



Faculty of Engineering

**OPTIMIZATION AND KINETIC STUDY OF PLECTRANTHUS
AMBOINICUS ESSENTIAL OIL EXTRACTION**

SIM SIEW MING

**Bachelor of Engineering with Honours
(Chemical Engineering)**

2018

UNIVERSITI MALAYSIA SARAWAK

Grade: _____

Please tick (✓)

Final Year Project Report.

Masters

PhD

<input checked="" type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>

DECLARATION OF ORIGINAL WORK

This declaration is made on the 12th day of June 2018.

Student's Declaration:

I, SIM SIEW MING (48927) DEPT. OF CHEMICAL ENGINEERING AND ENERGY SUSTAINABILITY, FACULTY OF ENGINEERING hereby declare that the work entitled, OPTIMIZATION AND KINETIC STUDY OF PLECTRANTHUS AMBOINICUS ESSENTIAL OIL EXTRACTION is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

12th June 2018
Date submitted

Sim Siew Ming (48927)
Name of the student (Matric No.)

Final Year Project Supervisor's Declaration:

I IR. DR. LIM SOH FONG hereby certifies that the work entitled, OPTIMIZATION AND KINETIC STUDY OF PLECTRANTHUS AMBOINICUS ESSENTIAL OIL EXTRACTION was prepared by the above named student, and was submitted to the "FACULTY" as a fulfilment for the conferment of BACHELOR OF ENGINEERING WITH HONOURS (CHEMICAL ENGINEERING), and the aforementioned work, to the best of my knowledge, is the said student's work.

Received for examination by: IR. DR. LIM SOH FONG Date: 12th June 2018

(Name of the supervisor)

I declare this Report is classified as (Please tick (√)):

- CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*
- RESTRICTED** (Contains restricted information as specified by the organisation where research was done)*
- OPEN ACCESS**

Validation of Project/Thesis

I therefore duly affirmed with free consent and willingness declared that this said Project/Thesis shall be placed officially in the Centre for Academic Information Services with the abide interest and rights as follows:

- This Project/Thesis is the sole legal property of Universiti Malaysia Sarawak (UNIMAS).
- The Centre for Academic Information Services has the lawful right to make copies for the purpose of academic and research only and not for other purpose.
- The Centre for Academic Information Services has the lawful right to digitise the content to for the Local Content Database.
- The Centre for Academic Information Services has the lawful right to make copies of the Project/Thesis for academic exchange between Higher Learning Institute.
- No dispute or any claim shall arise from the student itself neither third party on this Project/Thesis once it becomes sole property of UNIMAS.
- This Project/Thesis or any material, data and information related to it shall not be distributed, published or disclosed to any party by the student except with UNIMAS permission.

Student's signature _____ Supervisor's signature _____
(12th June 2018) (12th June 2018)

Current Address:

Lot 361, Lorong Unigarden 12, 94300 Kota Samarahan, Sarawak.

Notes: * If the Report is **CONFIDENTIAL** or **RESTRICTED**, please attach together as annexure a letter from the organization with the period and reasons of confidentiality and restriction.

APPROVAL SHEET

This project report which entitled “**OPTIMIZATION AND KINETIC STUDY OF PLECTRANTHUS AMBOINICUS ESSENTIAL OIL EXTRACTION**” was prepared by Sim Siew Ming (48927), as a partial KNC 4344 Final Year Project course fulfilment for the Degree of Bachelor of Engineering with Honours (Chemical Engineering) is hereby read and approved by:

IR. DR. LIM SOH FONG
(Final Year Project Supervisor)

12th June 2018
Date

OPTIMIZATION AND KINETIC STUDY OF PLECTRANTHUS
AMBOINICUS ESSENTIAL OIL EXTRACTION

SIM SIEW MING

A dissertation submitted in partial fulfilment
of the requirement for the degree of
Bachelor of Engineering with Honours
(Chemical Engineering and Energy Sustainability)

Faculty of Engineering
Universiti Malaysia Sarawak

2018

Dedicated to my beloved parents and my family who always bestow me sustainable
motivations and encouragements

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincerest gratitude to my Final Year Project supervisor, Ir. Dr. Lim Soh Fong for her aspiring guidance, patience, motivation and friendly advice during the completion of Final Year Project. Without her assistance and dedicated involvement throughout the process, this FYP would have never been accomplished. I believed that all her advices and critics are for the benefit of producing a quality final year project.

