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Chemical content of agarwood-producing trees from Buru Island, Maluku, Indonesia

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Abstract. *Uar NI, Karlinasari L, Siregar IZ, Pertiwi S. 2024. Chemical content of agarwood-producing trees from Buru Island, Maluku, Indonesia. Biodiversitas 25: 2629-2636.* Agarwood or gaharu is a plant that grows abundantly and naturally throughout almost all of Indonesia, including Buru Island and Moluccas. The exploration of agarwood-producing plants has been motivated by the superior quality of agarwood, which is closely linked to its chemical composition. This study aimed to determine the chemical components and resin contents of cultivated and natural agarwood-producing trees on Buru Island. The research was carried out in three areas, considered the centers of agarwood production on Buru Island: Airbuaya, Fenaleisela, and Batabual. The identification of tree species was carried out as an initial stage to identify the tree species that produce agarwood. The quality of agarwood was determined by reference to the Indonesian standard, resin content analysis, and chemical component identification results evaluated through GC-MS laboratory testing. The results showed that agarwood-forming compounds were present in cultivated and natural plants. *Aquilaria filaria* is the agarwood-producing tree found at the research location. The chemical components of agarwood from three locations contained sesquiterpene alcohol, chromone, and acid compounds, with the resin content in natural forests showing higher values than in cultivated plants. The quality of agarwood depends on its constituent compounds and chemical content. Based on the research results, the agarwood plants on Buru Island, a testament to the richness of Indonesia's natural resources, have the potential to be developed to a greater extent so that, with good management, they can contribute significantly to the development of local communities.

Keywords: Agarwood, *Aquilaria*, Buru Island, chemical content, sesquiterpene

INTRODUCTION

Indonesia has a strategic position in the world agarwood market, where approximately 27 species of plants can produce agarwood. Agarwood-producing trees are one of the non-timber forest products (NTFP), which are among the largest foreign exchange contributors to the country and a source of income for communities around the forest (Mpapa and Lamusu 2014; Pasaribu et al. 2015). Several agarwood-producing trees, including *Aquilaria* spp. and *Grynops* spp., belong to the Thymelaeaceae family. *Aquilaria* spp. is a source of high-quality agarwood (Pasaribu et al. 2015; Naziz et al. 2019).

Agarwood, also known as *gaharu*, aloeswood, oud, or oudh, is a type of resin produced from infection in agarwood-producing trees, either mechanically or artificially (Karlinasari et al. 2015). The fragrance of agarwood-producing trees indicates the presence of resin in agarwood trees, which can be utilized as a raw material for cosmetics and medicinal industries. The multi-use of agarwood-producing plants with high economic value makes this plant a forest product that is highly sought by the public.

The resin content in agarwood of each type varies depending on the tree species and the organisms that infect the plant. The presence of resin in the trees that produce agarwood indicates their quality. Agarwood can be classified into *gubal gaharu*, *kemedangan*, and powder. The classification system was based on color, weight, and odor. Testing of the chemical content and the content of the agarwood resin is one of the tests carried out to manipulate the selection subjectively in determining the classification of the quality of agarwood. High-quality agarwood has a high selling value and is usually traded in the form of logs, blocks, chips, and powder to meet the needs of the cosmetic and medical industries. The lower ones are usually used for oil products and other products such as incense. Several studies regarding the excellent quality of *Aquilaria* spp. species (Pasaribu et al. 2015) were the main reasons for research to determine the resin content and chemical composition of the aloes of the wood species on Buru Island.

The resin content and dominant chemical content of the agarwood determine agarwood quality. The presence of agarwood can be easily detected based on its fragrance and color. The fragrance became more intense, and the black color deepened, indicating a higher quality of agarwood. Methods for determining the quality of agarwood have been well developed, but international standardization is yet to be achieved (Mohamed and Lee 2016). Each country has developed standards to determine the quality of its agarwood. The evaluation of agarwood quality in Indonesia refers to SNI 7631-2011 based on the color, aroma after burning, and sinking weight, and this evaluation depends on the ability and experience of the agarwood quality grade. Therefore, it is necessary to obtain other quantitative and objective parameters that can determine the quality of agarwood, particularly from laboratory testing.

