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Sesquiterpenes and Chromones of Agarwood: A Review

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This study is to characterize and profile the chemical constituents of Aquilaria species, mainly *Aqularia malaccensis*, *Aqularia sinensis*, and *Aqularia crassna*. This precious wood has long been used traditionally in religious ceremonies in the form of incense and oil. There are variations among the chemical group that has been identified in this species, mostly sesquiterpenoids, chromones and volatile aromatic compounds. Studies on the chemistry of agarwood smoke are discussed. Emphasis is given to structural and analytical aspects through this study. The agarwood grading system totally depended on its physical characteristics; there was no scientific approach based on the chemical profile which was used to classify the different grades of agarwood. A different type of analytical technique was used to isolate single pure compounds from chip wood of agarwood, and solvent refluxing was the most popular among them. The polar solvent was found to be used to obtain the polar compounds and chromium, while most of the sesquiterpene was obtained from the non-polar solvent. For extraction of agarwood, hydrodistillation was the most common technique to extract the oil and followed by supercritical fluid extraction, while steam distillation and Soxhlet distillation was rarely used. Different analytical instrumentation were used for the investigation of the chemical profile of agarwood such as GC-FID, GC-MS, GC-MS-OLF which were the most common research tools. The chemical profile of the wood from the different species and countries all looked different except the Vietnamese *Aquilaria sinensis*, and *A. agallocha* which seemed to have a very closed chemical profile. There were remarkable similarities in the chemical profile of *A. agallocha India* (wood), *A. agallocha* Vietnam (wood), and *A. sinensis* Vietnam (wood) with the minor absence of some compounds from *A. agallocha* India (wood). From the literature, we could say that the 6-methoxy-2-[2-(4 -methoxypheny1)-ethyl]chromone and2-(2 (4methoxyphenyl)ethyl)chromone was the most dominate chromones found in all species.

Key words: *Aquilaria malaccensis*; *Aquilaria sinensis*; *Aquilaria crassna*; GC-FID; GC-MS; SPME; sesquiterpene

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NAME AND DISTRIBUTION

Agarwood is the resin emarginated inside the heartwood of the Aquilaria tree, a genus that is taxonomically belonging to the Thymelaeaceae [1−6]. *Aquilaria* genus contain about 20 species, mainly found in the Indo-Malaysian region, growing from India through Burma, Laos, Vietnam and Cambodia to Malaysia, Sumatra, Borneo, the Philippines, and Papua New Guinea [7−9] although the actual number of recognized species in the genus is still under debate [1,4,10]. The precious, fragrant agarwood, also called as aloewood, eaglewood, gaharu, oud, Oudh, kanankoh, kyara, jinkoh, Chen Xiang and kalamabak by people from different cultures. The Japanese name for

agarwood is jin-koh which, like the Chinese 'Ch'en Hsiang', literally translates as 'sinking fragrance'. This name came from the physical phenomena of the agarwood when containing the high amount of resin as it is about to sink in water, which can be used as an indication of high-quality chip wood of agarwood. The resin content in low-quality chip wood will be low, making its weight lighter, enabling it to float when immersed in water [2,4,7,8,11,12].

The first agarwood-producing species to be included in Appendix II of CITES was *Aquilaria malaccensis* in 1995. This species is the most common Aquilaria species found throughout Peninsular Malaysia and Sabah [8]. The species is widespread. However, it does not appear to occur at unusually high stocking densities. Accurate identifications of Aquilaria species are often difficult or even impossible to achieve as there are trees that are rarely spotted with fruits and flowers in the wild. The flowering period does not follow an annual cycle [13], thus making identification efforts an even more challenging task. Trees of other genera, namely Gonystylus, Gyrinops and others, also produce agarwood. In practice, only the heartwood of *A. malaccensis* (synonymous *A. agallocha*), *A. crassna*, *A. sinensis* and, recently, *A. filaria* are commercially exploited [7,12].

Economical Value

Reports have shown that superior, pure wood material can fetch up to USD 100 000 per kg, while the lower quality material is valued at only USD 100 per kg. In contrast to that, the extracted essential oil (normally referred to as agarwood oil) can reach up to USD 1500 per tola (ca.11.7 g) for high quality or superior grade [5,14,15]. The high price is considered as an indicator of its value as a precious and luxurious product, and the quality of aroma can be viewed as an indicator of status and prestige [16]. The aroma of agarwood is a complex mixture of many volatile constituents which results in its unique and elegant oriental aroma characters [14,17−20]. In the recent decades, agarwood has been harvested from *A. malaccensis*; *A. agallocha* and *A. secundaria* are synonyms for *A. malaccensis* [12,14].

Grading System

The agarwood grading system is dependent on its physical properties. The Japanese grading system of agarwood is a codified system of assessment based on various physical characteristics, such as color, resin content, shape, and weight of chip wood [11,14,16, 21−23]. There are two major regions around the globe for agarwood trading and consumption: The North-East Asia and the markets of Taiwan, Japan, and the Republic of Korea; and the West Asia, Middle East or countries of the Arabian Gulf area. In Malysia, the appreciable effort has been done to grade the oil according to the sensory response in attempt to find a scentific base to grade the wood and oil of agarwood; this team has published many research article describing their effort [11, 4, 16, 22−27].

Uses

Agarwood has been used as a traditional aromatic and perfume in many forms, from high-grade woodchips to personal perfuming before special occasions. It is sold as raw form (wood chips and pieces), as an oil (both pure and blended with other fragrances), as perfume products, and in various other forms using small shavings of wood mixed with other fragrant ingredients [2,8,12,16,28−30].

Agarwood has been used for traditional medicine in Japan on account for its effectiveness as a sedative or tranquilizer in detoxifying the body and in maintaining stomach health [2−4,11,29,30]. Agarwood has been used extensively in the incense industry more than in the medicinal sector in Japan, and from the 20–30% of Japan's total agarwood imports, it is estimated that approximately 20% of this amount comes from *A. malaccensis* [2,8,11, 28−31].

Conservation Satus

Agarwood tree has been declared as an endangered species as it is under the threat of extinction following the concerns over the sustainability of supply. In August 2002, at the CITES Asia Regional Meeting, only one species, *Aquilaria*

malaccensis was listed in CITES Appendix II. In 2004, when more species in natural forests were listed under CITES [4-6,16,28], only 7–10% of trees contain agarwood [5,32]. Experts from the indigenous peoples can identify agarwood deposits through observing the intact stem. However, the trees have to be cut open to determine the content and quality of the wood impregnated with resinoid [32]. This results in a drastic decrement in the number of wild Aquilaria trees causing the species to reach the near-extinction stage. Nine species are threatened and are included in the IUCN red list [4] [The International Union for Conservation of Nature 2010.3). The list of CITES, Appendix II (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2005) contains all Aquilaria species requiring export certificates for agarwood; paradoxically, the listing does not apply to agarwood oil and extracts [5].

Agarwood Formation Theory

There are many hypotheses behind agarwood formation. It is believed that agarwood formation is due to the immunological response of the host tree due to wound or infection. It may be the result of pathological, wounding. However, studies have not resolved this mystery yet [5,29,30,32−34].

Studies have shown that monoterpenic and sesquiterpenic hydrocarbons, oxygenated monoterpenes and sesquiterpenes (comprised of ketone, aldehyde, oxide, alcohol, lactone, keto-alcohol, and diol), norterpenoids, diterpenoids, short chain glycols, carboxylic acids and phenylethyl chromone derivatives are the primary compounds in agarwood [2,5,8,28-30,35].

Extraction, Identification, Isolation and Analysis Technique

Different extraction methods for the subsequent gas chromatographic determination of the composition of volatile compounds in essential oils and related compounds from agarwood chip wood have been reported in past studies. In most of the published work in agarwood suggest hydrodistillation as the method of choice for determining the essential oil content of plants [8,36]. For investigating the composition of agarwood essential oils and related aroma active compounds, hydrodistillation is not very useful. This is due to discrimination and transformation processes following high temperatures and acidic conditions [36]. With cold solvent extraction, accelerated solvent extraction, and supercritical fluid extraction, discrimination of high and non-volatile aroma-active components, as well as transformation processes can be diminished; but non-aroma-active fats, waxes, or pigments are often extracted as well [36]. As solid phase micro-extraction is a solvent-free and fully automatable sample preparation technique, this was the most sparing method to sensitive components and the most time-saving method for rapid determination of the aromatic compounds composition in much volatile oil investigation [12,23,37]. Finally, solid phase micro-extraction could be successfully optimized for the extraction of aromatic components from plants for their subsequent gas chromatographic determination [12,23,37−44]. Hydrodistillation when compared to the cold solvent extraction with n-hexane, the extraction with supercritical carbon dioxide, accelerated solvent extraction, and the solid phase micro-extraction, the most useful sample preparation method for a rapid analysis of essential oils and related compounds has to be the solid phase micro-extraction [8,36].

