ANALYSIS OF CHEMICAL COMPOUNDS IN AGARWOOD (*AQUILARIA MALACCENSIS*) AT UMK TRACE, PULAU BANDING PERAK.

by

AMIR ZAIM BIN MD RADZI

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DECLARATION

I declare that this thesis entitled "Analysis of Chemical Compounds in Agarwood (*Aquilaria malaccensis*) at UMK TraCe, Pulau Banding Perak" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ____________________

Name : AMIR ZAIM BIN MD RADZI

Date : 15 SEPTEMBER 2024

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Analysis of Chemical Compounds in Agarwood (*Aquilaria malaccensis*) at UMK TraCe, Pulau Banding Perak.

ABSTRACT

This study aims to analyze the chemical composition of agarwood (*Aquilaria malaccensis*) oil extracted from the stems and roots of trees at UMK TRaCe, Pulau Banding, Perak. Agarwood, known for its valuable aromatic resin, contains a complex array of chemical compounds that contribute to its distinctive scent and potential therapeutic properties. Utilizing advanced analytical techniques such as gas chromatography-mass spectrometry (GC-MS), this research identifies and quantifies the key compounds present in agarwood oil. The study reveals significant differences in the chemical between the stem and root extracts. Key compounds identified include sesquiterpenes, phenolic compounds, chromones, and various volatile organic compounds. The findings suggest that the unique chemical makeup of agarwood oil from different parts of the tree can influence its aroma and potential uses in perfumery, traditional medicine, and other commercial applications. The analysis data used is T-test and Qualitative Analysis. Furthermore, understanding the chemical composition of agarwood can enhance sustainable harvesting practices and conservation efforts, ensuring the survival of *Aquilaria malaccensis*. This research contributes valuable insights into the complex chemistry of agarwood, with implications for its use in various industries and its conservation.

Profil Sebatian Kimia dalam Gaharu (*Aquilaria malaccensis)* UMK TraCe, Pulau Banding Perak.

ABSTRAK

Kajian ini bertujuan untuk menganalisis komposisi kimia minyak gaharu (*Aquilaria malaccensis*) yang diekstrak daripada batang dan akar pokok di UMK TRaCe, Pulau Banding, Perak. Gaharu, yang terkenal dengan resin aromatiknya yang berharga, mengandungi rangkaian kompleks sebatian kimia yang menyumbang kepada baunya yang tersendiri dan sifat terapeutik yang berpotensi. Menggunakan teknik analisis lanjutan seperti kromatografi gas-spektrometri jisim (GC-MS), penyelidikan ini mengenal pasti dan mengukur sebatian utama yang terdapat dalam minyak gaharu. Kajian ini mendedahkan perbezaan ketara dalam profil kimia antara ekstrak batang dan akar. Sebatian utama yang dikenal pasti termasuk seskuiterpena, sebatian fenolik, kromo, dan pelbagai sebatian organik meruap. Penemuan menunjukkan bahawa solek kimia unik minyak gaharu dari bahagian pokok yang berlainan boleh mempengaruhi aroma dan potensi kegunaannya dalam minyak wangi, perubatan tradisional, dan aplikasi komersial lain. Data analisis yang digunakan ialah T-test dan Analisis Kualitatif. Tambahan pula, memahami komposisi kimia kayu gaharu boleh meningkatkan amalan penuaian mampan dan usaha pemuliharaan, memastikan kemandirian *Aquilaria malaccensis*. Penyelidikan ini menyumbangkan pandangan berharga tentang kimia kompleks gaharu, dengan implikasi untuk kegunaannya dalam pelbagai industri dan pemuliharaannya.

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LIST OF ABBREVIATIONS

ml	- milliliter
GC-MS	- Gas chromatography-mass spectrometry
HPLC	- High-performance liquid chromatography
NMR	- Nuclear magnetic resonance spectroscopy
CR	- Critically endangered
mm	- millimeters
cm	- centimeters
m	- meters
Kg	- kilogram
g	- gram
TRaCe	- Tropical Rainforest Research Centre
NIST	- National Institute of Standards and Technology
TIC	- Total ion chromatography
μL	- microliter

LIST OF SYMBOLS

E	- East
N	- North
°	- Degree
C	- Celsius
F	- Fahrenheit
%	- Percentage

CHAPTER 1

INTRODUCTION

1.1 Background of Study

According to Zahari et al. (2016), agarwood, commonly known as oud or agar, is a highly valued resinous wood coveted for its distinctive scent and potential therapeutic benefits. Agarwood's diverse aroma and potential medical benefits are greatly influenced by its complex chemical makeup, which includes a variety of volatile organic compounds, sesquiterpenes, phenolic compounds, chromones, sesquiterpenoids, and various aromatic compounds (Dahham et al., 2015). A thorough study of the distinct chemical components within agarwood and their functions in scent creation and potential therapeutic benefits remains an active topic of research (Hashim et al., 2019) despite the substance's long history of use in traditional medicine and perfumery.

Due to its commercial importance and potential uses in a variety of industries, the chemical study of agarwood has generated a great deal of attention (Attar, 2017). To identify and measure the complex components present in agarwood, researchers have used cutting-edge analytical techniques like gas chromatography- mass spectrometry (GC-MS), high-performance liquid chromatography (HPLC), and nuclear magnetic resonance spectroscopy (NMR) (Hashim et al., 2019). These analytical techniques seek to decipher the intricate chemical makeup of agarwood, offering information on its bioactive components, therapeutic potential, and aromatic properties for use in traditional medicine, perfume formulation, and pharmaceutical research (Zahari et al., 2016).

In order to fully utilize agarwood's potential for creating novel perfumes, all-natural therapeutic agents, and ground-breaking pharmaceutical goods, there has been an increasing focus on analyzing its chemical components in recent years (Dahham et al., 2015). Additionally, a thorough comprehension of the agarwood's chemical composition can help to promote sustainable harvesting methods, assuring the survival of the Aquilaria and Gyrinops tree species as well as the preservation of this priceless natural resource (Attar, 2017).

Given the complexity of agarwood and its importance to numerous industries, a thorough examination of its chemical makeup not only advances knowledge of this revered natural product but also holds the possibility of identifying novel bioactive compounds with potential uses in aromatherapy, conventional medicine, and fragrance production (Hashim et al., 2019; Zahari et al., 2016).

According to Harvey-Brown (2018), this species is critically endangered (CR), a species categorized by the International Union for the Restoration of Nature as facing a very high risk of extinction in the wild. Next, regarding the geographical range of the Agarwood tree, most of the distribution of previous studies was done in various Southeast Asian countries including, Indonesia, Thailand, and Malaysia because this tree is easily found in tropical rainforests. For the specific height limit for Agarwood trees is started from the low-level limit which is 0m up to 1000 m at the upper limit. Then, for the general description of the population flow for the Agarwood tree, it was decreasing. (The IUCN Red List of Threatened Species, 2022).

1.2 Problem Statement

Agarwood's chemical components and how each one contributes to the aroma and potential medicinal effects of the wood are still poorly understood. This information gap makes it difficult to maximize the use of agarwood in adjacent fields like traditional medicine and perfumery.

Furthermore, it is difficult to use agarwood to its full potential for a variety of commercial uses due to the absence of a thorough understanding of its chemical complexity. Therefore, in order to unlock the variety of uses and potential advantages of agarwood, it is imperative to address the restricted knowledge of its chemical makeup.

1.3 Objective

1. To identify the chemical compounds, present in Agarwood (*Aquilaria malaccensis*) extracts oil from the stem and root of the Agarwood tree.
2. To study the difference in Agarwood oil extracted from the stem and root of Agarwood (*Aquilaria malaccensis*).

1.4 Scope of Study

This study focuses on conducting a thorough investigation of the chemical components found in agarwood using several analytical techniques, gas chromatography-mass spectrometry (GC-MS), and other related approaches. The scope includes investigation of a wide range of substances, including sesquiterpenes, phenolic compounds, chromo, volatile organic compounds, sesquiterpenoids and aromatic compounds. This study also aims to see how these ingredients can be used in traditional medicine, perfumery, and allied business.

However, it be not go into detail about the methods of growing or harvesting agarwood or the socioeconomic factors that influence its trade and production.

1.5 Significant of Study

It is crucial to conduct a thorough examination of the chemical constituents in agarwood because it sheds light on the distinctive scent and potential medicinal benefits of this priceless natural resource. The creation of innovative scents and natural medicinal agents can be aided by an understanding of the precise chemical components of agarwood and their functions in fragrance formulation and conventional medicine (Dahham et al., 2015). Additionally, this research has the potential to open new doors for creative applications in a variety of fields, such as herbal medicine, fragrance, and pharmaceuticals, broadening agarwood's commercial and therapeutic potential.

CHAPTER 2

LITERATURE REVIEW

2.1 Classification of Agarwood

Agarwood, also referred to as "oud" or "gaharu," is a highly prized aromatic resinous heartwood that originates in the tropical rainforests of Southeast Asia and the Indian subcontinent. Gyrinops and Aquilaria trees are the main producers of it. According to taxonomy, these trees belong to the Thymelaeaceae family, which has over 450 species and 50 genera. Many of these species are prized for their fragrant and valuable wood (Sasidharan et al., 2019). Especially valued for its part in the manufacture of agarwood is the genus Aquilaria. It is made up of about fifteen species that are spread out across the area, including some well-known species such as *Aquilaria crassna*, *Aquilaria sinensis*, and *Aquilaria malaccensis*. Due to their capacity to yield valuable heartwood, these species are frequently referred to as "Agarwood trees".

2.2 Morphology of Agarwood

The nature of the Agarwood tree is that it can live in various habitats such as rocky, sandy, or limestone areas, on hillsides, and areas near swamps. The leaves found on agarwood trees are oval and pointed. The leaf surface is shiny or waxy and is evergreen. The size of agarwood tree leaves is about 5 to 6 mm. The wood of *Aquilaria malaccensis* Agarwood is usually striped, the bark is gray and smooth. Agarwood trees are usually extreme and can reach a height of up to 40m. While the diameter of agarwood trees can reach up to 60cm (Chang et al., 2002). The average rate of

Agarwood tree diameter in Malaysia is quite low which is 0.33 cm per year. Agarwood trees take eight years to mature. The *Aquilaria malaccensis* species is more suitable for living in Peninsular Malaysia, Sabah, and Sarawak because this species is tougher than other Aquilaria species. This is because the agarwood tree species *Aquilaria malaccensis* does not die easily when there is a strong storm, or flood and is more resistant to live in uncertain weather conditions. This species of *Aquilaria malaccensis* can also produce high-quality agarwood essence compared to other species of Aquilaria.

2.3 The Life Cycle of Agarwood

Agarwood-producing trees go through a complex and lengthy life cycle that begins with seed germination and lasts for several decades before the highly valued material known as agarwood is formed. A thorough comprehension of this life cycle is essential to produce Agarwood in a sustainable manner (Nikolov et al., 2018). Agarwood's voyage starts when its seeds germinate, which usually happens in their native habitat. These seeds require a variety of environmental conditions to germinate successfully, such as the kind of soil, temperature, humidity, and shade. The future development and well-being of the Agarwood tree are influenced by these factors taken together.

Agarwood trees mostly produce regular heartwood during their early growth phases this heartwood lacks the distinctive scent and resinous characteristics that characterize mature Agarwood. These formative years are critical because they establish the tree's future ability to generate Agarwood. Agarwood trees are more vulnerable to environmental stresses as they get older. Physical harm from pests, animals, or fungal infections are examples of these stresses. The tree responds to these threats by triggering its defensive mechanisms, which causes the heartwood to produce resinous substances.

2.4 Production of Agarwood Resin

The resin produced from the stems and roots of the agarwood tree is caused by the agarwood tree being infected by fungi and bacteria. The period for the resin to form naturally takes about twenty years or more. Resin formation is caused by parasitic fungi such as Ascomycetous mold, Phaeoacremonium parasitica, and Dematiaceous (Pant, P. and Rastogi, R.P, 1980). The part of the wood that has produced resin has changed color from light or white to dark brown or black.

There is also an unnatural way to produce resin in the agarwood tree, which is the way human activity forces the agarwood tree to produce resin by injuring the tree. The resin on the agarwood tree produced when the trunk of the agarwood tree is drilled, cut, and nailed. For example, the trunk of Agarwood tree is drilled about one- third into the diameter of the tree with a hole size of at least 1.3 cm in diameter and inject 10 ml of inoculant into the hole that has been drilled (Pojanagaroon & Kaewrak 2006). The process is done because it can speed up the resin production process in the trunk of the Agarwood tree by taking nine to twenty-four months compared to the natural process that takes twenty years or more. Resin produced in the core part of the Agarwood tree as shown in (Figure 2.2) and the resin cell structure in the Agarwood tree as shown in (Figure 2.1).

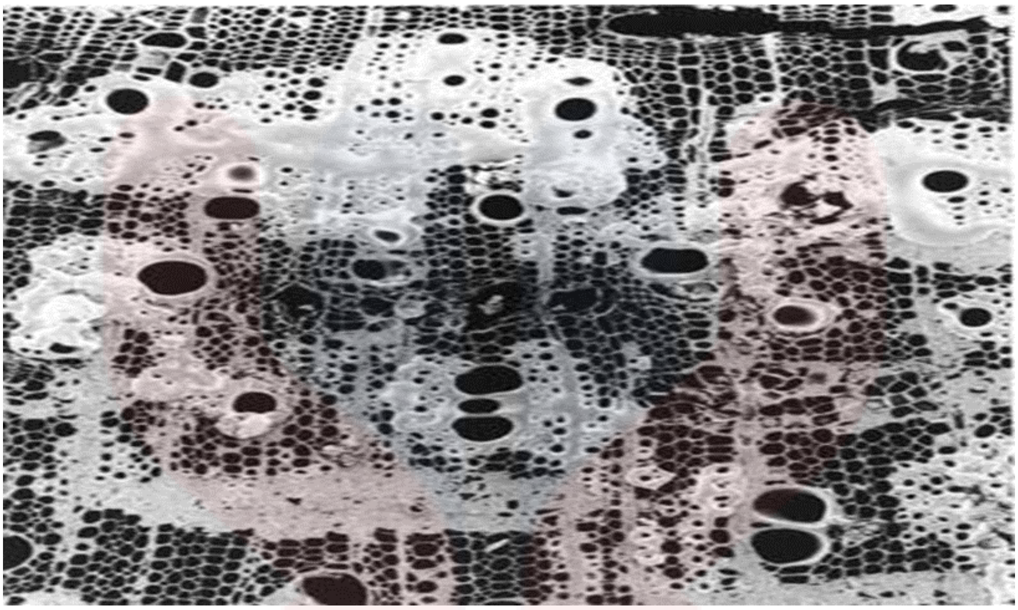


Figure 2.1: The white area of the cell structure of the agarwood tree shows the formation of resin.

