



RESEARCH COMMUNICATION

Phytochemical composition and antioxidant activity of four naturally growing *Aquilaria* species from North Padang Lawas, Indonesia

Ridwanti Batubara^{1,2*}, T Ismanelly Hanum², Oding Affandi^{1,2}, Shafira Chairunnisa Chery^{1,3}

¹Faculty of Forestry, Universitas Sumatera Utara (University of North Sumatra), Deli Serdang 20353, Indonesia

²Center for Social Forestry Studies, Universitas Sumatera Utara (University of North Sumatra), Medan 20222, Indonesia

³School of Postgraduate Studies, Faculty of Natural Resources and Environmental Management, Universitas Sumatera Utara (University of North Sumatra), Medan 20222, Indonesia

*Correspondence email - ridwanti@usu.ac.id

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Abstract

Agarwood-producing species of the genus *Aquilaria* occur naturally in Sumatra, including North Padang Lawas Regency, Indonesia. Leaves of *Aquilaria* are increasingly explored as raw material for herbal tea due to their bioactive compounds. This research aims to assess the phytochemical composition, tannin levels and antioxidant potential of four agarwood species that grow naturally in North Padang Lawas, Indonesia. Fresh agarwood leaves were powdered and extracted using a 96 % ethanol solution for further testing. The phytochemical analysis indicated the presence of various bioactive compounds such as flavonoids, alkaloids, tannins, saponins and triterpenoids, which are recognized for their biological functions. The evaluation of antioxidant capacity was conducted using the DPPH radical scavenging assay. In addition, gas chromatography-mass spectrometry (GC-MS) analysis detected a variety of chemical compounds, including phenolic compounds and particular fatty acids, which may be linked to the antioxidant effects noted. Both dried leaf material and ethanol extracts contained similar classes of secondary metabolites, although the presence of specific compounds varied among species. All four species were classified in the “very strong” category of antioxidant activity with IC₅₀ values below 40 µg/mL. GC-MS analysis revealed dominant compounds in each species, including Nortopsentin B in *A. microcarpa* (13.46 %), Propanamide in *A. beccariana* (14.66 %), Acetaldehyde in *A. malaccensis* (26.39 %) and 2'-oxa-3'-adeninylyl-4',5'-dihydroxycyclopentyl in *A. hirta* (14.43 %). Overall, the findings support the traditional use of agarwood leaves as a healthful tea and warrant further development as an alternative raw material for functional food or pharmaceutical applications.

Keywords: agarwood leaves; antioxidants; *Aquilaria*; compounds; phytochemicals

Introduction

Agarwood, locally known as *Gaharu*, is an aromatic resin produced in certain tree species in response to fungal infection. This resin-producing process primarily occurs in members of the genus *Aquilaria*, which are widely distributed across tropical regions of Asia. Indonesia is recognized as one of the major centers of agarwood biodiversity with at least 26 species identified among the 33 species reported in Asia, distributed across various regions including Sumatra, Kalimantan, Sulawesi, Nusa Tenggara, Maluku, Halmahera and Papua (1).

Agarwood is used not only for resin extraction but also in traditional medicine. Agarwood resin is widely used as a key raw material in perfumery, traditional medicines and cosmetics, thus gaining high commercial value. Traditionally, agarwood has been used in herbal medicine to treat a variety of diseases (2). The traditional use of *Aquilaria* has been shown to provide benefits based on research exploring new uses of agarwood leaves as an abundant source of antioxidants, which can be obtained through tea production. The use of agarwood leaves provides an additional

economic resource during the growth period of agarwood trees (3). Safety assessments of *Aquilaria malaccensis* leaf tea from induced trees, including acute oral toxicity and 90-day subchronic toxicity tests, reported no harmful effects (4, 5). These findings confirm the promising future of agarwood tea as a health product, potentially enhancing the traditional value of the agarwood resources sector. Considering the wide range of potential uses and markets, the crucial step in enhancing the utility of agarwood leaves is to conduct fundamental research.

Studies regarding the phytochemical composition and antioxidant activity of naturally growing agarwood species remain limited, particularly in specific regions of North Padang Lawas Regency. Differences in environmental conditions and species variation may influence the chemical profile and biological activity of agarwood leaves. Therefore, additional research is essential to gain a deeper insight into the potential of agarwood leaves as a natural antioxidant source. This study examined the phytochemical composition, tannin levels and antioxidant properties of four agarwood species grown in North Padang Lawas Regency to assess their feasibility as ingredients for antioxidant-rich gaharu tea.

