COMPARISON BETWEEN CHEMICAL COMPOUNDS IN GAHARU SMOKE (BURNING) AND GAHARU OIL (HIDRODISTILLATION)

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BORANG PENGESAHAN STATUS TESIS

JUDUL **COMPARISON BETWEEN CHEMICAL COMPOUNDS IN GAHARU SMOKE (BURNING) AND GAHARU OIL (HIDRODISTILLATION).**

SESI PENGAJIAN: **2007/2008**

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COMPARISON BETWEEN CHEMICAL COMPOUNDS IN GAHARU SMOKE (BURNING) AND GAHARU OIL (HIDRODISTILLATION)

SURITA BINTI SOKIMA

A thesis submitted in fulfillment
of the requirements for the award of the degree of
Bachelor of Chemical Engineering

Faculty of Chemical Engineering & Natural Resources
University Malaysia Pahang

May, 2008

I declare that this thesis entitled *"Comparison between Chemical Compounds in Gaharu Smoke (Burning) and Gaharu Oil (Hydrodistillation)"* 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.

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Special Dedication of This Grateful Feeling to My…

Beloved parent;
Mr. Sokima b Saria & Mrs. Rohani bt Yunus

Loving brothers and sister;
Suriani, Mohd Issammudin and Shafie

Understanding families;
Grandma, Uncles and Aunties

Supportive friends;
Munirah, Nabila, Marni, Faradila, Haikal, Shaiful, etc

For Their Love, Support and Best Wishes

ACKNOWLEDGEMENT

First and foremost, I wish to express my sincere appreciation to my thesis supervisor, Mr. Saiful Nizam Tajuddin, for constantly guiding and encouraging me throughout this study. Thanks a lot for giving me a professional training, advice and suggestion to bring this thesis to its final form. Without his support and interest, this thesis would not have been the same as presented here.

I am grateful to the staff of Faculty of Chemical Engineering of University College of Engineering and Technology Malaysia for their cheerfulness and professionalism in handling their work. In preparing this thesis, I was in contact with many people, researches, academicians and practitioners. They have contributed towards my understanding and thoughts.

In particular, my sincere thankful is also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. And last, but not least I thank my mother and other family members for their continuous support while completing this thesis.

ABSTRACT

Gaharu is known as one of the most expensive wood in the world. It is valued in many cultures for its distinctive fragrance, and used extensively in incense and perfumes. The gaharu that was used in this study is grade C gaharu from peninsular of Malysia or known as ‘karas’ among the locals. The objective of this study is to determine the different between chemical compounds exist in gaharu smoke and gaharu oil. For burning process, the smoke was trapped using sample bottles and then was analyzed using GC-MS. Meanwhile for extraction process, the gaharu was extracted using hidrodistillation method. Then, the oil formed was analyzed using GC-MS too. From the result, about 20 to 30 chemicals compounds found in gaharu smoke and about 80 to 90 chemical compounds found in gaharu oil. After make comparison, only 6 compounds exist in both condition of gaharu. Most of them are pulp wood pyrolysis product and aromatic compounds. There are also fragrant sesquiterpenes found in gaharu oil but not in gaharu smoke which are copaene and 7-methanoazulene.

ABSTRAK

Kayu Gaharu terkenal sebagai antara kayu yang termahal di dunia. Ia banyak digunakan oleh pelbagai budaya sebagai pewangi tersendiri dan juga digunakan sebagai setanggi dan minyak wangi. Kayu gaharu yang digunakan dalam kajian ini adalah kayu gaharu gred C dari semenanjung Malaysia yang mana juga dikenali sebagai ‘karas’ oleh penduduk tempatan. Kajian ini dijalankan bagi menentukan perbezaan antara sebatian kimia yang wujud dalam asap gaharu dan minyak gaharu. Untuk proses pembakaran, asap gaharu di simpan di dalam botol sampel dan kemudian di analisis dengan menggunakan GC-MS (*Gas Chromathography- Mass Spectometry*). Manakala untuk proses pengesktrakan pula, gaharu di ekstrak dengan meggunakan kaedah penyulingan hidro. Berdasarkan keputusan eksperimen, lebih kurang 20 ke 30 sebatian kimia didapati dalam asap gaharu dan lebih kurang 80 ke 90 sebatian kimia didapati dalam minyak gaharu. Selepas membuat perbandingan, hanya enam sebatian kimia wujud dalam kedua-dua keadaan gaharu. Kebanyakan sebatian kimia yang wujud adalah dari produk pirolisis dan sebatian aroma. Selain itu terdapat juga campuran *sesquiterpene* wujud di dalam minyak gaharu iaitu *copaene* and *7-methanoazulene.*

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Gaharu is a resinous wood that sometimes occurs in trees belonging to the Aquilaria genus, Thymelaeceae family. There are many names for this resinous wood, including agar, agarwood, aloeswood, eaglewood and kalambak. Table 1.1 shows the scientific classification of gaharu.

Table 1.1 : Scientific Classification of Gaharu/Agarwood

Kingdom	**Plantae**
Division	Magnoliophyta
Class	Magnoliopsida
Order	Malvales
Family	Thymelaeacea
Genus	*Aquilaria*

(Source: www.wikipedia.org)

Gaharu wood being in high demand for medicine, incense and perfumes across Asia and Middle East (Chang *et al.*, 1997). In Arabic, gaharu woodchips are meant to be used as incense. A sliver should be placed on charcoal and it will smoulder for sometimes hours depending on the woodchip size. A sliver is all that is needed to enjoy the wonderfully hypnotic aroma for about an hour. Figure 1.1 shows the example of gaharu chips which is the C grade of gaharu.

Gaharu is one of the rarest and precious woods on the planet, prized for its rich and wonderful fragrance. One of the reasons for the relative rarity and high cost of gaharu is the depletion of the wild resource. Unlike other fragrant woods or materials, the gaharu chips produce fragrance only when burned. Only burned gaharu releases in the atmosphere a fresh and fascinating spiritual scent. In comparison with fragrance of other woods, the fragrance of burnt gaharu is very long-lasting and a small quantity of burned gaharu may scent the air for the whole hours.

Figure 1.1 Example of Gaharu Chips

As mentioned above, gaharu is generally used in an incense stick. When burned it emits a type of smoke which possesses a pleasant odor (Ishihara *et al.*, 1992). Therefore, it is very important to clarify the components of the smoke generated by heating as well as the constituent in essential oil of gaharu. So, this research will focus on the differences between components in gaharu smoke and gaharu oil.

1.2 Objective

The objective of this research is to determine the chemical compounds that exist in the smoke during the burning and extraction process.

1.3 Scope of study

In order to achieve the objective, the following scopes are going to be applied:

1. To study the chemical compounds of gaharu wood based on GCMS analysis.
2. To compare the chemical compounds exist during extraction (hydro distillation) and burning process.

1.4 Problem Statement

Currently, the method used to determine the grade of gaharu is using the physical properties of the wood. Some countries used sinking method to grading the gaharu and others depend on the colour of the gaharu. For this research, I try to use the scientific way to grading the gaharu so that the method to grade the gaharu can be standardize among the countries.

Another problem is we still cannot identified the real compounds exist in gaharu smoke. Many researchers have done the research to define the chemical compounds in gaharu essential oil but not in gaharu smoke.

CHAPTER 2

LITERATURE REVIEW

2.1 Gaharu

Gaharu, also known as agarwood, aloeswood, agalloch or eaglewood in English and jinkoh in Japanese, is a fragrant wood and one of the valuable non-timber products in Asian tropical forest. Gaharu is produced from the action of damages on Aquilaria plants (Thymelaeaceae) and then infections by fungi (Ueda *et al.,* 2006). The trees occasionally become infected with a parasite mould and begin to produce an aromatic resin in response to this attack. As the fungus grows, the tree produces a very rich, dark resin within the heartwood. It is the precious resinous wood that is treasured around the world.

The degree to which the resin saturates the heartwood phloem fibers determines the market value of this product. In lesser quality specimens, the resin creates a mottled or speckled appearance in the naturally pale wood, but higher quality specimens are nearly solid in color—glossy and black (Donovan *et al.,* 2004). Gaharu has three principle uses which are medicine, perfume and incense. Smaller quantities are used for other purposes, such as carvings.

2.2 Grading and Prizing of Gaharu

As noted by Barden *et al.*, 2000, grading gaharu or agarwood is a complicated process. It is classified according to various grading systems that differ according to the product in trade and country in which trade is taking place. The grade of gaharu and gaharu derivatives such as oil is determined by a complex set of factors including country of origin, fragrance strength and longevity, wood density, product purity, resin content, colour and size of the form traded.

In Taiwan, the quality of gaharu is assessed according to whether or not it sinks in water. Gaharu pieces which sink are assumed to have a higher resin content (and hence be of a higher grade) than those which float (Heuveling van Beek and Phillips, 1999). Burned gaharu is another indication of resin content. Resin can be seen to exude with a bubble-like appearance when the wood is burnt.

In Papua New Guinea, grading of gaharu is based on colour, shape and density of the wood. At present there are five grades of gaharu which are Super A, A, B, C and D as presented in Table 2.1 below:

Table 2.1 : Guidelines for grading gaharu based on size, shape and weight of wood

Grading on colour	**Heavy irregular shape**	**Heavy irregular shape**	**Light large pieces**	**Heavy thick chips**
Black shiny	Super A	A	B	C
Mixture of dark black & chocolate brown	B	B	C	C
Mixed colour (pale	C	C	C	C

black/chocolate brown				
Brown	D	D	D	D
Pale yellow or tan brown	D mostly rejected	D mostly rejected	D mostly rejected	D mostly rejected
White	reject	reject	reject	reject

(Source: RMAP Working Papers, 2003)

2.3 Gaharu in Malaysia

In Malaysia, the tree of Aquilaria is called karas and its fragrant is known as gaharu. The gaharu is traditionally used to produce incense in the Far East and have tonic and therapeutic properties (Burkill 1966, Okugawa *et al.,* 1993). Recently, the range of uses for gaharu has widened to include new products such as gaharu essence, soap and shampoo (Chakrabarty *et al.,* 1994).

Based on available trade data, Indonesia and Malaysia appear to be the main sources of gaharu in international trade. Over 340 tonnes of gaharu were reported as exported from Peninsular Malaysia from 1995 to 1997 (Barden *et al.,* 2000). One of the states that produce gaharu in Malaysia is Kelantan. High quality gaharu can fetch RM10, 000 per kg and is burned like incense stick. A 12g of oil is sold at between RM50 and RM200. Table 2.1 below shows the price of gaharu in Kelantan.

Table 2.2 : Price of Gaharu in Kelantan

Grade	Price
Double Super Grade	RM10, 000 to RM12, 000 per kg
Super Grade	RM8, 000 to RM10, 000 per kg
A Grade	RM4, 000 to RM8, 000 per kg
B Grade	RM3, 000 to RM4, 000 per kg
C Grade	RM 1, 000 to RM 2, 000 per kg
Mix Grade	RM 60 to RM 250 per kg

According to Heuveling van Beek and Phillips (1999), as a general rule Malaysia produces eight grades of gaharu: grades one to three are dark, highly resinous and sink in water, whereas grades four to eight are brown to light brown and float in water. Gaharu is often adulterated with kerosene or other coloured oils to resemble higher grade gaharu.

2.4 Chemical Compounds in Gaharu

2.4.1 Gaharu Essential Oil

The first investigation on the chemical components of gaharu was done on 1935 (Shimada *et al.,* 1982). Generally, gaharu oils are mixture of sesquiterpenes, sesquiterpene alcohols, oxygenated compounds, chromone derivatives and resins. Some of the more important compounds are agarospirol, jinkohol-eremol, jinkohol and kusenol that may contribute to the characteristic aroma of gaharu (Nakanishi *et al*., 1984, Ishihara *et al*., 1993).

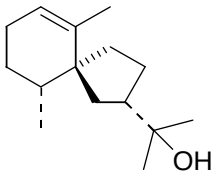
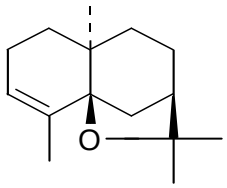
Similar chemical studies were conducted on gaharu from A. agallocha and other species of Aquilaria. The results from the study suggest that gaharu of different origins may be distinguished chemically as shown in Table 2.3 (Yoneda *et al.,* 1984).

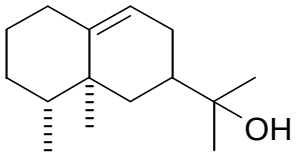
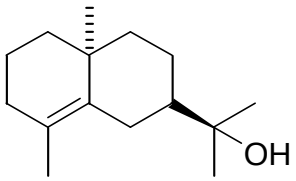
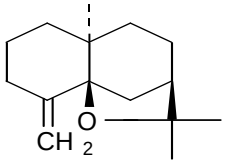
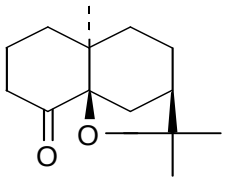
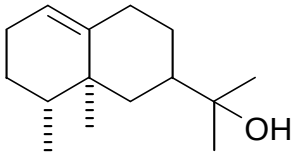
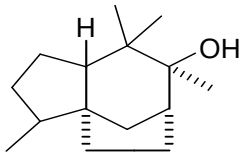
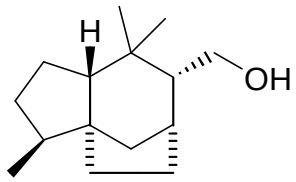
Table 2.3 : Chemical comparisons between gaharu of different origins

Gaharu	**Chemical components**
Type A (A. agallocha)	Agarospirol Jinkoh-eremol Oxo-agarospirol α- and β-agarofuran Dihydroagarofuran Kesunol
Type B (Aquilaria spp.)	Agarospirol Kusunol Jinkoh-eremol Oxo-agarospirol α-agarofuran (-)-10epi-γ-eudesmol Jinkohol

Different chemical component in gaharu oil will determine the characteristic or quality of the gaharu. Figures in table below will show some chemical component structure in gaharu essential oil.