Source: (https://malayherbsonline.blogspot.com/)

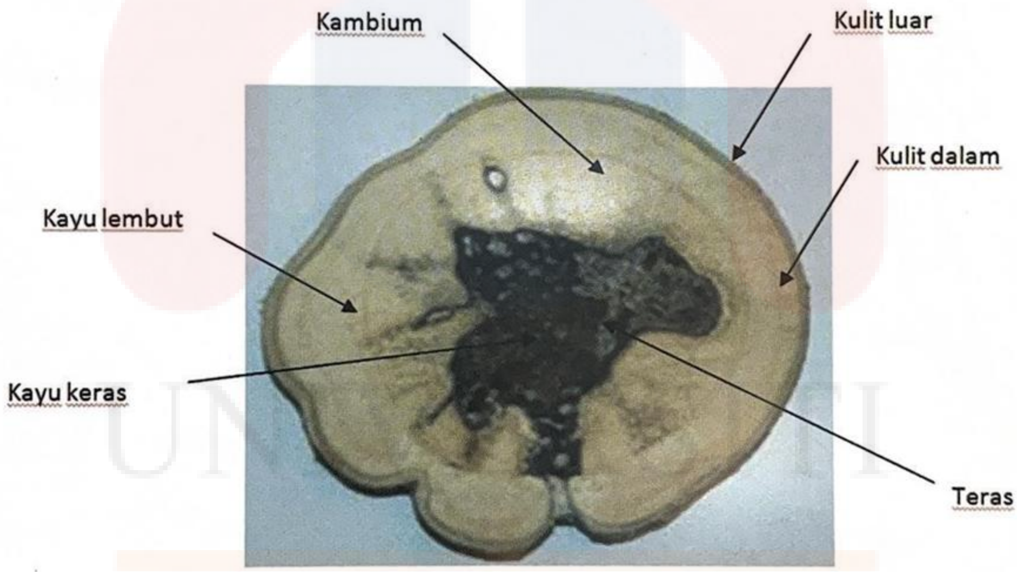


Figure 2.2: The cross-section of the trunk of an Agarwood tree.

Source: (https://forestpathology.cfans.umn.edu/research-projects/agarwood)

2.5 Basic Properties of Chemical Resin of Agarwood Tree

A surprising number of compounds are present in the Agarwood tree's essential oil. Sesquiterpene compounds, sesquiterpene alcohols, chromone derivatives, esters, and resins are typical components of Agarwood oil essence. In the context of Agarwood essential oil, the primary constituents responsible for defining the distinctive attributes of the aromatic essence are agarospirol, jinkolhol-eremol, jinkohol, and kusenol. In addition, additional compounds, including 2-(2-4'-methixyphenylethyl) chromone, inhibit the combustion-induced prolongation of the aroma of Agarwood oil.

Research has examined the phytochemical composition of Agarwood derived from various species, including *Aquilaria malaccensis* (Ishihara et al., 1991; Ng et al., 1997), and has identified the presence of sesquiterpen and multiple chromone fractions. Agarospirol compounds (Figure 4), dihydroagarofuran, a-agarofuran, B-agarofuran, kusonol (Figure 3), karanone, and jinkoh-eremol (Figure 5) are additional principal chemical components present in Agarwood oil essence (Ishihara et al. 1993; Nakanishi et al. 1984). Notwithstanding their common genus origin, the compounds extracted from agarwood vary from country to country. In contrast, specific Agarwood oil essences manufactured in Malaysia also yielded jinkohol (Figure 7) and jinkohol II (Chang et al. 2002).

Sesquiterpene compounds of various kinds have been documented in Agarwood oil essence. For the last three decades, intensive research has been devoted to sequester-pena in Agarus. Agarwood tree contains over thirty distinguished sesquiterpene compounds, of which fewer than ten are sesquiterpene hydrocarbons. Astaxanthin, selinane, prezizane, and agarospiran nootkatone are examples of sesquiterpene frameworks from which sesquiterpenes are derived. The attributes of the aroma of agarwood are influenced by the chemical composition of significant oxygenated sesquiterpenes, including agarospirol, jinkohol, jinkolhol-eremol, and kusenol. Agarwood oil typically comprises a complex blend of chemicals, including oxygenated compounds, sesquiterpene compounds, and sesquiterpene alcohol.

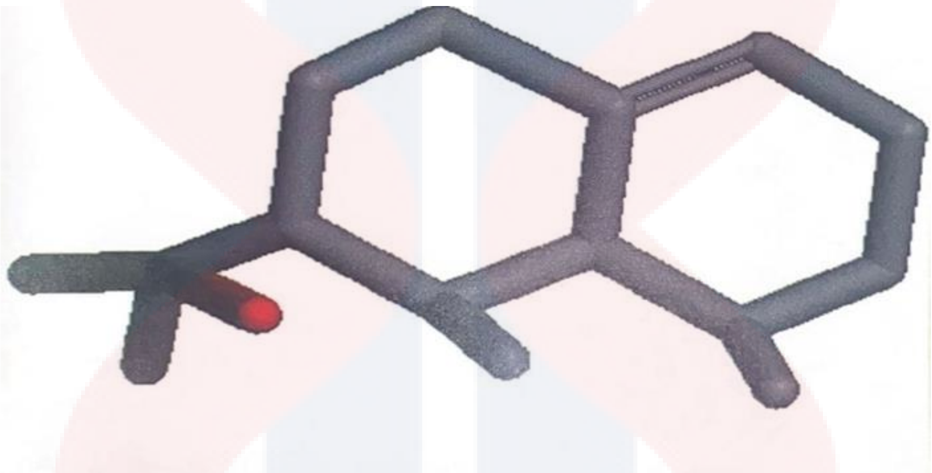


Figure 2.3: The molecular structure of Kusonol which is one of the main active compounds.

Figure 2.4: The molecular structure of Agarospirol which determines the quality of Agarwood oil.

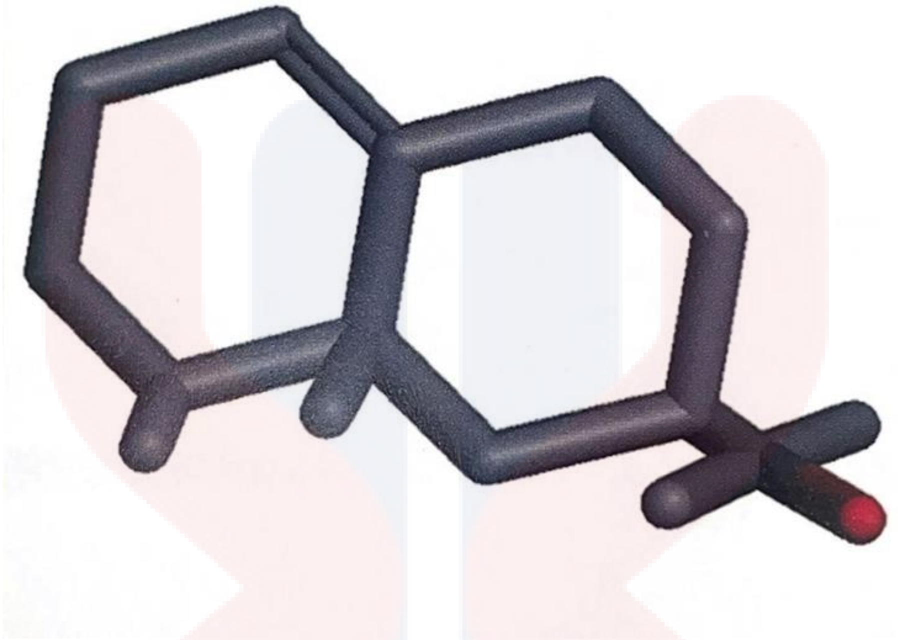


Figure 2.5: The molecular structure of jinkolhol-eremol which is also an important component in determining the level of quality of Agarwood oil essence.

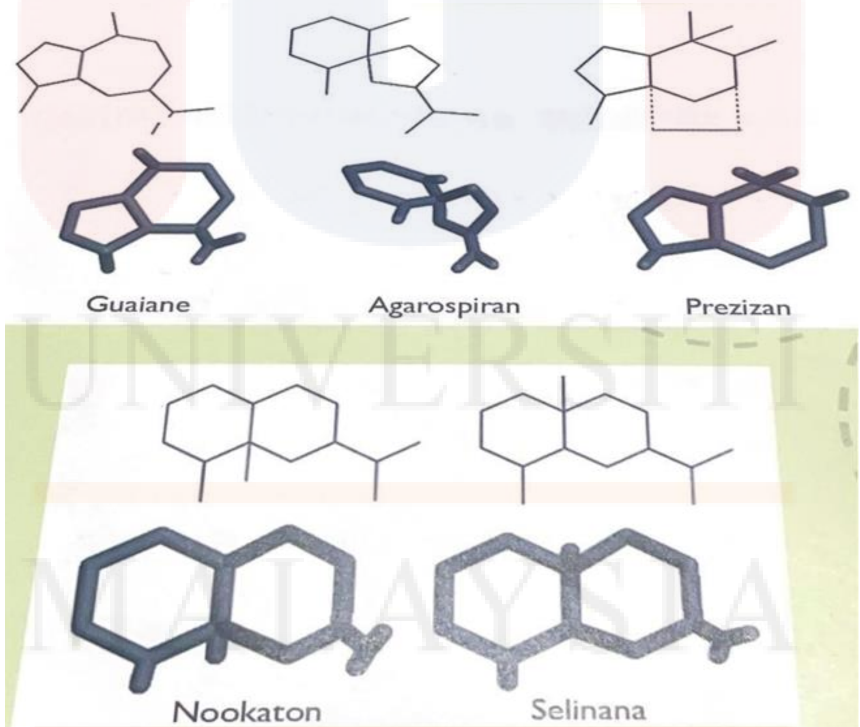


Figure 2.6: The Sesquiterpene hydrocarbon framework of Agarwood essential oil.

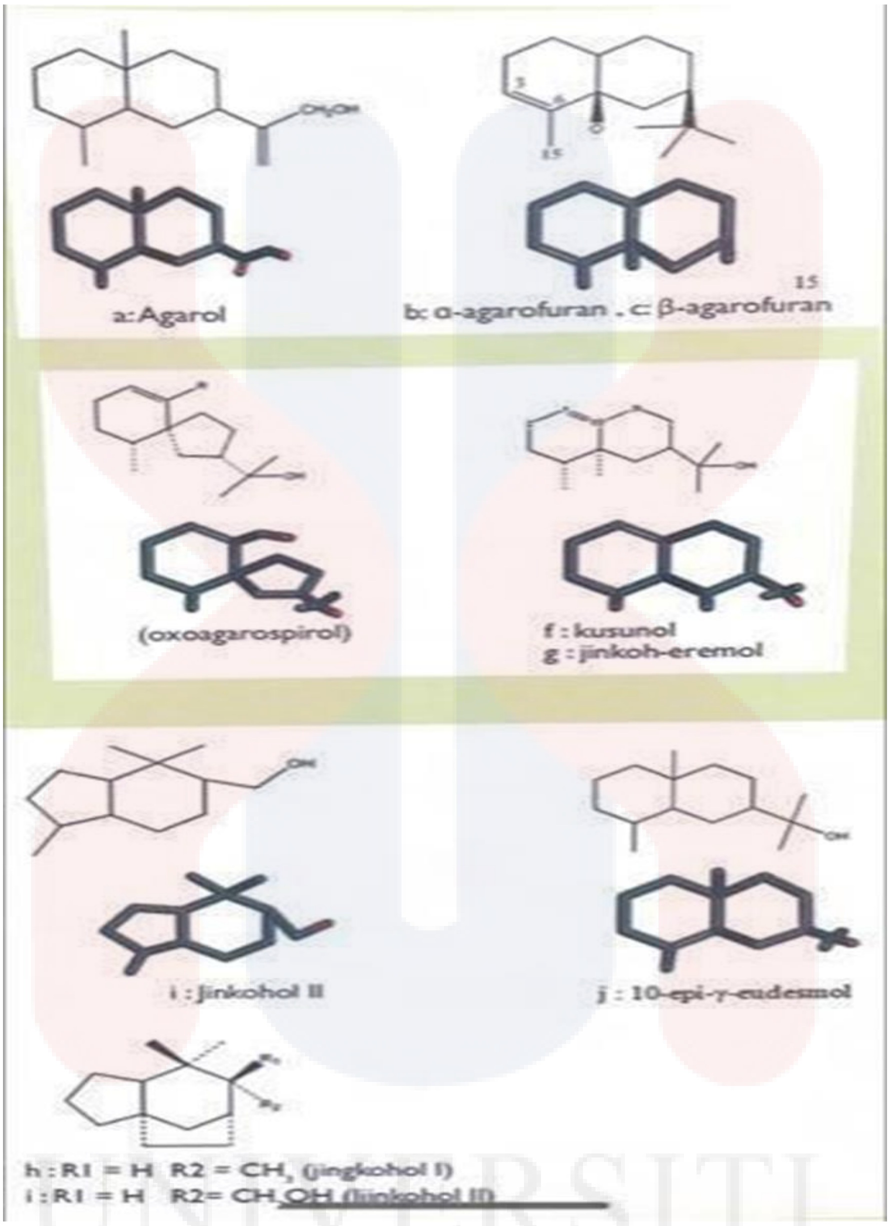


Figure 2.7: The oxygenated sesquiterpene skeleton of Agarwood oil Essence.

2.6 Origin, Distribution, and Habitats of Agarwood

Agarwood-producing trees find their native home in the lush landscapes of Southeast Asia, encompassing countries such as Thailand, Malaysia, Cambodia, and Indonesia. Flourishing primarily in tropical rainforests, these trees exhibit an extraordinary adaptability to a wide array of ecological niches within these verdant realms. They prefer well-drained, loamy soils, commonly along riverbanks and regions with consistent rainfall, where the dappled sunlight and humid climate provide an ideal environment for Agarwood's growth, ultimately yielding the coveted aromatic heartwood (Li et al., 2020).

The origins of Agarwood production can be traced back through the annals of history to Southeast Asian nations, where Thailand, Malaysia, Cambodia, and Indonesia stand as the historical cradles of these prized trees. Deeply entwined with cultural traditions and economic practices, Agarwood has been a fundamental element in traditional medicines, incense production, and perfumery in these regions (Sasidharan et al., 2019).

The distribution of Agarwood trees in these regions is intricately linked to a complex interplay of ecological factors, encompassing climate, geography, and soil conditions. From the rainforests of Thailand to the islands of Indonesia and the forests of Malaysia, Agarwood's adaptability is evident in its presence across diverse ecological niches (Nikolov et al., 2018). The conservation and responsible cultivation of these trees are crucial to ensure their enduring presence and the sustainable utilization of Agarwood resources within their native ecosystems.

2.7 Economic Uses of Agarwood

Agarwood, prized for its unique fragrance, has a wide range of economic applications. These applications extend to various sectors, including food, ornament, medicine, and even structural materials.