Gyrinops ledermannii, G. maluccana, G. verseetgii, G. salicifolia, Aquilaria cumigiana, and *A. filaria* are agarwood-producing trees in Buru Island (Kamaruddin et al. 2021; Lee et al. 2022). *A. filaria* and *A. cumingiana* are tree species distributed originally from the Philippines region, where the distribution starts from the Mindanao Islands, North Sulawesi, and spreads to Moluccas. The quality of agarwood is greatly influenced by the tree species, the location where it grows, and other factors that support the quality of the plant that produces agarwood. Therefore, it is necessary to identify the tree species and the quality of agarwood produced from either natural or cultivated growth on Buru Island. This study aimed to determine the quality of agarwood from Buru Island, Moluccas, based on its chemical content.

MATERIALS AND METHODS

Plant material and growing conditions

Cultivated and natural agarwood-producing trees were removed from three regions known as centers of agarwood production on Buru Island, i.e.: Airbuaya, Fenaleisela, and Batabual Sub-districts of Buru District, Maluku, Indonesia, which are located at 126°23'47.832″ E, 3°5'23.075″ S to 127°14'12.23″ E, 3°30'35.971″ S (Figure 1).

Procedures

Seven agarwood-producing trees were randomly selected from each location based on the characteristics of trees that formed agarwood. Information regarding the presence of agarwood is based on local people who have experience identifying it. Regardless of whether the agarwood was naturally derived, cultivated, or deliberately inoculated, trees producing agarwood were selected. However, information on tree treatments was recorded. The selected research tree had a diameter at breast height (DBH) with a diameter of-15-18 cm with a height ranging from 6-8 m, referring to Karlinasari et al. (2015) and Sitepu et al. (2011). The first stage of the research was to confirm the tree species through tree species identification, followed by taking wood samples with an increment bore (Figure 2), which was used to analyze the quality of the chemical content of agarwood. Laboratory testing for resin content was performed at the Forest Products Chemistry Laboratory, Department of Forest Products, Institut Pertanian Bogor, and Gas Chromatography and Mass Spectrometry (GC-MS) testing was performed at the Jakarta Regional Health Laboratory (KESDA).

Tree species identification

Tree species identification was carried out by identifying the species based on the morphology of the tree leaves and reproductive organs, if any, obtained from vegetation analysis. Identifying tree species includes analyzing test samples of the leaves, stems, bark, fruit, and flowers. Leaf sample handling in the field involved preparing samples found in each plot, cleaning them using distilled water, placing them in the newspaper, which was sprayed with 70% alcohol, and then placing them in plastic measuring 30 × 40 cm. The laboratory preparations were adjusted for the herbarium process (Setiawan 2018). Species identification was based on identification results from the Herbarium Institute of the National Research and Innovation Agency (BRIN), referring to the available literature.