Table 2.4 : Chemical structure of chemical components in gaharu essential oil

Chemical components	**Chemical structure**
Agarospirol	
α-agarofuran	

Jinkoh-eremol	
10-epi-γ-eudesmol	
β-agarofuran	
Nor-ketoagarofuran	
Kusunol	
Jinkohol	
Jinkohol II	

In peninsular of Malaysia, the gaharu were mostly of grade C quality. Gas chromatograms showed similar gas chromatography profile suggesting a region of peaks with retention times ranging from 28.0 to 42.0 min to be indicative of gaharu presence (Chang *et al.,* 2002).

2.4.2 Gaharu Wood

In Vietnam, the smoke of two kinds of agarwood (Kanankoh and Jinkoh) generated by heating was analyzed by using fused silica capillary GC/MS. Kanankoh smoke contained many kinds of fragrant sesquiterpenes along with a small amount of pulp wood pyrolysis products such as acetic acid, benzaldehyde, and vanillin as a top note. On the other hand, many aromatic compounds that might be produced by pyrolysis of ligneous part were detected from Jinkoh smoke (Ishihara *et al.,* 1993).

2.5 Burning Method

Sampling of smoke volatiles emitted from burning incense using SPME was performed in two ways. Figure 2.1 shows the set up for extraction of smoke volatiles, where the SPME fiber is directly exposed to the smoke stream from the incense stick burning inside the inverted glass funnel. This experiment allows sorption of smoke volatiles and also potentially particulates from the smoke onto the fiber (Philip *et al.,* 2006).

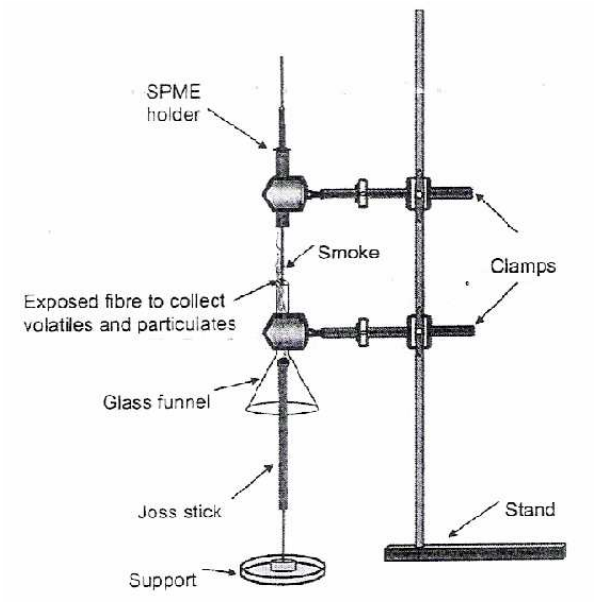


Figure 2.1 Diagram of SPME set up for sampling of smoke by direct sampling

Figure 2.2 shows the SPME set up for side stream extraction. A T-piece was attached to the glass funnel, with the incense burnt in the bottom portion of the inverted funnel, and the fiber was inserted into the side arm of the T-piece. The mainstream smoke was vented through the funnel neck, and volatile compounds diffuse into the side arm of the T-piece for SPME sampling.

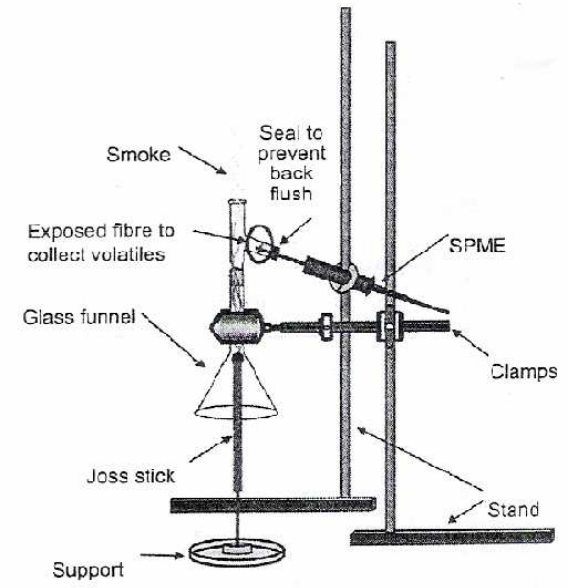


Figure 2.2 Diagram of SPME set up for sampling of smoke by side stream sampling

2.6 Analysis Equipments

2.6.1 Solid-Phase Microextraction (SPME)

SPME is a solvent-less extraction technique, usually used for analyte collection for determination by gas chromatography and is based on adsorption. A fused silica fiber is coated with a solid adsorbent or an immobilized polymer. Figure 2.3 below show the schematic diagram of SPME.

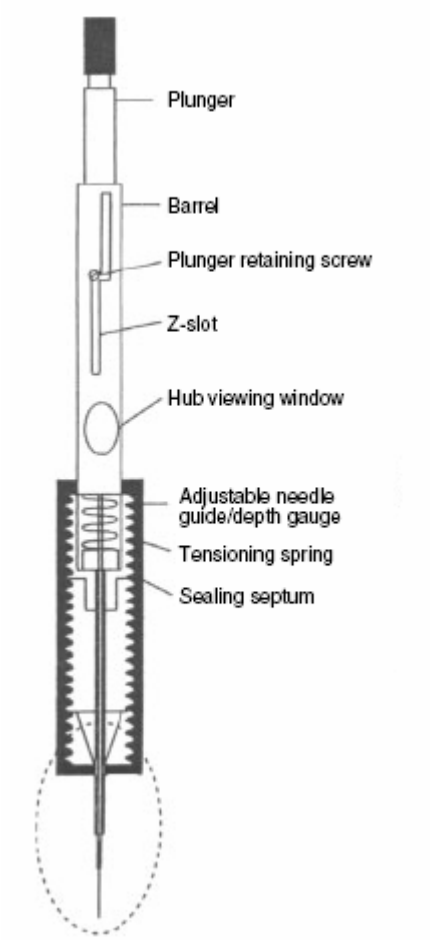


Figure 2.3 Schematic Diagram of SPME

(Source: Gyorgy and Karoly, 2003)

SPME relies upon the extraction of solutes from a sample into the SPME absorptive layer. After a sampling period, the absorbed solutes are transferred with the SPME layer into an inlet system that desorbs the solutes into a gas (for GC) or liquid (for LC) mobile phase (Hinshaw, 2003).

The primary advantages of SPME are its ability to decouple sampling from matrix effects that would distort the apparent sample composition or disturb the chromatographic separation; its simplicity and ease of use; and its reduced or non-existent solvent consumption. These characteristics combine to make SPME an attractive alternative to classic headspace or thermal-desorption sampling, solid-phase extraction and classic liquid–liquid extraction.

2.6.2 Gas Chromatography-Mass Spectrometry

Gas chromatography-mass spectrometry (GC-MS) is a method that combines the features of gas-liquid chromatography and mass spectrometry to identify different substances within a test sample. The schematic diagram of GC-MS is shown in figure below.

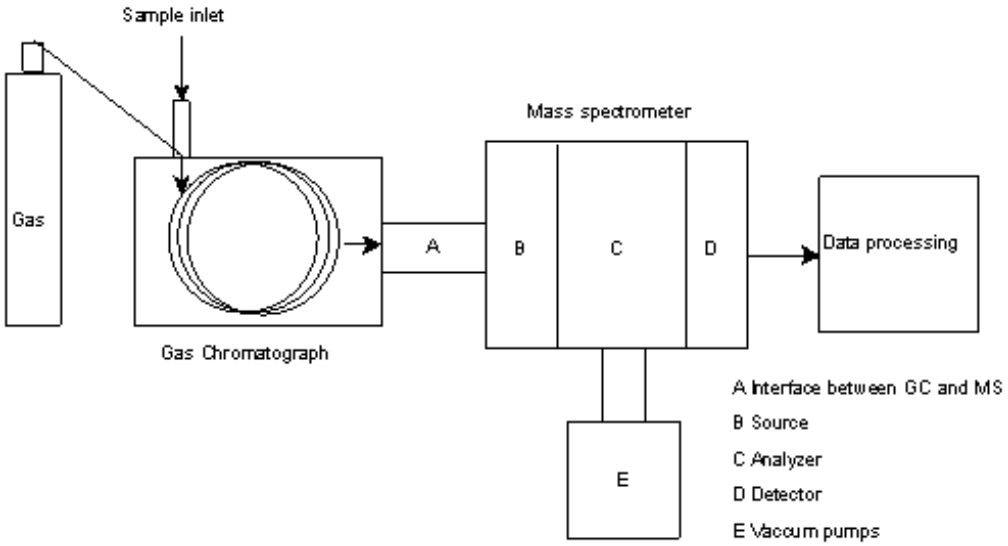


Figure 2.4 Schematic diagram of GC-MS

The GC-MS is composed of two major building blocks which are the gas chromatograph and the mass spectrometer. The gas chromatograph utilizes a capillary column and depending on the column's dimensions as well as the phase properties. The molecules take different amounts of time to come out of the gas chromatograph, and this allows the mass spectrometer downstream to capture, ionize, and detect the molecules separately. The mass spectrometer does this by breaking each molecule into ionized fragments and detecting these fragments using their mass to charge ratio.

CHAPTER 3

METHODOLOGY

3.1 Introduction

For this research, the experiment was only focus on burning process. The detailed procedure of the experimental work is discussed through out this chapter. The purpose of the experimental work phase is to understand the requirement for the experiment. This phase will include the two major steps which are requirement laboratory testing, and data analysis.

3.2 Process Flow

The overall methodology in this study is summarized in Figure 3.1 below. The main activities in this research were the experimental study and the subsequent analysis.

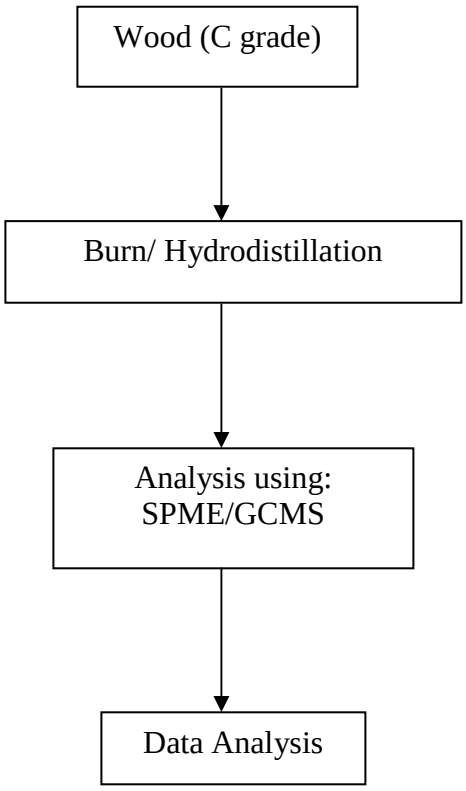


Figure 3.1 Process flow of the Experiment

3.3 Process Description

3.3.1 Materials or samples

The source plant of gaharu used in this study was identified as Aquilaria Malaccensis species. C grade of gaharu was used for both process (burning and hydrodistillaion). The gaharu wood was bought at Kelantan which was supplied by orang asli collectors and the remainder from local villagers.

3.3.2 Burning process

Sampling of smoke volatiles emitted from burning incense was performed using sample bottles. There are some apparatus used for this experiment as shown in figure 3.2 such as glass funnel, Bunsen burner, retort stand, air pump and sample bottle. The gaharu was burned under the glass funnel and the smoke released was directly flow into the sample bottle. Air pump was used to make sure there was smoke trapped in the sample bottle. The picture of air pump was shown in figure 3.3.

Figure 3.2 Apparatus for burning process

Figure 3.3 Air Pump

3.3.3 Hydrodistillation

Hydrodistillation method involves several processes like drying, grinding, soaking and finally distillate. Drying process need to be done so that the wood is completely dry from any moisture. It is also to get rid of any substance that can distract the impurities of oil when it has been extracted. Then, grinding process is to give the maximum surface area for extraction process and to maximize the contact time between the solvent and gaharu particle. Before the extraction process, grinded gaharu must be soaked in water. Finally, the soaked gaharu will be extract using hydrodistillation process.

3.3.4 Solid Phase Microextraction

Solid-phase microextraction (SPME) coupled to capillary gas chromatography-mass spectrometry (GC-MS) was used for determination of volatile gaharu components. This combination offers a simple, quick, and sensitive approach suitable for characterization of gaharu compounds without a complicated sample preparation procedure.

The fiber that was used in this experiment is black fiber (CAR/PDMS). SPME was injected into the sample bottle and was exposed for about 10 minutes to make sure the smoke was fully absorbed into the fiber. The fiber was then transferred to the GCMS and was run for about 22 minutes.