2.7.1 Food

Agarwood finds use in the culinary world due to its aromatic properties. While it is not a direct ingredient in dishes, it is employed to impart a distinctive aroma to foods. In some cultures, Agarwood smoke is used in food preparation to enhance the flavor of meats and rice dishes. Additionally, Agarwood is utilized in the production of high-quality tea, infusing the brew with its characteristic fragrance (Li et al., 2020).

2.7.2 Ornamental

The richly aromatic Agarwood is also used in the creation of ornamental items, particularly beads and carvings. These Agarwood ornaments are not only valued for their aesthetic appeal but also for the enduring fragrance they emit. They are often incorporated into jewelry and decorative items (Sasidharan et al., 2019).

2.7.3 Medicine

Agarwood has a long history of use in traditional medicine. Its essential oils and resins are believed to possess various therapeutic properties, including anti-inflammatory, analgesic, and sedative effects. Agarwood is used in traditional remedies to treat ailments such as digestive disorders, asthma, and skin conditions. Additionally, Agarwood's aromatic compounds are thought to have mood- enhancing and stress-relieving properties, making it a valued component in aromatherapy (Gao et al., 2021).

2.7.4 Structural Materials

Agarwood, although primarily recognized for its aromatic qualities, has been employed in the construction of structural materials. The wood's durability and resistance to decay make it suitable for crafting durable architectural components. In some instances, Agarwood has been used in the construction of temples and sacred structures in regions where it is prevalent, providing both strength and a distinctive aroma (Nikolov et al., 2018).

2.8 Pests and Diseases of Agarwood

Pests and diseases pose significant challenges to Agarwood cultivation, particularly in Southeast Asia. Insect infestations, led by Curculionidae beetles, create pathways within the heartwood, stimulating resin production that defines Agarwood's aromatic qualities. However, excessive infestations can damage the tree and reduce Agarwood quality, necessitating pest management strategies (Sasidharan et al., 2019).

Fungal diseases, notably from the Fusarium genus, also threaten Agarwood trees, compromising resin formation and heartwood quality. Preventative measures and interventions are required to protect Agarwood resources (Ismail et al., 2021). These challenges highlight the importance of integrated pest management and vigilant monitoring for sustainable Agarwood production (Nurfazi et al., 2019).

2.9 Threats and Conservation of Agarwood

The increasing demand for Agarwood, coupled with habitat destruction, has presented a significant threat to Agarwood-producing trees in the wild. This has led to the depletion of these valuable species. Agarwood trees, primarily belonging to the genera Aquilaria and Gyrinops, are facing various ecological pressures due to the escalating global interest in their aromatic heartwood. To address this challenge, numerous conservation efforts and regulations have been implemented to protect these endangered trees and promote sustainable Agarwood production (Wong et al., 2020).

The foremost threat to Agarwood-producing trees is the overharvesting of these slow-growing species. The relentless demand for Agarwood in perfumery, traditional medicines, and religious practices has resulted in widespread illegal logging and poaching. Furthermore, habitat destruction due to deforestation and land development has further diminished the natural habitats of Agarwood trees. These combined pressures pose a severe risk to the continued existence of these valuable trees in their native environments.

Efforts to address the threats facing Agarwood include the establishment of protected areas, controlled cultivation programs, and strict regulations on the harvest and trade of Agarwood. Protected areas and conservation initiatives are aimed at preserving the natural habitats of Agarwood-producing trees. Controlled cultivation programs promote sustainable Agarwood production by allowing trees to mature in managed environments, reducing the pressure on wild populations.

Regulations on Agarwood harvest and trade are essential to combat illegal logging and poaching. These regulations, often imposed at the national and international levels, help to monitor and control Agarwood production and trade, ensuring that it complies with sustainable practices.

In summary, Agarwood, renowned for its aromatic properties, is intrinsically tied to the life cycle of its producing trees and their ecological habitats. The overarching challenge is to meet the demand for Agarwood while conserving the species and their habitats. Sustainable cultivation and conservation measures, supported by rigorous regulations and protective efforts, are imperative to prevent the extinction of Agarwood-producing trees and ensure their enduring availability for future generations.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

This study conducted at UMK-Tropical Rainforest Research Centre (UMK-TRaCe) (5.5515° N, 101.3465° E), Pulau Banding, Perak. UMK-Tropical Rainforest Research Centre is located in the Temenggor Lake area. UMK-Tropical Rainforest Research Centre was established on 31st January 2022. This forest area is located high above sea level which is 250m to 2000m. The area of the forest in the Temenggor Lake area is around 300,000 hectares. There are more than 1000 Agarwood species trees (*Aquilaria Maleccensis*) planted in the UMK-Tropical Rainforest Research Centre and Pulau Banding area. Agarwood trees at UMK-Tropical Rainforest Research Centre live in hillside areas. Due to the biological diversity and relevance to my research, the agarwood tree, or its scientific name, (*Aquilaria malaccensis*), which is common in my area, has chosen the UMK TRaCe, Pulau Banding Perak.

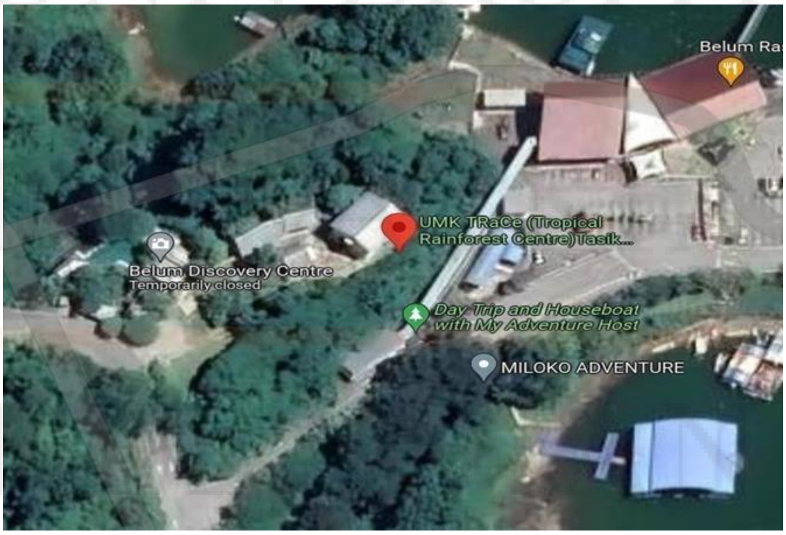


Figure 3.1: Map of UMK TRaCe, Pulau Banding Perak.

3.2 Materials and Methods

3.2.1 Experiment Design

This study conducted at UMK-Tropical Rainforest Research Centre (UMK-TRaCe) (5.5515° N, 101.3465° E), Pulau Banding, Perak. The reason I chose the UMK-Tropical Rainforest Research Centre area for the research that conducted is that there is a tree species that I want to study, which is the Agarwood tree (*Aquilaria malaccensis*). There are more than 1000 Agarwood trees planted in the area. In this study, I used three Agarwood trees (*Aquilaria malaccensis*) that have different levels of injury such as high damage, medium damage, and low damage by using the same method for the three Agarwood trees. Three Agarwood trees of the same species *Aquilaria malaccensis* divided into Tree A with high damage, Tree B with medium damage, and Tree C with low damage.

The study that carried out only uses the roots and trunks of the Agarwood trees, which is to study the chemicals found in the resin on the roots and trunks of the Agarwood trees. The first step I made in this study was to identify the identity of the Agarwood trees by using the Plant net application. The next step is to identify areas on the trunk and roots of the Agarwood trees that have produced resin by observation. The parts of the roots and stems of the Agarwood trees that have produced resin taken using a wooden saw. The part that has resin is taken and brought to the laboratory to carry out the process of extracting Agarwood oils. Agarwood oils extracted using a steam distillation technique.

Agarwood oils that was successfully extracted underwent an analysis technique using Gas Chromatography-mass Spectrometry (GC-MS). Each sample is injected into the GC, where it undergoes separation as it moves through the stationary phase. The separated compounds are then put into a mass spectrometer, where they are ionized and split up. Then the resulting mass spectra provide information on the molecular weight and structural characteristics of the compounds, enabling precise identification. GC-MS finds applications in various scientific disciplines, including environmental monitoring, forensic science, and pharmaceutical analysis (Smith et al., 2019). After carrying out GC-MS analytical techniques, I performed data analysis to identify and compare the chemical substances found in Agarwood oils from the root and trunk of Agarwood trees (*Aquilaria malaccensis*).

3.2.2 Sampling Resin at Root and Stem Agarwood

The steps that taken to take the resin found on the roots and stems of the Agarwood trees is to prepare equipment such as gloves, wood saws, containers, and hoes. Next, identify the part of the root and trunk from three Agarwood trees that have resin by observing bruises and injured areas on the part of the Agarwood trees. After identifying the resin found in the root and trunk of the Agarwood trees, the part split using a wooden saw to take the part of the wood that has the resin. Whileon the root part, it is hoeed to find the part that has resin and cut to take the resin. Thepart that has resin is taken and placed in a container. The estimated wood that has resin needed in this study is below 2kg from the stem and 600g from the root of each Agarwood trees. The part of the wood that has resin is taken and placed in a container to be taken to the laboratory to carry out the next process which is the process of extracting Agarwood oils.

Figure 3.2: The weight of the Agarwood stem.

Figure 3.3: The weight of the Agarwood root.

3.2.3 Process Extraction of Agarwood Oil

Prepare all necessary equipment, including knives, wood grinders, water, and steam distillation technique, before beginning the process of producing Agarwood oils. Next, use a knife to thinly slice the resin-containing wood portion so that grinding easier. After it has been chopped, the wood left to dry at room temperature for a week. To help speed up the decomposition of the agarwood oil after it is extractedin a steam distillation technique, the grinding process is done using a wood grinding machine. This is because the ground wood has broken down the Agarwood oil faster than the still solid wood causing the breaking down process to be slower. I decided to use the steam distillation technique unit to study the process of extracting Agarwood oil. This is because, compared to other processes, steam distillation technique equipment can process Agarwood oil faster between seven to nine hours.

For instance, the conventional approach to extracting Agarwood oils takes 48 to 72 hours and a significant amount of fuel energy (Adam et al.). I utilize a 0.015:1 ratio, which calls for utilizing 15g of Agarwood resin and 1L of tap water, to extract Agarwood oils. The extraction procedure takes place at the boiling point of water, which is 100 C, for seven to nine hours after adding Agarwood resin and water to the pressure cooker. Following successful extraction, the oil is extracted and used to begin the process of dissolving the compounds contained in the Agarwood oils.

Figure 3.4: The weight of each part of the agarwood tree that used to extract.

Figure 3.5: Each part of the stem and root of the agarwood tree that has been weighed.

Figure 3.6: The process of extracted Agarwood oil using steam distillation process.

3.2.4 Process to Identify Chemical Compounds of Agarwood Oil

The technique that used in this study is gas chromatography-mass spectrometry (GC-MS) analysis. According to Hashim et al., (2014) GCMS analysis was performed using an Agilent 7890A gas chromatography system (Agilent Technologies) coupled with a 5975 C quadrupole MSD detector. The first step that needs to be done for the analysis of chemicals found in Agarwood oil is to insert hexane solvent into 6 test tubes that have been filled with Agarwood oil, 3 from the root part and 3 from the trunk part of Agarwood tree A, B, and C.

The amount of hexane solvent that used is 1% of 100ml of hexane that put into the test tube of each sample for the purpose of dilution and reaching the concentration of the sample in hexane. Next, the amount of Agarwood oil that filled into the test tube is 0.2ml in each test tube. After each agarwood oil is dissolved with hexane solvent, each sample filtered using a syringe filter and put the sample into a GCMS vial. After that, each sample put into a gas chromatography-mass spectrometry (GC- MS) with an injection volume of 1 μL , a gas flow (helium) of 2ml/min, and a scan range of 32 to 500 Target Mass Rangedius to carry out the decomposition process. Finally, the MSD quadrupole 5975 C detector has detected the chemicals found in Agarwood oil which are GCMS highlights detected based on total ion chromatography (TIC) and mass chromatogram and further identified using the National Institamuute of Standards and Technology (NIST) 2008 mass spectrum library.

Figure 3.7: The process of filtering the sample to be inserted into the GCMS vial.

Figure 3.8: Gas chromatography-mass spectrometry (GC-MS).

3.3 Data Analysis

3.3.1 T-test

T-test data analysis was also used in this study. The T-test was used in this study to compare the difference in the volume of Agarwood oil that has been extracted from the roots and stems of Agarwood trees from trees A, B, and C. The T- test is a statistical test used to determine the same there is a significant difference between the way the two groups and how they relate. It is used for hypothesis testing in statistics and requires three basic data values, including the difference between the mean values from each data set, the standard deviation of each group and the number of data values. The T-test produces two values as its output: the t-value and degrees of freedom. The t-value is the ratio of the difference between the means of two sets of samples and the variation inherent in the sets of samples. The T-test can only be used when comparing the means of two groups that follow a normal distribution and have unknown variance.

3.3.2 Qualitative Analysis

Qualitative analysis was also used in this study. Qualitative analysis of Agarwood oil focuses on identifying the various chemical compounds present in the Agarwood oil of stems and roots tree A, tree B, and tree C without quantifying their exact amounts.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Agarwood oil extracts from stem and roots of *Aquilaria malaccensis.*

Stems of *Aquilaria malaccensis* produce more oil that can be extracted compared to roots using steam distillation process with a weight of 15g of dried Agarwood samples. There are 3 samples from stems and 3 more samples from roots.

Table 4.1: Fresh weight and volume of oil extracts from stems and roots of *Aquilaria malaccensis* .

Parameters by organs	***Aquilaria malaccensis***			
	Tree A	Tree B	Tree C	Average
Stems (Tree Bark)				
Fresh weight (g)	15	15	15	45
Volume of oil extracts (ml)*	0.4	0.2	0	0.6
Roots				
Fresh weight (g)	15	15	15	45
Volume of oil extracts (ml)*	0.2	0	0	0.6
* 15g of dried Agarwood samples, steam distillation process				

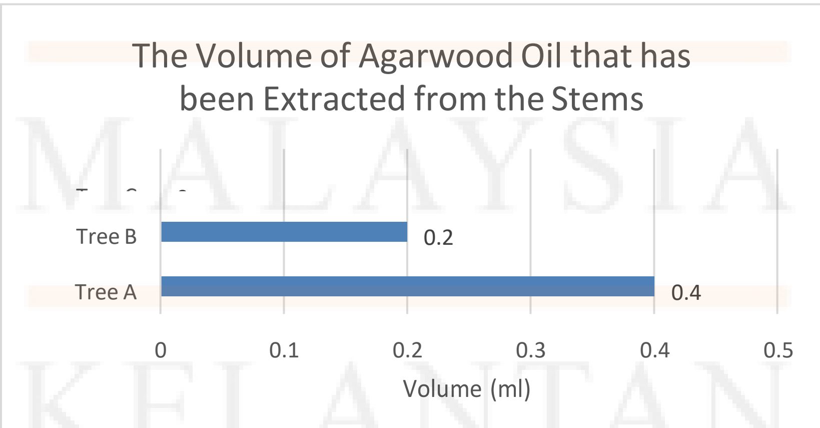


Figure 4.1: The volume of Agarwood oil that has been extracted from the stems of trees A, B, and C (ml).