Identification and Analysis Technique

There are many techniques available and has been used to analyze the volatile organic compounds; gas chromatography (GC), gas chromatography/ mass spectrometric (GC/MS), solid phase micro-extraction (SPME), gas chromatography-flame ionization detector (GC-FID), gas chromatography-olfactometry (GC-O) and comprehensive two-dimensional gas chromatography (GC×GC) [5,8,12,23,37,39,45−58], electronic nose (E-nose) [25−27,59]. GC-O is the odor compounds extraction method in combination with gas chromatography and human sensory panel [12]. This method is limited to the subject of fairness since human nose cannot tolerate with many samples at the same time [3]. In GC×GC, chemical compounds are separated by a single

column based on its properties; the size, length and stationary phase. In GC-FID, the flame ionization detector is used to sense molecule with a carbon-hydrogen atom. The technique is mass-sensitive more than concentration-sensitive. Furthermore, the flame ionization detectors require a high data rate at 200 Hz to operate. The GC/MS technique is proven and has shown its promising result in analyzing the chemical compounds of agarwood oil [7,12,14,17−20, 22−25,28,31,42,45,53,59−81]. The GC/MS technique combined with GC-O is the appropriate method for the analysis of odor-active components in determining the aroma profile of essential oils by combining chromatographic separation with human sensory detection. The SPME has been widely used for extracting volatile components from plant material [12,14,36,82].

EXPERIMENTAL

Chemical Constituents of Agarwood

A survey of the analytical investigations on various *Aquilaria* species, including the origin of raw materials, the different methods used to extract volatile constituents from the woody biomass, and the main chemical constituents isolated from these extracts is distributed. The use of polar solvents, such as acetone, methanol, and ethanol, has been used for the extraction of terpenic acids and chromones, compounds soluble in water or compounds with a very low vapour pressure that cannot be hydrodistilled. The three commercial agarwood oils are most likely to be hydrodistillation.

It is interesting to mention that the names of the species given by their authors will be used, being aware that these names may have changed today as the case of *Aquilaria agallocha*, a frequently studied species, is now considered as a synonym of *A. malaccensis* [7]. The chemical investigation on agarwood mainly can be classified into three broad categories:

- Isolation of chemical constituents from agarwood chip wood by solvent extraction under reflux and as mentioned before, the use of polar solvents, such as acetone, methanol or ethanol, has been used for the extraction of terpenic acids and chromones. Whereas, the terpenes and Sesquiterpene are obtained in the non-polar solvent as benzene, diethyl ether, petroleum ether, or the after fractionation of the acetone extract in a non-polar solvent.
- Investigation of the chemical profile of the agarwood oil, different extraction methods to obtain the oil are employed and then analyzed by GC.MS, GC-FID or GC_MS.Q.TOF; and
- Investigation of wood chemical profile from smoke analysis.

It is remarkable also to mention that the early studies on agarwood were carried out in the lower capacity of the used GCMS instrument today since some of the investigation used 20 eV, and not, as usual, at 70 eV.

Many comprehensive bibliographies and reviews present a useful data about the chemical composition of agarwood as per reviews covering work from 1935 to 2011 by Cropwatch, Neaf, and Chen.

The chemical constituents of agarwood originated from the genus Aqularia include sesquiterpenes, chromone, aromatic compounds, terpenes, sesquiterpenes in agarwood can be mainly divided mainly into:

- Agarofurans
- Agarospiranes
- Guaianes
- Eudesmanes
- Eremophilanes; and
- Prezizananes.

RESULTS AND DISCUSSION

A-sesquiterpenes

Analytical investigations on agarwood from various Aquilaria species, their geographical origins, extraction modes and main constituents with identification methods were provided as far as possible.

A. agallocha chipwood India

In the species *A. agallocha* from India, many researchers have come out with different compounds from the species; petroleum ether, ethanol, and acetone were used as solvent to obtain these compounds in pure form. The following compounds were isolated by using petroleum ether, agarol [83], β-dihydro agarofuran, β-agarofuran, α-agarofuran [84] nor-keto agarfuran, 4-hydroxydihydroagarofuran, 3,4-dihydroxydihydroagarofuran [85]. Meanwhile ethanol extract was used to obtain agarol and gmelofuran [86] beside aquillochin [87]. All compounds structure were confirmed by NMR, MS while the acetone extract used to isolate Agarotetrol and elucidated by using NMR, MS, IR, UV [88].

A. agallocha oil India

A. agallocha oil from India also has been investigated by Meier and his research team, the oil obtained by hydrodistillation, and the isolated compounds elucidate by NMR, MS, GC and FTIR. This research team has successfully isolate Anisyl acetone, the main constituents were agarospirol (12.1%) and jinkoh-eremol (10.0%) beside β-agarofuran, epi-γ-eudesmol, valerianol, dihydrokaranone [89].

A. agallocha Vietnam

The Vietnams species *A. agallocha* has been investigated for chemical constituents by using benzene, acetone, and tenax trap in case of the smoke profile with diethyl ether as solvent. Beside hydrodistillation as extraction technique, the sesquiterpenes obtained from this genes were found to be β-agarofuran, nor-ketoagarofuran, agarospirol, jinkoh-eremol, kusunol, dihydrokaranone, oxo-agarospirol. These compounds were identified by using GC-MS and GC-FID as attempt to profile the chemical constituents of the species by using benzene as solvent. Some of these compounds were isolated from the same genes of Indian agarwood as β-agarofuran and nor-ketoagarofuran [90]. Acetone has been used as isolation solvent widely with this species from Vietnam, (-)-selina-3,11-dien-9-one, and (+)-selina-3,11-dien-9-ol, have been isolated from *Aquilaria agollocha* (agarwood). Their structures have been established on the basis of detailed spectroscopic analyses and synthesis. [91,92] (-)-guaia-l(10),l1-diene-15-ol,(-)-guaia-l(10),11-diene-15carboxylicacid,methylguaia-l(10),11-diene-15 carboxyiate, -guaia-l(l0),l l-dieng-9-one, (-)-l,10-epoxyguai-ll-ene were isolated by using acetone extract from the Vietnam species *A. agallocha* and characterized by NMR,MS,IR [93].

Ishihara team investigate the solvent extracts for the chemical profile purpose, the oil obtained from four kinds of agarwood (Kanankoh and Jinkoh), using GC and MS techniques and acetone as the solvent for extraction. In their work, they mention that the difference between Kanankoh (*A. agallocha*) and another agarwood (Jinkoh), tentatively identified as *A. sinensis* was investigated by comparing the chemical compositions of their extracts. One of them was rich in oxygenated guaiane and eudesmane derivatives, while the other contained oxo-agarospirol as a major sesquiterpene component and can be summarized as β-agarofuran, nor-ketoagarofuran, agarospirol, jinkoh-eremol, kusunol, agarol, (-)-guaia-l(10),11-dien-15,2-olide, α-guaiane, guaia-l(10),11-dien, 1,5-epoxy-nor-ketoguaiene, dehydrojinkoh-eremol, (-)-guaia-l(l0),11-dien-l5-ol, (+)-guaia-l(10),11-dien-9-one,(-)-rotundone,(-)-guaia-l(10),11-diene-15-ol, baimux-3,11-dien-14-al, 9,11-eremophiladien-8-one,selina-3,11-dien-14-ol,selina-4,11-dien-14-al,(-)-guaia-l(10),11-dien-15-ol,sinenofuranol, dihydrokaranone, karanone, selina-4,11-dien-14-oicacid, selina-3,11-dien-14-oicacid, (-)-guaia-l(10),11-dien-15-oicacid, 2-hydroxyguaia-l(10),11-dien-15-oicacid, 9-hydroxyselina-4,11-dien-14-oicacid [19]. From the previous result we can see the similarity between some of the chemical feature in the constituents of the Vietnam and Indian agarwood from the species *A. agallocha*, in spite of existence of some compounds for the first time and not mentioned in the Indian species before and that can be referred to the different chemotype of the plant since their origin are different.