Materials and Methods

Time and place

The study was carried out from September 2019 to January 2020. Leaf samples were collected from three villages in Sigompulon District, North Padang Lawas Regency. Species identification was performed at the Medan Herbarium, Faculty of Mathematics and Natural Sciences, North Sumatra University. The processes for sample preparation and extraction were executed at the Forest Products Technology Laboratory, Faculty of Forestry, North Sumatra University. Phytochemical screening was performed in the Phytochemical Laboratory of the Faculty of Pharmacy, North Sumatra University, while the analysis of tannin content was undertaken at the Food Chemistry Laboratory, Faculty of Agriculture, North Sumatra University. The gas chromatography-mass spectrometry (GC-MS) test was conducted at the PT. Gelora Djaja Laboratory, Surabaya.

Plant material identification

The plant materials consisted of four naturally growing *Aquilaria* species collected from North Padang Lawas Regency. Species identification was confirmed at the Medan Herbarium.

Sample preparation

Fresh leaves were dried in a drying cabinet until a constant weight was achieved and processed into dried plant material (simplicia). The aim of drying was to obtain long-lasting simplicia that can be stored longer than fresh samples. The dried material was powdered using a blender.

Extraction procedure

Extraction was carried out using the maceration method. Two hundred grams of simplicia and 1500 mL of 96 % ethanol were mixed in a glass container for five days at room temperature. The substance was stirred for ten minutes every day and kept protected from light. The extract was filtered after maceration and the excess content was further extracted with an ethanol solution to obtain a total extract volume of 2000 mL. The combined filtrates were stored in a closed container under cool and dark conditions for two days, followed by re-filtration. Afterwards, the solvent was removed through evaporation using a rotary evaporator set at 40 °C and the resultant extract was freeze-dried to produce a concentrated dry extract (6).

Phytochemical screening

Phytochemical screening was performed as a qualitative assessment to identify the presence of secondary metabolites, which included alkaloids, glycosides, flavonoids, tannins, steroids/terpenoids and saponins. The identification of alkaloids was achieved through Mayer's test, by treating the extract with hydrochloric acid and Mayer's reagent. The appearance of a creamy white precipitate signified a positive outcome. Glycosides were identified through Borntrager's test, involving boiling with sulfuric acid, followed by chloroform extraction and ammonia treatment, where a pink to red coloration indicated a positive reaction.

Flavonoids were tested using the Shinoda test; the extract was mixed with ethanol, hydrochloric acid and magnesium ribbon. The formation of pink or red coloration confirmed the presence of flavonoids. The Salkowski test was conducted to identify steroids, indicated by a reddish-brown ring forming at the boundary after treatment with chloroform and sulfuric acid.

Tannins were detected through the ferric chloride test, with a blue-black or greenish-black coloration confirming their existence. Saponins were detected using the foam test; stable froth after shaking with distilled water confirmed their presence (7).

Antioxidant assay

The DPPH free radical scavenging method was used to determine antioxidant activity, as per standard protocols, with slight adjustments (7, 8). In the process, a 35 ppm DPPH solution was prepared in methanol. One mL of DPPH solution was mixed with 0, 40, 60 and 100 µg/mL sample solution. The mixtures were left in the dark for 30 min at room temperature. The absorbance was assessed at 516 nm using a UV-Visible spectrophotometer, with ascorbic acid serving as the positive control. The percentage of inhibition was calculated and IC₅₀ values were determined to assess antioxidant activity.

GC-MS analysis

An HP 6890 gas chromatograph was used for GC-MS analysis, which included an Agilent HP-5 MS capillary column (30 m × 0.25 mm, 5 % phenyl methyl siloxane) in a single-well sampler. Helium acted as the carrier gas at a consistent flow rate of 1.0 mL/min. The oven temperature was incrementally increased from 80 °C to 325 °C. The injector temperature was maintained at 300 °C with 1 µL of sample introduced in split mode utilising a split ratio of 20:1. The mass spectrometer functioned under electron ionisation (EI) mode at 70 eV. The identification of compounds was performed by comparing the mass spectra against the mass spectral database of Wiley 275.L.

Statistical analysis

One-way analysis of variance (ANOVA) was used to assess tannin levels and antioxidant activity data for each species. The threshold for statistical significance was established at $p < 0.05$. Due to the small sample size ($n = 3$ per group), normality testing was not performed and the data were assumed to follow a normal distribution. All statistical analyses were conducted using Microsoft Excel.