Figure 4.1 shows the volume of Agarwood oil that has been extracted from the stems. Tree A recorded the highest amount of oil extract which was 0.4 ml obtained from the trunk which is the bark of the tree followed by tree B, recording as much as 0.2 ml tree C was empty.

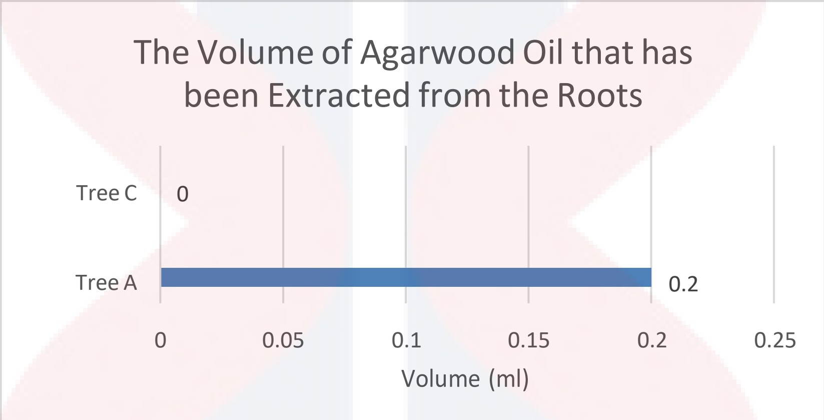


Figure 4.2: The volume of Agarwood oil that has been extracted from the roots oftrees A, B, and C (ml).

Figure 4.2 shows the volume of Agarwood oil that has been extracted from the roots of trees A, B, and C (ml) However, the volume of Agarwood Oil roots from pad tree A recorded 0.2ml, other than tree B and tree C did not record any volume. Overall, the volume of Agarwood oil that has been extracted from the stem is the highest in tree 1 which is 0.4ml while the volume of Agarwood oil that has been extracted from the root is the highest in the tree. This is due to several factors that cause the volume of stems and roots. Roots are primarily underground plant organs, which means they are usually not as susceptible to disturbance or physical attack as above- ground parts such as stems and leaves. Because of this, environmental differences grow into the cause of change in each sample. (Lynch, J.P. 2007).

Table 4.2: T-test data means of volume of oil extract from stems and roots tree *Aquilaria malaccensis.*

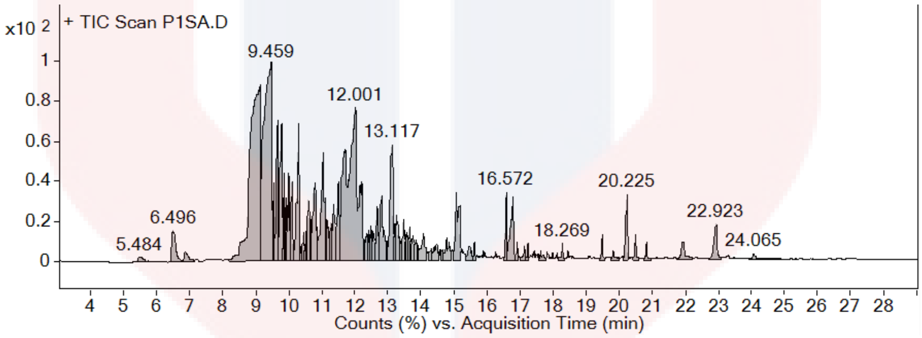
Group	N	M	SD	SE
Stems	3	0.2	0.2	0.11547
Roots	3	0.0667	0.1155	0.066667

T-test for paired two samples for means compare the volume of oil extracts between stems and roots. It has been hypothesized that there more volume in stems than in roots. The results of stems show that (M=.2, SD=.2), compared to roots (M.0667, SD=.115), T(2)=2, P<.091.

4.2 Chromatogram of Agarwood Oil Extracts from Stems and Roots of *Aquilaria malaccensis*

a

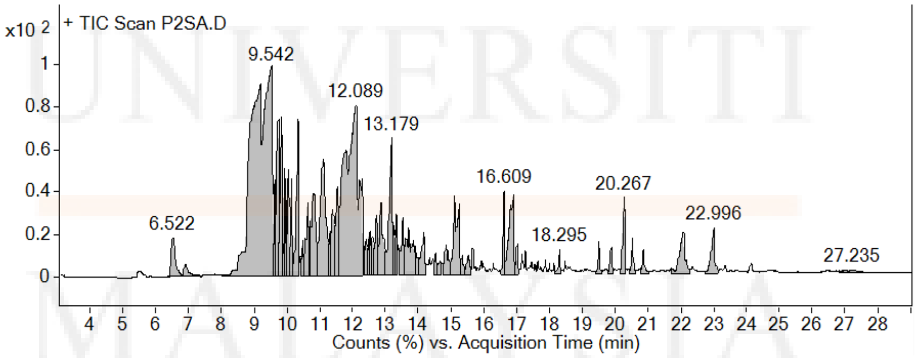
Steams (Tree Bark)



Integration Peak List

Peak	Start	RT	End	Height	Area	Area %
1	8.182	9.126	9.152	62156982.39	1381235883	100
2	9.152	9.459	9.51	70477616.23	1165270556	84.36
3	9.562	9.661	9.676	49918376.01	217495850.8	15.75
4	9.676	9.765	9.811	49009783.37	225476926.4	16.32
5	9.811	9.853	9.874	31529499.9	69904094.9	5.06
6	9.936	9.988	10.04	30853631.92	123014119	8.91
7	10.133	10.289	10.335	48891705.61	218856883.9	15.85
8	10.875	11.041	11.103	38711613.83	289699415.9	20.97
9	11.544	12.001	12.26	54164177.28	1367956412	99.04
10	12.987	13.117	13.174	41324362.52	241278882.9	17.47

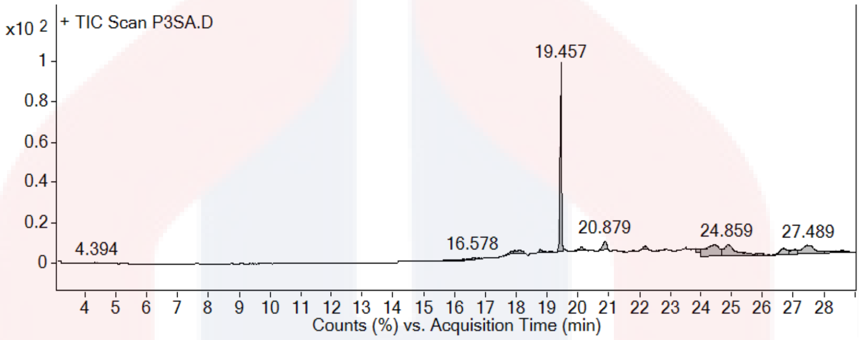
b)



Integration Peak List

Peak	Start	RT	End	Height	Area	Area %
1	8.016	9.542	9.588	73177819.65	3071887834	100
2	9.63	9.729	9.744	54558496.95	266329935	8.67
3	9.744	9.832	9.869	55261064.21	266457043.7	8.67
4	9.869	9.915	9.931	37843683.39	87312157.63	2.84
5	9.988	10.04	10.087	37120597.59	148992924.9	4.85
6	10.087	10.133	10.18	33794864.23	100572576.1	3.27
7	10.18	10.336	10.377	54191164.45	273248346.5	8.9
8	10.922	11.098	11.259	40610652.55	483499612.1	15.74
9	11.581	12.089	12.318	59113411.26	1716203939	55.87
10	12.992	13.179	13.236	47603577.77	339265764.3	11.04

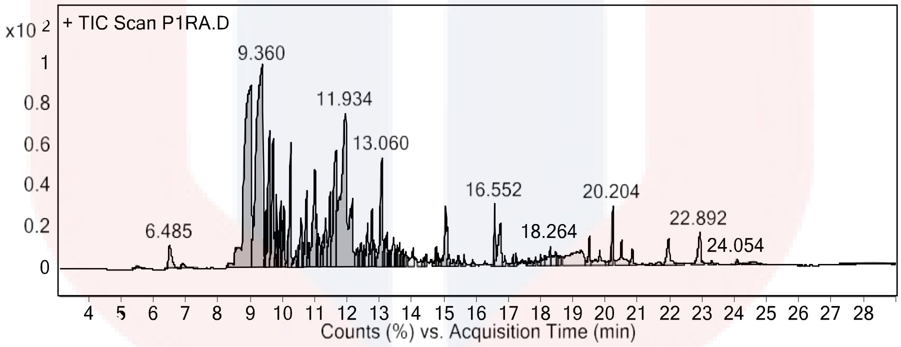
c)



Integration Peak List

Peak	Start	RT	End	Height	Area	Area %
1	17.656	18.139	18.266	594501.28	13508540.01	12.11
2	18.669	18.752	19.198	580596.61	4753820.67	4.26
3	19.344	19.457	19.525	27460742.61	111571595.1	100
4	20.701	20.879	20.993	1301025.57	11461769.54	10.27
5	23.821	23.852	23.987	645212.32	5949104.09	5.33
6	23.987	24.438	24.667	1647676.82	54121904.13	48.51
7	24.667	24.859	25.658	1693346.96	47468116.33	42.54
8	26.317	26.68	26.867	1022875.86	19055276.69	17.08
9	26.867	27.033	27.152	781344.43	11756482.71	10.54
10	27.152	27.489	27.998	1275908.32	38464675.04	34.48

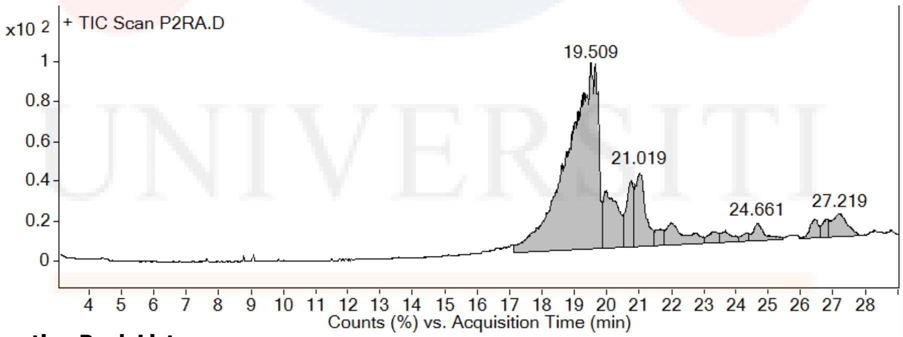
d) Roots



Integration Peak List

Peak	Start	RT	End	Height	Area	Area %
1	8.27	9.007	9.049	62168429.04	1007557984	100
2	9.049	9.36	9.427	69129505.61	966880659.4	95.96
3	9.474	9.578	9.604	46679770.09	175774024.5	17.45
4	9.604	9.687	9.754	44001711.82	174950984.5	17.36
5	10.175	10.226	10.289	42548059.23	128223280.8	12.73
6	10.647	10.74	10.761	26410643.26	111445810.8	11.06
7	10.844	10.984	11.051	33437566.1	212642125.3	21.1
8	11.503	11.643	11.669	40056536.78	279931440.4	27.78
9	11.669	11.934	12.245	52363658.07	807812620.5	80.18
10	12.919	13.06	13.117	37374226.33	187851516.3	18.64

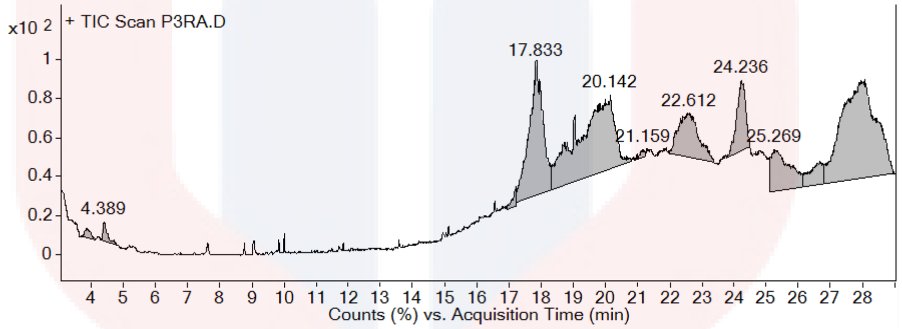
e)



Integration Peak List

Peak	Start	RT	End	Height	Area	Area %
1	17.143	19.509	19.857	6267894.89	414686153	100
2	19.857	19.971	20.526	1948477.99	62009817.04	14.95
3	20.526	20.739	20.837	2283749.93	33636267.47	8.11
4	20.837	21.019	21.46	2516579.7	55571058.22	13.4
5	21.46	21.605	21.776	545203.4	10107333.78	2.44
6	21.776	21.994	23.011	739494.95	31149608.56	7.51
7	24.402	24.661	25.445	595911.13	15791363.53	3.81
8	25.948	26.436	26.597	642437.97	12455031.14	3
9	26.597	26.804	26.867	632223.01	8779624.62	2.12
10	26.867	27.219	27.889	770872.63	26336817.49	6.35

f)



Integration Peak List

Peak	Start	RT	End	Height	Area	Area %
1	3.725	3.855	4.14	53765.59	681726.51	1.68
2	4.286	4.389	4.813	106378.66	1139556.73	2.81
3	16.941	17.19	17.221	109249.74	867277.4	2.14
4	17.221	17.833	18.305	736256.68	21882914.73	54.05
5	18.305	20.142	20.796	407210.15	32611893.92	80.55
6	21.959	22.612	23.358	238923.24	10721193.42	26.48
7	23.759	24.236	24.479	386323.91	7519719.33	18.57
8	25.118	25.269	26.13	231111.2	8979504.34	22.18
9	26.13	26.654	26.784	129071.1	3762825.05	9.29
10	26.784	28.05	28.966	538901.99	40485094.76	100

Figure 4.2: Peak Chromatogram of Agarwood oil extracts derived from (a-c) stems and (d-f) roots of *Aquilaria malaccensis.*

In this section, here is the result of the chromatogram peak that refers to the chemical compounds present in the sample of stems and roots of tree A, tree B, and tree C of *Aquilaria malaccensis*. The sample of stem tree A shows 41 chemical compounds present which are Cyclohexanol, 5-methyl-2-(1-methylethyl)- for peak 1 that present in retention time 5.385-5.749 minutes, 2-Butanone, 4-phenyl- for peak 2 that present in retention time 6.418-6.667 minutes, and beta.-Guaiene for peak 10 that present in retention time 9.874-9.910 minutes. Besides that, the sample of stem tree B shows 32 chemical compounds present which are 2-Butanone, 4-phenyl- for peak 1 that present in retention time 6.423-6.714 minutes, 2-Propenal, 3-phenyl- for peak 2 that present in retention time 6.818-7.321 minutes, and gamma.-HIMACHALENE for peak 10 that present in retention time 10.087-10.180 minutes.