In 1993 Ishihara group investigate the fragrant sesquiterpene of agarwood from Vietnams species

A. agallocha and they isolate five sesquiterpene by using acetone as solvent for isolation, and identified by spectroscopic technique NMR, MS, IR these compounds were baimux-3,11-dien-14-al, selina-4,11-dien-14-al, (-)- methylselina-3,11-dien-14-oate, (+)- methylselina-4,11-dien-14-oate, (+)-methyl9-hydroxyselina-4,11-dien-14-oate [94]. The smoke of Vietnamese agarwood (Kanankoh and Jinkoh) collected by heating was analyzed by Ishihara team work using GC/MS. Kanankoh smoke contained many fragrant sesquiterpenes with pyrolysis products of wood such as acetic acid, benzaldehyde, and vanillin. The study shows that many of the compounds are presented simultaneously as in the previous work, which indicates the chemical constituents of the same species are quite similar, in term of sesquiterpene content, with slightly different in the amount of these compounds. The compounds were adsorbed in tenax trap then extracted with diethyl ether to obtained the chemical profile of the smoke, which consist of β-agarofuran , α-guaiene, guaia-l(10),11-dien, agarospirol, jinkoh-eremol, kusunol, oxo-agarospirol, (-)-l0-epi-γ-eudesmol, (+)-selina-3,11-dien-9-ol, (-)-guaia-l(10), 1 l-diene-15carboxylic acid, dehydrojinkoh-eremol, (-)-guaia-l(l0),11-dien-l5-ol, (-)-guaia-l(10),11-dien-15,2-olide, baimux-3,11-dien-14-al, selina-3,11-dien-14-ol, selina-4,11-dien-14-al, dihydrokaranone, karanone, Selina-4,11-dien-14-oicacid, selina-3,11-dien-14-oicacid, (-)-guaia-l(10),11-dien-15-oicacid, 2-hydroxyguaia-l(10),11-dien-15-oicacid, 9-hydroxyselina-4,11-dien-14-oicacid, while Bhuiyan and his team work study the chemical composition of *A. agallocha* oil from Vietnam obtained from healthy agarwood tree by hydrodistillation, in two different oil source healthy and naturally infected using gas chromatography-mass spectrometry (GCMS)analysis.

Natural healthy plants agarwood contained γ-eudesmol, viridiflorol, caryophylleneoxide,γ-gurjunene,valencene,alloaromadendreneepoxide,spathulenol,tricyclo[5.2.2.0(1,6)]undecan-3-ol,2-methylene-6,8,8-trimethyl-,patchoulene,eremophila-1(10),11-dien,isolongifolene,neoisolongifolene,8,9-dehydro-, isolongifolen-5-one, (.+-.)-cadinene, longiverbenone, α-cedrene oxide, in this study there were remarkably different from the oil under investigation [89].

A. agallocha oil from India also has been investigated by Meier and his research team, the oil obtained by hydrodistillation, and the isolated compounds elucidate by NMR, MS, and GCFTIR.this research team has successfully isolate Anisyl acetone, the main constituents were agarospirol (12.1%) and jinkoh-eremol (10.0%) beside β-agarofuran, epi-γ-eudesmol, valerianol, dihydrokaranone, anisyl acetone was isolated as a minor constituent [89].

A. agallocha Cambodia

The acetone extract of the Cambodian *A. agallocha* has been studied by Alkhathlan and others ,the isolated compounds were elucidated by NMR, MS, IR, the compounds were found to be dehydrofukinone (-)-selina-3,11-dien-9-one, dehydroabietane and three chromones [60] meanwhile, the diethyl ether extract from the same species Cambodian *A. agallocha* has been used to isolate (4R,5R,7R)-1(10)-spirovetiven-11-ol-2-one [95].

Several studies has been done to isolate sesquiterpenes from Cambodian *A. Agallocha* oil, the source of the oil was found to be from different companies, Neaf, R and his research team isolated six sesquiterpenes from *A. Agallocha* oil bought from A. Jagat Aroma Oil Distillery, Kannauj (India) these compounds were (2R,4As)-2-(4a-rnethyl-l,2,3,4,4a,5,6,7-octahydro-2-naphthyl)-propan-2-ol, (S)-4a-rnethyl-2- (1–methylethy1)-3.4.4a,5,6,7-hexahydronaphthalene, (S)-4a-methyl-2-(1–rnethylethylidene) 1,2,3.4,4a,5,6,7-octa-hydronaphthalene, (S)-4a-rnethyl-2-(1–methylethy1)-3.4.4a,5,6,7-hexahydronaphthalene,(1R,6S,9R)-6,10,10-trirnethyI-11-oxatricyclo[7.2.1.0] dodecane,(1R, 2R, 6S, 9R)-6.10,10-trimethyl-l1–oxatricyclo[7.2.1.0] ydroxyl-2-ol, the structure were elucidated by NMR/Ms.(96) in another work the same researchers above isolate Rel-(2R8S,8a R) -2- (1,2,3,5,6,7,8,8a-octahydro-8,8u-dimethyl-2-nuphthyl)-prop-2-en-1-ol, Rel-(3R, 7R,9R,10S)-9,10-dimethyl-6-methylene-4-oxatricyclo[7,4,0,0] tridec-1–en, Re1-(2R,8S,8aR)-2-(1,2,6,7,8,8a-hexahydro-8,8a-dimethyl-2-naphthyl)-propan-2-ol, Rel- (5R,10R)-2-isopropylidene-10-

methyl-spiro[4.5]dec-6-ene-6-carbaldehyde, Rel(5R,7R,10R)-2-isopropylidene-10-methyl-6 methylene-spiro[4.5]decan- 7-ol, Rel-(lR,2R)-9-isopropyl-2- methyl-8-oxatricyclo[7,2.1.0] dodec-5-ene, Rel-(lR,2R)-(9Isopropyl-2-methyl-8-oxatricyclo[7.2.1. 0]dodeca-4,6-dien,2-(1,2,3,4,5,6,7.8,8a-octahydro-8,8a dimethyl-2-naphthy1)-propanal [17].

A. malaccensis Malaysia

The Malaysian agarwood has been subjected to chemical constituent investigation to profile and grade the oil according to its chemical compounds that can be found in the oil, it's remarkable this species has not widely studied widely in term of chemical compounds isolation, most of the oil has been obtained by hydrodistillation, GC-MS and GC-FID were the popular technique used to profile these compounds, Tajuddin and Yusoff tentatively investigate the chemical constituents of the agarwood oil from Malaysia, the compounds found to be β-agarofuran , nor-ketoagarofuran, agarospirol, jinkoh-eremol, kusunol, oxo-agarospirol, (-)-l0-epi-γ-eudesmol, (-)-guaia-l(l0),11-dien-l5-ol, 3,4dihydroxydihydroagarofuran, (+)-guaia-l(10),11-dien-9-one, (-)-rotundone, α-guaiene, guaia-l(10),11 dien, 1,5-epoxy-nor-ketoguaiene, dehydrojinkoh-eremol, 9,11-eremophiladien-8-one, selina-3,11-dien-14-ol, selina-4,11-dien-14-al, (-)-guaia-l(10),11-dien-15-ol, sinenofuranol, selina-3,11-dien-14-oicacid, (-)-guaia-l(10),11-dien-15,2-olide, (-)-selina-3,ll-dien-9-one, dihydrokaranone, (+)-selina-3,ll-dien-9-ol, karanone, (-)-guaia-l(10),11-dien-15-oicacid,2-hydroxyguaia-l(10),11-dien-15-oicacid, 9-hydroxyselina-4,11-dien-14-oicacid, epoxybulnesene, elemol, caryophyllene oxide, guaiol, α-eudesmol, ß-maaliene, aromadendrene, γ-gurjunene, α-muurolen, γ-guaiene, epi-α-cadinol, epi-α- bisabolol, α- bisabolol, selina-3,11-dien-9-al, eudesmol (8). Nor Azah in 2008 studied the comparison of chemical profiles of selected agarwood oils from peninsular Malaysia using MS/GCFID as identification tool and hydrodistillation as extraction methods, many sesquiterpenes has been found in her work as β-agarofuran , α-agarofuran , nor-ketoagarofuran, agarospirol, jinkoh-eremol, (-)-l0-epi-γ-eudesmol, jinkohol ii, α-guaiene, β-eudesmol [97]. The analysis of Malaysian high quality agarwood oil chemical compounds by means of SPME/GC-MS and Z-score technique, the study reveal the flowing compounds: β-dihydro agarofuran, β-agarofuran , α-agarofuran, (-)-l0-epi-γ-eudesmol, α-guaiene, guaia-l(10),11-dien, β-eudesmol, cyperotundone, γ-eudesmol, α-humulene, β-elemene, elemol, viridiflorol, α-eudesmol, α-gurjunene, β-gurjunene, α-selinene, δ-cadinene, aromadendrene, γ-gurjunene, α- bisabolol, α-muurolene, α-cedrene, α-copaene, α-funebrene, valencene, ϒ-muurolene, ar-curcumene, cis-β-guaiene, ϒ-cadinene, selina-3,7(11)-diene, β-vetivenene, allo aromadendrene epoxide, spathulenol, the new concept in this study is to use the solventless technique, SPME for extraction of the chemical compounds from the oil [23].