Results and Discussion

Species identification and sampling

Species identification was carried out at the Medan Herbarium. The identified agarwood species are presented in Table 1. The identification results showed that all species belonged to the *Aquilaria* genus. The *Aquilaria* species are distributed across the islands of Sumatra, including North Sumatra. This species of agarwood is commonly utilised in fragrances, cosmetics and traditional herbal medicines for various diseases. Additionally, the leaves are commonly brewed into tea, which helps reduce fatigue, restore energy, improve mental clarity and boost overall vitality, making them a valuable plant resource in local health practices (9).

Apart from the *Aquilaria* genus, agarwood has seven other genera, namely *Aetoxylon*, *Dalbergia*, *Enkleia*, *Excoecaria*, *Gonystylus*, *Gyrinops* and *Wikstroemia*. These genera collectively include various species of agarwood that thrive in certain ecological regions, each adapting to unique environmental conditions. In Indonesia, 27

Table 1. Identification of Agarwood species

No.	Village Where to Grow	Species of Agarwood Found
1.	Sayur Matinggi	<i>Aquilaria microcarpa</i> Baill.
2.	Sayur Matinggi	<i>Aquilaria beccariana</i> van Tiegh.
3.	Sayur Matinggi	<i>Aquilaria malaccensis</i> Lam.
4.	Pasar Sayur Matinggi	<i>Aquilaria hirta</i> Ridl.

species of agarwood have been documented, in the form of trees, shrubs and vines (10).

Phytochemical screening results

Phytochemical screening revealed the presence of various secondary metabolites in agarwood leaves, including alkaloids, flavonoids, phenolics, tannins, saponins and steroids/terpenoids, which play an important role in the pharmacological and therapeutic potential of plants. Differences were observed between simplicia and ethanol extracts, as detailed in Table 2. Detected compounds are indicated by a '+' sign, while undetected compounds are denoted by a '-' sign.

The absence of alkaloids in simplicia did not prevent them from being found in ethanol extracts, suggesting that ethanol improves the extraction process. Previous studies have reported similar outcomes, where ethanol extracts of *A. microcarpa* and *A. malaccensis* leaves contained multiple bioactive compounds such as flavonoids, tannins and phenolics (11, 12).

On the other hand, saponins were detected in all simplicia but absent in ethanol extracts. This suggests that the compound was small and insoluble in the solvent. Saponin vary in shape and structure depending on factors such as species, plant source, temperature, pH and electrolyte concentration. Saponins are generally classified into two main types: triterpenoid saponins and steroidal saponins. Both types are widely found across different plant families. The key distinction between them lies in their molecular structure, with triterpenoid saponins containing 30 carbon atoms, whereas steroidal saponins have only 27 (13).

The variation in detected compounds across species and sample forms highlights the influence of both environmental conditions and extraction methods on phytochemical composition. This screening establishes a foundation for the further exploration of agarwood leaves as a source of bioactive compounds, especially for medicinal applications (14).

Tannin content variation

Tannin analysis showed that all samples contained relatively low levels, ranging from 1.3898 % to 2.1325 % (Table 3). According to classification criteria, these values fall within the low tannin category.

Tannins are phenolic compounds characterized by high molecular weights. Tannin content is classified as high if the value is >10 % and low otherwise (15). Statistical analysis indicated no significant differences among species ($p = 0.055$), suggesting a relatively uniform distribution of tannins (Fig. 1).

Tannins, which belong to the phenolic compound group, are known for their antioxidant properties (16). Their presence in plant tissues contributes to astringency, resulting from interactions with salivary proteins (17, 18). Although tannins are often associated with

Table 3. Average tannin content of four species of Agarwood leaves

No.	Species of Agarwood leaves	Tannin content (%)
1.	<i>A. microcarpa</i> Baill.	1.3898 ± 0.47544
2.	<i>A. beccariana</i> van Tiegh.	2.1325 ± 0.19317
3.	<i>A. malaccensis</i> Lam.	1.7226 ± 0.16185
4.	<i>A. hirta</i> Ridl.	1.6278 ± 0.08180

bitterness, the low tannin content in agarwood leaves may be advantageous for herbal tea applications, as it can balance sensory acceptance while preserving their functional benefits.