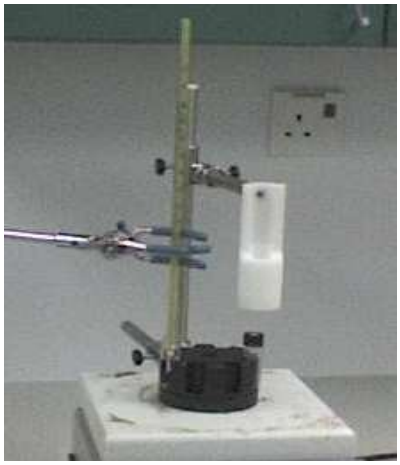


Figure 3.4 SPME holder

3.3.5 Gas Chromatography- Mass Spectrometry

The relatively new technique of SPME/GC-MS has been applied to a wide variety of analytical problems. The SPME fiber can be thought of as a very short GC column turned inside out. An outer polymer coating absorbs volatiles, which are then desorbed in the hot GC inlet and chromatographed in the usual manner. These volatiles are subsequently identified using a mass spectrometer. Before it is used the first time, each fiber is conditioned until a clean chromatogram is obtained under normal run conditions. In addition, to minimize background signals, the fibers are heated in the GC inlet for 2 to 5 minutes before each headspace sampling. To eliminate carryover, the fibers are left in the inlet for the full length of a run, typically 20 to 30 minutes.

Qualitative characterizations of the extract were performed by means gas chromatography-mass spectrometry. An AGILENT GC-MS (model G3171A) equipped with a HP-5 capillary column (30m x 0.25mm x 0.25µm) was used. Analysis was carried out by using helium as the carrier gas, with the column temperature programmed at 325^{o}C and at rate 10^{o}C/min.

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Introduction

The experiment of burning and extraction of gaharu had been completed. The procedure of doing this experiment is carefully followed to ensure the objective was achieved. The result was discussed and analyzed based on the GC-MS graph.

4.2 Results for Gaharu Smoke

The experiment of burning was done three times using same type and same grade of gaharu which is C grade. Before the SPME fiber was injected into the GC-MS, the smoke was exposed to the fiber for about ten minutes to ensure the smoke fully absorbed. The fiber turned a brownish colour over time with increased sampling events. Figure 4.1, 4.2 and 4.3 shows the working curve or graph for smoke. The chemical compounds exist in gaharu was determined based on the peak from the graph.

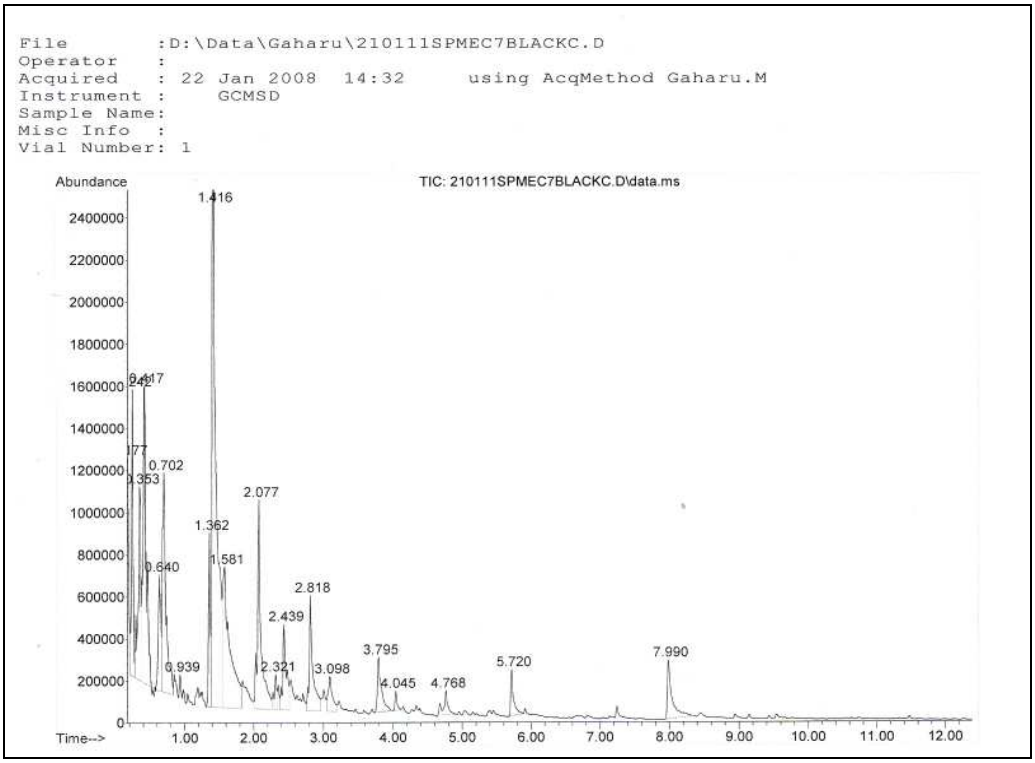


Figure 4.1 GC-MS charts of smoke (1st sample)

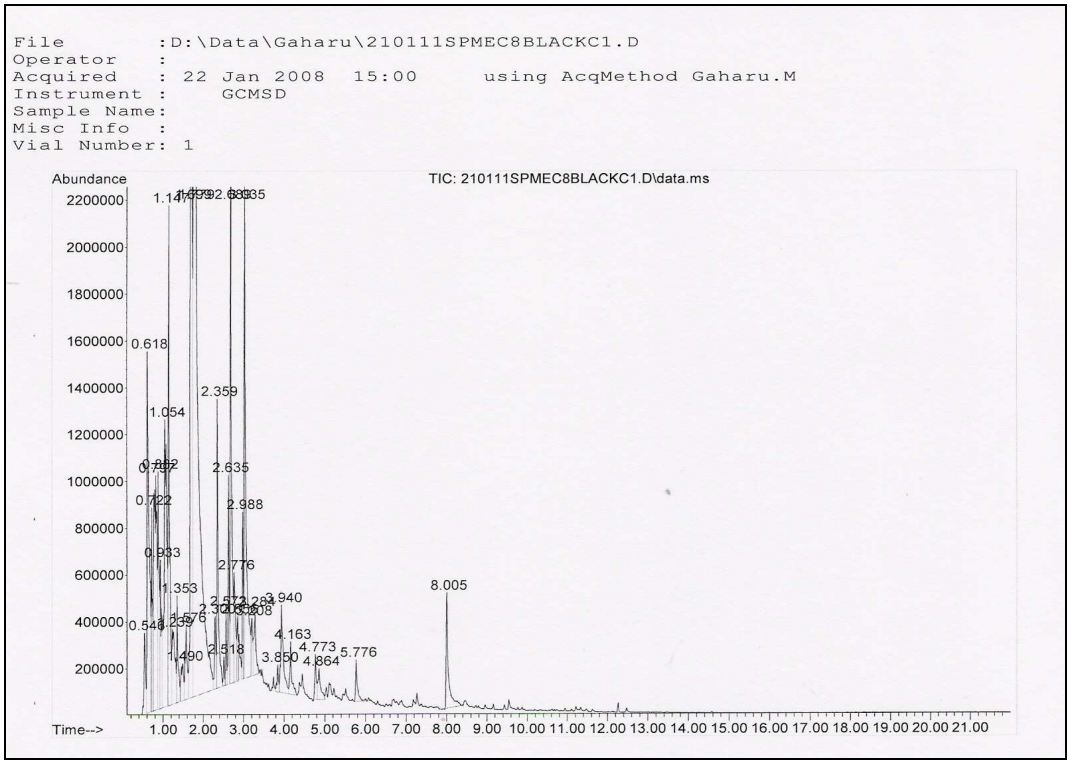


Figure 4.2 GC-MS charts of smoke (2nd sample)

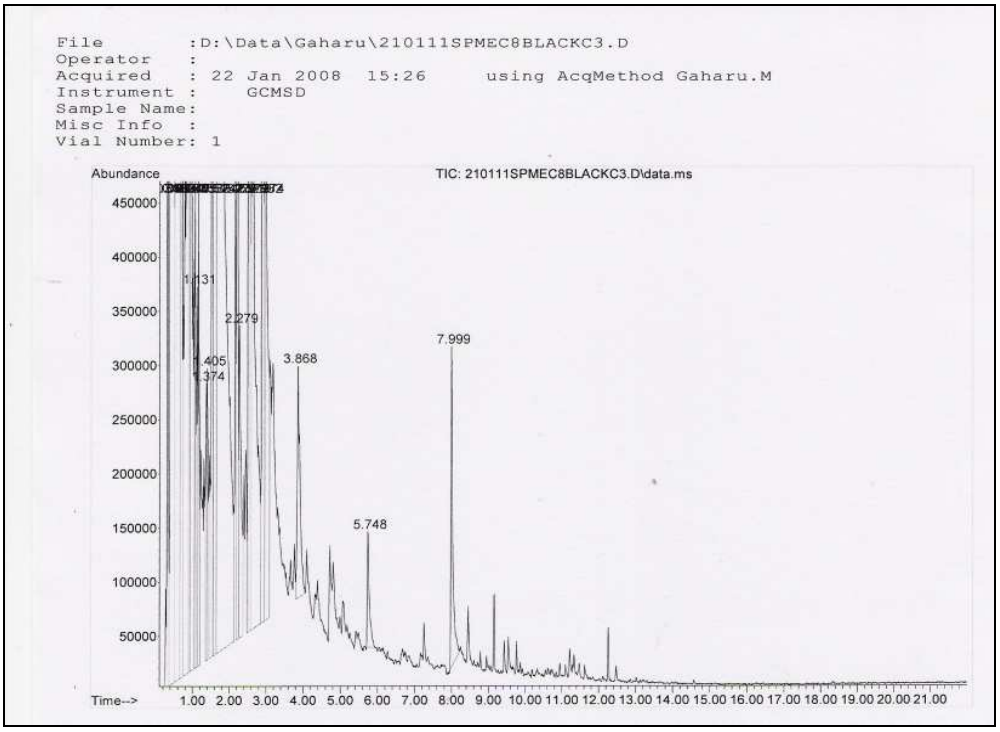
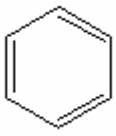
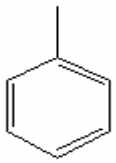
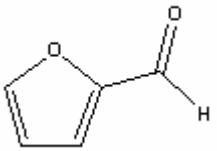
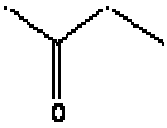
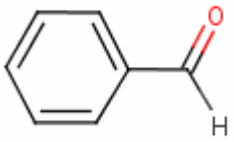
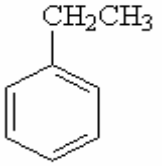
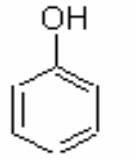
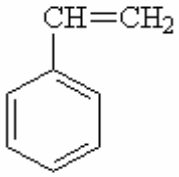


Figure 4.3 GC-MS charts of smoke (3rd sample)

From the result above, there are about 20 to 30 chemical compounds found. After analyzing the data, there are only 9 chemical compounds exist in those three samples. Table 4.1 below show the chemical compounds exist in gaharu smoke with their formula structure and formula molecule.

Table 4.1 : Chemical compounds founds in gaharu smoke

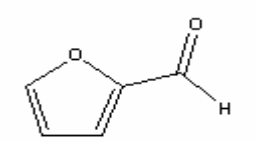
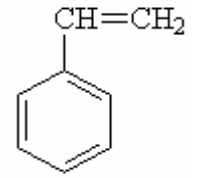
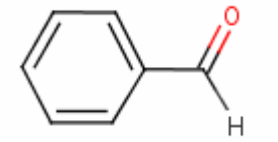
Chemical Compounds	**Formula Structure**	**Formula Molecule**
Benzene		C_6H_6
Furan		C_4H_4O

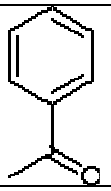
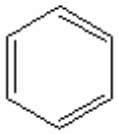
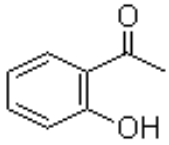
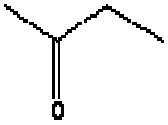
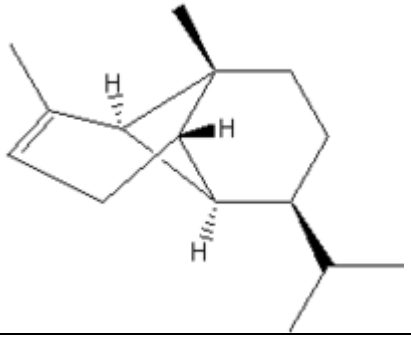
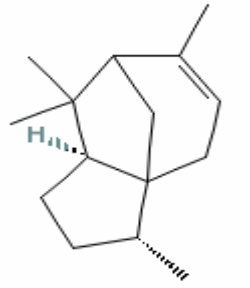
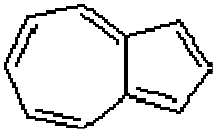
Toluene		C_7H_8
Furfural		$C_5H_4O_2$
2-Butanone		C_4H_8O
Benzaldehyde		C_7H_6O
Ethylbenzene		C_8H_{10}
Phenol		C_6H_6O
Styrene		C_8H_8

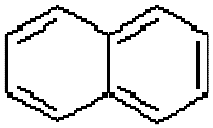
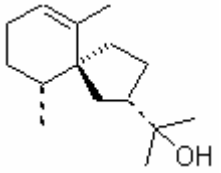
4.3 Results for Gaharu Oil

There are few processes involved in extracting gaharu oil which was begun with drying, grinding, soaking and finally extraction. The extracted oil then was injected into GC-MS using SPME fiber for analysis. From the result, there are about 83 chemical compounds found in gaharu oil. But after analyzed the data, there are only 17 major compounds exist. The compound that has highest quality is azulene which is 97%. Table 4.2 below show the major chemical compounds exist in gaharu oil with their formula structure and formula molecule.