Next, the sample of stem tree C shows only 4 chemical compounds present which are Limonen-6-ol, pivalate for peak 1 that present in retention time 4.311- 4.773 minutes, Betulin for peak 2 that present in retention time 15.618-16.676 minutes, and Chrysene-D12 for peak 5 that present in retention time 19.369-19.473 minutes. Stems tree A and tree B show more chemical compounds presents compared to stem tree C. This is because stems from tree A and tree B have Agarwood oil while tree C doesn't have Agarwood oil.

In addition, the chromatogram peak also shows chemical compounds present in the sample of roots tree A, tree B, and tree C. The sample of root tree A shows 43 chemical compounds present which are Cyclohexanol, 5-methyl-2-(1-methylethyl)- for peak 1 that present in retention time 5.401-5.749 minutes, 2-Butanone, 4-phenyl- for peak 2 that present in retention time 6.423-6.662 minutes, and beta.-Guaiene for peak 11 that present in retention time 9.848-9.879 minutes.

Besides that, the sample of root tree B shows only 2 chemical compounds present which are Lup-20(29)-en-3-one for peak 1 that present in retention time 17.641-19.857 minutes, and Betulin for peak 2 that present in retention time 19.857-20.526 minutes. Next, root tree C shows only 4 chemical compounds present which are p-Menth-8(10)-ene-2,9-diol for peak 1 that present in retention time 3.741-4.140 minutes, Octadecane, 1-chloro- for peak 2 that present in retention time 4.317-4.747 minutes, and Betulin for peak 3 that present in retention time 16.941-17.221 minutes.

Root tree A shows more chemical compounds present compared to roots tree B and tree C. This is because the root of tree A has Agarwood oil while the roots of tree B and tree C don't have Agarwood oil.

4.3 Chemical Compounds in Agarwood Oil Extracts from *Aquilaria malaccensis*

This section uses qualitative analysis to analyze the chemical compounds of Agarwood oil extracted from the stems and roots of *Aquilaria malaccensis* from trees A, B, and C. The measured parameters are the types of chemical compounds of different classes such as sesquiterpene compounds, sesquiterpenoids, and other compounds. Sesquiterpenes and sesquiterpenoids refer to the compounds that produce the fragrant aroma found in agarwood oil. Other compounds are compounds that provide additional aroma in Agarwood oil or compounds that are present accidentally during the identification process of chemical compounds using GCMS, as illustrated in Table 4.3.1 and Table 4.3.2.

Table 4.3.1: Shows chemical compounds in Agarwood oil extracts from stems of *Aquilaria malaccensis* at UMK-TRaCe

Parameters	***Aquilaria malaccensis* (Stems)**		
Type of Compounds	**Tree A**	**Tree B**	**Tree C**
Sesquiterpenes	.beta.-Guaiene	.beta.-Guaiene	
	.beta.-Santanol acetate	gamma.-HIMACHALENE	
	.gamma.-HIMACHALENE	1,4,7,Cycloundecatriene,1,5,9,9- tetramethyl-, Z,Z,Z-	
	Naphthalene, decahydro-4a-methyl-1-methylene-7-(1-methylethylidene)-, (4aR- trans)-	1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-octahydro-1,1,4,7-tetramethyl-, [1aR-(1a.alpha.,4.alpha.,4a.beta.,7b.alpha.)]-	
		4,6,6-Trimethyl-2-(3- methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octan e	

Sesquiterpenoids	.gama.-eudesmol	.beta.-Santanol acetate	
	1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-	.gama.-eudesmol	
	1H-2,8a-Methanocyclopenta[a]cyclopropa[e]cyclodecen-11-one, 1a,2,5,5a,6,9,10,10a-octahydro-5,5a,6-trihydroxy- 1,4-bis(hydroxymethyl)-1,7,9-trimethyl-, [1S-(1.alpha.,1a.alpha.,2.alpha.,5.beta.,5a.beta.,6.beta.,8a.alpha.,9.alpha.,10a.alpha.)]-	1H-2,8a-Methanocyclopenta[a]cyclopropa[e]cyclodecen-11-one, 1a,2,5,5a,6,9,10,10a-octahydro-5,5a,6-trihydroxy- 1,4-bis(hydroxymethyl)-1,7,9-trimethyl-, [1S-(1.alpha.,1a.alpha.,2.alpha.,5.beta.,5a.beta.,6.beta.,8a.alpha.,9.alpha.,10a.alpha.)]-	
	1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene-, [1ar-(1a.alpha.,4a.alpha.,7.beta.,7a.beta.,7b.alpha.)]-	2(1H)-Naphthalenone, 4a,5,6,7,8,8a-hexahydro-6-[1-(hydroxymethyl)ethenyl]- 4,8a- dimethyl-, [4ar-(4a.alpha.,6.alpha.,8a.beta.)]	
	1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-octahydro-1,1,4,7-tetramethyl-, [1aR-(1a.alpha.,4.alpha.,4a.beta., 7b.alpha.)]-	2-Pentenoic acid, 5-(decahydro-5,5,8a-trimethyl- 2-methylene-1-naphthalenyl)-3-methyl-, methyl ester, [1R-[1.alpha.(E),4a.beta.,8a.alph a.]]-	
	1H-Cyclopropa[a]naphthalene, 1a,2,3,5,6,7,7a,7b-octahydro-	3-Oxo-10(14)-epoxyguai-11(13)-en-6,12-olide	

	1,1,7,7a-tetramethyl-, [1aR-(1a.alpha.,7.alpha., 7a.alpha., 7b.alpha.)]-		
	2(1H)-Naphthalenone, 4a,5,6,7,8,8a-hexahydro-6- [1-(hydroxymethyl)ethenyl]- 4,8a-dimethyl-, [4ar-(4a.alpha.,6.alpha.,8a.beta.)] -	6-Isopropenyl-4,8a dimethyl-1,2,3,5,6,7,8,8a-octahydronaphthalene-2,3-diol	
	2-Pentenoic acid, 5- (decahydro-5,5,8a-trimethyl-2-methylene-1-naphthalenyl)-3-methyl-, methyl ester, [1R-[1.alpha.(E),4a.beta.,8a.alph a.]]-	Acetic acid, 3-hydroxy-6- isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-octahydronaphthalen-2-ylester	
	3-Oxo-10(14)-epoxyguai-11(13)-en-6,12-olide	Azulene, 1,2,3,3a,4,5,6,7-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,3a.beta.,4.alpha.,7. beta.)]-	
	4,6,6-Trimethyl-2-(3-methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octan e	Corymbolone	
	5,19-Cyclo-5.beta.-androst-6-ene-3,17-dione	Cyclohexanemethanol, 4-ethenyl-.alpha.,.alpha.,4-trimethyl-3-(1-methylethenyl)-, [1R-(1.alpha.,3.alpha.,4.beta.)]-	
	6-Isopropenyl-4,8a- dimethyl-1,2,3,5,6,7,8,8a-octahydronaphtha	Longifolenaldehyde	

	lene-2,3- diol		
	9-Methoxycalamenene	Naphthalene, decahydro-4a-methyl-1-methylene-7-(1-methylethylidene)-, (4aR- trans)-	
	Acetic acid, 3-hydroxy-7- isopropenyl-1,4a-dimethyl-2,3,4,4a,5,6,7,8-octahydronaphthalen-2-ylester	Propanoic acid, 2-methyl-, (dodecahydro-6a-hydroxy- 9a-methyl-3-methylene-2,9-dioxoazuleno[4,5-b]furan-6- yl)methyl ester, [3aS-(3a.alpha.,6.beta.,6a.alpha.,9 a.beta.,9b.alpha.)]-	
	Azulene, 1,2,3,3a,4,5,6,7-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,3a.beta.,4.alpha.,7. beta.)]-	Selina-3,7(11)-diene	
	Corymbolone		
	Cyclohexanemethanol, 4-ethenyl-.alpha.,.alpha.,4-trimethyl-3-(1-methylethenyl)-, [1R-(1.alpha.,3.alpha.,4.beta.)]-		
	Cyclohexanol, 5-methyl-2-(1-methylethyl)-		
	Dasycarpidan-1-methanol, acetate (ester)		
	Longifolenaldehye		

	Murolan-3,9(11)-diene-10-peroxy		
	Propanoic acid, 2-methyl-, (dodecahydro-6a-hydroxy-9a-methyl-3-methylene- 2,9-dioxoazuleno[4,5- b]furan-6-yl)methyl ester, [3aS-(3a.alpha.,6.beta.,6a.alpha.,9a.beta.,9b.alpha.)]-		
	Selina-3,7(11)-diene		
Other Compounds	1-Heptatriacotanol	1-Heptatriacotanol	Betulin
	2,3Dihydroxypropyl elaidate	2,3-Dihydroxypropyl elaidate	Chrysene-D12
	2-Butanone, 4-phenyl-	2-Butanone, 4-phenyl-	Fenretinie
	3-Pentanone, 1,5-diphenyl-	2-Propenal, 3-phenyl-	Limonen-6-ol, pivalate
	6-Octadecenoic acid	5,19-Cyclo-5.beta.-androst- 6-ene-3,17-dione	
	Betulin	6-Octadecenoic acid	
	Bis(2-ethylhexyl) phthalate	Betulin	
	Cinnamaldehyde, (E)-	Bis(2-ethylhexyl) phthalate	
	Estra-1,3,5(10)-trien-17.beta.-ol	Dasycarpidan-1-methanol, acetate (ester)	
	Fenretinide	Estra-1,3,5(10)-trien- 17.beta.-ol	

	Isopropyl linoleate	Fenretinide	
	N,N'Bis(Carbobenzyloxy)-lysine methyl(ester)	trans-Geranylgeraniol	
	Retinal, 9-cis-	Hexadecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester	
Total Number of Sesquiterpenes	4	5	0
Total Number of Sesquiterpenoids	23	15	0
Total Number ofOther Compounds	14	12	4
Overall Total	41	32	4

Based on table 4.3.1 shows the chemical compounds in Agarwood *Aquilaria malaccensis* oil extract at UMK-TRaCe from tree stems A, B, and C that have been separated according to the type of compounds such as sesquiterpene compounds, sesquiterpenoids, and other compounds. The stem of the A tree showed a total of 4 sesquiterpene compounds, such as .beta.-Guaiene, .gamma.-HIMACHALENE, and Naphthalene, decahydro-4a-methyl-1-methylene-7-(1-methylethylidene).)-, (4aR-trans)-. For example, the compound .beta.-Guaiene can produce the woody, earthy, and spicy aromas found in agarwood oil. As for sesquiterpenoid compounds, the stem of tree A has shown as many as 23 total compounds consisting of .gama.- eudesmol, Selina-3,7(11)-diene, and 3-Oxo-10(14)-epoxyguai-11 (13) - ene-6,12- olide. For example, .gama.-eudesmol can give an aromatic smell such as woody, slightly sweet, and floral. For other compounds, the stem of tree A has shown as many as 14 compounds consisting of 1-Heptatriacotanol, 2-Butanone, 4-phenyl-, and Betulin. For example, the compound 2-Butanone, 4-phenyl- can give a very pleasant fruity and floral aromatic smell. The total number of chemical compounds found in the stem of tree A is 41 compounds.

In addition, the stem of tree B has shown as many as 5 sesquiterpene compounds such as. beta. -Guaiene,. gamma.-HIMACHALENE, and 1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl- , Z , Z, Z-. For example, the compound.gamma.-HIMACHALENE has a woody, balsamic, and slightly sweet smell. While for sesquiterpenoid compounds there are only 15 compounds such as. gama.-eudesmol,6-Isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a octahydronaphthalene-2,3- diol, and Selina-3,7(11)-diene. For example, the compound 6-Isopropenyl-4,8a- dimethyl-1,2,3,5,6,7,8,8a-octahydronaphthalene-2,3- diol can provide a unique aromatic odor that makes it potentially useful in the fragrance industry. As for other compounds found in the stem of tree B, there are only 12 compounds consisting of compounds 2-Propenal, 3-phenyl-, 2-Butanone, 4- phenyl-, and Hexadecanoic acid, 1-(hydroxymethyl)-1,2-ethanediol esters. For example, the compound 2-Propenal, 3-phenyl- known as cinnamaldehyde has a warm aromatic smell, spicy, and sweet smell. The total number of compounds found in the stem of tree B is 32 compounds.

Next, the stem of tree C only shows other compounds found in the sample and does not show any sesquiterpene and sesquiterpenoid compounds. This is because stem tree C does not extract any Agarwood oil compared to stem trees A, and B. Tree trunk C only shows 4 compounds consisting of Betulin, Chrysene-D12, Fenretinide, and Limonen-6-ol, pivalate. For example, the compound Chrysene-D12 is used as an internal standard in the GC-MS analysis of agarwood oil, improving the accuracy, consistency, and reliability of analytical results, enabling more accurate identification and quantification of compounds in agarwood oil.

4.3.2 : Chemical compounds in Agarwood oil extracts from roots of *Aquilaria malaccensis* at UMK-TRaCe.

