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Article

Phytochemical Compounds from Various Grades of Sumatra Benzoin Resin

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Abstract

Sumatra benzoin (*Styrax paralleloneurum*) is a significant non-timber forest product originating from North Sumatra. Benzoin resin is widely used in perfumes, medicines, and cosmetics. However, scientific studies on phytochemical composition based on resin grades are limited. This study aimed to analyze the phytochemical compounds of benzoin oil extracted from three different resin grades. The resin was collected directly from benzoin trees in Humbang Hasundutan Regency. It was then extracted using 96% ethanol and analyzed by GC-MS method. The results showed that the highest quality resin produced higher oil yield (73.08%) with a longer extraction time. This indicates that resin quality influences extraction efficiency and composition. Chemical analysis identified key active compounds, such as cinnamic acid, benzoic acid, eugenol, vanillin, and various esters and aromatic hydrocarbons. High grade resin contains higher levels of volatile compounds such as D-limonene, endo-borneol, and β-caryophyllene. These are essential for aromatic and therapeutic activities. In contrast, lower quality resins are dominated by carboxylic acids. Cinnamic acid is prominent in all grades, reinforcing its potential as an active agent in natural-based cosmetic and pharmaceutical formulations. This research provides a scientific foundation for standardizing benzoin resin quality. It also supports its strategic utilization in natural bioactive-based industries.

Keywords: aromatic; benzoin resin; extraction; ester; hydrocarbon; phytochemical composition; resin grade

1. Introduction

Sumatra benzoin (*Styrax* paralleloneurum, synonym *S. sumatrana*), also locally known as Toba benzoin, is a major non-timber forest product from resin-producing trees endemic to Lake Toba region of North Sumatra, Indonesia (Harada et al., 2022; Kholibrina & Aswandi, 2021a). It holds cultural, medicinal, and economic significance and is widely traded both locally and internationally, with production of up to eight tons of raw resin annually (Harada et al., 2022). Although it is used in incense, medicine, and perfume, there is limited research on the phytochemical composition of Sumatra benzoin resin, particularly regarding the quality of resin grade (Aswandi & Kholibrina, 2020; Burger et al., 2016; Fernandez et al., 2003).

Essential oils from plant resins contain complex mixtures of small, volatile aromatic compounds produced by plants. Over 3,000 essential oils are known, but approximately 300 are utilized for their bioactive properties, including antibacterial, antioxidant, and anti-inflammatory effects (Anwar et al.,

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2022; Ariani et al., 2022, 2023; Aryani et al., 2023; Aswandi et al., 2024; Hamad et al., 2017; Kuspradini et al., 2019). Benzoin resin thus offers strong potential for bioprospecting, particularly in the cosmetics and biopharmaceutical industries (Burger et al., 2016; Fernandez et al., 2003; He et al., 2023; Kholibrina & Aswandi, 2021a). This aligns with the growing demand for natural health products.

While numerous studies have examined essential oils from species such as *Cinnamomum camphora* (Bhandari et al., 2022; Jiang et al., 2016; Lee et al., 2022; H. Zhang et al., 2022), there has been no systematic research on the chemical characterization of Sumatra benzoin oil based on resin grade (Fernandez et al., 2003). The novelty of our research lies in the first comprehensive identification and comparison of the phytochemical content of Sumatran benzoin resins across different grading classes, specifically those obtained directly from the Styrax trees. This novel approach is a key step in value-added product development. Understanding these grade-dependent variations in bioactive compound profiles will enhance quality control and standardization in the benzoin trade, supporting innovation in downstream applications, particularly in functional cosmetics and biopharmaceutical formulations.

In this study, benzoin oil was extracted from different grades of resins using standardized methods and analyzed using Gas Chromatography–Mass Spectrometry (GC-MS). The objective of the study is to determine the chemical composition across resin grades and assess their potential biological and functional properties. This study thereby contributes to both scientific knowledge and sustainable economic utilization of this valuable forest commodity.