Tajuddin and his research team provide one of the most advanced steps attempting to profile the chemical constituents of Malaysian agarwood oil, thy investigate the characterization of the chemical constituents of agarwood oils from Malaysia by comprehensive two-dimensional gas chromatography-time-of-flight mass spectrometry. they used oil obtained by supercritical fluid extraction, they state that the chemical constituent of the oil found to be agarospirol, α-guaiene, epoxybulnesene, γ-eudesmol, aristolene, γ-gurjunene, elemol, α-selinene,δ-cadinene, aromadendrene, ß-selinene, copaene, α-cedrene, trans-α-bergamotene,caryophyllene,α-caryophyllene, alloaromadendrenec1,2-epoxide-humulene, γ -gurjunenepoxide, isoaromadendrene epoxide, cis-nerolidol, ledene oxide-(II), trans-longipinocarveol, longipinocarvone [77].

It is remarkable to mention there are a few studies has been carried out on Malaysian agarwood oil using comprehensive two-dimensional gas chromatography-time-of-flight mass spectrometry, beside this study by Tajudinn there was another research done by wong and others, they summarize their finding as β-dihydro agarofuran, agarospirol, β-eudesmol, β-elemene, α-eudesmol, α-gurjunene, β-gurjunene, δ-guanine, α-selinene, 8-epi-γ-eudesmol, epiglobulol, (8S,14)- cedran-diol. the oil was extracted by using hydrodistillation technique [5]. Agarwood oil (*A. Malaccensis*) obtained

by hydrodistillation was investigated by Ismail *et al*. [14] using GCMS to identify the chemical constituent of the oil, the results are same with the previous study by the same author [98].

A. malaccensis from Indonesia

There was a wide range of compounds has been isolated by many researchers from Indonesian *A. Malaccensis* species, almost benzene is the universal solvent used isolation and extraction of the chemical constituents from this species in Indonesia. GC-MS with GC-FID has been used to investigate the chemical profile by Yoneda, his results shows α-agarofuran, jinkoh-eremol, kusunol, oxo-agarospirol, (-)-l0-epi-γ-eudesmol, agarospirol, jinkohol, jinkohol ii [90]. From the same species of Indonesian *A. Malaccensis* Nakanishi, T. Successfully isolates jinkohol, a prezizane sesquiterpene alcohol by using benzene as solvent, structure was elucidated by NMR/IR, MS [99]. The benzene extract of *A. Malaccensis* (Indonesia when studied for chemical compounds isolation by Nakanishi, T. results came with jinkohol ii, jinkoh-eremol, agarospirol, kusunol, jinkohol ii, nootkatane, the structure confirmed by NMR/MS, IR [100]. Nakanishi *et al*. also isolate from Indonesian *A. Malaccensis* three other compounds, by using benzene as the solvent, NMR/MS has been used to confirm the structure of the isolated compounds, α-agarofuran with (-)-l0-epi-γ-eudesmol and oxo-agarospirol were among the isolated compounds [101].

A. Malaccensis Vietnam

Different solvent and different extraction technique has been used to isolate and investigate the chemical profile of Vietnamese *A. Malaccensis*, diethyl ether, acetone, and methanol are solvent system that has been used while the solventless technique SPME also has been used to investigate the chemical constituents of this species, all the previous solvent mentioned above except methanol has been used to isolate different chromones skeleton [101−106]. The methanolic extract of Vietnams *A. Malaccensis* species has been used to isolate 2-[(2b,4ab,8b,8ab)-Decahydro-4a-hydroxy-8,8a-dimethylnaphthalen-2-yl]prop-2-enal,Selina-3,11-dien-14-oicacid,1b,4ab,7b,8ab)-Octahydro-7-[1-(hydroxymethyl)ethenyl]-1,8a-dimethylnaphthalen4a(2H)-ol,(4ab,7b,8ab)-3,4,4a,5,6,7,8,8a-Octahydro-7-[1-(hydroxymethyl)ethenyl]-4amethylnaphthalene-1-carb-oxaldehyde,(1aβ,2β,3β,4aβ,5β,8aβ)-Octahydro-4a,5-dimethyl-3-(1-methylethenyl)-3H-naphth[1,8a-b]oxiren-2-ol, selina-4,11-diene-12,15-dial, eudesm-4-ene-11,15-diol, these compounds identified by HR-ESI-MS/NMR [107].

A. Malaccensis Thailand

No available data indicate that this *A. Malaccensis* species has been studied for isolation of chemical compounds, however the available data shows attempted of investigation of chemical profile by using solventless technique SPME with GC-MS and GC-FID simultaneously by Pripdeevech, P and his team, the Oil profile shows the present of β-dihydroagarofuran, β-agarofuran, nor-ketoagarofuran, agarospirol, jinkoh-eremol, kusunol, (-)-guaia-l(l0), 11-dien-l5-ol,guaia-l(10),11-dien, dehydrojinkoh-eremol, baimux-3,11-dien-14-al, 9, 11-eremophiladien-8-one, karanone, epoxybulnesene, β-acorenone, β-eudesmol, baimux-3,11-dien-9-one, cyclocolorenone, α-(Z)-santalol acetate, α-bisabolol acetate, β-E-santalol acetate, E-α-bergamotene, baimuxifuranic acid, α-humulene [12].

A. crassna Thailand

A. crassna (Thailand) species has been investigated for oil chemical profile by using solventless technique SPME with GC-MS and GC-FID simultaneously by Pripdeevech, P and his team, the chemical investigation results on β-dihydroagarofuran, β-agarofuran, α-agarofuran, nor-ketoagarofuran, agarospirol, jinkoh-eremol, kusunol, oxo-agarospirol, (-)-guaia-l(l0),11-dien-l5-ol, α-guaiene, guaia-l(10),11-dien, dehydrojinkoh-eremol, baimux-3, 11-dien-14-al, 9,11-eremophiladien-8-one, selina-3,11-dien-14-ol, selina-4,11-dien-14-al, (-)-guaia-l(10),11-dien-15-ol, karanone, valerianol, epoxybulnesene,

β-acorenone, cyperotundone, baimux-3, 11-dien-9-one, E-nerolidol acetate, γ-eudesmol, cyclocolorenone, α-(Z)-santalol acetate, β-eudesmol, α-bisabolol acetate, β-E-santalol acetate, β-elemene, E-α-bergamotene, α-humulene [12].

Water distillation and supercritical fluid carbon dioxide extraction has been used to extract the oil from heartwood of *Aquilaria crassna* obtained from (Thailand), Chemical constituents of the oil has been investigated using GC-MS and GC-FID, the results show β-agarofuran, nor-ketoagarofuran, agarospirol, jinkoh-eremol, kusunol, oxo-agarospirol, (-)-l0-epi-γ-eudesmol, (-)-selina-3,11-dien-9-one, (+)-guaia-l(10),11-dien-9-one(-)-rotundone, guaia-l(10),11-dien, 1,5-epoxy-nor-ketoguaiene, dehydrojinkoh-eremol, selina-4,11-dien-14-al, (-)-guaia-l(10),11-dien-15-ol, 9,11-eremophila-dien-8-one, dihydrokaranone, selina-4,11-dien-14-oicacid, (-)-guaia-l(10),11-dien-15-oicacid, selina-3,11-dien-14-oicacid, γ-eudesmol, benzyl acetone, γ-selinene, α-humulene, guaiol, δ -guaiene, α-selinene, epoxybulnesene, selina-3,11-dien-14-al [108].

Aquilaria crassna Vietnam

The Vietnamese agarwood species of *Aquilaria crassna* has been used to isolate three chromones with their structure elucidated by Yagura *et al*. No sesquiterpene was reported in his investigation [3].

A. sinensis China

In general, this species has been intensively investigated by many researchers, many chromones and sesquiterpene have been isolated, Yang *et al.* [109], reported the present of agarospirol, baimuxifuranic acid, baimuxinal(oxo-agarofuran) benzyl acetone, p-methoxybenzyl acetone, anisic acid and β-agarofuran in their Studies on the constituents of *Aquilaria sinensis* (Lour.) Gilg. I. Isolation and structure elucidation of two new sesquiterpenes, baimuxinic acid, and baimuxina were elucidated by NMR and 2D-NMR as well as MS [109,110].