Table 4.2 : Chemical compounds founds in gaharu oil

Chemical Compounds	**Formula Structure**	**Formula Molecule**
Furfural		$C_5H_4O_2$
Styrene		C_8H_8
Benzaldehyde		C_7H_6O
Furan		C_4H_4O
Octanal		$C_8H_{16}O$

Acetophenone		C_8H_8O
2-Nonanone		$C_7H_{15}COCH_3$
Benzene		C_6H_6
Ethanone		$C_{14}H_{12}O_2$
2-Butanone		C_4H_8O
Copaene		$C_{15}H_{24}$
7-Methanoazulene		$C_{15}H_{24}$
Azulene		$C_{10}H_8$

Naphthalene		$C_{10}H_8$
Cycloheptane		C_7H_{14}
Agarospirol		$C_{15}H_{26}O$
n-Hexadecanoic acid		$CH_3(CH_2)_{14}COOH$

4.4 Discussion

The experiment for this research (burning) was done three times with different sample of smoke. As shown in Table 4.1, there are nine major chemical compounds that were found in each sample. The compounds are benzene, furan, toluene, furfural, 2-butanone, benzaldehyde, ethylbenzene, phenol and styrene.

Based on the previous research (Ishihara *et al.*, 1993), gaharu smoke contained many kinds of fragrant sesquiterpenes along with a small amount of pulp wood pyrolysis products such as acetic acid, benzaldehyde, and vanillin. From the result, there was no fragrant sesquiterpenes found in the smoke sample but there was pulp wood pyrolysis product found which are furfural and benzaldehyde.

Most of the chemical compounds found in gaharu smoke were aromatic compounds. This characteristic makes the gaharu useful as fragrance products. For example, benzaldehyde can produce pleasant almond-like odor. That is why gaharu wood was used to make incense stick.

According to the peak from the graph, compounds that have highest quality are benzene and styrene which is 97%. Styrene is an aromatic hydrocarbon which evaporates easily and has a sweet smell. It is used as precursor to polystyrene, an important synthetic material. Meanwhile, benzene is also aromatic hydrocarbon which is colorless and highly flammable with a sweet smell. Benzene was used as additive in gasoline and precursor in the production of drugs, plastics, synthetic rubber, and dyes.

For gaharu oil, there were seventeen major chemical compounds found. Most of them are fragrant sesquiterpenes such as copaene and 7-methanoazulene and aromatic compounds such as benzene, benzaldehyde and styrene. Copaene is the common chemical name of an oily liquid hydrocarbon that is found in a number of essential oil-producing plants. Chemically, the copaenes are tricyclic sesquiterpenes.

Aromatic compounds that were found in gaharu oil make gaharu oil suitable for perfume and other fragrance product such as soap and shampoo. For example, phenol and styrene has sweet tarry odor meanwhile furfural and benzaldehyde has almond odor.

In gaharu oil, compound that has highest quality is azulene which is 97%. Azulene is a monoterpene and an isomer of naphthalene. It has aromatic properties even though it is not a single ring system like benzene and it is used for cosmetic industry.

Based on both result, it shows that chemical compounds exist in gaharu smoke is not exactly same with chemical compounds exist in gaharu oil. Only six compounds exist in both condition of gaharu which are furfural, styrene, benzaldehyde, furan, benzene and 2-butanone.

These six compounds that exist in gaharu are aromatic compounds. One of the chemical compounds exists are benzene. As we know, benzene is a colorless and highly flammable liquid with a sweet smell and a relatively high melting point. This characteristic shows that this kind of gaharu is not suitable for incense product but can be used for other product like insect repellent.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Based on the result that has been produce in this research, it shows that the objective of this research was achieved. The objective for this project is to determine and to compare the chemical compounds exists in gaharu smoke and gaharu oil. Table 5.1 below shows the chemical compounds found in both gaharu smoke and gaharu oil.

Table 5.1 : Summary of comparison on chemical compounds in gaharu smoke and oil

Chemical Compounds	Smoke	Oil
Benzene	√	√
Furan	√	√
Toluene	√	
Furfural	√	√
2-Butanone	√	√
Benzaldehyde	√	√
Ethylbenzene	√	
Phenol	√	
Styrene	√	√
Octanal		√
Acetophenone		√

2-Nonanone		√
Ethanone		√
Copaene		√
7-Methanoazulene		√
Azulene		√
Naphthalene		√
Cycloheptane		√
Agarospirol		√
n-Hexadecanoic acid		√

There are only six compounds exist in both condition of gaharu. Most of them are pulp wood pyrolysis product and aromatic compounds. In gaharu smoke, there are no fragrant sesquiterpenes found but only aromatic compounds. Meanwhile in gaharu oil, there are sesquiterpenes compounds, aromatic compounds and pulp wood pyrolysis products found.

5.2 Recommendation

From this experiment, there are some possible way that this experiment can be improve in order to determine more chemical compounds. The first recommendation is use other SPME fiber such as blue fiber. For this research, black SPME fiber was used. By using different fiber maybe we can detect other chemical compounds and can compare the different.

Next recommendation is apply other method for burning process. Direct sampling method can be used for this process. The fiber must directly expose to the smoke and we did not have to use sample bottle to trap the smoke. With this method, more smoke can be absorbed into the fiber and maybe more chemical compounds can be found.

REFERENCES

1. Barden A., Awang Anak N., Mulliken T. (2000). "Heart of the Matter: *Agarwood Use and Trade, and CITES implemention for Aquilaria Malaccencis"*. TRAFFIC International.

2. Burkill, I. (1966). *A Dictionary of Economic Products of the Malay Peninsula*, I. Government of Malaysia and Singapore. The Ministry of Agricultural and Cooperatives, Kuala Lumpur.

3. Chakrabarty K., Kumar A., and Menon V. (1994). *Trade in Agarwood.* TRAFFIC-India Publications, New Delhi

4. Chang, Y.S., Ng, L.T. and Azizol, A.K. (1997). "A Review on Agar(Gaharu) Producing *Aquilaria* Species". *Journal Tropical Forest Product.*

5. Christian G. D. (2002). Analytical Chemistry. 6th Edition

6. D.R. Donovan, R.K. Puri (2004). "Learning from Traditional Knowledge of Non-timber Forest Products: Penan Benalui and the Autecology of Aquilaria in Indonesian Borneo". Ecology and Society 9(3): 3.

7. Gyorgy, V. and Karoly, V. (2003). "Solid-phase microextraction: a powerful sample preparation tool prior to mass spectrometric analysis". *Journal of mass spectrometry* 39: 233–254.

8. Heuveling van Beek, H. and Phillips, D. (1999). *Agarwood: Trade and CITES Implementation in Southeast Asia*. Unpublished report prepared for TRAFFIC Southeast Asia, Malaysia.

9. Isihara M., Tsuneya T. and Uneyama K. (1993). Components of agarwood smoke on heating. *Journal of Essential Oil Research* 5(4) : 419-423

10. Konishi T., Konoshima T., Shimada Y., and Kiyosawa S. (2001). Six New 2-(2-Phenylethyl)chromones from Agarwood.

11. Nakanishi T., Yamagata E., Yoneda K., (1984). Three fragrant sesquiterpenesof agarwood. Phytochemistry 23 (9) : 2066-2067

12. Okugawa H., Ueda R., Matsumoto K., Kawanishi K., and Kato A. (1993).”Effects of Agarwood Extract on the Central Nervous System”. *Planta Medica 59(1)* :32-36

13. RMAP Working Paper(2003). Resource Management in Asia Pasific. Working Paper No.51.

14. Y. S. Chang, M. A. Nor Azah, A. Abu Said, E. H. Lok, S. Reader & Spiers (2002).“Gaharu”. *FRIM Technical Information*. No. 69.

World Wide Web

1. http://en.wikipedia.org/wiki/Agarwood (viewed on 14 Julai 2007)
2. http://allmalaysia.info (viewed on 25 Julai 2007)
3. http://pubchem.ncbi.nlm.nih.gov (viewed on 5 August 2007)

APPENDIX A

Library Search Report

Data Path : D:\Data\Gaharu\
Data File : 210111SPMEC7BLACKC.D
Acq On : 22 Jan 2008 14:32
Operator :
Sample :
Misc :
ALS Vial : 1 Sample Multiplier: 1

Search Libraries: C:\Database\NIST05a.L Minimum Quality: 30
C:\Database\Flavor2.L Minimum Quality: 30

Unknown Spectrum: Apex
Integration Events: ChemStation Integrator - autoint1.e

Pk#	RT	Area%	Library/ID	Ref#	CAS#	Qual
1	0.173	3.68	C:\Database\Flavor2.L			
			2-Methylbutyraldehyde; 2-methylbutanal	397	000096-17-3	4
			isobutyl alcohol	62	000078-83-1	1
			xxx	259	000000-00-0	1
2	0.237	4.56	C:\Database\Flavor2.L			
			Isobutyraldehyde	394	000078-84-2	9
			Isobutylacetate	269	000110-19-0	2
			Methyl ethyl ketone	257	000079-93-3	2
3	0.355	5.31	C:\Database\NIST05a.L			
			Acetic acid	257	000064-19-7	86
			Acetic acid	256	000064-19-7	64
			Acetic acid	255	000064-19-7	59
4	0.419	10.17	C:\Database\NIST05a.L			
			Acetic acid	256	000064-19-7	50
			Acetic acid	257	000064-19-7	50
			Acetic acid	258	000064-19-7	38
5	0.643	2.88	C:\Database\NIST05a.L			
			Benzene	998	000071-43-2	90
			Benzene	1000	000071-43-2	90
			1,5-Hexadiyne	1005	000628-16-0	80
6	0.707	8.45	C:\Database\NIST05a.L			
			Benzene	1000	000071-43-2	96
			Benzene	998	000071-43-2	95
			Benzene	1001	000071-43-2	95
7	0.942	0.33	C:\Database\NIST05a.L			
			Furan, 2,5-dimethyl-	2742	000625-86-5	93
			Furan, 2,5-dimethyl-	2739	000625-86-5	76
			Furan, 2,5-dimethyl-	2743	000625-86-5	76
8	1.359	2.78	C:\Database\NIST05a.L			
			Toluene	2400	000108-88-3	95
			Toluene	2395	000108-88-3	94
			Toluene	2396	000108-88-3	94
9	1.412	25.78	C:\Database\NIST05a.L			
			Toluene	2400	000108-88-3	95
			Toluene	2395	000108-88-3	94
			Toluene	2397	000108-88-3	94
10	1.583	10.76	C:\Database\NIST05a.L			
			Toluene	2397	000108-88-3	60
			Toluene	2396	000108-88-3	60
			Toluene	2395	000108-88-3	60
11	2.074	7.80	C:\Database\NIST05a.L			
			Furfural	2677	000098-01-1	91
			Furfural	2674	000098-01-1	91
			3-Furaldehyde	2678	000498-60-2	86
12	2.320	0.71	C:\Database\NIST05a.L			
			2-Furanmethanol	3017	000098-00-0	90

Data Path : D:\Data\Gaharu\
Data File : 210111SPMEC7BLACKC.D
Acq On : 22 Jan 2008 14:32
Operator :
Sample :
Misc :
ALS Vial : 1 Sample Multiplier: 1

Search Libraries: C:\Database\NIST05a.L Minimum Quality: 30
C:\Database\Flavor2.L Minimum Quality: 30

Unknown Spectrum: Apex
Integration Events: ChemStation Integrator - autoint1.e

Pk#	RT	Area%	Library/ID	Ref#	CAS#	Qual
			3-Furanmethanol	3019	004412-91-3	76
			2-Furanmethanol	3018	000098-00-0	72
13	2.438	3.19	C:\Database\NIST05a.L			
			Ethylbenzene	4955	000100-41-4	93
			Ethylbenzene	4957	000100-41-4	93
			Ethylbenzene	4956	000100-41-4	90
14	2.822	4.22	C:\Database\NIST05a.L			
			Styrene	4750	000100-42-5	97
			1,3,5,7-Cyclooctatetraene	4757	000629-20-9	96
			Styrene	4751	000100-42-5	95
15	3.100	1.55	C:\Database\NIST05a.L			
			1H-Imidazole, 4,5-dihydro-2-methyl	1343	000534-26-9	49
			2(5H)-Furanone	1316	000497-23-4	38
			1H-Imidazole, 4,5-dihydro-2-methyl	1344	000534-26-9	38
16	3.794	2.26	C:\Database\NIST05a.L			
			Benzaldehyde	4934	000100-52-7	96
			Benzaldehyde	4937	000100-52-7	96
			Benzaldehyde	4936	000100-52-7	96
17	4.051	0.41	C:\Database\NIST05a.L			
			Phenol	2529	000108-95-2	92
			Phenol	2533	000108-95-2	89
			Phenol	2532	000108-95-2	70
18	4.766	0.86	C:\Database\Flavor2.L			
			2-Ethyl-1-hexanol	133	000104-76-7	27
			2-Methylbutyraldehyde; 2-methylbutanal	397	000096-17-3	2
			Ethyl-2methylbutyrate	82	007452-79-1	1
19	5.717	1.38	C:\Database\NIST05a.L			
			Phenol, 2-methoxy-	10081	000090-05-1	96
			Phenol, 2-methoxy-	10080	000090-05-1	95
			Mequinol	10072	000150-76-5	94
20	7.992	2.91	C:\Database\NIST05a.L			
			2-Butanone, 4-phenyl-	21741	002550-26-7	95
			2-Butanone, 4-phenyl-	21740	002550-26-7	95
			2-Butanone, 3-phenyl-	21739	000769-59-5	95