Parameters Type of Compounds	***Aquilaria malaccensis* (Roots)**		
	Tree A	**Tree B**	**Tree C**
Sesquiterpenes	beta-Guainene		
	1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-		
	.gamma.-HIMACHALENE		
	1H-Cyclopropa[a]naphthalene, 1a,2,3,5,6,7,7a,7b-octahydro-1,1,7,7a-tetramethyl-, [1aR-(1a.alpha.,7.alpha.,7a.alpha.,7b.alpha.)]-		
	4,6,6-Trimethyl-2-(3-methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octane		
	Naphthalene, 1,2,3,4,4a,5,6,8a-octahydro-7-methyl-4-methylene-1-(1-methylethyl)-, (1.alpha.,4a.beta.,8a.alpha.)-		
	Naphthalene, decahydro-4a-methyl-1-methylene-7-(1-methylethylidene)-, (4aR-trans)-		
Sesquiterpenoids	gama.-eudesmol		

	1,6,10-Dodecatrien-3-ol,3,7,11-trimethyl-		
	1H-2,8a-Methanocyclopenta[a]cyclopropa[e]cyclodecen-11- one, 1a,2,5,5a,6,9,10,10a-octahydro-5,5a,6-trihydroxy-1,4-bis(hydroxymethyl)-1,7,9- trimethyl-, [1S-(1.alpha.,1a.alpha.,2.alpha. ,5.beta.,5a.beta.,6.beta.,8a. alpha.,9.alpha.,10a.alpha.)] -		
	1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-octahydro-1,1,4,7-tetramethyl-, [1aR-(1a.alpha.,4.alpha.,4a.beta. ,7b.alpha.)]-		
	1H-Cyclopropa[3,4]benz[1,2-e]azulene-5,7b,9,9a-tetrol, 1a,1b,4,4a,5,7a,8,9-		
	octahydro-3-(hydroxymethyl)-1,1,6,8-tetramethyl-, 5,9,9a-triacetate, [1aR-(1a.alpha.,1b.beta.,4a.beta. ,5.beta.,7a.alpha.,7b.alpha. ,8.alpha.,9.beta.,9a.alpha.)]		
	2(1H)-Naphthalenone, 4a,5,6,7,8,8a-hexahydro-6-[1-(hydroxymethyl)ethenyl]-4,8a-dimethyl-, [4ar-(4a.alpha.,6.alpha.,8a.beta.)]-		

	2-[4-methyl-6-(2,6,6-trimethylcyclohex-1-enyl)hexa-1,3,5- trienyl]cyclohex-1-en-1- carboxaldehyde		
	2- Naphthalenemethanol, 1,2,3,4,4a,5,6,7-octahydro-.alpha.,.alpha.,4a,8-tetramethyl-, (2R-cis)-		
	3- Oxo-10(14)-epoxyguai-11(13)-en-6,12-olide		
	5.beta.,7.beta.H,10.alpha.-Eudesm-11-en-1.alpha.-ol		
	6-(1-Hydroxymethylvinyl)-4,8a-dimethyl-3,5,6,7,8,8a-hexahydro-1H-naphthalen-2-one		
	6-Isopropenyl-4,8a-dimethyl- 1,2,3,5,6,7,8,8a-octahydronaphthalene-2,3-diol		
	9-Methoxycalamenene		
	Acetic acid, 3-hydroxy-7-isopropenyl-1,4a-dimethyl- 2,3,4,4a,5,6,7,8-octahydronaphthalen-2-yl ester		
	Azulene, 1,2,3,3a,4,5,6,7-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,3a.beta.,4.alpha.,7.beta.)]-		
	Corymbolone		
	Cyclohexanemethanol, 4-ethenyl-.alpha.,.alpha.,4-trimethyl-3-(1-methylethenyl)-, [1R-		

	(1.alpha.,3.alpha.,4.beta.)]-		
	Longifolenaldehyde		
	Murolan-3,9(11)-diene-10-peroxy		
	Propanoic acid, 2-methyl-, (dodecahydro-6a-hydroxy- 9a-methyl-3-methylene-2,9-dioxoazuleno[4,5-b]furan-6-yl)methyl ester, [3aS-(3a.alpha.,6.beta.,6a.alpha.,9a.beta.,9b.alpha.)]-		
	Selina-3,7(11)-diene		
Other Compounds	1,3-Bis(cinnamoyloxymethyl)adamantane	Betulin	Betulin
	1-Heptatriacotanol	Lup-20(29)-en-3-one	Fenretinide
	2,3-Dihydroxypropyl elaidate		Octadecane, 1-chloro-
	2-Butanone, 4-phenyl-		p-Menth-8(10)-ene-2,9-diol
	5,19-Cyclo-5.beta.-androst- 6-ene-3,17-dione		
	6-Octadecenoic acid		
	Betulin		
	Cyclohexanol, 5-methyl-2-(1-methylethyl)-		
	Di-n-octyl phthalate		

	Estra-1,3,5(10)-trien-17.beta.-ol		
	Fenretinide		
	Lup-20(29)-en-3-one		
	Retinal, 9-cis-		
	Ursodeoxycholic acid		
Total Number of Sesquiterpenes	8	0	0
Total Number of Sesquiterpenoids	21	0	0
Total Number of Other Compounds	14	2	4
Overall Total	43	2	4

Based on table 4.3.2 shows the chemical compounds in Agarwood *Aquilaria malaccensis* oil extract at UMK-TRaCe from the roots of trees A, B, and C that have been separated according to the type of compounds such as sesquiterpene compounds, sesquiterpenoids, and other compounds. The roots of tree A show a total of 8 sesquiterpene compounds consisting of .beta.-Guaiene, .gamma.- HIMACHALENE, and Naphthalene, decahydro-4a-methyl-1-methylene-7-(1- methylethylidene)-, (4aR - trans) -. For example, the compound Naphthalene, decahydro-4a-methyl-1-methylene-7-(1-methylethylidene)-, (4aR-trans)- or known as -trans-Isolongifolene which produces the aromatic smell of wood and earth.

As for sesquiterpenoid compounds, the roots of tree A have shown as many as 21 compounds consisting of .gama.-eudesmol, 5.beta.,7.beta.H,10.alpha.-Eudesm-11-en-1.alpha .-ol, and Selina-3,7(11)-diene. For example, the compound 5. beta.,7.

beta.H,10. alpha. -Eudesm-11-en-1.alpha.-ol has a woody, earthy or spicy smell, making it useful in perfumery. Other compounds have shown as many as14 compounds consisting of 2-Butanone, 4-phenyl-, Betulin, and Bis (cinnamoyloxymethyl) adamantane. For example, the compound Bis (cinnamoyloxymethyl) adamantane serves as an internal standard, retention marker, and instrument calibration tool to help ensure accurate, consistent, and reliable analysis, thus facilitating the identification and quantification of compounds in agarwood oil. The total number of chemical compounds produced by the roots of tree A is 43 compounds.

In addition, the roots of trees B and C only produce other compounds and do not produce sesquiterpene and sesquiterpenoid compounds. This is because the root samples of trees B and C do not have agarwood oil compared to the roots of tree A. This happened because there was no injury or infection on the roots of trees B and C compared to the injured roots of tree A. The roots of tree B only produce 2 other compounds consisting of Betulin, and Lup- 20(29)-en-3-one. While the roots of tree C only produce 4 other compounds consisting of Betulin, Fenretinide, Octadecane, 1-chloro-, and p-Menth-8(10)-ene- 2,9-diol. For example, the compound Betulin found in the roots of trees B and C serves as a reference to compare and identify other compounds in the sample, helpingin qualitative analysis.

Overall, referring to table 4.3.1 and table 4.3.2, tree A has recorded a very large number of chemical compounds because there are compounds on the stem and roots of tree A, which are as many as 41 compounds on the stem and 43 compounds on root compared to tree B which only produces 32 compounds on stems and 2 compounds on roots. While tree C has produced the least chemical compounds which are 4 compounds on the stem and 4 compounds on the roots. This is due to Agarwood tree

A receiving high levels of infection and injury compared to Tree B and Tree C. In addition, the stemand roots of tree A, and the stem of tree B showed a very large amount of sesquiterpenoid compounds compared to sesquiterpene compounds and other compounds. This is because according to (Hezelin Elayana Shaian et al. 2021) oil high-quality agarwood should contain many high sesquiterpenoids, due to the woody aroma that is mostly produced by this group. Next, according to (Hashim et al. 2014) the compound 2-Butanone, 4-phenyl- found in the trunk and roots of tree A, and the trunk of tree B is a compound that is often observed in all Agarwood oil *Aquilaria malaccensis.*

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study aims to examine the difference in volume Agarwood oil extracted from the stems and roots of *Aquilaria malaccensis* and to identify the chemical compounds found in *Aquilaria malaccensis* Agarwood extract oil from the stems and roots of Agarwood trees. The objective of this study has been achieved with results showing different variations in chemical composition between stem and root extracts. The stem extract exhibits a higher concentration of sesquiterpenoid compounds, which are important in determining the aromatic and quality of Agarwood oil. The root extract, although containing fewer sesquiterpenoids, showed a variety of other aromatic and phenolic compounds. This differential composition emphasizes the importance of both parts of the tree in contributing unique properties to the overall quality and use of Agarwood oil. Comprehensive profiling of these compounds improves our understanding of factors influencing the odor and potential therapeutic benefits of Agarwood, thereby informing its use in various industries such as perfumery and traditional medicine.

5.2 Recommendation

Emphasize selective harvesting techniques that consider the different chemical of stems and roots. This approach can optimize the extraction process and ensure the production of high-quality Agarwood oil that is tailored to specific industrial needs. Additionally, it is important to develop and standardize extraction methods that can efficiently isolate the desired compounds from both stems and roots. This may involve refining solvent extraction techniques or exploring innovative methods such as supercritical fluid extraction. In addition, in-depth chemical analysis should be conducted using advanced techniques such as NMR and HPLC to identify and quantify lesser-known compounds that may contribute to the overall efficacy and aroma of Agarwood oil. This could lead to the discovery of new bioactive compounds with potential applications in pharmaceuticals and aromatherapy. By implementing these recommendations, the findings of the study can significantly contribute to the sustainable and efficient use of *Aquilaria malaccensis*, ensuring the continued availability and commercial viability of high-quality Agarwood oil.

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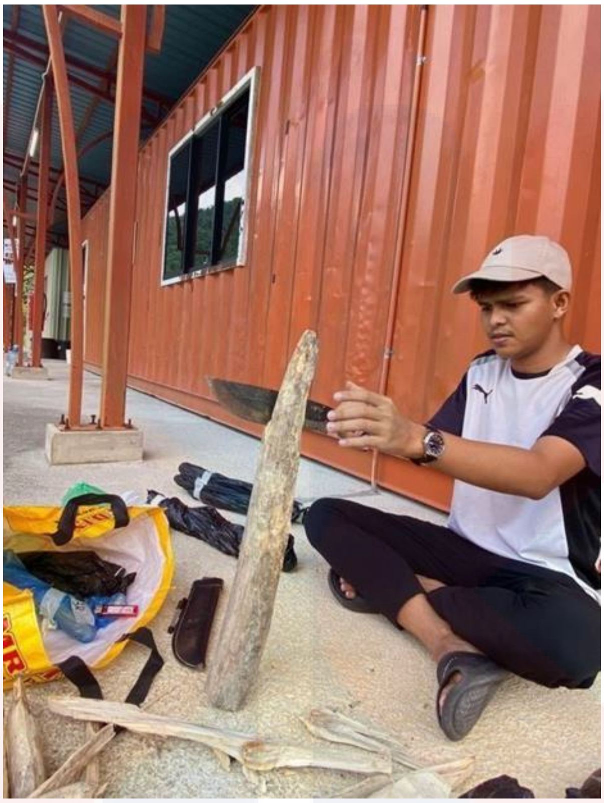
APPENDIX A

The place where the sample was taken.

A sample of the root part of the tree has been taken.

Pick up tree roots using a hoe.

The process of removing the bark of the Agarwood tree.

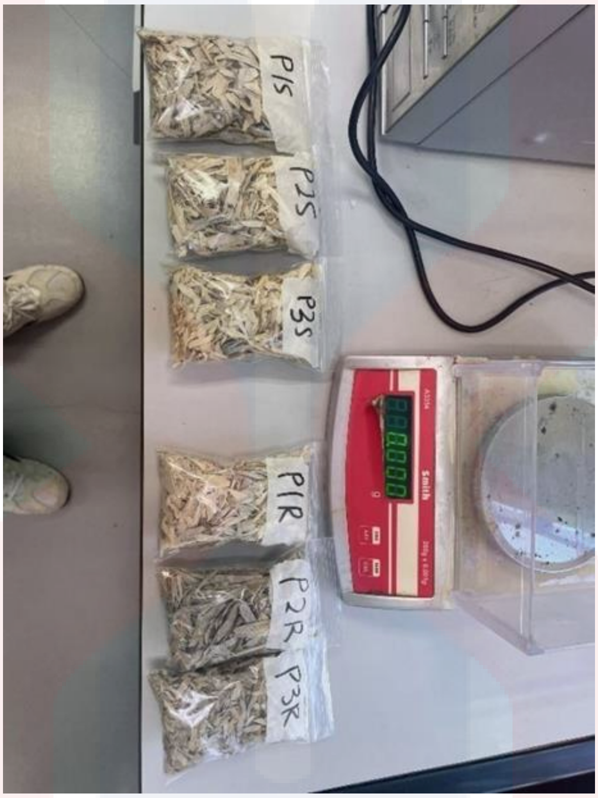


The process of splitting Agarwood tree trunks into smaller sizes.

The process of drying the root stem that has been cut to a smaller size until it dries.

The process of slicing tree wood into smaller sizes for the steam distillation process.

APPENDIX B

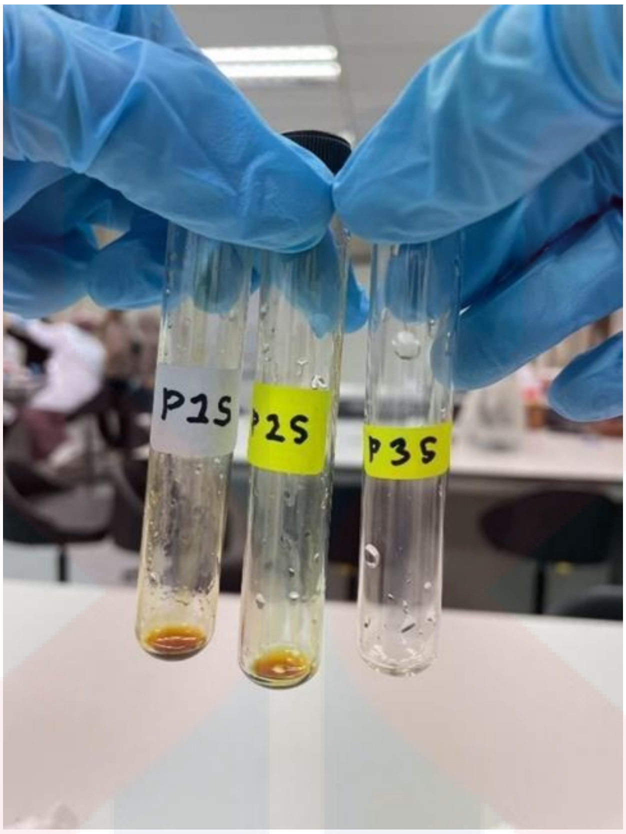


The sample obtained is 15g per sample.

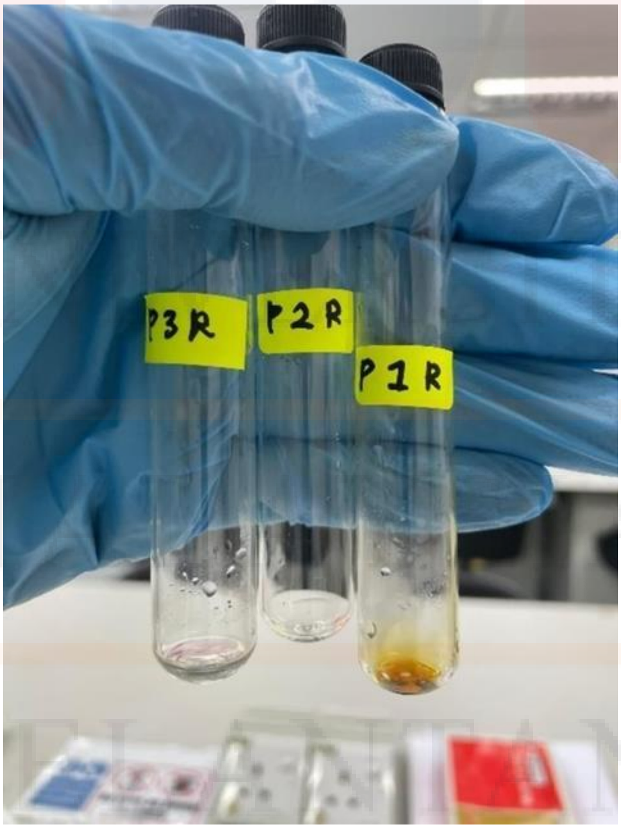
The extraction process uses steam distillation.