The oil obtained by hydrodistillation from heartwood *A. sinensis* (China) has been investigated for the chemical constituent by using GC-MS/GC-FID, the results show the present of (1 R,6S,9R)-6,10,10-trirnethyI-11-oxatricyclo[7.2.1.0]dodecane, β-dihydroagarofuran, β-agarofuran, α-agarofuran, agarospirol, Jinkoh-eremol, (-)-l0-epi-γ-eudesmol, (S)-4a-rnethyl-2-(1methylethy1)-3.4.4a,5,6,7-hexahydronaphthalene,(1 R,2R,6S,9R)-6.10,10-trimethyl-11-oxatricyclo[7.2.1.0] hydroxyl-2-ol, Epi-ligulyl oxide, (1 R,2R,6S,9R)-6.10,10-trimethyl-11oxatricyclo[7.2.1.0] hydroxyl-2-ol,(S)-4a-methyl-2-(1–rnethylethylidene) 1,2,3.4,4a,5,6,7-octa-hydronaphthalene, kusunol, 4hydroxydihydroagarofuran, elemol, α-santalol, hinesol, β-eudesmol, viridiflorol, anisyl acetone, sinenofuranol, neopetasane, dihydrokaranone, baimuxinol, aristolenepoxide, baimuxinol(oxo-agarofuran), isobaimuxinol [111]. The petroleum ether extract of A. sinensis (China) found to contain 4-Hydroxyl-baimuxinol, 7β-H-9(10)-ene-11, 12-epoxy-8oxoeremophilane, 7α-H-9(10)-ene-11, 12-epoxy-8-oxoeremophilane, neopetasane when investigated for isolation. The elucidation of the compounds was achieved by using NMR/MS/UV/IR [2] meanwhile studies on the chemical constituents of *A. sinensis* (Lour.) Gilg. II. shows the isolation and structure elucidation of baimuxinol and dehydrobaimuxinol. NMR was used as the elucidation technique [112]. The whole tree agarwood-induction technique was used to produce agarwood from *A. sinensis*. The results showed similarities in characteristics to those of high-grade wild agarwood in terms of chemical constituents, and essential oil content, the analysis of the sample were done by GC-MS, GC-FID and TLC, the compound that found to be caryophyllene oxide, β -eudesmol, hinesol, agarospirol, cubenol, aristolene, guaiol, α-eudesmol, eudesm-7(11)-en-4a-ol, aromadendrene oxide, α-copaen-11-ol, baimuxinal, santalol, guaia-1(10), 11-dien-9-one, eremophila-7(11), 9-dien-8-one. (31) while the leave of *A. sinensis* from china has been investigated by Jin Tang and his team, they isolate these compound by using ethanol as solvent, Aquilacallane A, Aquilacallane B, 24-methylene-25-methyltirucall -7-en-3-one, 11-oxo-b-amyrin, hederagenin, 3b-acetoxyfri-edelane, ursolic acid, luteolin-7,30,40-trimethyl,

5-hydroxy-7,40-dimethoxyflavon, genkwanin, 5,7-dihydroxy-40-meth-oxyflavon, luteolin -7,40-dimethyl, 5,7,30,40-tetramethoxy –flavon, 5,7,40-trimethoxyflavon, 5-hydroxy-3,40,6,7-tetramethoxyflavon, benzophenone C-glycoside and iriflophenone 2-O-a-L-rhamnopyr-anoside, the structure of the isolated compounds were identified basis of extensive spectroscopic analyses [33].

A. sinensis Vietnam

Ishihara *et al.* also investigate the smoke of *A. sinensis* (Vietnam) chemical constituent, they used GC-MS and GC-FID as analysis tools, and the compounds were trapped using tenax trap, the revealed smoke compounds found to be β-agarofuran, nor-ketoagarofuran, agarospirol, jinkoh-eremol, kusunol, dihydrokaranone, oxo-agarospirol, dehydrojinkoh-eremol, baimux-3,11-dien-14-al, 9,11-eremophiladien-8-one, selina-3,11-dien-14-ol, selina-4,11-dien-14-al, sinenofuranol, karanone [18], while the acetone extract of the same species of *A. sinensis* (Vietnam) when investigated using GCMS-GCFID gives nor-ketoagarofuran, gmelofuran, agarospirol, jinkoh-eremol, kusunol, dihydrokaranone, oxo-agarospirol, (-)-selina-3,ll-dien-9-one, dehydrojinkoh-eremol, baimux-3,11-dien-14-al, 9,11-eremophiladien-8-one, selina-3,11-dien-14-ol, selina-4,11-dien-14-al, sinenophuranol, karanone [19].

B: CHROMONES

A. agallocha Vietnam

2 -12 – (4’-methoxyphenyl)-ethyllchromone, 6-methoxy-2-[2-(4 ’-methoxypheny1)-ethyl] chromones has been isolated from *A. agallocha* Vietnam species by using acetone as solvent and elucidate by NMR and MS [91). 2-(2-phenylethyl) chromones and 2-(2 (4methoxyphenyl)ethyl) chromones are identified in studying of the components of the volatile concentrate of agarwood (19]. 2-(2-4’-methoxyphenylethyl) chromone, 2-(2phenylethyl) chromone have been identified while ishihara were investigating the Components of the agarwood smoke on heating [18].

A. agallocha India

A. Agallocha oil oil bought from Arabian Oil company, Riyadh (Saudi Arabia), has been used to isolate 6-methoxy-2-[2-(4 ’-methoxypheny1)-ethyl]chromone, 7,8-dimethoxy-2-[2-(3’-acetoxyphenyl)ethyl]chromone, [60].

A. agallocha (Cambodia)

The Cambodian *A. agallocha* give two chromone isolated by acetone as solvent, 6-methoxy-2-[2-(4 ’-methoxypheny1)-ethyl]chromone. And 7,8-dimethoxy-2-[2-(3’-acetoxyphenyl)ethyl] chromone, the structure conformation was done by NMR, MS, IR [(60].

A. Malaccensis (Malaysia)

The investigation of the Malaysian oil for chemical constituent reveals the chromone content as 6-methoxy-2-[2-(4 ’-methoxypheny1)-ethyl]chromone, 2-(2-4’-methoxyphenylethyl) chromone, 2-(2phenylethyl) chromone, solvent less SPME technique has been used to extract and investigate the chemical compounds, GC-MS,GC-FID has been used as analytical investigation tool [8].

A. Malaccensis Vietnam

6-Hydroxy-2-(2-phenylethyl)chromone, 6,7-dimethoxy-2-(2-phenylethyl) chromone, and 6-methoxy-2-[2-(3 methoxyphenyl)ethyl] chromone, were isolated from the Vietnamese *A. Malaccensis* by using diethyl ether as solvent and NMR/MS, IR as structural elucidation tools [102] mean while acetone has been used to isolate 2-(2-4’-methoxyphenylethyl)chromone and 2-(2phenylethyl) chromone (5S,6R,7R,8S)-2-(2-phenylethyl)-5α’,6β,8α’-tetrahydroxy5,6,7,8-tetrahydrochromone, in another research work it give 5α, 6β, 7α, 8β, tetrahydroxy2-[2-(4-(Methoxy-phenyl)ethyl]5-6-7-8-tetrahydro chromone, from the same species, the elucidation carried out by NMR, MS [103, 104]. The acetone extract also used to isolate 5,8-dihydroxy-2-(2-phenylethyl)chromone,

Table 1. (1) Sesequtepene of agarwood in diferent specise.

No	Compound name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Agarol	+			+			+							
2	β-dihydro agarofuran	+		+				+			+	+		+	+
3	β-agarofuran	+	+	+	+			+			+	+		+	
4	α-agarofuran	+						+	+			+		+	
5	nor-keto agar furan	+		+	+			+			+	+			+
6	4-hydroxydihydroagarofuran	+													
7	3,4-dihydroxydihydroagarofuran	+													
8	Aquillochin	+													
9	Agarospirol		+	+	+			+			+	+		+	+
10	jinkoh-eremol		+	+	+			+	+		+	+		+	+
11	epi-γ-eudesmol		+												
12	Valerianol		+												
13	benzyl acetone											+		+	
14	anisyl acetone		+											+	
15	Kusunol			+	+			+	+		+	+		+	+
16	Dihydrokaranone			+	+			+				+		+	+
17	oxo-agarospirol			+	+			+	+			+			+
18	(-)-selina-3,11-dien-9-one,			+		+		+				+			+
19	(+)-selina-3,11-dien-9-ol			+				+							
20	(-)-guaia-l(10),l1-diene-15-ol			+	+			+			+	+			
21	(-)-guaia-l(10),l l-diene-15carboxylic acid			+											
22	methylguaia-l(10),11-diene-15-carboxyiate			+											
23	(+)-guaia-l(10),l l-dien-9-one			+	+			+				+	+		
24	(-)-l,10-epoxyguai-ll-ene			+											
25	(-)-guaia-l(10),11-dien-15,2-olide			-	+			+							
26	α-guaiane			+	+			+				+			
27	guaia-l(10),11-dien			+	+			+			+	+			
28	1,5-epoxy-nor-ketoguaiene			-	+			+				+			
29	dehydrojinkoh-eremol			+	+			+			+	+			+
30	(-)-rotundone			-	+			+				+			
31	baimux-3,11-dien-14-al			-	+	-					+	+			+
32	9,11-eremophiladien-8-one			-	+										+
33	selina-3,11-dien-14-ol			+	+			+				+			+
34	selina-4,11-dien-14-al			+	+			+				+			+
35	Sinenofuranol			-	+			+						+	+
36	Karanone			+	+			+			+				+
37	selina-4,11-dien-14-oicacid			+	+			+				+			
38	selina-3,11-dien-14-oicacid			+	+					+		+			
39	(-)-guaia-l(10),11-dien-15-oicacid			+	+			+				+			

Table 1. (1) Sesequtepene of agarwood in diferent specise.