2. Results and Discussion

2.1. Resin Hasvesting and Grading

Benzoin resin is synthesized in the inner epithelial layer of the bark of the Sumatran benzoin tree; therefore, bark tapping is the optimal method for resin extraction (Aswandi & Kholibrina, 2020; Kholibrina & Aswandi, 2021a). Benzoin resin is extracted by piercing the bark to open a space between the inner bark and the woody part of the trunk. After a certain period, usually within 3 months of tapping, the resin will completely fill the space (Figure 1). Once the resin has dried, farmers harvest it by prying off the bark and the resin that is attached to it. Once sufficiently dry, the resin is separated from the bark. This first harvest yields the highest-grade resin (Grade A), with larger resin pieces (3–5 cm), denser, and cleaner in colour (Figure 1). At the scars left by the bark prying during the first harvest, resin will drip and then harden after 1–2 months. Resin harvested from the surface of the trunk is classified as Grade B, which is smaller (2–3 cm), tends to be softer and has a light yellow–reddish brown colour. Furthermore, the lowest quality resin is obtained from waste generated during the cleaning of the trunk bark. It includes thin pieces, low-quality fragments, flakes, or the smallest particles that resemble dust. This resin is classified as Grade C (Figure 1).

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Figure 1. Resin tapping and grading of Sumatra benzoin resin.

Based on tapping conducted on five sample benzoin trees with a diameter of between 30 cm and using 12 tapping points per tree at the research location in Pollung District, Humbang Hasundutan Regency, an average total resin production of 1485.6 ± 33.54 grams per tree was obtained. The resulting resin was then classified into three quality categories: Grade A, 514.0 ± 21.73 g/tree (34.62%); Grade B, 571.2 ± 10.15 g/tree (38.44%); and Grade C, 400.4 ± 13.06 g/tree (26.96%). The largest percentage was obtained from Grade B resin, which reflects medium quality but in dominant amounts, followed by Grade A (high-quality resin) and Grade C (lower-quality resin). These results indicate that although tapping produces variations in resin quality, the amount of high and medium-quality resin still dominates the total production. This proportion is important to know because it influences the economic value of resin, the potential for developing grade-based downstream products, and strategies for utilizing and conserving non-timber forest resources such as benzoin resin.

2.2. Benzoin Oil Extraction

The results of benzoin resin extraction using 96% ethanol under 150 rpm shaking show significant differences in oil yield and extraction efficiency across resin quality grades (Table 1).

Table 1. Experimental results of extraction of benzoin resin.

Material	Benzoin resin (g)	Benzoin oil (g)	Time (minutes)	Extraction Rate (%)
Grade A	514.0 ± 21.73	375.4 ± 20.95	58.2 ± 7.11	73.08 ± 4.44
Grade B	571.2 ± 10.15	265.4 ± 24.14	40.4 ± 5.16	46.44 ± 3.77
Grade C	400.4 ± 13.06	112.8 ± 16.83	29.2 ± 5.08	28.18 ± 4.39

Extraction was carried out using 96% ethanol as a solvent and shaking at 150 rpm for the duration. The experiment was repeated five times, and the average value was taken.

Table 1 shows that Grade A yields the most oil, both absolutely (375.4 g) and relatively (73.08% of raw material). Although Grade B contains more raw resin than Grade A, it yields less oil at 46.44%

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of the starting material. Grade C produces the least oil, both in grams and percentage (28.18%). Thus, higher resin quality (Grade A) delivers greater extractable oil, demonstrating that resin grade directly affects extraction yield and efficiency.

However, Grade A resin required the longest extraction time (an average of 58.2 minutes) to produce the highest yield. Meanwhile, Grade B resin required a shorter time (40.4 minutes) and produced a lower yield. Grade C had the shortest extraction time (29.2 minutes) and the lowest extraction yield. This suggests a direct relationship: as extraction time increases, oil yield also tends to increase (Bakhshabadi et al., 2025). Longer extraction times appear to allow more oil to be extracted from the resin, especially from high-quality resins. This could be related to the density and complexity of the Grade A resin structure, which requires more time for the solvent to penetrate and dissolve its components.

Interestingly, Grade B had the highest amount of raw material, yet its extraction yield was lower than that of Grade A. This suggests that the quantity of resin is not the primary factor, but rather the chemical composition of each grade that determines the extraction yield (López-Álvarez et al., 2023). In this case, quality is more important than quantity in the benzoin oil extraction process. This should be a crucial consideration in selecting raw materials for industrial-scale production.