Take the liquid hexane and pour it into another beaker.

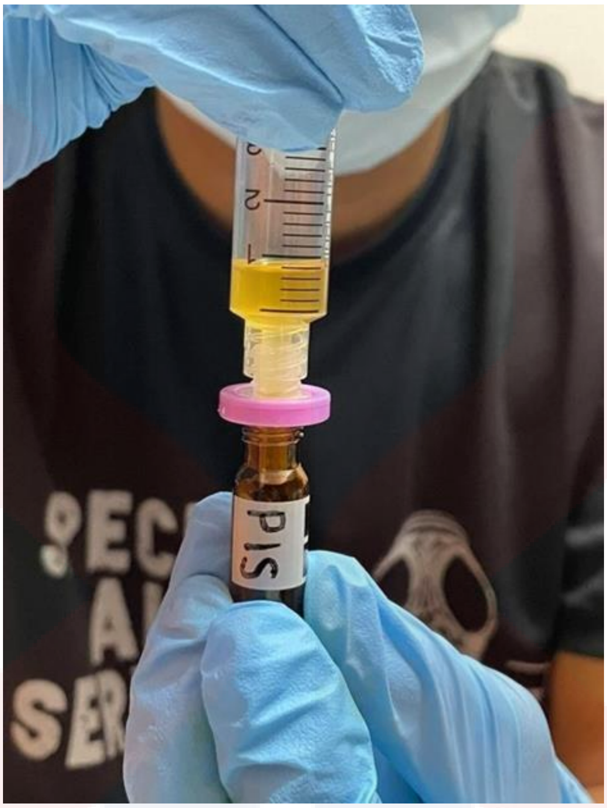
Agarwood oil that has been extracted.



Sample Agarwood oil on the stem.



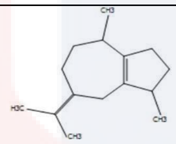
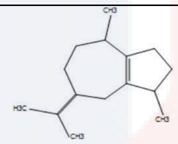
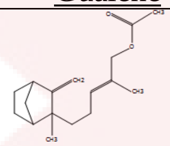
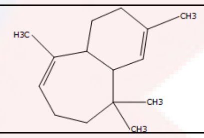
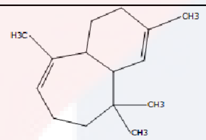
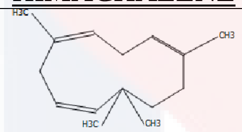
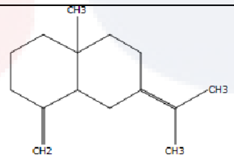
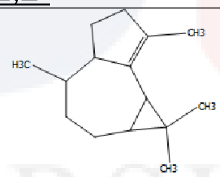
Sample Agarwood oil on the root.

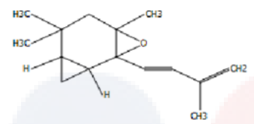
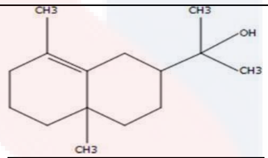
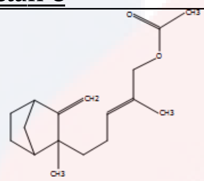
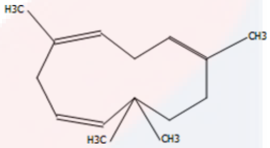
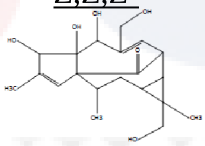
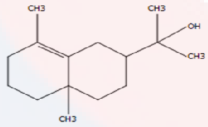
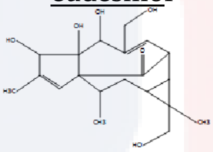


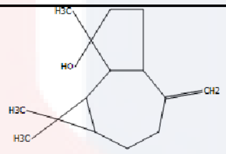
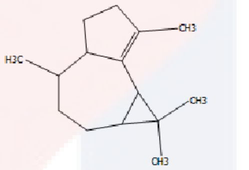
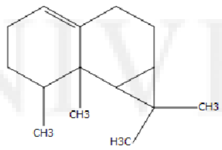
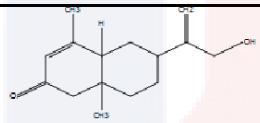
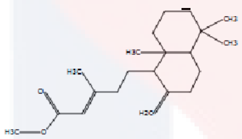
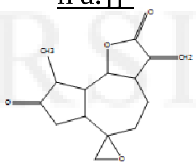
A sample of agarwood oil that has been filtered is put into a GCMS vial.

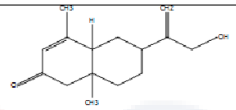
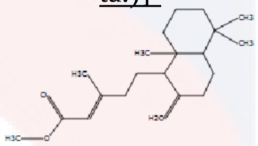
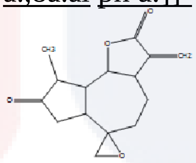
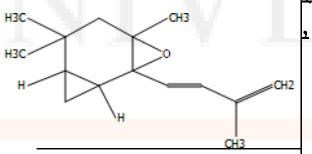
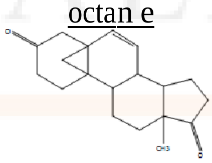
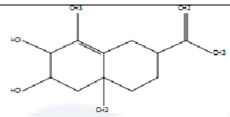
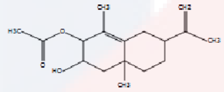
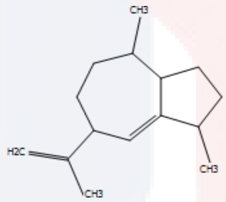
APPENDIX C

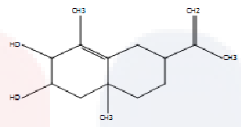
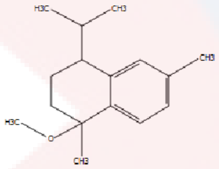
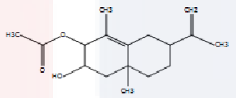
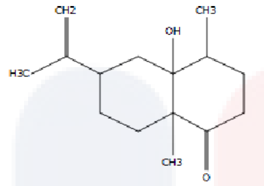
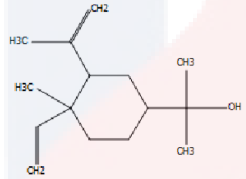
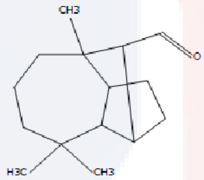
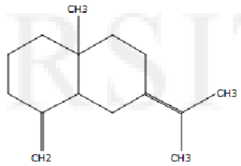
Chemical compounds in Agarwood oil extracts from stems of *Aquilaria malaccensis* at UMK-TRaCe.

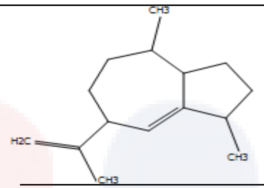
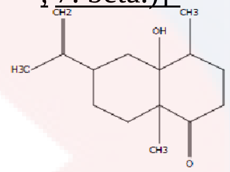
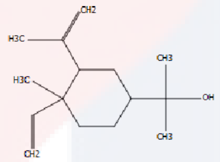
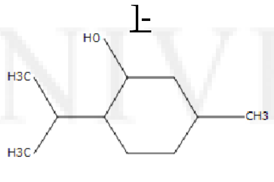
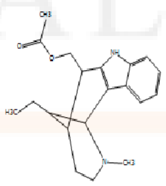
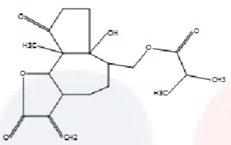
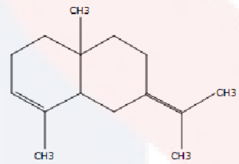
Parameters Type of Compounds	*A. malaccensis* (Stems)		
	Tree A	Tree B	Tree C
Sesquiterpenes	 .beta.-Guaiene	 .beta.-Guaiene	
	 .beta.-Santanol acetate	 .gamma.-HIMACHALENE	
	 .gamma.-HIMACHALENE	 1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-	
	 Naphthalene, decahydro- 4a-methyl-1-methylene- 7-(1-methylethylidene)-, (4aR- trans)-	 1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-octahydro-1,1,4,7-tetramethyl-, [1aR-(1a.alpha.,4.alpha.,4a.beta.,7 b.alpha.)]-	

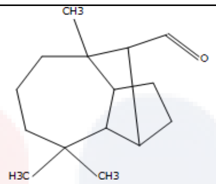
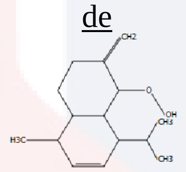
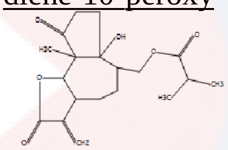
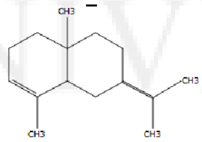
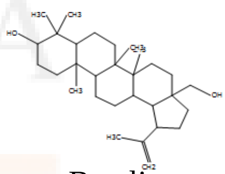
		 4,6,6-Trimethyl-2-(3- methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octan e	
Sesquiterpenoids	 .gama.-eudesmol	 beta.-Santanol acetate	
	 1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-  1H-2.8a-Methanocyclopent a[a]cyclo pr opa[e]cyclodecen -11- one, 1a,2,5,5a,6,9,10, 10a- octahydro-5,5a,6-trihydroxy- 1,4-bis(hydroxymethyl)-1,7,9-trimethyl-, [1S-(1.alpha.,1a.alpha.,2.alpha.,5.beta.,5a.beta.,6. beta.,8a.a lp ha.,9.alpha.,10a alpha.)]-.	 .gama.-eudesmol  1H-2,8a-Methanocyclopenta[a]cyclo pr opa[e]cyclodecen-11-one1a,2,5,5a,6,9,10, 10a- octahydro-5,5a,6- trihydroxy-1,4-bis(hydroxymethyl)-1,7,9- trimethyl-, [1S-(1.alpha.,1a.alpha.,2.alpha., 5.beta.,5a.beta.,6.beta.,8a. alpha.,9.alpha.,10a.alpha.)]-	

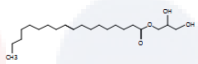
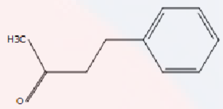
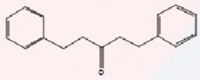
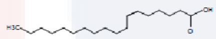
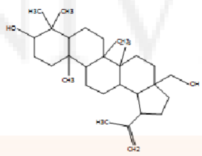
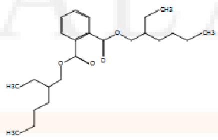
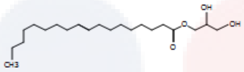
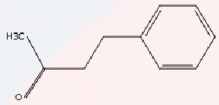
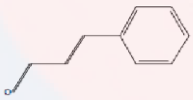
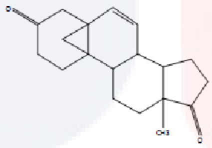
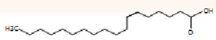
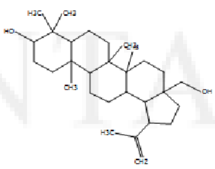
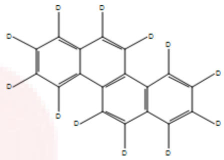
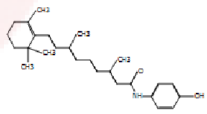
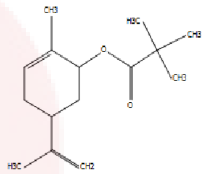
	 1HCycloprop[e]azulen-7-ol,decahydro-1,1,7- trimethyl-4-methylene-, [1ar-(1a.alpha.,4a.alpha.,7.beta.,7a.beta.,7b.alpha.)]-  1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b-octahydro-1,1,4,7-tetramethyl-, [1aR-(1a.alpha.,4.alpha., 4a.beta. ,7 b.alpha.)]-  1H-Cyclopropa[a]naphthalen e, 1a,2,3,5,6,7,7a,7b-octahydro- 1,1,7,7a-tetramethyl-, [1aR-(1a.alpha.,7.alpha.,7a.alpha., 7b.alpha.)]-	 2(1H)-Naphthalenone, 4a,5,6,7,8,8a-hexahydro-6-[1-(hydroxymethyl)ethenyl]- 4,8a-dimethyl-, [4ar-(4a.alpha.,6.alpha.,8a.beta.)] -  2-Pentenoic acid, 5-(decahydro-5,5,8a-trimethyl- 2-methylene-1-naphthalenyl)-3-methyl-,methyl ester, [1R-[1.alpha.(E),4a.beta.,8a.alpha.]]-  3-Oxo-10(14)-epoxyguai- 11(13)-en-6,12-olide	

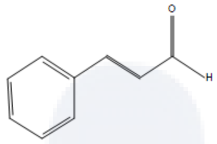
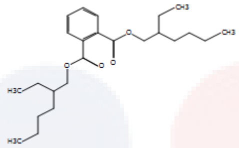
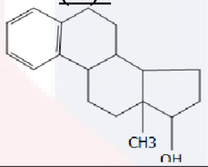
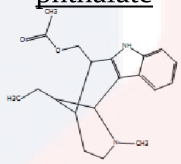
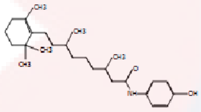
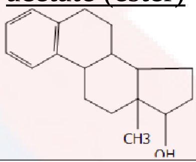
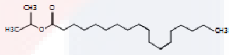
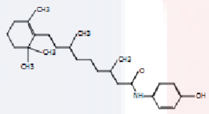
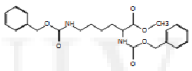
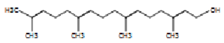
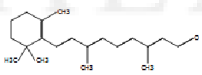
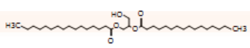
	 2(1H)-Naphthalenone,4a,5,6,7,8,8a-hexahydro-6- [1-(hydroxymethyl)ethenyl]- 4,8a-dimethyl[4ar-(4a.alpha.,6.alpha.,8a.beta.)]-  2-Pentenoic acid, 5- (decahydro-5,5,8a- trimethyl-2-methylene-1-naphthalenyl)- 3-methyl-, methyl ester, [1R-[1.alpha.(E),4a.beta.,8a.al ph a.]]-  3-Oxo-10(14)-epoxyguai- 11(13)-en-6,12-olide  4,6,6-Trimethyl2-(3-methylbuta-1,3dienyl)-3oxatricyclo[5.1.0.0(2,4)]octan e  5,19-Cyclo-5.beta.-androst- 6- ene-3,17-dione	 6-Isopropenyl-4,8a- dimethyl-1,2,3,5,6,7,8,8a-octahydronaphthalene-2,3- diol  Acetic acid, 3-hydroxy-6-isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-octahydronaphthalen-2-ylester  Azulene,1,2,3,3a,4,5,6,7-octahydro-1,4 dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,3a.beta.,4.alpha., 7. beta.)]-	