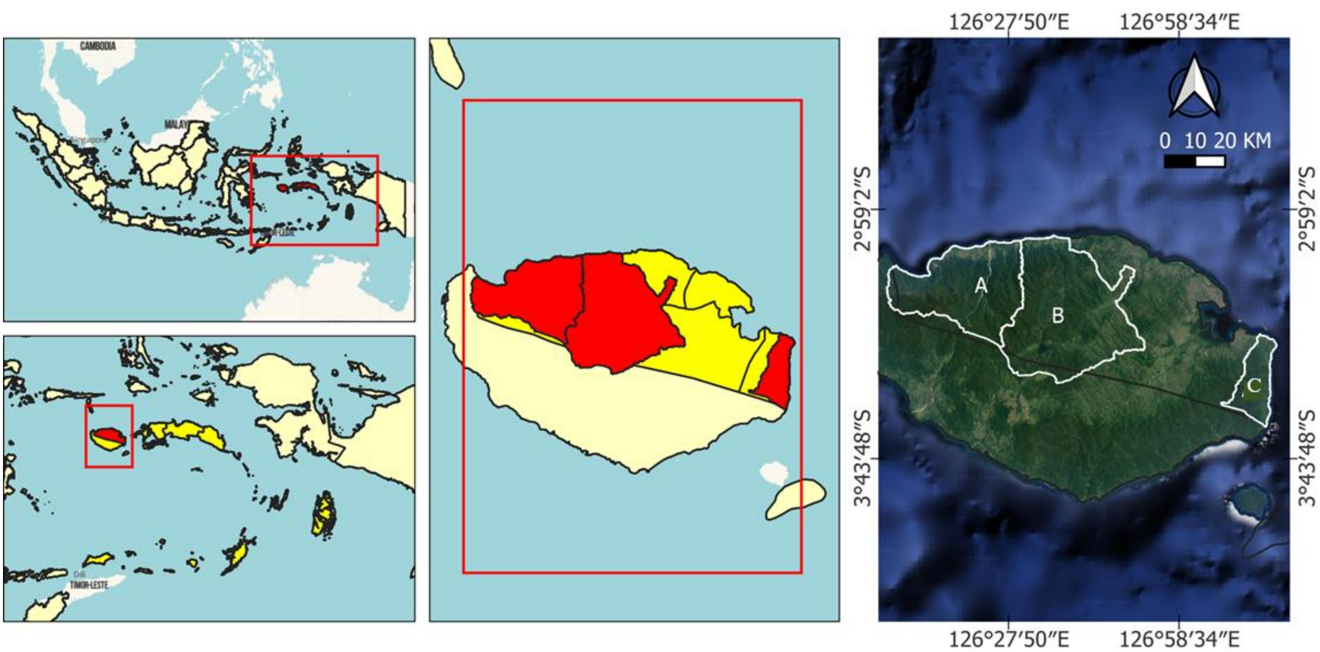

Figure 1. Three research locations of Aibuaya (A), Fenaleisela (B), and Batabual (C) sub-districts in Buru Island, Maluku, Indonesia

Analysis of resin content

Quality analysis of agarwood was performed by burning to smell the aroma of the chip sample obtained by peeling the bark of agarwood-producing trees and analyzed using SNI 7631 (BSN 2011). The chemical resin content was analyzed in the laboratory following WHO guidelines (1989). The laboratory test samples were obtained from incremental core samples (Figure 2.A), which were processed to become smaller in size in powder form (Figure 2.B). Agarwood powder (4 g) was then placed in a glass bottle and 100 mL of ethanol (95%) was added, followed by stirring for one hour. The mixture was then conditioned at room temperature for 24 hours. The process was continued by filtering and drying for approximately 1.5 hours to obtain the solid resin content. Next, 5 mL of ethanol was added to clean the resin deposited in the flask. The solid resin was filtered using filter paper and dried at 103±2°C for two hours. The dried resin was then placed in a desiccator and weighed. The resin content was determined using the following equation:

$$Resin\ content\ (\%) = \frac{Dried\ resin - initial\ weight\ of\ agarwood}{Dried\ resin} x\ 100$$

The analysis of the resin content at each research location used a randomized block design with the Minitab software application to identify factors that influence each other, with a confidence level of 5%.

Analysis of chemical compound content

The chemical content of the suspected agarwood was analyzed using increment core samples. The analysis used the GC-MS-pyrolysis method with a Shimadzu Pyr GC-MS QP2010 chromatograph equipped with a quartz capillary column coated with a polyamide precipitate. This tool operated at a pyrolysis temperature of 400°C for 1 h, injection temperature of 280°C, detector temperature of 280°C, and initial column temperature of 50°C, with an increase of 15°C/min to 280°C. Compound identification was performed by matching the mass spectrum data, along with ion fragmentation of a compound in the extract, with data from the WILEY 7th library database (Sari et al. 2011).

RESULTS AND DISCUSSION

Tree identification

Identification was performed to confirm the tree species by referring to the leaves and other morphological characteristics. The identification results showed that *A. filaria* was confirmed for some leaves, whereas others were identified only in the genus *Aquilaria* sp. (Figure 3). The validation results on nine samples identified two tree species of *A. filaria*. In comparison, seven samples were *Aquilaria* sp. *A. filaria*, an agarwood-producing tree identified in the Airbuaya natural forest, and the cultivated agarwood-producing trees from the Fenaleisela.

The identification of this tree species followed the results of a study by Lee et al. (2020), in which *Aquilaria* spp. were spread on Buru Island, as well as several other tree species on the Moluccas Islands (Susilo et al. 2014; Kamaruddin et al. 2021). *Aquilaria* spp. grow and are distributed in eastern Indonesia, especially *A. filaria* tree species (Destri et al. 2020). Apart from *Aquilaria, Grynops* is a tree species spread across eastern Indonesia (Susilo et al. 2014; Lee et al. 2022). The potential and distribution of agarwood-producing trees in the Moluccas region are quite high. This potential comes from natural forests and plantation forests. It is based on the master plan for developing agarwood-producing trees from 2013 to 2023, which includes planting 1.5 ha of agarwood-producing trees in Moluccas and as many as 1,500 trees. This shows that the potential of agarwood-producing trees in Moluccas is promising.