Figure A-1 GC-MS analysis result for gaharu smoke (1st sample)

Library Search Report

Data Path : D:\Data\Gaharu\
Data File : 210111SPMEC8BLACKC1.D
Acq On : 22 Jan 2008 15:00
Operator :
Sample :
Misc :
ALS Vial : 1 Sample Multiplier: 1

Search Libraries: C:\Database\NIST05a.L Minimum Quality: 30
C:\Database\Flavor2.L Minimum Quality: 30

Unknown Spectrum: Apex
Integration Events: ChemStation Integrator - autoint1.e

Pk#	RT	Area%	Library/ID	Ref#	CAS#	Qual
1	0.547	0.77	C:\Database\Flavor2.L			
			No matches found			
2	0.622	4.76	C:\Database\NIST05a.L			
			2-Propenal	164	000107-02-8	30
			2-Propenal	162	000107-02-8	27
			2-Propyn-1-ol, acetate	3032	000627-09-8	25
3	0.718	1.46	C:\Database\Flavor2.L			
			Isobutyraldehyde	394	000078-84-2	9
			isobutyl alcohol	62	000078-83-1	2
			1-Hexanol	316	000111-27-3	2
4	0.793	4.71	C:\Database\NIST05a.L			
			Pentane, 2,3,4-trimethyl-	7461	000565-75-3	40
			3,3-Dimethyl-2,4-pentane dione	11870	003142-58-3	33
			1-Butanol, 2-methyl-, acetate	13056	000624-41-9	28
5	0.878	1.91	C:\Database\Flavor2.L			
			2-Pentanone	217	000107-87-9	9
			Diacetyl	379	000431-03-8	4
			Methyl isobutyrate	168	000547-63-7	2
6	0.931	1.43	C:\Database\NIST05a.L			
			Furan, 2-methyl-	1147	000534-22-5	95
			Furan, 2-methyl-	1146	000534-22-5	90
			Furan, 2-methyl-	1148	000534-22-5	86
7	1.049	5.23	C:\Database\NIST05a.L			
			Benzene	1001	000071-43-2	94
			1,3-Hexadien-5-yne	1010	010420-90-3	91
			Benzene	1002	000071-43-2	91
8	1.145	4.21	C:\Database\NIST05a.L			
			Benzene	1002	000071-43-2	95
			Benzene	1001	000071-43-2	95
			Benzene	999	000071-43-2	91
9	1.241	1.43	C:\Database\NIST05a.L			
			2-Pentenal, (E)-	1379	001576-87-0	32
			2-Butenal, 2-methyl-, (E)-	1414	000497-03-0	30
			2-Butenal, 2-methyl-, (E)-	1415	000497-03-0	30
10	1.348	0.93	C:\Database\NIST05a.L			
			Furan, 2,5-dimethyl-	2739	000625-86-5	91
			Furan, 2,5-dimethyl-	2742	000625-86-5	83
			Ethanone, 1-(methylenecyclopropyl)	2763	062266-35-7	72
11	1.487	0.62	C:\Database\NIST05a.L			
			Cyclopropane, (1-methyl-1,2-propadienyl)-	2577	051549-86-1	64
			(E)-2-Butenylcyclopropane	2841	076588-98-2	62
			2,4-Hexadienal, (E,E)-	2746	000142-83-6	53
12	1.572	0.99	C:\Database\NIST05a.L			
			cis-1-Methyl-2-(2'-propenyl)cyclopropane	2870	076588-97-1	64
			1-Penten-3-yne, 2-methyl-	1073	000926-55-6	53

Data Path : D:\Data\Gaharu\
Data File : 210111SPMEC8BLACKC1.D
Acq On : 22 Jan 2008 15:00
Operator :
Sample :
Misc :
ALS Vial : 1 Sample Multiplier: 1

Search Libraries: C:\Database\NIST05a.L Minimum Quality: 30
C:\Database\Flavor2.L Minimum Quality: 30

Unknown Spectrum: Apex
Integration Events: ChemStation Integrator - autoint1.e

Pk#	RT	Area%	Library/ID	Ref#	CAS#	Qual
			3,4-Pentadienal	1141	004009-55-6	50
13	1.701	12.12	C:\Database\NIST05a.L			
			Toluene	2395	000108-88-3	95
			Toluene	2400	000108-88-3	93
			Toluene	2398	000108-88-3	91
14	1.775	33.99	C:\Database\NIST05a.L			
			Toluene	2400	000108-88-3	95
			Toluene	2395	000108-88-3	94
			Toluene	2398	000108-88-3	91
15	2.299	0.66	C:\Database\NIST05a.L			
			Furfural	2675	000098-01-1	91
			Furfural	2674	000098-01-1	87
			3-Furaldehyde	2678	000498-60-2	80
16	2.363	2.36	C:\Database\NIST05a.L			
			Furfural	2674	000098-01-1	90
			3(2H)-Pyridazinone	2665	000504-30-3	72
			2H-Pyran-2-one	2681	000504-31-4	72
17	2.512	0.18	C:\Database\NIST05a.L			
			2-Furanmethanol	3017	000098-00-0	91
			3-Furanmethanol	3019	004412-91-3	89
			N-Methyl-7-azabicyclo(2,2,1)hept-2-ene	5469	055590-26-6	52
18	2.577	0.39	C:\Database\NIST05a.L			
			3-Furanmethanol	3019	004412-91-3	89
			2-Furanmethanol	3018	000098-00-0	87
			2-Furanmethanol	3015	000098-00-0	72
19	2.630	1.35	C:\Database\NIST05a.L			
			Ethylbenzene	4955	000100-41-4	94
			Ethylbenzene	4954	000100-41-4	91
			Ethylbenzene	4956	000100-41-4	91
20	2.694	5.12	C:\Database\NIST05a.L			
			Ethylbenzene	4955	000100-41-4	94
			Ethylbenzene	4957	000100-41-4	91
			Ethylbenzene	4956	000100-41-4	91
21	2.779	1.28	C:\Database\NIST05a.L			
			o-Xylene	4953	000095-47-6	93
			o-Xylene	4952	000095-47-6	93
			Ethylbenzene	4957	000100-41-4	91
22	2.854	0.53	C:\Database\NIST05a.L			
			Phenylethyne	4393	000536-74-3	70
			Phenylethyne	4391	000536-74-3	55
			Phenylethyne	4392	000536-74-3	55
23	2.982	0.99	C:\Database\NIST05a.L			
			Styrene	4752	000100-42-5	97
			Styrene	4751	000100-42-5	97
			Bicyclo[4.2.0]octa-1,3,5-triene	4759	000694-87-1	97

Library Search Report

Data Path : D:\Data\Gaharu\
Data File : 210111SPMEC8BLACKC1.D
Acq On : 22 Jan 2008 15:00
Operator :
Sample :
Misc :
ALS Vial : 1 Sample Multiplier: 1

Search Libraries: C:\Database\NIST05a.L Minimum Quality: 30
C:\Database\Flavor2.L Minimum Quality: 30

Unknown Spectrum: Apex
Integration Events: ChemStation Integrator - autoint1.e

Pk#	RT	Area%	Library/ID	Ref#	CAS#	Qual
24	3.036	5.77	C:\Database\NIST05a.L			
			Styrene	4751	000100-42-5	97
			Styrene	4752	000100-42-5	97
			Bicyclo[4.2.0]octa-1,3,5-triene	4759	000694-87-1	97
25	3.207	0.51	C:\Database\NIST05a.L			
			Styrene	4750	000100-42-5	93
			Styrene	4749	000100-42-5	93
			1,3,5,7-Cyclooctatetraene	4756	000629-20-9	93
26	3.282	0.90	C:\Database\NIST05a.L			
			Bicyclo[4.2.0]octa-1,3,5-triene	4758	000694-87-1	94
			Bicyclo[4.2.0]octa-1,3,5-triene	4759	000694-87-1	86
			Styrene	4752	000100-42-5	83
27	3.848	0.25	C:\Database\NIST05a.L			
			1,3,5-Cycloheptatriene, 7-ethyl-	9148	017634-51-4	68
			Benzene, propyl-	9110	000103-65-1	60
			Benzene, propyl-	9111	000103-65-1	53
28	3.944	1.46	C:\Database\NIST05a.L			
			Benzaldehyde	4935	000100-52-7	96
			Benzaldehyde	4937	000100-52-7	94
			Benzaldehyde	4934	000100-52-7	81
29	4.157	0.63	C:\Database\NIST05a.L			
			Phenol	2529	000108-95-2	94
			Phenol	2533	000108-95-2	93
			Phenol	2530	000108-95-2	93
30	4.777	0.40	C:\Database\NIST05a.L			
			Benzene, 1-methoxy-4-methyl-	9661	000104-93-8	98
			Benzene, 1-methoxy-4-methyl-	9665	000104-93-8	93
			1,3,5-Cycloheptatriene, 1-methoxy-	9677	001728-32-1	83
31	4.862	0.56	C:\Database\NIST05a.L			
			Benzene, 2-propenyl-	8680	000300-57-2	91
			Benzene, 1-propenyl-	8681	000637-50-3	83
			Benzene, 1-ethenyl-2-methyl-	8699	000611-15-4	64
32	5.781	0.45	C:\Database\NIST05a.L			
			Phenol, 2-methoxy-	10081	000090-05-1	94
			Mequinol	10072	000150-76-5	94
			Phenol, 2-methoxy-	10080	000090-05-1	94
33	8.003	1.63	C:\Database\NIST05a.L			
			2-Butanone, 4-phenyl-	21740	002550-26-7	96
			2-Butanone, 4-phenyl-	21741	002550-26-7	96
			2-Butanone, 4-phenyl-	21737	002550-26-7	95

Figure A-2 GC-MS analysis result for gaharu smoke (2nd sample)

Library Search Report

Data Path : D:\Data\Gaharu\
Data File : 210111SPMEC8BLACKC3.D
Acq On : 22 Jan 2008 15:26
Operator :
Sample :
Misc :
ALS Vial : 1 Sample Multiplier: 1

Search Libraries: C:\Database\NIST05a.L Minimum Quality: 30
C:\Database\Flavor2.L Minimum Quality: 30