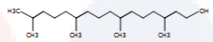
	 6-Isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-octahydronaphthalene-2,3- diol  9-Methoxycalamenene  Acetic acid, 3-hydroxy-7- isopropenyl-1,4a-dimethyl-2,3,4,4a,5,6,7,8-octahydronaphthalen-2-yl ester	 Corymbolone  Cyclohexanemethanol, 4-ethenyl-.alpha.,.alpha.,4-trimethyl-3-(1-methylethenyl)-, [1R-(1.alpha.,3.alpha.,4.beta.)]-  Longifolenaldehyde  Naphthalene, decahydro- 4a- methyl-1-methylene-7-(1- methylethylidene)-, (4aR-trans)-	

	 Azulene, 1,2,3,3a,4,5,6,7-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,3a.beta.,4.alpha., 7. beta.)]-  Corymbolone  Cyclohexanemethanol, 4-ethenyl-.alpha.,.alpha.,4-trimethyl-3-(1-methylethenyl)-, [1R-(1.alpha.,3.alpha.,4.beta.)]-  Cyclohexanol, 5-methyl-2-(1-methylethyl)-  Dasycarpidan-1-methanol, acetate (ester)	 Propanoic acid, 2methyl-, (dodecahydro- 6a-hydroxy- 9a-methyl-3-methylene-2,9-dioxoazuleno[4,5-b]furan-6-yl)methyl ester,[3aS-(3a.alpha.,6.beta.,6a.alpha., 9a.beta.,9b.alpha.)]-  Selina-3,7(11)-diene	

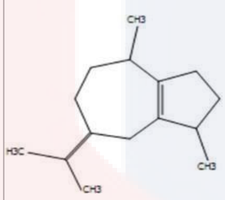
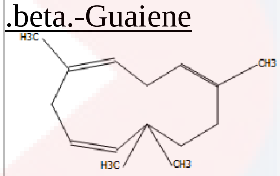
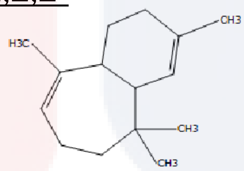
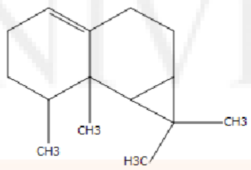
	 Longifolenaldehyde  Murolan-3,9(11)-diene-10-peroxy  Propanoic acid, 2-methyl-, (dodecahydro- 6a-hydroxy- 9a-methyl-3-methylene-2,9-dioxoazuleno[4,5-b]furan-6-yl)methyl ester,[3aS-(3a.alpha.,6.beta.,6a.alpha., 9a.beta.,9b.alpha.)]-  Selina-3,7(11)-diene		
Other Compounds	 1-Heptatriacotanol	 1-Heptatriacotanol	 Betulin

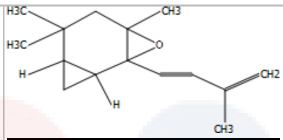
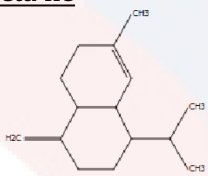
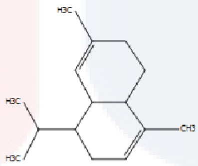
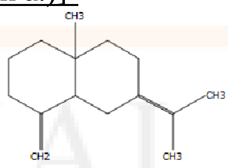
	 2,3-Dihydroxypropyl elaidate  2-Butanone, 4-phenyl-  3-Pentanone, 1,5-diphenyl-  6-Octadecenoic acid  Betulin  Bis(2-ethylhexyl) phthalate	 2,3-Dihydroxypropyl elaidate  2-Butanone, 4-phenyl-  2-Propenal, 3-phenyl-  5,19-Cyclo-5.beta.-androst- 6-ene-3,17-dione  6-Octadecenoic acid  Betulin	 Chryse ne-D12  Fenreti nide  Limonen -6-ol, pivalate

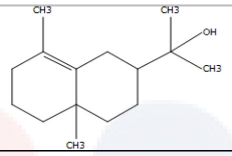
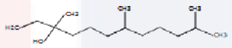
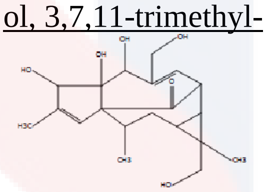
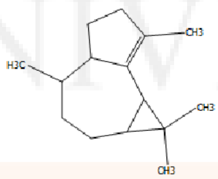
	 Cinnamaldehyde, (E)-	 Bis(2-ethylhexyl) phthalate	
	 Estra-1,3,5(10)-trien- 17.beta.-ol	 Dasycarpidan-1-methanol, acetate (ester)	
	 Fenretinide	 Estra-1,3,5(10)-trien- 17.beta.-ol	
	 Isopropyl linoleate	 Fenretinide	
	 N,N'-Bis(Carbobenzyloxy)-lysine methyl(ester)	 trans-Geranylgeraniol	
	 Retinal, 9-cis-	 Hexadecanoic acid, 1-(hydroxymethyl)-1,2- ethanediyl ester	

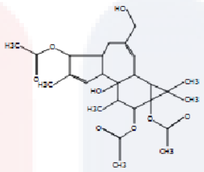
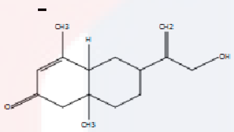
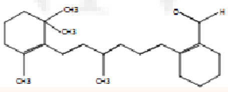
	 trans-Geranylgeraniol		
Total Number of Sesquiterpenes	4	5	0
Total Number of Sesquiterpenoids	23	15	0
Total Number of Other Compounds	14	12	4
Overall Total	41	32	4

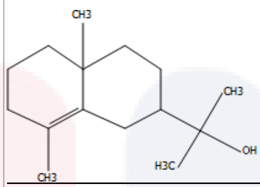
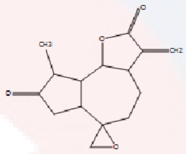
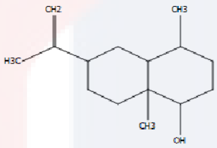
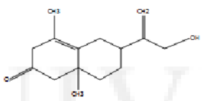
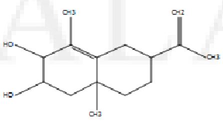
Chemical compounds in Agarwood oil extracts from roots of *Aquilaria malaccensis* at UMK-TRaCe.

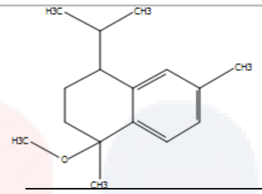
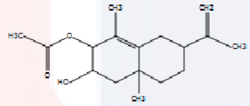
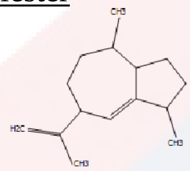
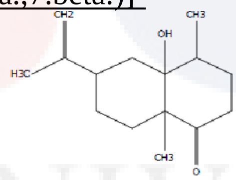
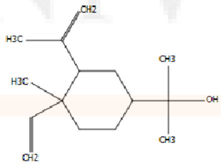
Parameters Type of Compounds	***A. malaccensis* (Roots)**		
	Tree A	**Tree B**	**Tree C**
Sesquiterpenes	 .beta.-Guaiene  1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-  .gamma.-HIMACHALENE  1H-Cyclopropa[a]naphthalene, 1a,2,3,5,6,7,7a,7b-octahydro-1,1,7,7a-tetramethyl-,[1aR-(1a.alpha.,7.alpha.,7a.alpha.,7b.alpha.)]-		

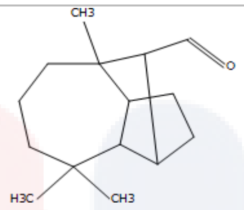
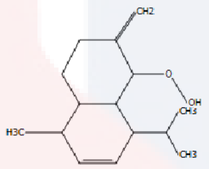
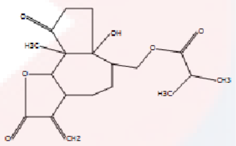
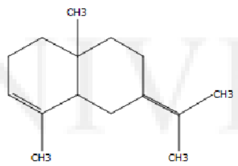
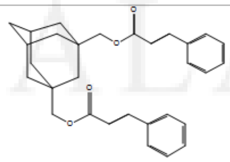
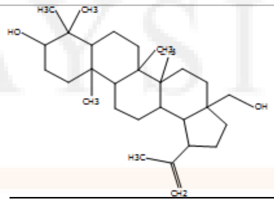
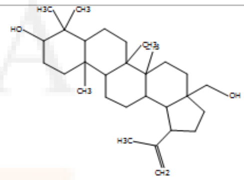
	 4,6,6-Trimethyl-2-(3-methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octa ne  Naphthalene, 1,2,3,4,4a,5,6,8a-octahydro-7-methyl-4-methylene-1-(1-methylethyl)-, (1.alpha.,4a.beta.,8a.alpha.)-  Naphthalene,1,2,4a,5,6,8a-hexahydro- 4,7-dimethyl-1-(1-methylethyl)-,[1R-(1.alpha.,4a.alpha.,8a.alph a.)]-  Naphthalene, decahydro- 4a- methyl-1-methylene-7- (1-methylethylidene)-, (4aR- trans)-		

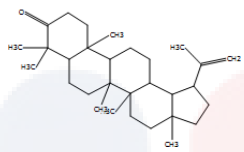
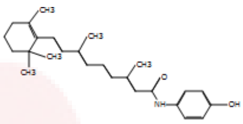
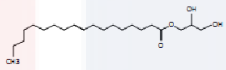
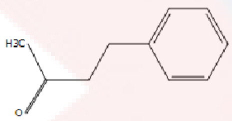
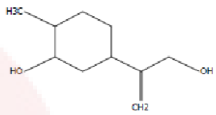
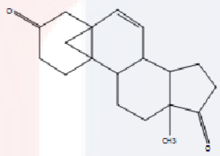
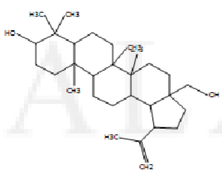
Sesquiterpenoids	 .gama.-eudesmol  1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-  1H-2,8a-Methanocyclopenta[a]cyclo propa[e]cyclo decen-11- one, 1a,2,5 ,5a,6,9, 10,10a-octahydro-5,5a,6-trihydroxy-1,4-bis(hydroxymethyl)-1,7,9- trimethyl-, [1S-(1.alpha.,1a.alpha.,2.alpha. ,5.beta.,5a. beta.,6.beta.,8a. alpha.,9.alpha.,10a.alpha.)] 1H-Cycloprop[e]azulene,  1a,2,3,4,4a,5,6,7b-octahydro-1,1,4,7-tetramethyl-, [1aR-(1a.alpha.,4.alpha.,4a .beta. ,7b.alpha.)]-		

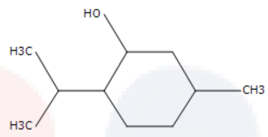
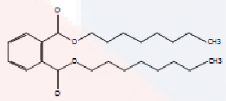
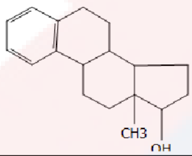
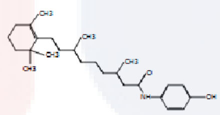
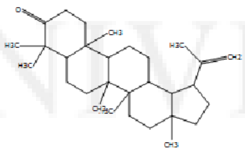
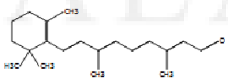
	 1HCyclopropa[3,4]benz[1,2-e]azulene-5,7b,9,9a-tetrol, 1a,1b,4,4a,5,7a,8,9-octahydro-3-(hydroxymethyl)-1,1,6,8-tetramethyl-, 5,9,9a- triacetate, [1aR(1a.alpha.,1b.beta.,4a.beta.,5.beta.,7a.alpha.,7b.alpha.,8.alpha.,9.beta.,9a.alpha.)] -  2(1H)Naphthalenone, 4a,5,6,7,8,8a-hexahydro-6-[1-(hydroxymethyl)ethenyl]- 4,8a-dimethyl-, [4ar(4a.alpha.,6.alpha.,8a.beta.)]-  2-[4-methyl-6-(2,6,6-trimethylcyclohex-1- enyl)hexa-1,3,5-trienyl]cyclohex-1-en-1-carboxaldehyde		

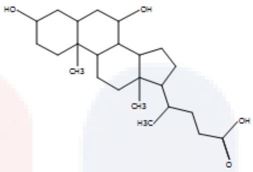
			
	2- Naphthalenemethanol,1,2,3,4,4a,5,6,7-octahydro .alpha.,.alpha.,4a,8-tetramethyl-, (2R-cis)-  3- Oxo-10(14)-epoxyguai-11(13)-en-6,12-olide  5.beta.,7.beta.H,10.alpha.-Eudesm-11-en-1.alpha.-ol  6-(1Hydroxy methylvinyl)-4,8a-dimethyl3,5,6,7,8,8a-hexahydro-1H-naphthalen-2-one  6-Isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-octahydronaphthalene-2,3-diol		

	 9-Methoxycalamenene  Acetic acid, 3hydroxy-7- isopropenyl-1,4a-dimethyl2,3,4,4a,5,6,7,8octahydronaphthalen-2-ylester  Azulene,1,2,3,3a,4,5,6,7-octahydro-1,4 dimethyl-7-(1 methylethenyl)-, [1R-(1.alpha.,3a.beta.,4.alpha.,7.beta.)]-  Corymbolone  Cyclohexanemethanol, 4- ethenyl-.alpha.,.alpha.,4-trimethyl-3-(1-methylethenyl)-, [1R-(1.alpha.,3.alpha.,4.beta.)]-		

	 Longifolenaldehyde  Murolan-3,9(11)-diene-10-peroxy  Propanoic acid, 2 methyl-(dodecahydro-6a-hydroxy- 9a-methyl-3-methylene-2,9-dioxoazuleno[4,5-b]furan-6-yl)methyl ester, [3aS-(3a.alpha.,6.beta.,6a.alpha.,9a.beta.,9b.alpha.)]-  Selina-3,7(11)-diene		
Other Compounds	 1,3-Bis(cinnamoyloxymethyl)ad amantane	 Betulin	 Betulin

	 1-Heptatriacotanol	 Lup-20(29)-en-3-one	 Fenretinide
	 2,3-Dihydroxypropyl elaidate		 Octadecane, 1-chloro-
	 2-Butanone, 4-phenyl-		 p-Menth-8(10)-ene-2,9-diol
	 5,19-Cyclo-5.beta.-androst- 6-ene-3,17-dione		
	 6-Octadecenoic acid		
	 Betulin		

	 Cyclohexanol, 5-methyl-2-(1-methylethyl)-  Di-n-octyl phthalate  Estra-1,3,5(10)-trien-17.beta.-ol  Fenretinide  Lup-20(29)-en-3-one  Retinal, 9-cis-		

	 Ursodeoxycholic acid		
Total Number of Sesquiterpenes	8	0	0
Total Number of Sesquiterpenoids	21	0	0
Total Number of Other Compounds	14	2	4
Overall Total	43	2	4