No	Compound name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
40	2-hydroxyguaia-l(10),11-dien-15-oicacid			+	+			+							
41	9-hydroxyselina-4,11-dien-14-oicacid			+	+			+							
42	E-nerolidol acetate											+			
43	(-)- methylselina-3,11-dien-14-oate			+											
44	(+)- methylselina-4,11-dien-14-oate			+											
45	Gmelofuran												+		
46	(+)- methyl9-hydroxyselina-4,11-dien-14-oate			+											
47	(-)-l0-epi-γ-eudesmol			+				+	+					+	
48	(-)-guaia-l(10),11-dien-15,2-olide			+											
40	γ-eudesmol				+			+				+			
50	Viridiflorol				+									+	
51	caryophyllene oxide				+								+		
52	γ-gurjunene				+										
53	Valencene				+			+							
54	allo aromadendrene epoxide				+			+							
55	Spathulenol				+										
56	tricyclo[5.2.2.0(1,6)]Undecan-3-ol				+										
57	2-methylene-6,8,8-trimethyl-				+										
58	Patchoulene				+										
59	eremophila-1(10),11-dien				+										
60	Isolongifolene				+										
61	neoisolongifolene,8,9-dehydro				+										
62	isolongifolen-5-one				+										
63	(.+-.)-cadinene				+										
64	Longiverbenone				+										
65	α-cedrene oxide				+										
66	Dehydrofukinone					+									
67	Dehydroabietane					+									
68	(4R,5R,7R)-1(10)-spirovetiven-11-ol-2-one					+									
69	(2R,4As)-2-(4a-rnethyl-l,2,3,4,4a,5,6,7-octahydro-2-naphthyl)-propan-2-ol						+								
70	(S)-4a-rnethyl-2- (1 –methylethy1)-3.4.4a,5,6,7-hexahydronaphthalene						+								
71	(S)-4a-methyl-2-(1 –rnethylethylidene) 1,2,3.4,4a,5,6,7-octa-hydronaphthalene						+								
72	(S)-4a-rnethyl-2- (1 –methylethy1)-3.4.4a,5,6,7-hexahydronaphthalene						+								
73	(1 R,6S, 9R)-6,10,10-trirnethyI-11-oxatricyclo[7.2.1.0]dodecane						+								
74	1R,2R,6S,9R)-6.10,10-trimethyl-l1 –oxatricyclo[7.2.1 .0] ydroxyl-2-ol						+								
75	Rel-(2R8S,8a R) -2- (1,2,3,5,6,7,8,8a-Octahydro-8, 8u-dimethyl-2-nuphthyl)-prop-2-en-1-ol									+					
76	Rel-(3R, 7R,9R,10S)-9,10-Dimethyl-6-methylene-4-oxatricyclo[7,4,0,0]tridec-1–en							+							
77	Re1-(2R,8S,8aR)-2-(1,2,6,7,8,8a-Hexahydro-8,8a-dimethyl-2-naphthyl)-propan-2-ol,							+							

Table 1. (1) Sesequtepene of agarwood in diferent specise.

No	Compound name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
78	Rel- (5R,10R)-2-isopropylidene-10-methyl-spiro[4.5]dec-6-ene-6-carbaldehyde						+								
79	Rel(5R,7R,10R)-2-lsopropylidene-10-methyl-6 methylene-Spiro[4.5]decan- 7-ol							+							
80	Rel-(lR,2R)-9-Isopropyl-2- methyl-8-oxatricyclo[7,2.1.0]dodec-5-ene						+								
81	Rel-(lR,2R)-(9Isopropyl-2-methyl-8-oxatricyclo[7.2.1. 0]dodeca-4,6-dien, 2-(1,2,3,4,5,6,7.8,8a-Octahydro-8,8a dimethyl-2-naphthy1)-propanal		+												
82	3,4dihydroxydihydroagarofuran							+							
83	9,11-eremophiladien-8-one							+			+	+			
84	Epoxybulnesene							+			+	+			
85	Elemol							+						+	
86	caryophyllene oxide							+							
87	Guaiol							+				+	+	+	
88	α-eudesmol							+					+		
89	ß-maaliene							+							
90	Aromadendrene							+							
91	γ-gurjunene							+							
92	α-muurolen							+							
93	γ-guaiene							+							
94	epi-α-cadinol							+							
95	epi-α- bisabolol							+							
96	α- bisabolol							+							
97	selina-3,11-dien-9-al							+							
98	Eudesmol							+							
99	jinkohol ii							+	+						
100	β-eudesmol							+			+	+	+	+	
101	Cyperotundone							+							
102	α-humulene							+			+	+			
103	β-elemene							+				+			
104	Viridiflorol							+							
105	α-gurjunene							+							
106	β-gurjunene							+							
107	α-selinene							+				+			
108	δ-cadinene							+							
109	α-cedrene							+							
110	α-copaene							+							
111	α-funebrene							+							
112	ϒ-muurolene							+							
113	ar-curcumene							+							
114	cis-β-guaiene							+							
115	ϒ-cadinene							+							

Table 1. (1) Sesequtepene of agarwood in diferent specise.

No	Compound name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
116	selina-3,7(11)-diene							+							
117	β-vetivenene							+							
118	Spathulenol							+							
119	Aristolene							+					+		
120	ß-selinene							+							
121	Copaene							+							
122	trans-α-bergamotene							+							
123	α-caryophyllene							+							
124	Alloaromadendrene							+							
125	1,2-Epoxide-humulene							+							
126	γ –gurjunenepoxide							+							
127	isoaromadendrene epoxide							+							
128	cis-nerolidol							+							
129	ledene oxide-(II)							+							
130	trans-longipinocarveol							+							
131	jinkohol							+	+						
132	Nootkatane								+						
133	2-[(2b,4ab,8b,8ab)-Decahydro-4a-hydroxy-8, 8a-dimethylnaphthalen-2-yl]prop-2-enal											+			
134	4ab,7b,8ab)-Octahydro-7-[1-(hydroxymethyl)ethenyl]-1, 8a-dimethylnaphthalen 4a(2H)-ol,(4ab,7b													+	
135	8ab)-3,4,4a,5,6,7,8,8a-Octahydro-7-[1-(hydroxymethyl)ethenyl]-4a methylnaphthalene-1-carb-oxaldehyde														+
136	,(1aβ,2β,3β,4aβ,5β,8aβ)-Octahydro-4a,5-dimethyl-3-(1-methylethenyl)-3H-naphth[1,8a-b]oxiren-2-ol														+
137	selina-4,11-diene-12,15-dial, Eudesm-4-ene-11,15-diol									+					
138	β –acorenone										+				
139	baimux-3,11-dien-9-one										+	+			
140	Cyclocolorenone										+	+			
141	α-(Z)-santalol acetate										+	+			
142	α-bisabolol acetate										+	+			
143	β-E-santalol acetate										+	+			
144	E-α-bergamotene										+	+			
145	baimuxifuranic acid										+				
146	γ-selinene											+			
147	baimuxifuranic acid													+	
148	Baimuxinal												+	+	
149	p-methoxybenzyl acetone													+	
150	baimuxinic acid												+		

Table 1. (1) Sesequtepene of agarwood in diferent specise.