2.3. Analysis of Phytochemical Component

Phytochemical screening using the GC-MS method reveals that various grades of Benzoin Toba resin contain major compounds, including cinnamic acid, cinnamyl cinnamate, methyl cinnamate, benzoic acid, eugenol, vanillin, and β-caryophyllene (Figure 2) with different levels, which contribute to the aroma, preservative qualities, and therapeutic applications of the resin. Additionally, different concentrations were also identified in minor compounds, such as benzyl benzoate, caryophyllene alcohol, caryophyllene oxide, (Z)-cinnamyl benzoate, D-limonene, endo-borneol, (+)-2-bornanone (camphor), humulene, 3,5-bis(1,1-dimethylethyl) ester, and N-hexadecanoic acid (Figure 2), provide supporting characteristics that influence the overall resin quality and application.

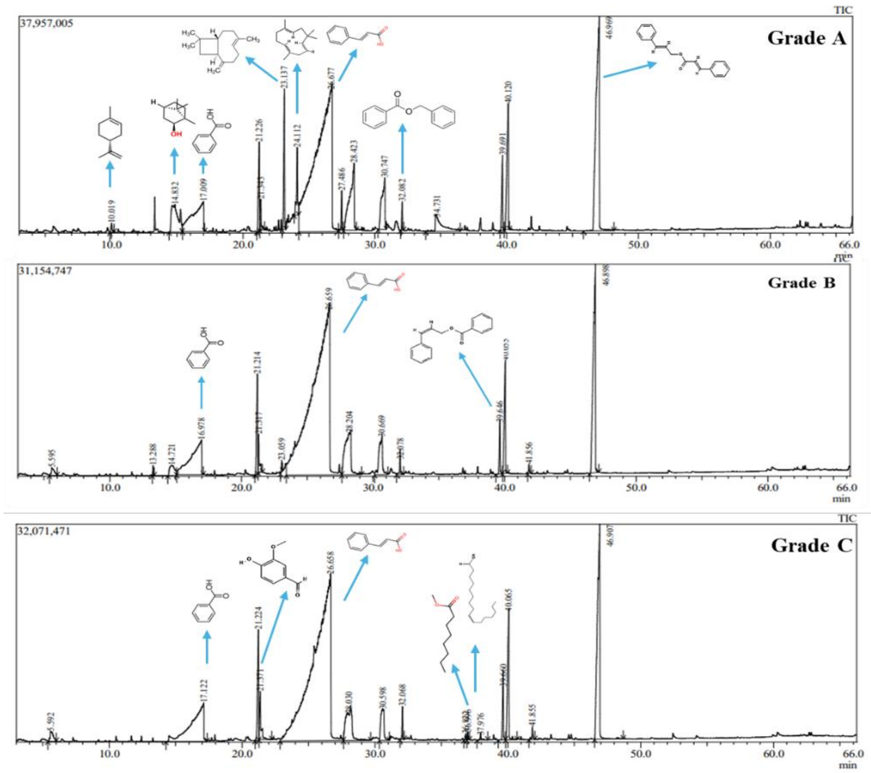

Figure 2. GC-MS of benzoin oil various resin grades.

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Table 2 shows that benzoin resin contains a diverse range of chemical compounds, including hydrocarbons, alcohols, ketones, carboxylic acids, phenols, aldehydes, esters, and oxides. This variety highlights the chemical complexity of benzoin resin and its potential for varied properties and benefits.

The GC-MS analysis results for benzoin resin grades are summarized in Table 2.

Table 2. Phytochemical content of Benzoin Toba from various grades.

No	Formula	Categories	Compound	CAS	Area of Content %		
					Grade A	Grade B	Grade C
1	$C_{10}H_{16}$	Hydrocarbon	D-Limonene	5989-27-5	0.23	-	-
2	$C_{10}H_{18}O$	Alcohol	Endo-Borneol	507-70-0	4.02	1.18	-
3	$C_{10}H_{16}O$	Ketone	(+)-2-Bornanone (camphor)	464-49-3	-	0.12	-
4	$C_7H_6O_2$	Carboxylic acid	Benzoic acid	65-85-0	6.78	8.02	9.96
5	$C_{10}H_{12}O_2$	Phenol	Eugenol	97-53-0	6.10	5.91	4.40
6	$C_8H_8O_3$	Aldehyde	Vanillin	121-33-5	4.18	3.79	3.81
7	$C_{15}H_{24}$	Hydrocarbon	β-Caryophyllene	87-44-5	2.53	0.14	-
8	$C_{15}H_{24}$	Hydrocarbon	Humulene	6753-98-6	1.51	-	-
9	$C_9H_8O_2$	Carboxylic acid	Cinnamic acid	140-10-3	48.80	62.98	60.88
10	$C_{15}H_{26}O$	Alcohol	Caryophyllenyl alcohol	56747-96-7	0.64	-	-
11	$C_{14}H_{12}O_2$	Ester	Benzyl benzoate	120-51-4	0.41	0.50	0.50
12	$C_{15}H_{24}O$	Oxide	Caryophyllene oxide	1139-30-6	2.40	-	
13	$C_{15}H_{22}O_2$	Carboxylic acid	3,5-Bis(1,1-dimethylethyl) benzoic acid	16225-26-6	-	-	0.10
14	$C_{18}H_{36}O_2$	Ester	Hexadecanoic acid, methyl ester	158274-92-1	-	-	0.10
15	$C_{16}H_{32}O_2$	Carboxylic acid	n-Hexadecanoic acid	57-10-3	-	-	0.16
16	$C_{16}H_{14}O_2$	Ester	(Z)-Cinnamyl benzoate	117204-78-1	1.59	1.02	1.31
17	$C_{10}H_{10}O_2$	Ester	Methyl cinnamate	103-26-4	5.91	5.30	6.24
18	$C_{18}H_{16}O_2$	Ester	Cinnamyl cinnamate	122-69-0	14.89	10.55	11.86