Figure 2. A. Agarwood sample from increment core; B. Small flakes of agarwood

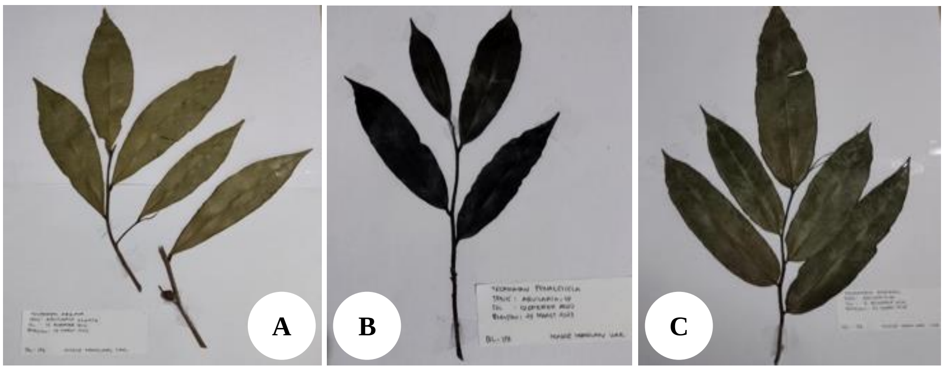

Figure 3. Leave samples for tree identification from three locations: A. *A. filaria* leave from Airbuaya, B. *A. filaria* from Fenaleisela, C. *Aquilaria* sp. from Batabual

Resin content analysis

Resins are complex compounds in plants, specifically agarwood, with distinct aromas and colors. The compound consistency in agarwood determines the agarwood quality; the higher the resins, the better the quality produced by Pasaribu et al. 2015; Subasinghe et al. 2015; Womsisor et al. 2018). The resins in natural Agarwood are 6.41-7.74% with a standard deviation of 0.50, and the cultivated Agarwood plant is 2.96-6.35% with a standard deviation of 1.42. Resins in natural plants were higher than those in cultivated plants found in the three sampling locations. The resin formation mechanisms in both plants cause different resin qualities between natural and cultivated plants. Resin formation in natural plants occurs relatively long with various microbial activities. In comparison, low resins in cultivated plants occur because of the absence of inoculation methods and the growing site effect on agarwood formation. Nevertheless, one of the locations was inoculated with *Fusarium* sp. in 2014 by the Department of Forestry, Maluku Province, but showed no significant difference compared with the other two locations. Statistical analysis showed no significant difference among the locations, with a difference of only 1.05. Thus, the role of fungi in the inoculation process is important. According to Turjaman et al. (2016) and Faisal et al. (2020), endophytic fungi and *Fusarium* had big roles in resin formation on Agarwood-producing trees. *Fusarium solani* is a fungus that contributes to resin formation in agarwood-producing trees.

Insignificant efforts from related parties or plantation owners cause the low resin content in cultivated plants. Techniques and fungal invasion into agarwood-producing trees do not guarantee resin formation (Santoso 2015). Although fungi are one of the factors that affect the resin content, minimum intensive plant maintenance at three sites occurred due to weeding absence, which could minimize the light intensity and growing site within 9-12 years. Good plant growth is determined by tree diameter and height, which can be assumed from the soil-carrying capacity in providing nutrients required for agarwood plant growth to achieve optimum productivity. Low soil nutrient levels can be overcome through various chemical or natural actions. For example, following environmental conditions, a proper dose of organic fertilizer, and appropriate nutrient administration to the planting medium. Nutrient availability in the soil can improve the ability of plants to perform both primary and secondary metabolism. Sulphur (S), as one of the nutrients, contributes to the formation of amino acids, namely cysteine and methionine. Both amino acids are coenzyme and secondary metabolite precursors (Triadiati et al. 2016). Secondary metabolites in plants are a response from plants due to injury or fungal infection.

The application of pathogenic fungi has been fully developed and has provided optimal results (Wangiyana 2017). Resin accumulation in agarwood-producing trees determines their quality, whereas the higher the resin content, the better the quality obtained (Pasaribu et al. 2015). The resin formation process in agarwood-producing trees, naturally or artificially, is often assisted in various ways, including injuring and nailing. (Vantompan et al. 2015). Naturally, agarwood formation occurs due to the microbial invasion of agarwood-producing trees (Liu et al. 2019).