No	Compound name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
151	1 R,6S, 9R)-6,10,10-trirnethyI-11-oxatricyclo[7.2. 1.0]dodecane													+	
152	(S)-4a-rnethyl-2-(1methylethy1)-3.4.4a,5,6,7-hexahydronaphthalene													+	
153	(1 R,2R,6S,9R)-6.10,10-trimethyl-11-oxatricyclo[7.2.1 .0] hydroxyl-2-ol													+	
154	epi-ligulyl oxide													+	
155	(1 R,2R,6S,9R)-6.10,10-trimethyl-11oxatricyclo[7.2.1 .0] hydroxyl-2-ol													+	
156	(S)-4a-methyl-2-(1 –rnethylethylidene) 1,2,3.4,4a,5,6,7-octa hydronaphthalene													+	
157	4hydroxydihydroagarofuran													+	
158	α-santalol													+	
159	Hinesol												+	+	
160	Neopetasane													+	
170	Baimuxinol													+	
171	Aristolenepoxide													+	
172	Isobaimuxinol													+	
173	4-hydroxyl-baimuxinol													+	
174	7β-H-9(10)-ene-11, 12-epoxy-8oxoeremophilane													+	
175	7α-H-9(10)-ene-11, 12-epoxy-8-oxoeremophilane													+	
176	Cubenol												+		
177	aromadendrene oxide												+		
178	eudesm-7(11)-en-4a-ol												+		
179	α-copaen-11-o												+		
180	eremophila-7(11), 9-dien-8-one												+		

Table 2. specise key

1	A.agallocha India(W ood)	2	A. agallocha India (Oil)	3	A. agallocha Vietnam (wood)	4	A. agallocha Vietnam(oil)
5	A. agallocha Cambodia(wood)	6	A. agallocha Cambodia(oil)	7	A.malaccensis Malaysia (oil)	8	A.malaccensis Indonesia (wood)
9	A.malaccensis Vietnam(wood)	10	A.malaccensis Thailand (oil)	11	A. crassna Thailand(Oil)	12	A. sinensis China (wood)
13	A. sinensis China (oil)	14	A. sinensis Vietnam (wood)				

6,7-dihydroxy-2-[2-(4-methoxyphenyl)ethyl] chromone, (5S,6S,7R)-2-[2-(2-acetoxyphenyl) ethacetoxy-5,6,7,8,8-pentahydrochromone [105] which were identified by NMR/MS,IR. However (5S,6R,7R,8S)-2-(2-phenylethyl)-5,6,7-trihydroxy5,6,7,8-tetrahydro-8-[2-(2-phenylethyl)-7-methoxychromonyl-6-oxy] chromone, (5S,6R,7R,8S)-2-(2-phenyl-ethyl)-5,6,7-trihydroxy-5,6,7,8-tetrahydro-8-[2-(2-phenyl-ethyl)chromonyl-6-oxy]chromone, (5S,6S,7S,8R)-2-(2-phenylethyl)-5,6,7-trihydroxy-5,6,7,8 tetrahydro-5-[2-(2 phenylethyl) chromonyl-6-oxy]chromone were isolate from the Vietnamese *A. Malaccensis* species using acetone as solvent and structure identified using NMR/MS,IR,UV besides 5α, 6β, 7β trihydroxy-8α-methoxy-2-(2-phenylethyl)chromone and 5α, 6β, 7β, 8α, tetrahydroxy-2-[2-(2-hydroxyphenyl) ethyl]5,6,7,8-tetrahydrochromone [106]. The isolation of chromone from the methanolic extract of *Vietnamese A. Malaccensis* has been found to deliver 5-hydroxy-6-methoxy-2-(2-phenylethyl -4H-chromen-4-one, 5-Hydroxy-6-methoxy-2-[2-(4-methoxyphenyl)ethyl]-4H-1-benzopyran-4-one, 6-methoxy-2-[2-(4-methoxyphenyl) ethyl]-4H-chromen-4-one, 6-methoxy-2-[2-(3-methoxypheny-l)ethyl]-4H-chromen-4-one, 1-hydroxy-1,5-diphenylpentan-3-one ,structure of the isolated compounds identified by HR-ESI-MS/NMR [107].

A. Malaccensis Thailand

In addition SPME technique with GC-FID, GC-MS has been used to detect 5α, 6β, 7β, 8α, tetrahydroxy-2-[2-(2-hydroxyphenyl) ethyl]5,6,7,8-tetrahydrochromone from *A. Malaccensis* (Thailand) species [12].

A. crassna Vietnam

Aquilaria crassna of Vietnam contains 5,6:7,8-diepoxy-2-(2- phenylethyl)-5,6,7,8 tetrahydrochromone, 5,6:7,8-diepoxy-2-[2-(4-methoxyphenyl)ethyl] 5,6,7,8-tetrahydrochromone and 5,6:7,8-diepoxy-2-[2-(3-hydr-oxy-4 methoxyphenyl)ethyl]-5,6,7,8-tetrahydrochromone.these compound isolated by using ethyl acetae as solvent and investigated for their structure by NMR/MS/IR/UV [3].

A. crassna Thailand

In the investigation of chemical constituents *Aquilaria* crassna from Thailand by usig GC-MS and GC-FID itshows the present of 6-methoxy-2-[2-(4'-methoxypheny1)-ethyl]chromone, with 2-(2-4'-methoxyphenylethyl)chromone [108], the oil under investigation from this species was obtained by hydrodistillation and super fluid extraction.

A. sinensis Vietnam

The heartwood of Vietnamese *A. sinensis* shows the present of 6-methoxy-2-[2-(4 '-methoxypheny1)-ethyl]chromone beside 2-(2-(4methoxyphenyl) ethyl)chromone, 2-(2phenylethyl) chromone when scanned for its chemical constituent after extracted by acetone and analyzed by MS/GCFID [19]. Also Ishihara when studied the components of the agarwood smoke on heating by GC-MS and GC-FID, after using tenax trap for extracting the volatile compounds from the agarwood, they indicate the presence of 2-(2phenylethyl) chromone [18].

A. sinensis Taiwan

The methanolic extract of *A. sinensis* fromTiwan can indicate the present of 5-hydroxy-6-methoxy-2-(2-phenylethyl)chromone,6-hydroxy-2-(2-hy-droxy-2 phenylethyl)chromone, 8-chloro-2-(2-phenylethyl)-5,6,7-trihydroxy-5,6,7,8-tetrahydrochromone, 6,7-dihydroxy-2-(2-phenylethyl)-5,6,7,8 tetrahydro chromone, this finding has been proved by the study of the structure of the isolated above compounds by NMR/MS/IR/UV [114].

A. sinensis China

Dai *et al*. [116] isolate three chromone from the Chinese species of agarwood *A. sinensis*, their

Table 1. Chromone of agarwood in diferent specise.

No	Compound name	*A.agallocha* Vietnam	*A.agallocha* India	*A.agallocha* Cambodi)	*A.malaccensis* (Malaysia)	A.*malaccensis* Vietnam	*A.malaccensis* Thailand	*A.crassna* Vietnam	*A.crassna* Thailand	*A.sinensis* Vietnam	*A.sinensis* Taiwan	*A.sinensis* China
1	2 -12 – (4-methoxyphenyl)-ethyllchromone	+										
2	6-methoxy-2-[2-(4 -methoxypheny1)-ethyl]chromone	+	+	+	+		+		+	+		
3	2-(2 (4methoxyphenyl)ethyl)chromones	+			+	+	+		+	+		
4	2-(2phenylethyl) chromone	+			+	+				+		
5	7,8-dimethoxy-2-[2-(3acetoxyphenyl)ethyl]chromone		+	+								
6	6-Hydtoxy-2-(2-phenylethyl)chromone					+						
7	6, 7-dimethoxy-2-(2-phenylethyl) chromone					+						
8	6-methoxy-2-[2-(3 methoxyphenyl)ethyl]chromone					+						
9	(5S,6R,7R,8S)-2-(2-phenylethyl)-5α',6β,8α' tetrahydroxy5,6,7,8-tetrahydrochromone					+						
10	5α, 6β, 7α, 8β, tetrahydroxy2-[2-(4-(Methoxy-phenyl)ethyl]5-6-7-8-tetrahydro chromone					+						
11	5,8-dihydroxy-2-(2-phenylethyl)chromone					+						
12	6,7-dihydroxy-2-[2-(4-methoxyphenyl)ethyl]chromone					+						
13	(5S,6S,7R)-2-[2-(2-acetoxyphenyl)ethacetoxy-5,6,7,8,8-pentahydrochromone					+						
14	(5S,6R,7R,8S)-2-(2-phenylethyl)-5,6,7-trihydroxy5,6,7,8-tetrahydro-8-[2-(2-phenylethyl)-7-methoxychromonyl-6-oxy]chromone					+						
15	(5S,6R,7R,8S)-2-(2-phenyl-ethyl)-5,6,7-trihydroxy-5,6,7,8-tetrahydro-8-[2-(2-phenyl-ethyl)chromonyl-6-oxy]chromone					+						
16	(5S,6S,7S,8R)-2-(2-phenylethyl)-5,6,7-trihydroxy-5,6,7,8 tetrahydro-5-[2-(2 phenylethyl)chromonyl-6-oxy]chromone					+						
17	5α, 6β,7β trihydroxy-8α-methoxy-2-(2-phenylethyl)chromone					+						
18	5α, 6β,7β, 8α, tetrahydroxy-2-[2-(2-hydroxyphenyl)ethyl]5,6,7,8-tetrahydrochromone					+						
19	5hydroxy-6-methoxy-2-(2-phenylethyl)-4H-chromen-4-one					+						
20	5-Hydroxy-6-methoxy-2-[2-(4-methoxyphenyl)ethyl]-4H-1-benzopyran-4-one					+						
21	6-methoxy-2-[2-(4-methoxyphenyl)ethyl]-4H-chromen-4-one					+						
22	6-methoxy-2-[2-(3-methoxypheny-l)ethyl]-4H-chromen-4-one					+						
23	1-hydroxy-1,5-diphenylpentan-3-one					+						
24	5α, 6β,7β, 8α, tetrahydroxy-2-[2-(2-hydroxyphenyl)ethyl]5,6,7,8-tetrahydrochromone						+					
25	5,6:7,8-diepoxy-2-(2- phenylethyl)-5,6,7,8							+				

Table 1. Chromone of agarwood in diferent specise.