In addition, the antimicrobial and anti-inflammatory properties of tannins lend support to their traditional use in treating burns and toxins (19). Dried leaves contain a higher percentage of tannins than fresh leaves (20). However, their biological effects depend on factors such as concentration, molecular structure and consumption patterns (21, 22).

Antioxidant activity comparison

The antioxidant activity was assessed using the DPPH free radical scavenging assay, where the IC_{50} value indicates the necessary concentration to inhibit 50 % of DPPH radicals (23). The effectiveness of antioxidants is commonly demonstrated through this measure, as lower IC_{50} levels indicate higher antioxidant activity. The DPPH method relies on the reduction of the DPPH radical in a methanolic solution, leading to a quantifiable reduction in absorbance (Fig. 2) (24).

The research revealed that all four species of agarwood demonstrated significant radical scavenging effectiveness, with IC_{50} values ranging from 25 to 36 $\mu\text{g/mL}$ (Table 4), placing all samples within the “very strong” antioxidant category. Statistical analysis

Table 2. Phytochemical screening of simplicia and extracts of four species of Agarwood leaves

Compound	Species of agarwood leaves							
	<i>A. microcarpa</i> Baill.		<i>A. beccariana</i> van Tiegh.		<i>A. malaccensis</i> Lam.		<i>A. hirta</i> Ridl.	
	Simplicia	Extract	Simplicia	Extract	Simplicia	Extract	Simplicia	Extract
Alkaloids	-	-	-	+	-	+	-	-
Flavonoids	+	+	+	+	+	+	+	+
Tannin	+	+	+	+	+	+	+	+
Steroids/ Triterpenoid	-	+	-	+	+	+	+	+
Saponins	+	-	+	-	+	-	+	-
Glycosides	+	+	+	+	+	+	+	+

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0,863048	3	0,287683	3,884413	0,055419	4,066181
Within Groups	0,592486	8	0,074061			
Total	1,455534	11				

Fig. 1. Tannin content statistical analysis result.

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	211,6589	3	70,55295	34,36788	6,42E-05	4,066181
Within Groups	16,423	8	2,052875			
Total	228,0818	11				

Fig. 2. Antioxidant activity statistical analysis result.

revealed no significant differences among species, indicating comparable antioxidant potential.

In contrast, analysis of antioxidant activity in three commercial teas sold in Malang found that the IC_{50} value ranged from 20 to 49 $\mu\text{g/mL}$ (25). The strength or weakness of antioxidants

Table 4. Antioxidant activity of extracts of four species of Agarwood leaves ($\mu\text{g/mL}$)

Species of Agarwood leaves	IC_{50} value ($\mu\text{g/mL}$)	Antioxidant activity strength category
<i>A. microcarpa</i> Baill.	27.6219	Very strong
<i>A. beccariana</i> van Tiegh.	26.6794	Very strong
<i>A. malaccensis</i> Lam.	25.4451	Very strong
<i>A. hirta</i> Ridl.	36.1159	Very strong

in plants is influenced by the growing place and the soil chemical composition (26). Antioxidant concentration is vital to consider while processing agarwood tea. The best drying method to maintain antioxidant levels in *A. malaccensis* Lam. leaves is the oven drying method (27).

Antioxidants have been widely studied for their function, safety and therapeutic value. Phenolic compounds are primarily responsible for the strong antioxidant activity (28). Antioxidants are

known to provide protective effects against oxidative stress and have been linked to reduced risks of chronic diseases, including cardiovascular disorders, cancer and inflammation (29).

Several supporting studies have shown that *A. malaccensis* Lam. leaf extracts exhibit strong antioxidant activity, particularly in methanol extracts and combined solvent fractions, with IC_{50} values reported as low as $17.39 \pm 1.43 \mu\text{g/mL}$ (30). Similarly, extracts of *A. microcarpa* have demonstrated high antioxidant potential across different formulations (31). This finding confirms that agarwood leaves are a promising natural source of antioxidants, with comparable activity levels to those reported in previous studies.

GC-MS chemical profiling

Based on the GC-MS test data presented in Table 5 to Table 8, 11–15 compounds were identified with concentrations above 3 % in the ethanol extracts of leaves from four species of agarwood. The results of quantitative GC-MS test showed that the compound with the highest concentration differed in each species. The highest concentration of compounds contained in *A. microcarpa* Baill. was Nortopsentin B (6-Bromo-3-4-indole-3-ylimidazol-2-yl) (13.46 %), in *A. beccariana* van Tiegh. was Propanamide (CAS) (14.66 %), in *A. malaccensis* Lam. was Acetaldehyde (CAS) (26.39 %) and in *A. hirta* Ridl. was 2'-oxa-3'-adeninylyl-4',5'-dihydroxy-cyclopentyl (14.43 %).