The analysis results show that the resin values at the three sites varied between 2.96-7.74%, which can be classified as grade D (Table 2), as the resin contents were from 1 to 3%. According to Azah et al. (2013), several commercial products of agarwood originating from various regions of Malaysia and Indonesia are classified as *Aquilaria* type, whereas the Indonesian agarwood had resin contents of 6.01-16.24%, which were then included in grades C and D. Meanwhile, Pasaribu et al. (2015); Karlinasari et al. (2021) reported that the resins from *Aquilaria* spp. and *Gyrinops* from Sumatera, Kalimantan, and Riau were classified as grades B and C, which were of good quality and similar conditions. Samples from natural and cultivated plants obtained and tested conventionally at the three sites produced a fairly strong aroma with cream-to-light brown wood. Although the cultivated plants in the Fenaleisela were inoculated with fungi, the induction process was carried out when the plants were four years old or still seedlings, thus producing similar resin content as other locations without induction. The agarwood induction in seedlings requires more effort than induction in trees due to different physiological conditions (Wahyuni et al. 2018). The agarwood color was affected by sesquiterpenes. The dark color of wood indicates a high amount of sesquiterpenes, which then affects wood density and color formation (Hashim et al. 2014a). The wood's light color indicates a compound deposit in the wood and an induction stage marker (Triadiati et al. 2016). Therefore, light brown is thought to result in inferior sesquiterpene formation and accumulation. The content of sesquiterpenes influences the color of agarwood; dark agarwood generally contains large amounts of sesquiterpenes, thus affecting the density and color of the wood and vice versa (Rachmawaty et al. 2021). Statistical analysis showed a significant difference among the study locations, which means the locations are also involved in different compound qualities; thus, similar resin quality will be different based on the tree-growing locations. This condition proves that classification among communities is highly subjective and no longer valid generally in different locations (Pasaribu et al. 2015). Dark and black agarwood, with a strong aroma and high durability, are considered high-quality agarwood (Ismail et al. 2017). A factor that also determines the agarwood quality is the fragrant aroma. Wahyuni et al. (2018) stated that nitrogen is one of the factors that contribute to agarwood fragrant aroma formation. Agarwood quality assessment has become the main concern in agarwood business development because of its association with agarwood price.

Chemical content analysis

The chemical composition based on gas chromatography and mass spectrometry (GC-MS) is presented in Table 3. Both plants contained sesquiterpene alcohols, chromone, furan, and acids in three locations. All chemicals from both plants had different percentages of content. The agarwood compound production in each sample, with different percentages and location characteristics, describes the agarwood quality at each location. There are 26 compounds confirmed from the analysis, namely, sesquiterpenes, chromones, furans, and acids. The sesquiterpene-alcohols are composed of Clylopetandecanone, 2-hydroxy, Cyclopropaneoctanal, 2-octyl, chromones are composed of 5-flouro-1,3-bis(phenylmethyl)-2,4(1H,3H)-pyrimidinedione, 14-methyl-8hexadecyn-1-ol, Benzene (3,4) Phenantro, 2,6,6-Trymethylbicyclo 3,1,1 heptane, -(2-(-4 Butylcyclohexyl)ethyl)4-(-4pentylcyclohexy)benzene, furans are composed of 2,5 furandione,3-(Dodycenyl)Dihydro, and acids are composed of acetic acid, palmitic acid, hexadecanoid acid, ethyl ester, 9,12-octadecadienoic acid. These compounds were also detected in the samples used in this study. Sesquiterpenes found in plant gums are composed of benzil acetone, anisilacetone, guainen, palustrol, 8-epi-gama-eudesmol, α-guainene, alloaromadendrene oxide-1, agarospirol, γ-eudesmol, 3-fenil-2-butanone, and α-cubebene (Hashim et al. 2014b; Mohamed et al. 2014; Jayaraman dan Mohamed 2015; Sen et al. 2017).

Sesquiterpenes are secondary metabolites from high-quality resins (gums) in agarwood-producing trees that produce a specific aroma similar to gums and agarwood oil (Hashim et al. 2014a). The analysis results show that the chemical components of agarwood are composed of sesquiterpene-alcohol, chromone, furan, and other ester derivatives. These derivatives produce a fairly strong fragrant aroma at similar concentrations; however, the highest concentration of all derivatives was found in natural plant sesquiterpenes are 1.0-3.39%, chromones are 1.02-6.11%, and furans are 1.97-3.31%. Low concentrations of agarwood compounds in cultivated plants affect resin content. This condition was similar to Pamungkas et al. (2015), who reported that resins in plants from the heterogeneous forest showed a low-quality condition characterized by a light wood color. The GC-MS analysis results confirm that the resin content indicates the agarwood quality is classified in grade D. The agarwood in Buru Island is of low quality because of the inferior production of resins from agarwood-producing trees. However, many derivatives contribute to agarwood compound formation in each sample. Wamsisor et al. (2018) also showed that the chemical contents of *Aquilaria* in Sorong District produced high and low-quality resins, which can be assumed that the chemical contents of agarwood from each region are different due to the plant growing-site condition. The quality of the agarwood content determines the economic value of the agarwood. The higher the quality of the agarwood, the higher the economic value. Low-quality *Aquilaria* is commonly utilized as the main ingredient for agarwood oil or incense (Womsisor et al. 2018).