No	Compound name	*A.agallocha* Vietnam	*A.agallocha* India	*A.agallocha* Cambodi)	*A.malaccensis* (Malaysia)	A.*malaccensis* Vietnam	*A.malaccensis* Thailand	*A.crassna* Vietnam	*A.crassna* Thailand	*A.sinensis* Vietnam	*A.sinensis* Taiwan	*A.sinensis* China
	tetrahydrochromone, 5,6:7,8-diepoxy-2-[2-(4-methoxyphenyl)ethyl] 5,6,7,8-tetrahydrochromone											
26	5,6:7,8-diepoxy-2-[2-(3-hydr-oxy-4 methoxyphenyl)ethyl]-5,6,7,8-tetrahydrochromone							+				
27	6-methoxy-2-[2-(4 '-methoxyphenyl)-ethyl]chromone											
28	5-hydroxy-6-methoxy-2-(2-phenylethyl)chromone										+	
29	6-hydroxy-2-(2-hy-droxy-2 phenylethyl)chromone										+	
30	8-chloro-2-(2-phenylethyl)-5,6,7-trihydroxy-5,6,7,8-tetrahydrochromone										+	
31	6,7-dihydroxy-2-(2-phenylethyl)-5,6,7,8 tetrahydro chromone										+	
32	5,6,7,8-tetra-hydroxy-2-(3-hydroxy-4 methoxyphenyl)-5,6,7,8-tetrahydro-4H-chromen-4-one											+
33	,(5S*,6R*,7S*)-5,6,7-trihydroxy-2-(3-hydroxy-4methoxyphenethyl) 5,6,7,8tetrahydro-4H-chromen-4 one											+
34	(5S*,6R*,7R*)-5,6,7-trihydroxy-2-(3-hydroxy-4-methoxyphenethyl)-5,6,7,8-tetrahydro-4H-chromen-4-one											+
35	6,7-dihydroxy-2-[2-(4-methoxyphenyl)ethyl]chromone,6-Hydroxy-7-methoxy-2-[2-(3-hydroxy-4 methoxyphenyl)ethyl]chromone											+
36	6,7-Dimethoxy-2-[2-(3-hydroxy-4-methoxyphenyl) ethyl]chromone											+
37	7-Hydroxy-6-methoxy-2-[2-(3-hydroxy-4-methoxy-phenyl)ethyl]chromone											+
38	6,7-Dimethoxy-2-[2-(4-hydroxy-3-methoxyphenyl)ethyl]chromone											+
39	6-Hydroxy-7-methoxy-2-[2-(4hydroxyphenyl)ethyl]chromone											+
40	6,8-Dihydroxy-2-[2-(3-hydroxy-4-methoxyphenyl) ethyl]chromone											+
41	6-Hydroxy-2-[2-(40-hydroxy-3 methoxyphenyl)ethenyl]chromone											+
42	6,7-Dimethoxy-2-[2-(4-hydroxyphenyl)ethyl]chromone											+
43	2-[2-Hydroxy-2-(4-hydroxyphenyl)ethyl]chromone											+
44	2-[2-Hydroxy-2-(4-methoxyphenyl)ethyl]chromone											+

structure were elucidated using NMR and MS, and ethanol has been used as a solvent for isolation. these compounds found to be 5,6,7,8-tetra-hydroxy-2-(3-hydroxy-4 methoxyphenyl)-5,6,7,8-tetrahydro-4H-chromen-4-one,(5S*,6R*,7S*)-5,6,7-trihydroxy-2-(3-hydroxy-4methoxyphenethyl) 5,6,7,8tetrahydro-4H-chromen-4 one and (5S*,6R*,7R*)-5,6,7-trihydroxy-2-(3-hydroxy-4-methoxyphenethyl)-5,6,7,8-tetrahydro-4H-chromen-4-one. [115,116] while the petroleum ether extract of the same species successfully delivered the isolation process by Yang and his team 6,7-dihydroxy-2-[2-(4-methoxyphenyl) ethyl]chromone,6-hydroxy-7-methoxy-2-[2-(3-hydroxy-4 methoxyphenyl)ethyl] chromone, 6,7-dimethoxy-2-[2-(3-hydroxy-4-methoxyphenyl) ethyl]chromone, 7-hydroxy-6-methoxy-2-[2-(3-hydroxy-4-methoxy-phenyl) ethyl]chromone,6,7-dimethoxy-2-[2-(4-hydroxy-3-methoxyphenyl)ethyl]chromone,6-hydroxy-7-methoxy-2-[2(4hydroxyphenyl)ethyl] chromone, 6,8-dihydroxy-2-[2-(3-hydroxy-4-methoxyphenyl) ethyl]chromone and 6-Hydroxy-2-[2-(40-hydroxy-3 methoxyphenyl)ethenyl] chromone [35] while the diethyl ether when used as solvent for isolation of chromone from the same species of chines agarwood it yield in 6,7-dimethoxy-2-[2-(4-hydroxyphenyl)ethyl] chromone, 2-[2-hydroxy-2-(4-hydroxyphenyl) ethyl]chromone, and 2-[2-hydroxy-2-(4-methoxyphenyl)ethyl]chromone [81].

CONCLUSIONS AND OUTLOOK

The GCMS, GCFID seemed to be the universalmethod of analysis of agarwood chemical constituent. The results from GCMS.Q.TOF indicated that the complexity of agarwood could be used as a power tool to resolve and overcome such complex profile. SPME could play key in resolving the aromatic profile of agarwood since it showed great capacity and accuracy in its analysis. Major agarwood compounds from different species consisting of different chemical groups such as monoterpenic and sesquiterpenic hydrocarbons, oxygenated monoterpenes and sesquiterpenes (comprised ketone, aldehyde, oxide, alcohols, lactone, keto-alcohol and diol), norterpenoids, diterpenoids, short chain glycols, carboxylic acids and others but at the same time each family had certain features of compound which could be considered as a signature of that species to make differential profile from others species.

GC × GC, in combination with a further mass spectrometry detection dimension, was reported as the most powerful analytical methodology available for the analysis of volatile and semivolatile organic compounds in complex samples. Few reports of GC × GC for the analysis of agarwood oil were achieved, and all prior work until Tajuddin and Yousef; and Y.F. Wong did not address the phyto-complexity of the metabolites present within the oils in detail since all previous work was done by 1D GC.MS [5, 77].

In general the chemical profile of the wood from the different species and countries looked different except the vitenames *A. sinensis* and *A. agallocha* which seemed to have very close chemical profile. Especially the common sesequiterpenes, that could be found in most agarwood chipwood as ß-agarfuran and agarspirol.

There were no available data for some species as oil or as chipwood, as *A. malaccensis* wood from malaysia, *A. malaccensis* oil from Vietnam, *A. crassna* wood Thailand, *A. crassna* wood and oil from vitenam, *A. sinensis* oil from Vietnam.

There were remarkable similarities in the chemical profile of *A. agallocha* India (wood), *A. agallocha* Vietnam (wood) and *A. sinensis* Vietnam (wood) with minor absence of some compounds from *A. agallocha* India (wood).

A. agallocha Cambodia (wood) showed a unique chemical profile that was different from the other species chip wood. *A. agallocha* Vietnam (oil), *A. malaccensis* Malaysia (oil), A. malaccensis Thailand (oil), *A. crassna* Thailand (oil), *A. sinensis* China (oil) have common feature in term of sesquiterpenes profile, with slight a slight difference in case of *A. malaccensis* Malaysia (oil) where the presence of sesquiterpenes were more intense and that might be due to the intensive investigation of their chemical profiles. Recently with the modren investigation tools such as GCMS-Q. TOF which was reflected in

the detailed compounds that could be present in the sample, while *A. agallocha* Cambodia (oil) was totally different from the other species and their sesequiterpene content also were poor when compared with the other oils.

From all literature search, we could say that 6-methoxy-2-[2-(4-methoxypheny1)-ethyl] chromone and 2-(2 (4methoxyphenyl)ethyl) chromones were the most dominant chromones found in all species with a few exceptions in some species, *A. malaccensis* Vietnam and *A. sinensis* from China were the most species which had been investigated with the high profile of chromone.

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