Thanks also to all the technicians for their willingness to share their knowledge and experiences as well as for their valuable supervision towards the completion of this project. In addition, not forget to thank my friend, Bong Sook Nee for her constant encouragement and exchange of knowledge throughout our struggles in completing this project.

Last but definitely not least to say thank you to my family members who always love me, be at my side, support and motivate me throughout my studies in Universiti Malaysia Sarawak (Unimas).

ABSTRACT

Plectranthus amboinicus leaves are the famous aromatic and medicinal herbs that widely used for medicinal purposes because they show antimicrobial, anti-inflammatory and antitumor properties. *P. amboinicus* essential oil plays an important role as naturally originated medicines that can be used as remedy to cure illness and diseases without bringing any side effects on the patients. Thus, the aim of this project is to extract essential oil from *P. amboinicus* leaves by using microwave pre-treatment followed by hydrodistillation (HD) extraction method. This method is proven to save heating and extraction duration, cost and energy (Azadmard-damirchi et al., 2010). The *P. amboinicus* essential oil extracted was characterized by using Fourier Transform Infrared Spectrophotometer (FT-IR) and UV-Vis Spectrophotometer. From the FTIR result obtained, at frequency of $3600-3106\text{ cm}^{-1}$, it shows the presence of phenolic –OH group in the *P. amboinicus* essential oil where thymol and carvacrol as the major phenolic components present in the essential oil. Besides, from Foulin-Ciocalteu method, a total of 2.92 mg/g of phenolic compounds were determined when a water-to-plant ratio of 20 was used. Moreover, a second order kinetic model proposed by Kusuma and Mahfud (2015) was fairly fitted to the experimental data. This means that the performance of hydrodistillation of *P. amboinicus* essential oil can be predicted by using this second order kinetic model. In the condition tested, the yield of *P. amboinicus* essential oil was optimised by using response surface methodology with the central composite design. There were three independent variables - the water-to-plant ratio, microwave pre-heating duration and microwave oven power with the yield of *P. amboinicus* essential oil as responding variable. From ANOVA analysis, the optimal conditions that yielded the highest production of *P. amboinicus* essential oil was microwave power of 260.86 W, microwave pre-heating duration of 3.83 min and water-to-plant ratio of 18.10.

ABSTRAK

Daun *Plectranthus amboinicus* adalah herba aromatik dan ubat-ubatan yang terkenal yang digunakan secara meluas untuk tujuan perubatan kerana ia menunjukkan sifat antimikroba, anti-radang dan antitumor. Minyak pati *P. amboinicus* memainkan peranan penting sebagai ubat-ubatan semula jadi yang boleh digunakan sebagai ubat untuk menyembuhkan penyakit tanpa membawa apa-apa kesan sampingan kepada pesakit. Oleh itu, matlamat projek ini adalah untuk mengekstrak minyak pati dari daun *P. amboinicus* dengan menggunakan pra-rawatan microwave diikuti dengan kaedah pengekstrakan hidrodistilasi (HD). Kaedah ini terbukti dapat menjimatkan masa pemanasan dan pengekstrakan, kos dan tenaga. Minyak pati *P. amboinicus* yang diekstrak dicirikan dengan menggunakan Spectrophotometer Inframerah Transformasi (FT-IR) dan Spektrofotometer UV-Vis. Dari hasil FTIR yang diperolehi, pada kekerapan $3600-3106\text{ cm}^{-1}$, ia menunjukkan kehadiran kumpulan fenolik -OH dalam minyak pati *P. amboinicus* di mana thymol dan carvacrol adalah komponen fenolik utama yang terbukti hadir dalam minyak pati. Selain itu, dari kaedah Foulin- Ciocalteu, jumlah kandungan fenikol yang terdapat dalam minyak pati adalah tertinggi iaitu 2.917mg/g untuk nisbah air ke tumbuhan sebanyak 20. Selain itu, model kinetik kedua yang dicadangkan oleh Kusuma dan Mahfud (2015) paling sesuai untuk data eksperimen. Ini bermakna prestasi hidrodistilasi minyak pati *P. amboinicus* boleh diramalkan dengan menggunakan model kinetik urutan kedua ini. Selain itu, hasil minyak penting *P. amboinicus* dioptimumkan dengan menggunakan kaedah permukaan respon dengan reka bentuk komposit pusat. Terdapat tiga pembolehubah bebas - nisbah air ke tumbuhan, tempoh pra pemanasan gelombang mikro dan kuasa ketuhar gelombang mikro dengan hasil minyak pati *P. amboinicus* sebagai pemboleh ubah yang bertindak balas. Dari analisis ANOVA, keadaan optimum yang menghasilkan pengeluaran minyak pati *P. amboinicus* tertinggi ialah kuasa gelombang mikro 260.86W, tempoh pemanasan microwave 3.83 minit dan nisbah air kepada tanaman 18.10.

