percent differential WBCs of individual rat in <i>O. grandiflorus</i> group II.....	146
56. Microsomal protein concentration of individual rat.....	147
57. Hepatic microsomal total CYP content of individual rat.....	148
58. Hepatic microsomal EROD activity of individual rat.....	149
59. Hepatic microsomal MROD activity of individual rat.....	150
60. Hepatic microsomal BROD activity of individual rat.....	151
61. Hepatic microsomal PROD activity of individual rat.....	152
62. Hepatic microsomal aniline 4-hydroxylase activity of individual rat.....	153
63. Hepatic microsomal erythromycin <i>N</i> -demethylase activity of individual rat.....	154
64. Normal lab values of rats.....	158



 ศูนย์วิทยทรัพยากร
 จุฬาลงกรณ์มหาวิทยาลัย

LIST OF FIGURES

Figure	page
1. Morphology of <i>O. grandiflorus</i>	5
2. Chemical constituents found in <i>O. grandiflorus</i>	8
3. Steps in P450 expression.....	31
4. TLC chromatogram of <i>O. grandiflorus</i> aqueous extract.....	52
5. Effect of <i>O. grandiflorus</i> aqueous extract on body weight gain of rats.....	55
6. Effect of <i>O. grandiflorus</i> aqueous extract on relative food consumption of rats.....	56
7. Effect of <i>O. grandiflorus</i> aqueous extract on relative water consumption of rats.....	57
8. Effect of <i>O. grandiflorus</i> aqueous extract on serum AST.....	59
9. Effect of <i>O. grandiflorus</i> aqueous extract on serum ALT.....	60
10. Effect of <i>O. grandiflorus</i> aqueous extract on serum ALP.....	61
11. Effect of <i>O. grandiflorus</i> aqueous extract on serum total bilirubin and direct bilirubin.....	62
12. Effect of <i>O. grandiflorus</i> aqueous extract on serum total protein, albumin and globulin.....	63
13. Effect of <i>O. grandiflorus</i> aqueous extract on BUN and SCr.....	64
14. Effect of <i>O. grandiflorus</i> aqueous extract on serum sodium concentration.....	65
15. Effect of <i>O. grandiflorus</i> aqueous extract on serum potassium concentration.....	66
16. Effect of <i>O. grandiflorus</i> aqueous extract on serum chloride concentration.....	67
17. Effect of <i>O. grandiflorus</i> aqueous extract on serum calcium concentration.....	68
18. Effect of <i>O. grandiflorus</i> aqueous extract on serum uric acid.....	69
19. Effect of <i>O. grandiflorus</i> aqueous extract on serum total cholesterol and triglyceride.....	70
20. Effect of <i>O. grandiflorus</i> aqueous extract on serum LDL-C and HDL-C	71
21. Effect of <i>O. grandiflorus</i> aqueous extract on serum glucose.....	72
22. Effect of <i>O. grandiflorus</i> aqueous extract on serum hematocrit and hemoglobin.....	74

Figure	page
23. Effect of <i>O. grandiflorus</i> aqueous extract on platelet count and WBC count.....	75
24. Effect of <i>O. grandiflorus</i> aqueous extract on RBC count.....	76
25. Effect of <i>O. grandiflorus</i> aqueous extract on RBC indices.....	77
26. Effect of <i>O. grandiflorus</i> aqueous extract on % differential WBCs.....	78
27. Effect of <i>O. grandiflorus</i> aqueous extract on rat hepatic total CYP contents.....	79
28. Effect of <i>O. grandiflorus</i> aqueous extract on rat hepatic CYP1A1 activity.....	80
29. Effect of <i>O. grandiflorus</i> aqueous extract on rat hepatic CYP1A2 activity.....	81
30. Effect of <i>O. grandiflorus</i> aqueous extract on rat hepatic CYP2B1/2 (BROD) activity.....	82
31. Effect of <i>O. grandiflorus</i> aqueous extract on rat hepatic CYP2B1/2 (PROD) activity.....	83
32. Effect of <i>O. grandiflorus</i> aqueous extract on rat hepatic CYP2E1 activity.....	84
33. Effect of <i>O. grandiflorus</i> aqueous extract on rat hepatic CYP3A activity.....	85
34. Calibration graph of potassium content was determined using atomic absorption spectrophotometer.....	155
35. Verification of alkoxyresorufin <i>O</i> -dealkylation.....	155
36. Verification of aniline 4-hydroxylation.....	156
37. Verification of erythromycin <i>N</i> -demethylation.....	156

LIST OF ABBREVIATIONS

α	= alpha
AC	= acetone
AhR	= aryl hydrocarbon receptor
ALP	= alkaline phosphatase
ALT	= alanine aminotransferase
ANOVA	= one way analysis of variance
AST	= aspartate aminotransferase
β	= beta
BNF	= β -naphthoflavone
BR	= benzyloxyresorufin
BROD	= benzyloxyresorufin O-dealkylase
BSA	= bovine serum albumin
BUN	= blood urea nitrogen
CAR	= constitutive androstane receptor
cm	= centimeter
CYP	= cytochrome P450
DEX	= dexamethasone
DMSO	= dimethyl sulfoxide
e.g.	= example gratia (for example)
ER	= ethoxyresorufin
EROD	= ethoxyresorufin O-dealkylase
et al.	= et alii (and others)
fL	= femtoliter
g	= gram
γ	= gamma
G6P	= glucose 6-phosphate
G6PD	= glucose 6-phosphate dehydrogenase

LIST OF ABBREVIATIONS (continued)

Hb	= hemoglobin
Hct	= hematocrit
HDL-C	= high density lipoprotein-cholesterol
ISF	= isosafrole
ISN	= isoniazid
kg	= kilogram
L	= liter
LD ₅₀	= median lethal doses
LDL-C	= low density lipoprotein-cholesterol
M	= molar (mole per liter)
MC	= methylcholanthrene
MCH	= mean corpuscular hemoglobin
MCHC	= mean corpuscular hemoglobin concentration
MCV	= mean corpuscular volume
mEq	= milliequivalent
mg	= milligram
μg	= microgram
min	= minute
ml	= milliliter
μl	= microliter
μM	= micromolar (micromole per liter)
MR	= methoxyresorufin
mRNA	= messenger ribonucleic acid
MROD	= methoxyresorufin O-dealkylase
MW	= molecular weight
NADP	= nicotinamide adenine dinucleotide phosphate
NADPH	= nicotinamide adenine dinucleotide phosphate (reduced form)

LIST OF ABBREVIATIONS (continued)

nm	= nanometer
nmol	= nanomole
°C	= degree celsius
PAHs	= polycyclic aromatic hydrocarbons
pg	= picogram
pmol	= picomole
PPAR	= peroxisome proliferators activated receptor
PR	= pentoxyresorufin
PROD	= pentoxyresorufin <i>O</i> -dealkylase
PXR	= pregnane (or pregnenolone) receptor
rpm	= revolution per minute
RBC	= red blood cell
SCr	= serum creatinine
SEM	= standard error of mean
SXR	= Steroid-Xenobiotic-Receptor
TCA	= trichloroacetic acid
TCDD	= 2,3,7,8-tetrachlorodibenzo- <i>p</i> -dioxin
TG	= triglyceride
TLC	= thin layer chromatography
TPA	= 12- <i>O</i> -tetradecanoylphorbol-13-acetate
U	= unit
v/v	= volume by volume
w/v	= weight by volume
WBC	= white blood cell