The higher the chemical content, the better the quality. Low-quality is generally used as a raw material for producing agarwood or incense oil. Oil quality is traded based on physical properties, color, and odor. Agarwood oil contains complex chemical compounds, such as sesquiterpenes, oxygenated-sesquiterpenes, and chromone derivatives. Ismail et al. (2014) reported that the agarwood oil quality was determined from the chemical compounds detected. These compounds can differ from the agarwood oil class, influencing their quality and commercial value (Ismail et al. 2015). In addition, several studies have previously explained a simple way to determine agarwood quality from resin content to minimize errors in selecting agarwood quality (Azah et al. 2013; Pasaribu et al. 2015). Agarwood has long been used as a medicinal fragrance, medical supply, traditional medicine, religious rites, spiritual support, incense, perfume, and aromatic fragrance in culinary components (Subasinghe et al. 2015; López-Sampson and Page 2018).

The GC-MS analysis in Table 3 shows the chemical components found in agarwood-producing plants, both natural and cultivated. Figures 4 and 5 show the chemical chromatography results for natural and cultivated plants. Based on chromatography analysis, natural plants have more chemical detection than cultivated plants. In contrast, natural plant samples show a darker color change than cultivated plant samples with a lighter color. The resin in agarwood-producing trees responds to pathogens that occur mechanically and inoculum invasion into the agarwood-producing tree samples, resulting in a darker color than the cultivated plant samples. However, each sample's chemical amount and composition are still very minimal. When burned, the aroma produced from natural plant samples had a fairly strong fragrant aroma, whereas samples from plantation forests had an extremely weak aroma.

Agarwood contains aromatic terpenes, with sesquiterpenes as the main active compounds and chromones contributing to the unique aroma of agarwood (Jong et al. 2014). Chromone derivatives found in natural agarwood plants were 6.11 %. The chromone derivatives that produce a fragrant aroma in agarwood are 4-phenyl-2-butanone, (1S,4S,7R)-1,4-dimethyl-7-(prop-1-en-2-yl)-1,2,3,4,5,6,7,8-octahydroazulene [guaiene], 1,1,4,7-tetramethyl-2,3,4,5,6,7,7a,7b-octahydro-1aH-cyclopropa[h]azulen-4a-ol [palustrol], and 4-(4-methoxyphenyl) butan-2-one [anisylacetone], in addition to agarospirol, alloaromadendre oxide (2), α-elemol, γ-eudesmol, and guaiol (Jong et al. 2014).

Table 1. The resin content of seven samples at three locations

Location	Resin content from	
	Natural tree	Cultivated trees
Airbuaya sub district	7.48 a	6.36 a
Fenaleisela sub district	6.43 b	5.31 b
Batabual sub district	6.42 b	2.96 b
Average	6.77	4.88
SD	0.50	1.42
CV	0.25	2.01

Note: Sd: standard deviation, Cv: coefficient of variation, numbers followed by the same letter indicate no significant effect (at the 5% level)

Table 2. Classification of agarwood based on resin content

Grades	Resin content
A	> 30%
B	20-29.99 %
C	9-19.99 %
D	< 9%

Note: Source: Azah et al. (2013)