Unknown Spectrum: Apex
Integration Events: ChemStation Integrator - autoint1.e

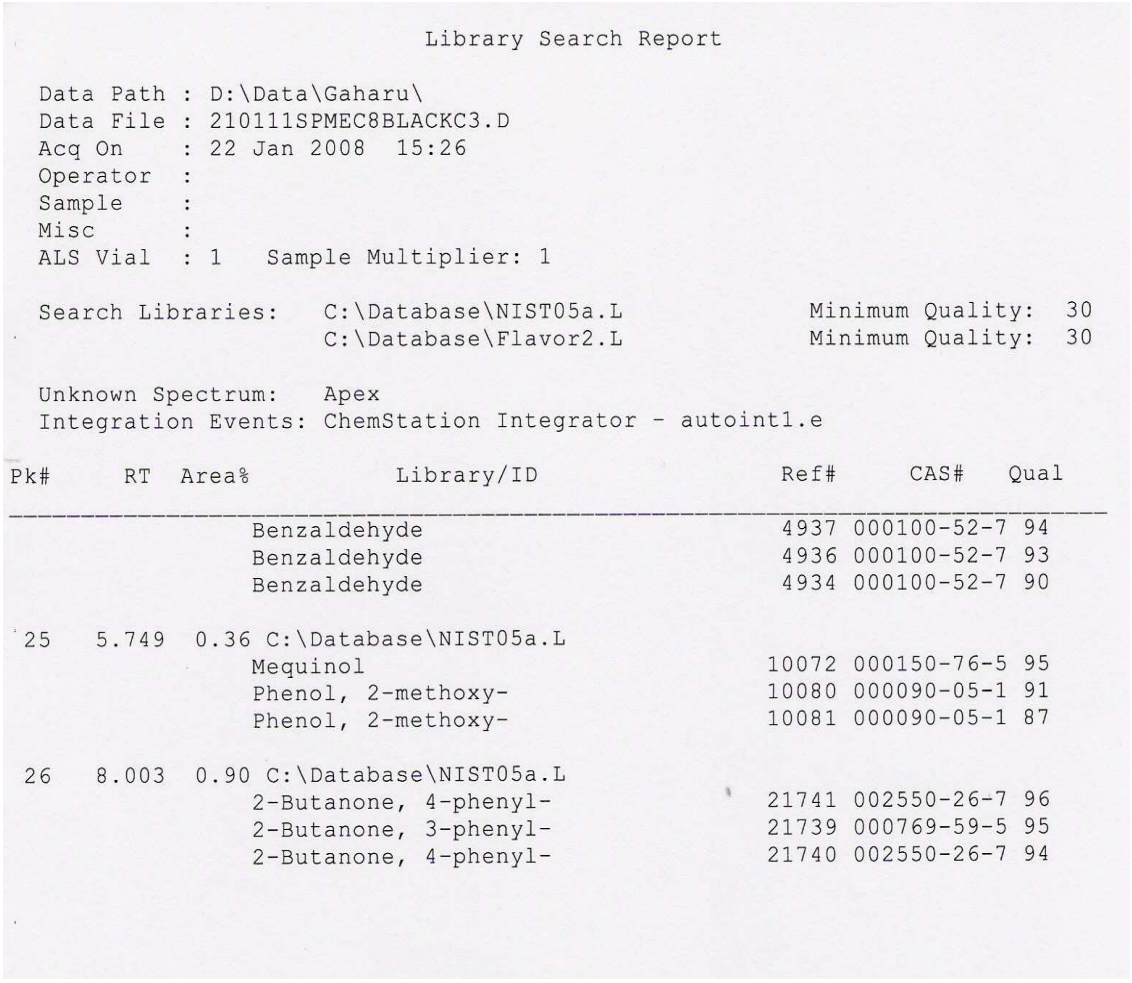
k#	RT	Area%	Library/ID	Ref#	CAS#	Qual
1	0.323	1.38	C:\Database\Flavor2.L			
			No matches found			
2	0.397	6.72	C:\Database\Flavor2.L			
			Isobutylacetate	269	000110-19-0	2
			2-Methylbutyraldehyde; 2-methylbut anal	397	000096-17-3	1
			isobutyl alcohol	62	000078-83-1	1
3	0.568	7.05	C:\Database\NIST05a.L			
			2-Pentanone	1683	000107-87-9	33
			Butanenitrile, 2,3-dioxo-, dioxime , o,o'-diacetyl-	65250	339246-62-7	32
			Pentane, 2,3,4-trimethyl-	7461	000565-75-3	25
4	0.675	3.00	C:\Database\NIST05a.L			
			Furan, 2-methyl-	1146	000534-22-5	93
			Furan, 2-methyl-	1147	000534-22-5	90
			Furan, 2-methyl-	1144	000534-22-5	86
5	0.846	4.69	C:\Database\NIST05a.L			
			Benzene	1000	000071-43-2	97
			Benzene	1001	000071-43-2	94
			1,3-Hexadien-5-yne	1010	010420-90-3	91
6	0.910	1.94	C:\Database\NIST05a.L			
			Benzene	1000	000071-43-2	96
			Benzene	1001	000071-43-2	95
			Benzene	1002	000071-43-2	94
7	0.942	3.59	C:\Database\NIST05a.L			
			Benzene	1000	000071-43-2	97
			Benzene	998	000071-43-2	95
			Benzene	1001	000071-43-2	95
8	1.070	0.93	C:\Database\Flavor2.L			
			No matches found			
9	1.134	0.58	C:\Database\NIST05a.L			
			Furan, 2,5-dimethyl-	2739	000625-86-5	91
			Furan, 2,5-dimethyl-	2743	000625-86-5	90
			Furan, 2,5-dimethyl-	2742	000625-86-5	90
10	1.166	0.96	C:\Database\Flavor2.L			
			4-Methyl-2-pentanone	334	000108-10-1	4
			n-Butyl acetate	335	000123-86-4	4
			Isopropyl acetate	268	000108-21-4	4
11	1.369	0.45	C:\Database\NIST05a.L			
			Furan, 2,5-dihydro-3-methyl-	1416	001708-31-2	70
			cis-1-Methyl-2-(2'-propenyl)cyclop ropane	2870	076588-97-1	64
			3,4-Heptadiene	2783	002454-31-1	47
12	1.401	0.59	C:\Database\NIST05a.L			
			1-Hexen-3-yne	1051	013721-54-5	86
			2-Penten-4-yne, 2-methyl-	1070	001595-53-5	86
			cis-1-Methyl-2-(2'-propenyl)cyclop	2870	076588-97-1	59

Data Path : D:\Data\Gaharu\
Data File : 210111SPMEC8BLACKC3.D
Acq On : 22 Jan 2008 15:26
Operator :
Sample :
Misc :
ALS Vial : 1 Sample Multiplier: 1

Search Libraries: C:\Database\NIST05a.L Minimum Quality: 30
C:\Database\Flavor2.L Minimum Quality: 30

Unknown Spectrum: Apex
Integration Events: ChemStation Integrator - autoint1.e

Pk#	RT	Area%	Library/ID	Ref#	CAS#	Qual
			ropane			
13	1.530	8.01	C:\Database\NIST05a.L			
			Toluene	2400	000108-88-3	95
			Toluene	2395	000108-88-3	95
			Toluene	2398	000108-88-3	91
14	1.615	21.48	C:\Database\NIST05a.L			
			Toluene	2400	000108-88-3	95
			Toluene	2395	000108-88-3	95
			Toluene	2398	000108-88-3	91
15	1.668	17.78	C:\Database\NIST05a.L			
			Toluene	2400	000108-88-3	95
			Toluene	2395	000108-88-3	94
			Toluene	2398	000108-88-3	91
16	2.171	0.74	C:\Database\NIST05a.L			
			Furfural	2674	000098-01-1	87
			Furfural	2675	000098-01-1	83
			2H-Pyran-2-one	2681	000504-31-4	64
17	2.224	1.98	C:\Database\NIST05a.L			
			Furfural	2676	000098-01-1	93
			Furfural	2674	000098-01-1	90
			3-Furaldehyde	2678	000498-60-2	87
18	2.277	1.10	C:\Database\NIST05a.L			
			Furfural	2677	000098-01-1	93
			Furfural	2675	000098-01-1	93
			Furfural	2674	000098-01-1	93
19	2.523	1.09	C:\Database\NIST05a.L			
			Ethylbenzene	4955	000100-41-4	94
			Ethylbenzene	4957	000100-41-4	94
			Ethylbenzene	4954	000100-41-4	94
20	2.576	3.24	C:\Database\NIST05a.L			
			Ethylbenzene	4955	000100-41-4	94
			Ethylbenzene	4957	000100-41-4	91
			Ethylbenzene	4956	000100-41-4	91
21	2.619	3.89	C:\Database\NIST05a.L			
			Ethylbenzene	4955	000100-41-4	94
			Ethylbenzene	4956	000100-41-4	91
			Ethylbenzene	4957	000100-41-4	91
22	2.929	3.79	C:\Database\NIST05a.L			
			Bicyclo[4.2.0]octa-1,3,5-triene	4759	000694-87-1	96
			Styrene	4751	000100-42-5	96
			Styrene	4752	000100-42-5	95
23	2.972	2.78	C:\Database\NIST05a.L			
			1,3,5,7-Cyclooctatetraene	4757	000629-20-9	96
			Styrene	4751	000100-42-5	95
			Styrene	4752	000100-42-5	95
24	3.869	0.98	C:\Database\NIST05a.L			



Library Search Report

Data Path : D:\Data\Gaharu\
Data File : 210111SPMEC8BLACKC3.D
Acq On : 22 Jan 2008 15:26
Operator :
Sample :
Misc :
ALS Vial : 1 Sample Multiplier: 1

Search Libraries: C:\Database\NIST05a.L Minimum Quality: 30
C:\Database\Flavor2.L Minimum Quality: 30

Unknown Spectrum: Apex
Integration Events: ChemStation Integrator - autoint1.e

Pk#	RT	Area%	Library/ID	Ref#	CAS#	Qual
			Benzaldehyde	4937	000100-52-7	94
			Benzaldehyde	4936	000100-52-7	93
			Benzaldehyde	4934	000100-52-7	90
25	5.749	0.36	C:\Database\NIST05a.L			
			Mequinol	10072	000150-76-5	95
			Phenol, 2-methoxy-	10080	000090-05-1	91
			Phenol, 2-methoxy-	10081	000090-05-1	87
26	8.003	0.90	C:\Database\NIST05a.L			
			2-Butanone, 4-phenyl-	21741	002550-26-7	96
			2-Butanone, 3-phenyl-	21739	000769-59-5	95
			2-Butanone, 4-phenyl-	21740	002550-26-7	94

Figure A-3 GC-MS analysis result for gaharu smoke (3rd sample)

Library Search Report

Data Path : D:\Data\Gaharu.PSM\
Data File : DIYANAETOAC.ESSENTIALOIL2.240108.D
Acq On : 25 Jan 2008 13:10
Operator :
Sample :
Misc :
ALS Vial : 1 Sample Multiplier: 1

Search Libraries: C:\Database\NIST05a.L Minimum Quality: 30
C:\Database\Flavor2.L Minimum Quality: 30

Unknown Spectrum: Apex
Integration Events: ChemStation Integrator - autoint1.e

Pk#	RT	Area%	Library/ID	Ref#	CAS#	Qual
1	1.145	0.64	C:\Database\NIST05a.L			
			Acetone	211	000067-64-1	40
			Acetone	210	000067-64-1	40
			Acetone	209	000067-64-1	9
2	1.359	18.93	C:\Database\NIST05a.L			
			Ethyl Acetate	1981	000141-78-6	53
			Ethyl Acetate	1982	000141-78-6	47
			Ethyl Acetate	1979	000141-78-6	47
3	1.562	0.76	C:\Database\NIST05a.L			
			Butanal, 2-methyl-	1715	000096-17-3	72
			Butanal, 2-methyl-	1711	000096-17-3	58
			1,2,3-Thiadiazole	1568	000288-48-2	40
4	1.743	0.35	C:\Database\NIST05a.L			
			n-Propyl acetate	4155	000109-60-4	59
			n-Propyl acetate	4156	000109-60-4	53
			n-Propyl acetate	4154	000109-60-4	53
5	1.850	0.26	C:\Database\NIST05a.L			
			1-Butanol, 3-methyl-	2085	000123-51-3	86
			1-Butanol, 3-methyl-	2084	000123-51-3	78
			1-Butanol, 3-methyl-	2079	000123-51-3	78
6	1.946	0.15	C:\Database\Flavor2.L			
			2-Methylbutyraldehyde; 2-methylbut anal	397	000096-17-3	9
			xxx	259	000000-00-0	2
			Ethyl acetate	92	000141-78-6	1
7	2.106	0.06	C:\Database\NIST05a.L			
			Acetic acid, 2-methylpropyl ester	7956	000110-19-0	72
			Acetic acid, 2-methylpropyl ester	7960	000110-19-0	64
			Acetic acid, 2-methylpropyl ester	7961	000110-19-0	56
8	2.309	0.13	C:\Database\NIST05a.L			
			Hexanal	3688	000066-25-1	86
			Hexanal	3689	000066-25-1	86
			Hexanal	3690	000066-25-1	86
9	2.416	0.10	C:\Database\NIST05a.L			
			Acetic acid, butyl ester	7879	000123-86-4	83
			Acetic acid, butyl ester	7884	000123-86-4	64
			Acetic acid, butyl ester	7885	000123-86-4	50
10	2.609	0.11	C:\Database\NIST05a.L			
			Furfural	2677	000098-01-1	93
			Furfural	2676	000098-01-1	93
			Furfural	2674	000098-01-1	81
11	2.747	0.03	C:\Database\NIST05a.L			
			Cyclopentanone, 3-methyl-	3175	001757-42-2	70
			Cyclopentanone, 3-methyl-	3176	001757-42-2	64

		(R)-(+)-3-Methylcyclopentanone	3193	006672-30-6	60
12	3.217	0.28 C:\Database\NIST05a.L			
		Styrene	4752	000100-42-5	96
		Bicyclo[4.2.0]octa-1,3,5-triene	4759	000694-87-1	96
		Styrene	4751	000100-42-5	96
13	3.719	0.07 C:\Database\NIST05a.L			
		3,3-Dimethyl-6-methylenecyclohexen	9738	020185-16-4	52
		1,2-Dimethyl cyclopropene	452	014309-32-1	42
		1,3-Cyclopentadiene, 5,5-dimethyl-2-ethyl-	9745	1000162-25-6	38
14	4.083	1.79 C:\Database\NIST05a.L			
		Benzaldehyde	4936	000100-52-7	97
		Benzaldehyde	4937	000100-52-7	97
		Benzaldehyde	4934	000100-52-7	94
15	4.307	0.13 C:\Database\NIST05a.L			
		1,3-Cyclohexadiene, 1,3,5,5-tetramethyl-	15302	004724-89-4	68
		Phenol, 3-(1-methylethyl)-	15906	000618-45-1	64
		Benzenemethanol, .alpha.,4-dimethyl-, (.+/-.)-	15989	005788-09-0	64
16	4.446	0.05 C:\Database\NIST05a.L			
		Furan, 2-pentyl-	16911	003777-69-3	90
		2-n-Butyl furan	10146	004466-24-4	64
		Furan, 2-pentyl-	16914	003777-69-3	59
17	4.595	0.08 C:\Database\NIST05a.L			
		Octanal	12028	000124-13-0	97
		Octanal	12031	000124-13-0	91
		Octanal	12030	000124-13-0	83
18	4.937	0.11 C:\Database\NIST05a.L			
		1-Hexanol, 2-ethyl-	13237	000104-76-7	50
		2-Ethylhexyl hydrogen maleate	76941	002370-71-0	50
		dl-2-Ethylhexyl chloroformate	51671	024468-13-1	47
19	5.194	0.42 C:\Database\NIST05a.L			
		Benzaldehyde, 2-hydroxy-	9583	000090-02-8	95
		Benzaldehyde, 2-hydroxy-	9587	000090-02-8	91
		Benzaldehyde, 3-hydroxy-	9584	000100-83-4	90
20	5.503	0.46 C:\Database\NIST05a.L			
		Acetophenone	9078	000098-86-2	94
		Acetophenone	9074	000098-86-2	94
		Acetophenone	9075	000098-86-2	94
21	5.835	0.06 C:\Database\NIST05a.L			
		2-Nonanone	19220	000821-55-6	94
		2-Nonanone	19221	000821-55-6	59
		2-Nonanone	19219	000821-55-6	58
22	6.721	0.15 C:\Database\NIST05a.L			
		Benzene, 1-ethenyl-4-methoxy-	14839	000637-69-4	96
		Benzene, 1-ethenyl-4-methoxy-	14849	000637-69-4	95
		Benzene, 1-ethenyl-4-methoxy-	14848	000637-69-4	95
23	6.881	0.20 C:\Database\NIST05a.L			
		Ethanone, 1-(2-hydroxyphenyl)-	15792	000118-93-4	97
		Ethanone, 1-(2-hydroxyphenyl)-	15793	000118-93-4	94
		Ethanone, 1-(2-hydroxyphenyl)-	15782	000118-93-4	91
24	6.935	0.21 C:\Database\NIST05a.L			
		o-Toluic acid, 1-adamantylmethyl ester	114887	1000292-22-6	38
		1H-Purin-6-amine, N-methyl-	22525	000443-72-1	30
		1H-Purin-6-amine, N-methyl-	22523	000443-72-1	30
25	7.383	0.16 C:\Database\NIST05a.L			