TABLE OF CONTENTS

	Page
Acknowledgement	i
Abstract	ii
Abstrak	iii
Table of Contents	iv
List of Tables	viii
List of Figures	x
List of Abbreviations	xiii
List of Nomenclatures	xiv
Chapter 1	
INTRODUCTION	
1.1 Background of Study	1
1.2 Problem Statement	2
1.3 Research Objectives	3
1.4 Scope of Study	3
1.5 Summary	4
Chapter 2	
LITERATURE REVIEW	
2.1 Introduction	5
2.1.1 Essential Oil	5
2.1.2 <i>Plectranthus Amboinicus</i> (Lour.) Spreng	6
2.2 <i>Plectranthus Amboinicus</i> Essential Oil	7
2.2.1 Importance of <i>Plectranthus Amboinicus</i> Essential Oil	7
2.2.2 Chemical Compounds of <i>Plectranthus</i> <i>Amboinicus</i> Essential Oil	8
2.2.2.1 Terpenes	8
2.2.2.1.1 Monoterpene	9
2.2.2.1.2 Sesquiterpene	9
2.2.2.2 Alcohols	10

2.2.2.3	Aldehydes	11
2.2.2.4	Esters	11
2.2.3	Constituents of <i>Plectranthus Amboinicus</i> Essential Oil	12
2.3	Essential Oil Extraction Method	14
2.3.1	Steam Distillation	14
2.3.2	Hydrodistillation	15
2.3.3	Solvent Extraction	15
2.3.4	Microwave Pre-Treatment followed by Conventional Extraction Method	16
2.3.5	Microwave-Assisted Hydrodistillation	16
2.3.6	Supercritical Fluid Extraction	17
2.3.7	Comparisons between Different Extraction Methods	17
2.4	Kinetic Modelling in Extraction of Essential Oil	22
2.4.1	Mechanism of Essential Oil Extraction by Hydrodistillation Method	22
2.4.2	Pseudo-First Order Model	22
2.4.3	Second Order Model	23
2.4.3.1	Kusuma, H. S. & Mahfud, M. (2015) Method	23
2.4.3.2	Milojevic, Stojanovic, Palic, Lazic, & Veljkovic (2008) Method	24
2.5	Analytical Instruments for Characterization	26
2.5.1	Fourier Transfer Infrared Spectroscopy (FT-IR)	26
2.5.2	UV-Vis Spectrophotometer	28
2.6	Optimization using Response Surface Methodology	28
2.6.1	Second-Order Designs	28
2.6.1.1	Full Three-Level Factorial Design	29
2.6.1.2	Box-Behnken Design	29
2.6.1.3	Central Composite Design	30
2.7	Summary	31

Chapter 3	METHODOLOGY	
3.1	Introduction	32
3.2	Preparation of <i>Plectranthus Amboinicus</i> Sample	32
3.3	Microwave Pre-Treatment of <i>Plectranthus Amboinicus</i> Leaves	32
3.4	Hydrodistillation Extraction Process	33
3.5	Experimental Design	34
3.6	Kinetic Experimental Run	36
3.6.1	Mathematical Kinetic Model Study	37
3.7	Model Fitting and Statistical Criteria	38
3.8	Characterization of <i>P. Amboinicus</i> Essential Oil	39
3.8.1	Fourier Transfer Infrared Spectroscopy (FT-IR)	39
3.8.2	Folin-Ciocalteu Method (UV-Vis Spectrophotometer)	40
3.8.2.1	Preparation of Gallic Acid Standard and Sodium Carbonate Solutions	40
3.8.2.2	Preparation of Calibration Curve	41
3.8.2.3	Preparation of Samples	41
3.9	Summary	42
Chapter 4	RESULTS AND DISCUSSION	
4.1	Comparison between Two Method of <i>P. Amboinicus</i> Essential Oil Extraction	43
4.2	Characterization of <i>Plectranthus Amboinicus</i> Essential Oil	45
4.2.1	Fourier Transfer Infrared Spectroscopy (FT-IR)	45
4.2.2	Total Phenolic Content by Folin-Ciocalteu Method	51
4.2.2.1	Standard Gallic Acid Calibration Curve	51
4.2.2.2	Total Phenolic Contents	51
4.3	Optimization by Using Response Surface Methodology (RSM)	53