Table 3. Chemical components of agarwood at 3 different locations

Location	Compound name	Chemical components natural tree	RT	%	Compounds	Chemical components cultivated trees	RT	%
Airbuaya	Sesquiterpene alcohol	Clylopetadecanone, 2-hydroxy	32.99	3.39	Acetic acid	Hexadecanoic acid	30.34	3.77
	Palmitic acid	9,12-octadecadienoic acid	34.46	2.30	Chromone	Benzene (3,4) Phenantro (1,2B) Thiophene, 11-methyl	30.10	2.44
	Acetic acid	Hexadecanoid acid, ethyl ester	30.19	1.83	Chromone	14-methyl-8hexadecyn-1-ol	34.47	2.21
	Chromone	2,6,6-Trymethylbicyclo 3,1,1 heptane	29.34	1.82	Furan	2,5 furandione,3-(Dodycenyl)Dihydro	30.71	1.97
	Furan	2,5 furandione,3-(dodycenyl)dihydro	30.71	1.50	Sesquiterpene	Cyclopropaneoctanal, 2-octyl	35.54	1.00
Fenaleisela	Acetic acid	Octadecanoic acid, ethyl ester	32.24	3.77	Sesquiterpene alcohol	Flavone,5-Hydroxy-4,7-dimethoxy	38.61	5.08
	Chromone	14-methyl-8hexadecyn-1-ol	34.44	3.75	Furan	2,5 furandione,3-(Dodycenyl)Dihydro	30.96	2.76
	Acetic acid	Hexadecanoid acid, ethyl ester	30.17	2.74	Palmitic acid	9,12-octadecadienoic acid	33.27	2.81
	Acetic acid	9,12-octadecadienoic acid	34.33	2.67	Acetic acid	Hexadecanoic acid, ethyl ester	30.20	1.33
	Chromone	2,6,6-Trymethylbicyclo 3,1,1 heptane	29.33	1.02	Chromone	14-methyl-8hexadecyn-1-ol	34.81	1.48
Batabual	Chromone	5-fluoro-1,3-bis(phenylmethyl)-2,4(1H,3H)-pyrimidinedione	37.46	6,11	Chromone	1-(2-(-4 Butylcyclohexyl)ethyl) 4-(-4pentylcyclohexy)benzene	37.62	5,10
	Palmitic acid	9,17-Octadecadienal, (Z)	34.48	3.53	Chromone	2,6,6-Trymethylbicyclo 3,1,1 heptane	30.78	2.13
	Furan	2,5 furandione,3-(dodycenyl)dihydro	31.41	3.31	Acetic acid	Hexadecanoic acid, ethyl ester	30.20	1.68
	Sesquiterpene alcohol	Cyclopropaneoctanal, 2-octyl	33.18	2.02	Sesquiterpene alcohol	Clyclopentadecanone,2 hydroxy-	32.86	1.51
	Acetic acid	Hexadecanoic acid, ethyl ester	30.22	1.76	Sesquiterpene alcohol	Cyclopropaneoctanal, 2-octyl	35.54	1.31

The different chemical contents of agarwood are due to the fragrant aroma of resins as a specific defense response to disturbances, thereby stimulating resin formation. Resins in agarwood trees are part of the tree's defense mechanism against the system caused by wounds or fungal infections (Tan et al. 2019). Rasool and Mohamed (2016) stated that wounding is a way to produce resin in trees. Agarwood production, marked by color changes in the infected area, indicates agarwood formation due to resin accumulation. Certain chemical compounds contribute to the aroma and quality of resin and agarwood oil. Sesquiterpenes are the main active components that play an important role in providing a pleasant aroma and odor to agarwood (Hashim et al. 2014). Azah et al. (2014) analyzed *Aquilaria* spp. using GC-MS analysis at pyrolysis temperatures (60-230°C) to produce essential oil from wood, while 400°C is usually used for charcoal pyrolysis. Similarly, Ismail et al. (2015) reported that agarwood oil could be extracted from plant material using a combination of GC-MS and solid-phase microextraction (SPME) techniques, which allows the volatile chemical compounds characteristic of the odor to be successfully extracted.