Table 5. GC-MS test results for *A. microcarpa* Baill.

Peak	R. Time	Conc %	Name
1	2.881	7.31	1,2-Propanediol, 3-chloro- (CAS)
2	13.537	5.06	Ethanol, 2-bromo- (CAS)
3	14.188	5.07	N, N'-dimethylcyclobutane-1,1-bis (methylamine
4	14.378	7.28	2-pyridinemethamine
5	15.520	6.32	2,4(1H,3H)-Pyrimidinedione, 5-nitro
6	16.250	7.11	Hexadecanoic acid, ethyl ester
7	18.609	4.42	6-Acetoxy-2,6,10,10-tetramethyl-1
8	18.810	11.26	3-hydroxycarbonyl-2,5-dimethylpyrrolidine
9	19.434	13.44	1,1-cyclobutanedimethanamine
10	20.259	13.46	Nortopsentin B(6-Bromo-3-4-indole-3-ylimidazol-2-yl)
11	20.375	10.61	2-aminononadecane

Table 6. GC-MS test results for *A. beccariana* van Tiegh.

Peak	R. Time	Conc %	Name
1	2.881	4.17	1,2-Ethenediol, 1-(2-phenyl-1,3,2-dioxaborolan-4-yl)-
2	8.693	4.98	1-methyldodecylamine
3	10.094	3.70	4-amino-2-
4	11.009	6.87	Pentanal (CAS)
5	11.073	3.79	2-methoxyamphetamine
6	11.543	14.66	Propanamide (CAS)
7	11.617	4.36	1,2-Benzenediol,4-[1-hydroxy-2-(methylamino)ethyl]
8	12.850	5.55	Rimantadine
9	13.246	4.58	2-aminononadecane
10	13.537	5.45	Tetrahydroxycyclopentadinone
11	15.526	3.66	Tetrahydroxycyclopentadinone
12	15.959	3.66	2-Butanamine (CAS)
13	16.250	8.02	2,4(1H,3H)-Pyrimidinedione, 5-nitro
14	16.435	5.38	Propanamide (CAS)
15	19.429	6.08	Tetrahydroxycyclopentadinone

Table 7. GC-MS test results for *A. malaccensis* Lam.

Peak	R. Time	Conc %	Name
1	2.764	8.98	Ethanol, 2-(methylamino)
2	2.881	7.40	Cyclobutanol (CAS)
3	3.029	3.31	Acetaldehyde (CAS)
4	7.873	26.39	Acetaldehyde (CAS)
5	8.862	11.97	Dimethylamino-dimethylphospene oxide
6	8.925	6.22	Dimethylamino-dimethylphospene oxide
7	13.537	9.20	Tetrahydroxycyclopentadinone
8	14.182	5.95	4H-Pyran—4-one, 2,6-dimethyl- (CAS)
9	15.526	7.91	2-Hexanamine, 5-methylmine
10	16.245	3.30	(R)-2-methyl-2, 5-diaminopentanoic acid
11	19.434	6.48	Tetrahydroxycyclopentadinone

Table 8. GC-MS test results for *A. hirta* Ridl.

Peak	R. Time	Conc %	Name
1	27.69	4.32	Pentene, 1,1-diethoxy-(CAS)
2	2.886	7.32	1,2,3,4-tetrahydroxybutane
3	8.915	3.05	Butanal, 3-methyl-(CAS)
4	11.501	7.63	1-Octamine (CAS)
5	13.537	6.78	Ethanol, 2-bromo- (CAS)
6	14.182	4.26	Tetrahydroxycyclopentadinone
7	14.357	3.92	Methanesulfonamide, N, N-dimethyl-
8	15.536	6.10	Tetrahydroxycyclopentadinone
9	16.250	11.67	Hexadecanoic acid, ethyl ester
10	18.291	14.43	2'-oxa-3'-adeninyl-4',5'-dihydroxy-cyclopentyl
11	19.434	10.62	3,4-methylene-6-hydroxy-4,8,10b-trimethyl-8-(1-bromo-2-hydroxyethyl
12	21.354	6.47	2-methoxyamphetamine

The highest concentration compound found was Acetaldehyde (CAS) in *A. malaccensis* Lam. Acetaldehyde is a chemical component with the molecular formula CH₃CHO. It is widely used in the food industry due to its fruity aroma (32); however, the use of this compound is strictly regulated because of its potential toxicity (33).