			1H-Indene, 2,3-dihydro-1,6-dimethyl-	20826	017059-48-2 94
			1H-Indene, 2,3-dihydro-1,2-dimethyl-	20824	017057-82-8 89
			Benzene, (3-methyl-2-butenyl)-	20810	004489-84-3 76
26	8.110	6.46	C:\Database\NIST05a.L		
			2-Butanone, 4-phenyl-	21740	002550-26-7 96
			2-Butanone, 3-phenyl-	21739	000769-59-5 96
			2-Butanone, 4-phenyl-	21741	002550-26-7 95
27	8.270	0.35	C:\Database\NIST05a.L		
			1H-Indene, 1,3-dimethyl-	19675	002177-48-2 83
			Phenol, 2,4-bis(1-methylethyl)-	41646	002934-05-6 42
			Naphthalene, 1,2-dihydro-6-methyl-	19689	002717-47-7 38
28	8.622	0.15	C:\Database\NIST05a.L		
			Benzene, 1,2,4-triethyl-	30810	000877-44-1 60
			Dewar benzene, hexamethyl-	30821	007641-77-2 59
			Benzene, 1,3-bis(1-methylethyl)-	30844	000099-62-7 46
29	8.740	0.12	C:\Database\NIST05a.L		
			1,3-Cyclopentadiene, 5,5-dimethyl-1,2-Dipropyl-	41750	1000163-88-0 49
			Benzeneacetaldehyde, 2-methoxy-.alpha.,5-dimethyl-	41537	053155-90-1 46
			2-(3-Methylbuta-1,3-dienyl)cyclohexanone	32086	1000191-75-5 38
30	8.804	0.11	C:\Database\NIST05a.L		
			1,3-Cyclopentadiene, 5,5-dimethyl-1,2-Dipropyl-	41750	1000163-88-0 76
			Benzenemethanol, 4-(1,1-dimethylethyl)-	32075	000877-65-6 49
			2-(1-Cyclohexenyl)cyclohexanone	41639	001502-22-3 49
31	9.018	0.12	C:\Database\NIST05a.L		
			5H-Pyrrolo(3,2-d)pyrimidine-2,4-diamine	22527	1000244-21-4 64
			Myrtene acid bromide	76761	1000159-35-0 59
			Benzene, 1-(1,1-dimethylethyl)-4-methoxy-	32091	005396-38-3 59
32	9.178	0.24	C:\Database\NIST05a.L		
			Benzene, 1-(1-formylethyl)-4-(1-buten-3-yl)-	48728	1000161-46-6 46
			Benzene, 2-ethenyl-1,3-dimethyl-	13625	002039-90-9 38
			Benzene, 4-ethenyl-1,2-dimethyl-	13628	027831-13-6 38
33	9.338	0.16	C:\Database\NIST05a.L		
			Benzene, 1,2-dimethoxy-4-(1-propenyl)-	41485	000093-16-3 43
			3,9-Epoxytricyclo[4.2.1.1(2,4)]decan-10-one, 9-methyl-	41543	1000186-17-1 42
			12-Oxatetracyclo[5,2,1,1(2,6).1(4,10)]dodecan-11-one	41540	1000186-51-6 25
34	9.413	0.18	C:\Database\NIST05a.L		
			Furan, 2-propyl-	5646	004229-91-8 47
			N-Furfurylaniline	38478	004439-56-9 45
			Pyridine, 2-chloro-6-(2-furanylmethoxy)-4-(trichloromethyl)-	139286	070166-48-2 38
35	9.498	0.27	C:\Database\NIST05a.L		
			Cyclohexanone, 2-cyclohexylidene-	41651	001011-12-7 53
			1H-Benzotriazole, 5-methoxy-	22545	027799-91-3 47
			Benzenemethanol, 4-(1,1-dimethylethyl)-	32081	000877-65-6 47
36	9.680	0.11	C:\Database\NIST05a.L		
			1,2,3,4,4a,5,6,8a-Octahydro-naphthalene	15291	031244-58-3 53

			Cyclopentanecarboxylic acid, 2-met hyl-4-methylene-, methyl ester	26605	074764-24-2 50
			2-Furoic acid, hex-4-yn-3-yl ester	50930	1000299-23-5 43
37	9.776	0.16	C:\Database\Flavor2.L		
			beta-Caryophyllene	110	000087-44-5 11
			4'-Methylacetophenone	252	000122-00-9 4
			p-Cymene	317	000099-87-6 1
38	9.840	0.24	C:\Database\NIST05a.L		
			Copaene	59780	003856-25-5 97
			Copaene	59779	003856-25-5 97
			Copaene	59778	003856-25-5 97
39	9.947	0.16	C:\Database\NIST05a.L		
			4,7-Methanoazulene, 1,2,3,4,5,6,7, 8-octahydro-1,4,9,9-tetramethyl-, [1S-(1.alpha.,4.alpha.,7.alpha.)]-	60013	000514-51-2 62
			Bicyclo[3.1.1]hept-2-ene, 2,6-dime thyl-6-(4-methyl-3-pentenyl)-	59930	017699-05-7 55
			Cyclohexene, 6-ethenyl-6-methyl-1- (1-methylethyl)-3-(1-methylethylid ene)-, (S)-	59984	005951-67-7 53
40	10.033	0.67	C:\Database\NIST05a.L		
			3,3-Dimethyl-6-methylenecyclohexen	9738	020185-16-4 49
			5-Acetylpyrimidine	9478	010325-70-9 46
			1,6-Dimethylhepta-1,3,5-triene	9726	1000196-61-0 46
41	10.214	0.20	C:\Database\NIST05a.L		
			Di-epi-.alpha.-cedrene	59852	1000156-13-3 49
			4a(2H)-Naphthalenol, octahydro-4,8 a-dimethyl-,(4.alpha.,4a.alpha.,8a .beta.)-	44583	019700-21-1 38
			Tricyclo[5.4.0.0(2,8)]undec-9-ene, 2,6,6,9-tetramethyl-	59907	005989-08-2 25
42	10.353	0.74	C:\Database\NIST05a.L		
			1H-3a,7-Methanoazulene, 2,3,4,7,8, 8a-hexahydro-3,6,8,8-tetramethyl-, [3R-(3.alpha.,3a.beta.,7.beta.,8a .alpha.)]-	60056	000469-61-4 97
			1H-3a,7-Methanoazulene, 2,3,4,7,8, 8a-hexahydro-3,6,8,8-tetramethyl-, [3R-(3.alpha.,3a.beta.,7.beta.,8a .alpha.)]-	60061	000469-61-4 97
			1H-3a,7-Methanoazulene, 2,3,4,7,8, 8a-hexahydro-3,6,8,8-tetramethyl-, [3R-(3.alpha.,3a.beta.,7.beta.,8a .alpha.)]-	60060	000469-61-4 96
43	10.470	0.65	C:\Database\NIST05a.L		
			Isolongifolene, 9,10-dehydro-	58523	1000151-67-1 64
			Cycloisolongifolene, 8,9-dehydro-	58528	1000151-28-0 49
			Biphenylene, 1,2,3,6,7,8,8a,8b-oct ahydro-4,5-dimethyl-	48796	106988-87-8 38
44	10.663	2.89	C:\Database\NIST05a.L		
			Azulene, 1,2,3,4,5,6,7,8-octahydro -1,4-dimethyl-7-(1-methylethenyl)- , [1S-(1.alpha.,4.alpha.,7.alpha.)]-	60026	003691-12-1 99
			Azulene, 1,2,3,4,5,6,7,8-octahydro -1,4-dimethyl-7-(1-methylethenyl)- , [1S-(1.alpha.,4.alpha.,7.alpha.)]-	60027	003691-12-1 99
			Azulene, 1,2,3,4,5,6,7,8-octahydro -1,4-dimethyl-7-(1-methylethenyl)- , [1S-(1.alpha.,4.alpha.,7.alpha.)]-	60028	003691-12-1 95
45	10.759	0.71	C:\Database\NIST05a.L		

				4,7-Methanoazulene, 1,2,3,4,5,6,7,8-octahydro-1,4,9,9-tetramethyl-, [1S-(1.alpha.,4.alpha.,7.alpha.)]-	60014	000514-51-2 90
				Naphthalene, 1,2,4a,5,8,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-, (1.alpha.,4a.beta.,8a.alpha.)-(.+/-.)-	60043	005951-61-1 64
				1H-Cycloprop[e]azulene, decahydro-1,1,7-trimethyl-4-methylene-, [1aR-(1a.alpha.,4a.beta.,7.alpha.,7a.beta.,7b.alpha.)]-	60073	025246-27-9 55
46	10.866	1.23	C:\Database\NIST05a.L			
				.alpha.-Caryophyllene	59848	006753-98-6 93
				1,4,7,-Cycloundecatriene, 1,5,9,9-tetramethyl-, Z,Z,Z-	59900	1000062-61-9 90
				.alpha.-Caryophyllene	59846	006753-98-6 81
47	10.994	0.35	C:\Database\NIST05a.L			
				Bicyclogermacrene	59828	067650-90-2 62
				1,5-Dimethyltricyclo[3.3.0.0(2,6)]octane	15297	103240-54-6 60
				1,3,6-Heptatriene, 2,5,6-trimethyl	15273	042123-66-0 50
48	11.133	3.11	C:\Database\NIST05a.L			
				Aromadendrene oxide-(1)	71360	1000151-98-4 48
				Tricyclo[5.2.2.0(1,6)]undecan-3-ol, 2-methylene-6,8,8-trimethyl-	71424	1000159-37-6 45
				4,7-Methanoazulene, decahydro-1,4,9,9-tetramethyl-	61555	020478-88-0 44
49	11.293	0.87	C:\Database\NIST05a.L			
				Cycloheptane, 4-methylene-1-methyl-2-(2-methyl-1-propen-1-yl)-1-vinyl-	59957	1000159-38-5 92
				Naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,8a-dimethyl-7-(1-methylethenyl)-, [1S-(1.alpha.,7.alpha.,8a.alpha.)]-	60051	010219-75-7 86
				1H-Cycloprop[e]azulene, decahydro-1,1,7-trimethyl-4-methylene-, [1aR-(1a.alpha.,4a.beta.,7.alpha.,7a.beta.,7b.alpha.)]-	60076	025246-27-9 84
50	11.560	10.67	C:\Database\NIST05a.L			
				Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1S-(1.alpha.,7.alpha.,8a.beta.)]-	60033	003691-11-0 99
				Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1S-(1.alpha.,7.alpha.,8a.beta.)]-	60035	003691-11-0 97
				Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1S-(1.alpha.,7.alpha.,8a.beta.)]-	60031	003691-11-0 97
51	11.710	1.39	C:\Database\NIST05a.L			
				Naphthalene, 1,2,3,4-tetrahydro-1,6-dimethyl-4-(1-methylethyl)-, (1S-cis)-	58550	000483-77-2 90
				Naphthalene, 1,2,3,4-tetrahydro-1,1,6-trimethyl-	39072	000475-03-6 50
				Naphthalene, 1,2,3,4-tetrahydro-1,1,6-trimethyl-	39071	000475-03-6 46
52	11.827	1.69	C:\Database\NIST05a.L			
				2,4-Quinolinediol	30432	000086-95-3 50
				.alpha.-Cubebene	59821	017699-14-8 47
				Benzene, 1,1'-(1,2-ethanediyl)bis[2,3,4,5,6-pentamethyl-	138132	052145-28-5 35