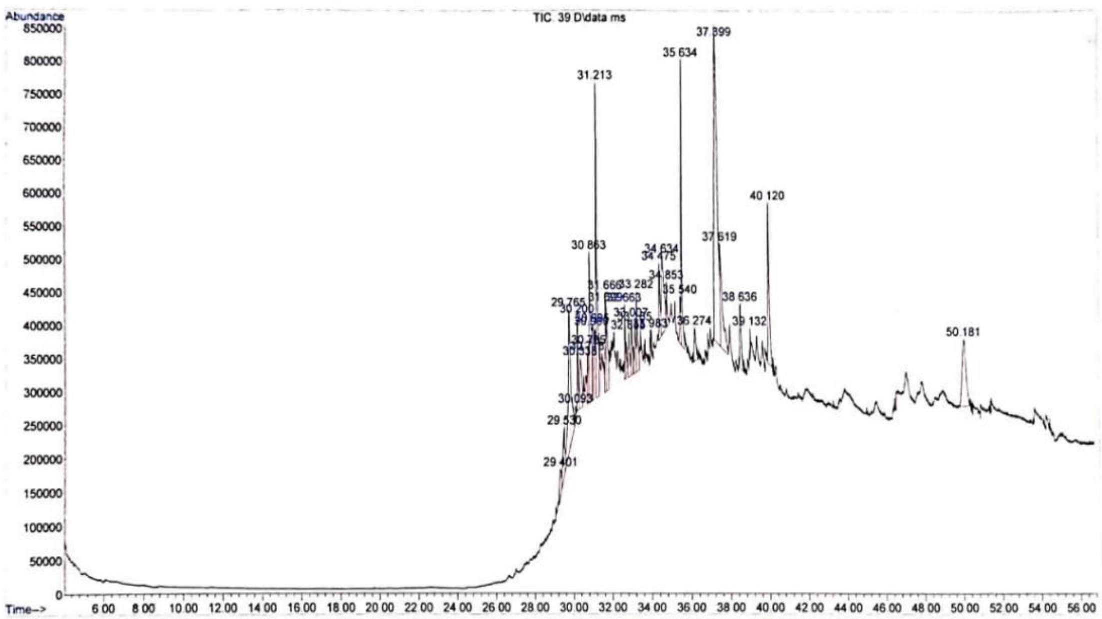

Figure 4. The GC chromatography of natural agarwood pants

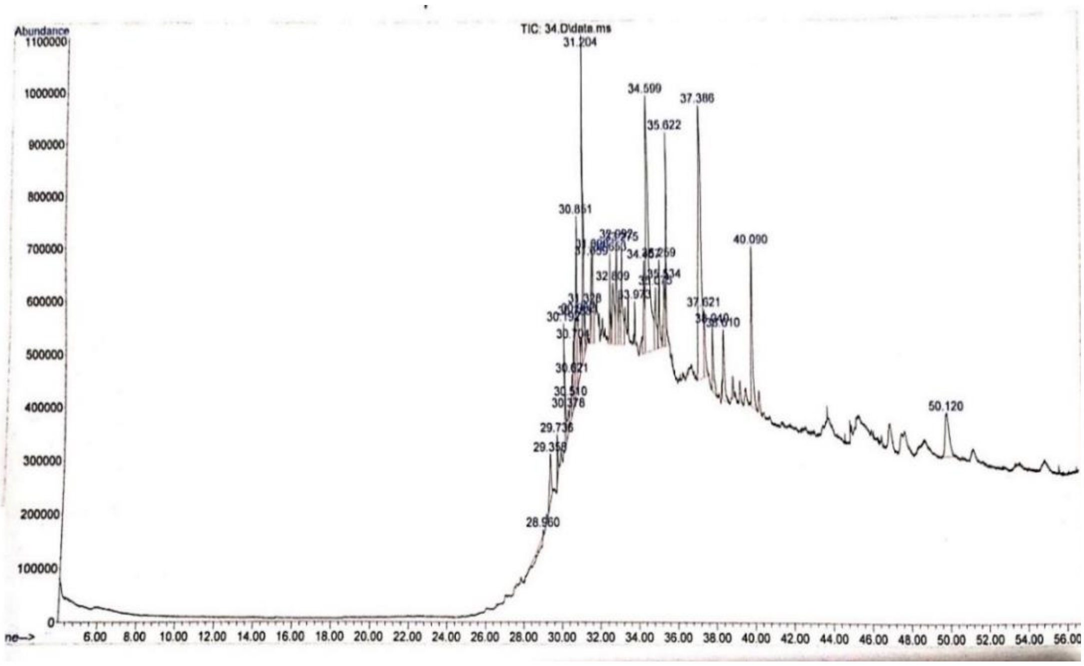

Figure 5. The GC chromatography of cultivated agarwood plants

The resin content in agarwood is an extractive substance that can provide a color indication, agarwood aroma, and wood defense against pathogenic organisms (Azwin 2016). Pasaribu et al. (2015) stated that the quality of agarwood is closely related to the agarwood price. Agarwood quality, distinguished from the resin content and chemical composition, is highly important for setting standards and obtaining more precise and objective systematic determinations.

In conclusion, the resin content of three locations is in grade D, with an average natural plant resin of 6.77% and cultivated tree resin of 4.88%. The resin contents of natural plants are greater than those of cultivated trees, and gas chromatography and mass spectrometry (GC-MS) tests show compounds of sesquiterpene alcohol, chromone, furan, and acid. The chemical content was relatively similar despite the different contents.

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