4.4	Kinetic Studies of <i>Plectranthus Amboinicus</i> Hydrodistillation	58
4.4.1	Effect of Water-to-Plant Ratio on Yield	58
4.4.2	Effect of Microwave Power on Yield	59
4.4.3	Effect of Microwave Pre-Heating Duration on Yield	61
4.4.4	Effect of Extraction Duration on Yield	62
4.5	Kinetic Modelling of <i>Plectranthus Amboinicus</i> Hydrodistillation	63
4.5.1	Pseudo-First Order Kinetic Model	63
4.5.2	Second Order Kinetic Model by Kusuma, H. S. & Mahfud, M. (2015)	64
4.5.3	Second Order Kinetic Model by Milojevic, Stojanovic, Palic, Lazic, & Veljkovic (2008)	66
4.5.4	Comparison between Mathematical Kinetic Models	67
Chapter 5	CONCLUSIONS AND RECOMMENDATIONS	
5.1	Conclusions	70
5.2	Recommendations	70
	REFERENCES	72

LIST OF TABLES

Table		Page
2.1	Volatile constituents of <i>P. Amboinicus</i>	8
2.2	Chemical Components in <i>P. Amboinicus</i> Essential Oil	13
2.3	Comparison between Various Extraction Methods	20
2.4	Advantages and Disadvantages of Various Extraction Methods and their Yield & Quality of Essential Oil	21
3.1	Experimental Design Summary	35
3.2	Kinetic Models Equation	38
4.1	Effect of traditional hydrodistillation and microwave pre-treatment followed by hydrodistillation on the yield of <i>P. amboinicus</i> essential oil	45
4.2	IR spectral analysis results of <i>P. Amboinicus</i> essential oil	47
4.3	Absorbance of each concentration of Gallic acid standard solutions	51
4.4	Absorbance of each sample at different concentration	52
4.5	Information on design of experiment	53
4.6	Optimal design with uncoded independent variables and the corresponding response	54
4.7	Analysis of Variance table for quadratic model (Response: Yield of <i>Plectranthus amboinicus</i> essential oil)	55
4.8	<i>P. amboinicus</i> oil yield for different water-to-plant ratio	59
4.9	<i>P. amboinicus</i> essential oil yield for different microwave power at 4 minutes microwave-preheating duration	60
4.10	<i>P. amboinicus</i> essential oil yield for different microwave pre-heating duration at 200W of microwave power	61
4.11	Linearization of pseudo first-order kinetic model of hydrodistillation of <i>P. amboinicus</i>	64
4.12	Linearization of second-order kinetic model of hydrodistillation of <i>P. amboinicus</i>	66
4.13	Linearization of second-order kinetic model of hydrodistillation of	67

P. amboinicus

4.14 Statistical criteria result

68

LIST OF FIGURES

Figure	Page	
2.1	Leaves of <i>Plectranthus amboinicus</i> (Lour.) Spreng	6
2.2	Structure of (a) 3-Carene (b) β -pinene (c) γ -terpinene	9
2.3	Structure of (a) β -Caryophyllene (b) α -Humulene	10
2.4	Structure of Caryophyllene Oxide	10
2.5	Structure of (a) Linalool (OCW, 1998) (b) Carvacrol (c) Terpinen-4-ol (d) Thymol	10
2.6	Structure of Aldehydes	11
2.7	Structure of Linalyl Acetate	11
2.8	Experimental Apparatus Setup for Steam Distillation	14
2.9	Experimental Apparatus Setup for Hydrodistillation	15
2.10	Solvent Extraction	15
2.11	Schematic Representation of Microwave-Assisted Hydrodistillation Apparatus	16
2.12	Experimental Apparatus for Supercritical Carbon Dioxide	17
2.13	Simple Spectrometer Layout	27
2.14	Infrared Radiation Passed through a Sample	27
2.15	Sample Analysis Process	27
2.16	Three-Level Factorial Design for the Optimization (a) two variables and (b) three variables (c) Box-Behnken design for optimization of three variables	29
2.17	Central Composite Designs for the Optimization of: (a) two variables ($\alpha=1.41$) and (b) three variables ($\alpha=1.68$) (●) Points of factorial design, (○) axial points and (□) central point	30
3.1	Samsung Microwave oven, ME711K	33
3.2	Microwave pre-heating of <i>Plectranthus Amboinicus</i> leaves that immersed in distilled water	33
3.3	Experimental setup of the hydrodistillation method	34
3.4	IRAffinity-1S FTIR Spectrophotometer	39