53	12.041	2.45	C:\Database\Flavor2.L		
			Carvone	204	000099-49-0 7
			2,6-Dimethyl-5-heptanal	262	000106-72-9 4
			Cyclohexyl acetate	338	000622-45-7 1
54	12.137	0.35	C:\Database\NIST05a.L		
			Caryophyllene oxide	71353	001139-30-6 64
			1-Oxaspiro[2.5]octane, 5,5-dimethyl-4-(3-methyl-1,3-butadienyl)-	61505	1000195-92-1 55
			.alpha.-Farnesene	59827	000502-61-4 55
55	12.190	0.27	C:\Database\NIST05a.L		
			4-Pentenoic acid, 4-(4-methylphenyl)-, ethyl ester	69885	032623-17-9 42
			1H-Pyrrolo[2,3-b]pyridine, 2-(1-methylethyl)-	29388	027257-18-7 30
			Benzene, (2,2-dimethyl-1-methylenepropyl)-	29583	005676-29-9 27
56	12.222	0.37	C:\Database\NIST05a.L		
			Naphthalene, 5-butyl-1,2,3,4-tetrahydro-	48777	066325-42-6 30
			Bicyclo[3.1.1]hept-3-ene-spiro-2,4'-(1',3'-dioxane), 7,7-dimethyl-	52732	1000149-76-2 27
			Benzene, 1-(1-methyl-2-propenyl)-4-(2-methylpropyl)-	48792	057438-46-7 25
57	12.318	1.17	C:\Database\NIST05a.L		
			1-(3-Methyl-cyclopent-2-enyl)-cyclohexene	30885	1000185-30-7 44
			1H-3a,7-Methanoazulene, octahydro-1,4,9,9-tetramethyl-	61560	025491-20-7 42
			Methylpropargyl-.beta.-phenylpropionate	58411	028048-99-9 41
58	12.468	0.59	C:\Database\NIST05a.L		
			1-Methoxy-1,3-cyclohexadiene	5685	002161-90-2 30
			1,4-Methano-1H-indene, octahydro-4-methyl-8-methylene-7-(1-methylethyl)-, [1S-(1.alpha.,3a.beta.,4.alpha.,7.alpha.,7a.beta.)]-	60092	003650-28-0 25
			5H-Inden-5-one, 1,2,3,3a,4,7a-hexahydro-7a-methyl-, trans-	22941	017429-25-3 25
59	12.521	0.59	C:\Database\NIST05a.L		
			Bicylo[4.1.0]heptane, 7-bicyclo[4.1.0]hept-7-ylidene-	48793	1000152-39-9 40
			Cycloheptane, 4-methylene-1-methyl-2-(2-methyl-1-propen-1-yl)-1-vinyl-	59957	1000159-38-5 40
			Santalol	71321	011031-45-1 35
60	12.618	0.62	C:\Database\NIST05a.L		
			Bicyclo[5.2.0]nonane, 2-methylene-4,8,8-trimethyl-4-vinyl-	59917	242794-76-9 48
			Isoaromadendrene epoxide	71364	1000159-36-6 46
			Cedran-diol, 8S,13-	83829	088588-48-1 43
61	12.682	0.46	C:\Database\NIST05a.L		
			2,3,5,6-Tetramethylbenzamide	40969	099858-56-7 50
			2-Methyl-5-nitro-2H-indazole	41144	005228-48-8 43
			Acetic acid, 2-(morpholin-4-yl)-2-(pyridin-2-yl)-	72354	1000277-26-2 38
62	12.767	0.78	C:\Database\NIST05a.L		
			1-Cycloheptene, 1,4-dimethyl-3-(2-methyl-1-propene-1-yl)-4-vinyl-	59937	1000159-38-6 52
			Cyclohexane, 1,2-dimethyl-3,5-bis(1-methylethenyl)-, (1.alpha.,2.beta.,3.beta.,5.alpha.)-	51388	074806-55-6 38
			2-Methyl-1-phenyl-1-butanol	32048	003968-86-3 38

63	12.927	4.46	C:\Database\NIST05a.L		
			Naphthalene, 1,2,4a,5,8,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-, (1.alpha.,4a.beta.,8a.alpha.)-(.+/-.)-	60045	005951-61-1 95
			2-Naphthalenemethanol, 1,2,3,4,4a,5,6,7-octahydro-.alpha.,.alpha.,4a,8-tetramethyl-, (2R-cis)-	72998	001209-71-8 94
			1H-Cyclopropa[a]naphthalene, 1a,2,3,3a,4,5,6,7b-octahydro-1,1,3a,7-tetramethyl-, [1aR-(1a.alpha.,3a.alpha.,7b.alpha.)]-	60074	000489-29-2 90
64	13.002	2.00	C:\Database\NIST05a.L		
			1H-Cycloprop[e]azulene, decahydro-1,1,7-trimethyl-4-methylene-, [1aR-(1a.alpha.,4a.alpha.,7.alpha.,7a.beta.,7b.alpha.)]-	60080	000489-39-4 95
			1H-Cycloprop[e]azulene, decahydro-1,1,7-trimethyl-4-methylene-	59928	072747-25-2 90
			4,6,6-Trimethyl-2-(3-methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octane	69975	1000190-22-2 80
65	13.077	3.18	C:\Database\NIST05a.L		
			Hinesol	72894	023811-08-7 91
			Agarospirol	72903	001460-73-7 60
			Naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,8a-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,7.beta.,8a.alpha.)]-	60046	004630-07-3 53
66	13.194	2.41	C:\Database\NIST05a.L		
			(-)-Aristolene	59805	006831-16-9 89
			Aristolene	59784	1000150-14-9 64
			1,4-Methanoazulene, decahydro-4,8,8-trimethyl-9-methylene-, [1S-(1.alpha.,3a.beta.,4.alpha.,8a.beta.)]	60023	000475-20-7 64
67	13.301	6.85	C:\Database\NIST05a.L		
			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.)]-	60067	022567-17-5 94
			Naphthalene, decahydro-4a-methyl-1-methylene-7-(1-methylethenyl)-, [4aR-(4a.alpha.,7.alpha.,8a.beta.)]	60015	017066-67-0 90
			.tau.-Cadinol	72906	005937-11-1 74
68	13.547	1.09	C:\Database\NIST05a.L		
			Azulene, 1,2,3,4,5,6,7,8-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1S-(1.alpha.,4.alpha.,7.alpha.)]-	60028	003691-12-1 55
			4,6,6-Trimethyl-2-(3-methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octane	69975	1000190-22-2 47
			Azulene, 1,2,3,4,5,6,7,8-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1S-(1.alpha.,4.alpha.,7.alpha.)]-	60027	003691-12-1 47
69	13.782	1.85	C:\Database\NIST05a.L		
			4,6,6-Trimethyl-2-(3-methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octane	69975	1000190-22-2 86
			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.)]-	60066	022567-17-5 49
			Bicyclo[4.3.0]nonane, 7-methylene-	59915	1000156-11-9 49

			2,4,4-trimethyl-2-vinyl-			
70	13.867	1.14	C:\Database\NIST05a.L			
			4,6,6-Trimethyl-2-(3-methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octane	69975	1000190-22-2	78
			.beta.-Humulene	59811	000116-04-1	76
			Cyclohexane, 1,2-dimethyl-3,5-bis(1-methylethenyl)-	51375	062337-99-9	58
71	13.953	0.67	C:\Database\NIST05a.L			
			Cycloheptane, 4-methylene-1-methyl-2-(2-methyl-1-propen-1-yl)-1-vinyl-	59957	1000159-38-5	81
			5-Methyl-3-phenyl-1,3-oxazolidine	31375	073861-82-2	30
			2H-1-Benzopyran, 3,4-dihydro-2,2-dimethyl-	30750	001198-96-5	27
72	14.028	1.30	C:\Database\NIST05a.L			
			(4-Methyl-cyclohex-3-enyl)-methano	11117	089690-46-0	35
			.alpha.-Farnesene	59827	000502-61-4	30
			6-Isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-octahydro-naphthalen-2-ol	71438	1000189-10-2	27
73	14.102	0.66	C:\Database\NIST05a.L			
			1-Methyl-6-methylenebicyclo[3.2.0]heptane	9743	1000210-90-0	83
			Humulen-(v1)	59795	1000159-39-4	70
			1H-Cycloprop[e]azulene, decahydro-1,1,7-trimethyl-4-methylene-, [1aR-(1a.alpha.,4a.beta.,7.alpha.,7a.beta.,7b.alpha.)]-	60076	025246-27-9	62
74	14.188	0.63	C:\Database\NIST05a.L			
			1H-Cycloprop[e]azulene, decahydro-1,1,7-trimethyl-4-methylene-, [1aR-(1a.alpha.,4a.beta.,7.alpha.,7a.beta.,7b.alpha.)]-	60075	025246-27-9	55
			13-Azabicyclo[7.3.1]trideca-1(13),9,11-triene, 3,3-dimethyl-	59091	042273-47-2	41
			Bicyclo[7.2.0]undec-4-ene, 4,11,11-trimethyl-8-methylene-, [1R-(1R*,4Z,9S*)]-	59970	000118-65-0	38
75	14.263	0.64	C:\Database\NIST05a.L			
			1H-Cycloprop[e]azulene, decahydro-1,1,7-trimethyl-4-methylene-, [1aR-(1a.alpha.,4a.beta.,7.alpha.,7a.beta.,7b.alpha.)]-	60075	025246-27-9	89
			Caryophyllene oxide	71352	001139-30-6	55
			Methylpropargyl-.beta.-phenylpropionate	58411	028048-99-9	46
76	14.433	0.37	C:\Database\NIST05a.L			
			Bicyclo[4.3.0]nonane, 7-methylene-2,4,4-trimethyl-2-vinyl-	59915	1000156-11-9	70
			Bicyclo[5.2.0]nonane, 4-methylene-2,8,8-trimethyl-2-vinyl-	59916	1000159-38-2	38
			1,3,6-Heptatriene, 5-methyl-	5336	000925-52-0	38
77	14.626	1.30	C:\Database\NIST05a.L			
			2-Cyclopenten-1-one, 3-methyl-2-(2,4-pentadienyl)-, (Z)-	30782	022610-79-3	64
			Benzene, 1-(1,1-dimethylethyl)-3,5-dimethyl-	30895	000098-19-1	45
			Benzene, 1,2-diethyl-3,4-dimethyl-	30866	054410-75-2	41
78	14.690	0.39	C:\Database\NIST05a.L			
			1,3,6-Trimethyladamantane	41740	024139-37-5	43
			1-Cycloheptene, 1,4-dimethyl-3-(2-methyl-1-propene-1-yl)-4-vinyl-	59937	1000159-38-6	42

			Cyclohexane, 1,2-dimethyl-3,5-bis(1-methylethenyl)-	51375	062337-99-9	30
79	14.850	0.64	C:\Database\NIST05a.L			
			2(3H)-Naphthalenone, 4,4a,5,6,7,8-hexahydro-4,4a-dimethyl-6-(1-methylethenyl)-, [4R-(4.alpha.,4a.alpha.,6.beta.)]-	69991	004674-50-4	38
			2(3H)-Naphthalenone, 4,4a,5,6,7,8-hexahydro-4,4a-dimethyl-6-(1-methylethenyl)-	69977	091416-23-8	35
			Naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,8a-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,7.beta.,8a.alpha.)]-	60047	004630-07-3	25
80	14.946	0.60	C:\Database\NIST05a.L			
			Biphenylene, 1,2,3,6,7,8,8a,8b-octahydro-4,5-dimethyl-	48796	106988-87-8	70
			Dispiro[4.2.4.2]tetradeca-6,13-diene	48773	078578-90-2	46
			Bicyclo[4.2.0]oct-1-ene, exo-7-(1-cyclohexen-1-yl)-	48787	1000142-22-1	43
81	15.032	0.47	C:\Database\NIST05a.L			
			4,6,6-Trimethyl-2-(3-methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octane	69975	1000190-22-2	46
			Naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,8a-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,7.beta.,8a.alpha.)]-	60047	004630-07-3	43
			10-Oxatricyclo[4.2.1.1(3,9)]dec-4-ene, 9-ethenyl-	30776	138146-11-9	25
82	15.213	0.45	C:\Database\Flavor2.L			
			Cuminaldehyde	264	000122-03-2	9
			beta-Caryophyllene	110	000087-44-5	9
			Carvyl acetate	244	000097-42-7	9
83	15.459	0.14	C:\Database\NIST05a.L			
			1,8-Nonadien-3-yne, 2,8-dimethyl-7-methylene-	29592	076003-41-3	50
			3-Pyridinecarbonitrile, 6-ethyl-5-methyl-	21387	110253-41-3	47
			2-Propenal, 2-methyl-3-phenyl-	20739	000101-39-3	46
84	15.683	0.12	C:\Database\NIST05a.L			
			Phenol, 2,6-dimethyl-	9622	000576-26-1	38
			5,8-Decadien-2-one, 5,9-dimethyl-, (E)-	43080	130876-99-2	38
			Phenol, 2,5-dimethyl-	9623	000095-87-4	38
85	16.292	0.20	C:\Database\NIST05a.L			
			n-Hexadecanoic acid	96235	000057-10-3	96
			n-Hexadecanoic acid	96234	000057-10-3	95
			Tetradecanoic acid	77275	000544-63-8	50
86	16.442	0.76	C:\Database\NIST05a.L			
			Benzenemethanol, 4-methyl-	9648	000589-18-4	47
			2(1H)-Naphthalenone, 4a,5,6,7,8,8a-hexahydro-4a-methyl-, trans-	32148	022844-34-4	43
			3,3-Dimethyl-6-methylenecyclohexen	9738	020185-16-4	43
87	21.740	0.32	C:\Database\NIST05a.L			
			13-Docosenamide, (Z)-	146308	000112-84-5	90
			9-Octadecenamide, (Z)-	112655	000301-02-0	90
			Hexadecanamide	95461	000629-54-9	59

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Figure A-4 GC-MS analysis result for gaharu oil

APPENDIX B

Figure B-1 Gaharu woodchips (Grade C)

Figure B-2 Sampling equipment