Several identified compounds are associated with antioxidant activity, including tetrahydroxycyclopentadinone, which was detected in all species. This compound is a polyhydroxy cyclopentanone, which is known to possess antioxidant activity. Other compounds that also indicate antioxidant activity include Hexadecanoic acid, ethyl ester (known as ethyl palmitate) and 4H-Pyran-4-one, 2,6-dimethyl (analog 2,6-diethyl-3,5-dimethyl-4H-pyran-4-one). Each of these compounds has previously been documented to exhibit antioxidant effects as demonstrated in DPPH and ABTS assays (34, 35).

Another compound detected was Hexadecanoic acid, a straight chain carboxylic acid with 16 carbon atoms and a molecular weight of 256.4241 g/mol. Hexadecanoic acid belongs to the fatty acid group. Fatty acids are commonly found in the *Aquilaria* or *Gyrinops* genera, for example, *G. walla* (36). Fatty acids have anti-diabetic biological activities (37), anti-cancer, anti-inflammatory (38), cardiovascular protective and hepato protective activities. Hexadecanoic acid and other fatty acids are known to offer various therapeutic options for many health issues, particularly those related to inflammation and chronic diseases. This makes them relevant for developing treatments for diabetes, cancer and inflammatory diseases (39).

Implications for herbal tea development

The four species of agarwood leaves tested in this study possess a high potential as a novel source for functional herbal tea. From a product development perspective, the relatively low tannin content (1.3898 %–2.1325 %) offers benefits in terms of sensory quality, particularly in reducing the bitter and astringent taste often associated with herbal teas. This study found that antioxidant activity in all species was in a similar range (25 to 36 µg/mL) to that of

the three commercial teas in Indonesia (20 to 49 µg/mL). The diversity of bioactive compounds identified through GC-MS profiling also suggests potential for multifunctional health benefits. However, the presence of certain volatile compounds, such as acetaldehyde, requires careful processing control to ensure product safety and compliance with food standards.

The utilisation of agarwood leaves, which are typically underused, offers an opportunity to enhance the economic value of agarwood cultivation systems while promoting sustainable resource use. The characteristics of agarwood leaf extract with a less bitter and astringent taste but offering multifunctional health benefits may improve consumer acceptance and allow for further formulation development, including blending with other herbal ingredients or flavour enhancers.

Conclusion

This study assessed the phytochemical profile, antioxidant activity and chemical components of leaves from four naturally growing *Aquilaria* species collected in North Padang Lawas Regency, Indonesia. The phytochemical analysis validated the existence of numerous bioactive compounds, including flavonoids, tannins, glycosides and steroids/triterpenoids in both dried leaf material and ethanol extracts. Tannin content was relatively low (1.3898 % to 2.1325 %) and consistent among species, supporting their suitability for herbal tea applications with improved sensory characteristics. Antioxidant evaluation demonstrated strong antioxidant activity, with IC₅₀ values between 25.45 µg/mL and 36.11 µg/mL, indicating the extracts possess high free-radical scavenging potential. The GC-MS analysis identified multiple chemical compounds in the ethanol extracts, with dominant constituents including Nortopsentin B in *A. microcarpa*, Propanamide in *A. beccariana*, Acetaldehyde in *A. malaccensis* and 2'-oxa-3'-adeninyl-4',5'-dihydroxycyclopentyl in *A. hirta*. The presence of these compounds, along with phenolic constituents such as tannins and flavonoids, contributes to the observed antioxidant properties. The study concludes that naturally growing *Aquilaria* leaves are a valuable source of health-promoting

bioactives and possess strong antioxidant potential. The findings support the possibility of developing agarwood leaves as a raw ingredient for antioxidant-rich herbal tea and other functional products. Further studies should focus on detailed bioactivity evaluation, compound isolation and safety assessment to support their application in food and pharmaceutical products.

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Authors' contributions

RB carried out extensive literature review, designed the methods, executed sample preparation and writing the manuscript. TIH executed the phytochemical analysis, tannin analysis, and antioxidant activity analysis. OF carried out the sample collection and species identification. SCC executed data analysis and assisting the manuscript writing. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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