3.5	Shimadzu UV-1800 UV-Vis Spectrophotometer	40
3.6	Gallic acid standard solution with concentration of (a) 320 ppm (b) 160 ppm (c) 80 ppm (d) 40 ppm (e) 20 ppm	41
3.7	Extracted samples with concentration of (a) 1000 ppm (b) 800 ppm (c) 500 ppm (d) 400 ppm (e) 300 ppm	42
4.1	(a) Formation of <i>P. Amboinicus</i> oil droplets for 90 minutes of traditional hydrodistillation extraction (b) Formation of <i>P. Amboinicus</i> oil layer for 4 minutes microwave pre-treatment followed by 90 minutes of hydrodistillation process	44
4.2	Yield of <i>P. amboinicus</i> essential oil against the extraction duration for different extraction method	44
4.3	Spectrum of <i>P. amboinicus</i> essential oil produced at different microwave heating power	48
4.4	Comparison between spectrums of <i>P. amboinicus</i> essential oil with hydrosol	49
4.5	IR absorption spectrum of <i>P. amboinicus</i> essential oil produced at different microwave heating power	49
4.6	IR absorption spectrum of <i>P. amboinicus</i> essential oil produced at different microwave heating duration	50
4.7	IR absorption spectrum of <i>P. amboinicus</i> essential oil produced at different water-to-plant ratio	50
4.8	Standard curve of Gallic acid	51
4.9	Optimized parameters for hydrodistillation of <i>Plectranthus amboinicus</i> essential oil	57
4.10	(a) Design Expert- Plot on the yield of essential oil (b) 3D response surface showing effects of factors on yield of <i>P. amboinicus</i> essential oil	57
4.11	Cumulative oil yield against extraction duration for different water-to-plant ratio	59
4.12	Essential oil yield against microwave power for different water-to-plant ratio	60
4.13	Essential oil yield against microwave pre-heating duration for different water-to-plant ratio	62

4.14	Effect of extraction duration on <i>P. amboinicus</i> essential oil yield being extracted by 200 W of microwave pre-treatment in water-to-plant ratio of 20:1	63
4.15	$\log (C_s-C_t)$ against extraction duration	64
4.16	The concentration of <i>P. Amboinicus</i> oil in the solution at any time, C_t (g/L) versus extraction duration (min) for different water-to-plant ratio	65
4.17	Second-order extraction kinetics of <i>P. Amboinicus</i>	66
4.18	$\ln \left(\frac{q_0-q}{q_0} \right)$ against extraction duration	67

LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
FT-IR	-	Fourier Transfer Infrared Spectroscopy
HD	-	Hydrodistillation
IR	-	Infrared
MAHD	-	Microwave-Assisted Hydrodistillation
RMSE	-	Root-Mean-Square Error
RSM	-	Response Surface Methodology
SD	-	Steam Distillation
SFE	-	Supercritical Fluid Extraction
TPC	-	Total Phenolic Content

LIST OF NOMENCLATURES

%	-	Percent
°C	-	Degree Celcius
cm	-	Centimeter
cm ⁻¹	-	Per centimeter
g	-	Gram
g/L	-	Gram per litre
kV	-	kiloVolt
m	-	Meter
mg GAE/ g	-	Milligram of Gallic Acid per gram of dry weight of extract
min	-	Minute
L	-	Litre
mL	-	Millilitre
mL/min	-	Millilitre per minute
mg/mL	-	Milligram per millilitre
mm	-	Millimeter
nm	-	Nanometer
µm	-	Micrometer
ppm	-	Parts per Million
s	-	Second
W	-	Watt

CHAPTER 1

INTRODUCTION

1.1 Background of Study

People nowadays concerns about living a healthy lifestyle. They prefer to consume natural products especially food, medicines and pharmaceutical products rather than that produced by synthetic chemicals because the natural product will not bring harmful effect to human health. Hence, natural essential oil that is usually found in plants such as rosemary, lavender, lemongrass and mint can replace synthetic chemical compounds in manufacturing healthy food and medicines. In addition, they are rich in nutrients and are commonly used as traditional medicines.

Plectranthus amboinicus (Mexican mint) which is a well-known aromatic perennial herb is used as medicines for centuries to cure asthma, coughs and diseases that caused by bacteria and virus (Ng, Wahida, & Chong, 2014). Apart from that, *P. amboinicus* is found to be very useful in medical fields where it exhibits anti-tumorigenic, anti-inflammatory, antimicrobial and antiviral properties against herpes virus-1 (Costa, Pereira, Rodrigues, & Lima, 2010). It also can be used to treat digestive, urinary, skin and respiratory problems such as bronchitis. This shows the importance of *P. amboinicus* essential oil towards human being in medicinal and pharmaceutical fields.

Hence, this research mainly studies the optimisation and mathematical kinetic modelling of the extraction of essential oil from *Plectranthus amboinicus* leaves by using hydrodistillation method aided by microwave pre-treatment.

1.2 Problem Statement

According to Fernandes et al. (2013), *P. amboinicus* is one of the most well-known medicinal herbs that have been used for centuries because it exhibits anti-microbial, balsamic and anti-inflammatory properties. The essential oil of *P. amboinicus* shows good inhibition activities on both acute and chronic inflammatory processes and also not induce any side effects during the treatment process (Manjamalai, Alexander, & Grace, 2012). Besides, this medicinal plant also contributes in medicinal fields where it possesses bronchodilator, anti-bacterial, antiviral, anti-fungal and anti-tuberculous properties. Apart from that, based on the study from Senthilkumar & Venkatesalu (2010), the essential oil from *P. amboinicus* was proven can be used to reduce the population of malarial vector mosquito *A. stephensi*. This finding benefits the countries of Africa and Asia that suffer from malaria disease which is known as a killer disease within those countries because *P. amboinicus* essential oil is a natural and inexpensive mosquito larvicidal agent that can be used to control the spread of malaria vector mosquito among people (Senthilkumar & Venkatesalu, 2010). Since the usage of modern medicines and drugs in the treatment of chronic diseases might lead to various and severe side effects on the patient, thus the application of naturally originated medicines are more favourable recently (Ng et al., 2014). Hence, the essential oil from *P. amboinicus* plays an important role as the remedy to cure illness and diseases nowadays.

The *P. amboinicus* essential oil extraction is most commonly performed using hydrodistillation method. This method is a conventional method that is quite time-consuming for full extraction process; energy consuming and also costly to conduct since the overall heating durations typically takes two to three hours (Manjamalai et al., 2012). Apart from that, even though Soxhlet method can also be used for *P. amboinicus* essential oil extraction, however, this method involved solvents such as ethanol, n-hexane or diethyl ether in the extraction process and the extraction time is too long which is four to six hours (Ng et al., 2014). Therefore, in this study, the microwave pre-treatment of the leaves is suggested before the hydrodistillation process. With the aid of microwave oven during pre-heating process, the extraction process will be sped up. This is because the glands that contain essential oil will break during the microwave pre-heating process and this will directly shorten the extraction time since the time for the release of essential oil from the gland will be greatly decreased. Thus, this method will

directly save both energy and cost in extracting the *P. amboinicus* essential oil. Besides, to the best of author's study, there are no optimization and kinetic study on *Plectranthus amboinicus* essential oil extraction. Hence, this project is important to study the extraction of *P. amboinicus* essential oil by microwave aided hydrodistillation despite optimizing and study the kinetics of essential oil extraction.

1.3 Research Objectives

The main aim of this research is to extract essential oil from *Plectranthus Amboinicus* leaves with the following objectives:

- i. To extract *P. amboinicus* essential oil by using microwave pre-treatment and hydrodistillation (HD) extraction method;
- ii. To characterize the *P. amboinicus* essential oil by using analytical instruments and methods;
- iii. To study the kinetics of the extraction of *P. amboinicus* essential oil by hydrodistillation method; and
- iv. To optimize the yield of *P. amboinicus* essential oil by using response surface methodology (RSM).

1.4 Scope of Study

This study focused on the extraction of the *P. amboinicus* essential oil by hydrodistillation method aided by microwave pre-treatment. Since hydrodistillation method involves no chemical solvent but only distilled water, thus the factors that may influence the extraction yield of essential oil from *P. amboinicus* leaves are the water-to-plant ratio, microwave pre-heating time and microwave power. These three variables are the important operating parameters that need to be investigated in optimizing the yield of *P. amboinicus* essential oil. Besides, the functional groups that present in the *P. amboinicus* essential oil is identified by using FT-IR and the total phenolic content that present in the essential oil is identified by using UV-Vis spectrophotometer. Also, the kinetic studies and kinetic modelling of the *P. amboinicus* essential oil are also being performed.