Table 2 shows that carboxylic acids such as cinnamic acid and benzoic acid dominate all grades. The highest content is found in Grades B and C, where cinnamic acid reaches approximately 60-63%. Benzoic acid content increases from Grade A to Grade C. Phenolic compounds such as eugenol remain relatively stable in all three grades but decrease slightly in Grade C (4.40%). Aldehydes, such as vanillin, are also quite consistent across all grades, with a content of around 3.7-4.2%. Aromatic compounds, such as cinnamic acid, eugenol, and vanillin, exhibit high and consistent contents. This confirms that benzoin resin has strong aroma and bioactive characteristics in all grades.

Simple hydrocarbons, such as D-Limonene, β-Caryophyllene, and Humulene, were only detected in Grades A and B and not found in Grade C, indicating that these fast-evaporating compounds are more common in higher-quality resins and are lost or released in lower-quality or smaller resin pieces. Similarly, the group of alcohol compounds, including endo-borneol and caryophyllenyl alcohol, also decreases significantly from Grade A to Grade B and is absent in Grade C, indicating a higher alcohol content in higher grade resins. These hydrocarbon and alcohol compounds, which evaporate easily, are highest in Grade A and contribute to the best aroma and potential health benefits, making these resins more valuable for cosmetics and medicines.

Ester compound groups such as benzyl benzoate, methyl cinnamate, and cinnamyl cinnamate were also found in significant quantities in all grades, with a relatively stable percentage, although it decreased slightly in Grade B and increased again in Grade C. Minor compounds such as camphor (Ketone), caryophyllene oxide (Oxide), and other acids were only found in several grades with low concentrations.

These differences in chemical composition are important for guiding resin utilization based on grade, for example, Grade A is for high-value-added products, while Grades B and C may be suitable for other applications that do not require a high volatile compound content. Various grades of Sumatran Benzoin also exhibit a more complex range of aromatic and bioactive compounds than Siamese Benzoin (Fernandez et al., 2003). Sumatran Benzoin contains high levels of cinnamic acid, with concentrations reaching 62.98% in grade C. Sumatran Benzoin also contains compounds such as cinnamyl cinnamate and benzoic acid, which enhance its effectiveness as an active ingredient in

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pharmaceuticals and cosmetics (del Olmo et al., 2017; Gunia-Krzyżak et al., 2018). Compounds such as eugenol, vanillin, and methyl cinnamate impart distinctive aromatic qualities to flavours and perfumes (García-Bofill et al., 2019) Components such as endo-borneol and β-caryophyllene enhance the therapeutic potential (Chung et al., 2019; Tang et al., 2025), especially in Grade A resins. Due to its high concentration of cinnamic acid, Toba Benzoin is particularly suitable for the pharmaceutical and natural cosmetics industries.

Siam Benzoin has a simple and diverse aroma, primarily determined by benzyl benzoate, which constitutes over 76% of its content (Fernandez et al., 2003). This compound is widely used as a fixative in perfumes and as an antiparasitic in topical pharmaceutical preparations (Kılıç Süloğlu et al., 2022). The low cinnamic acid content, combined with acetophenone and benzaldehyde, makes Siam Benzoin highly suitable for use in aromatic products.

Table 3 shows differences in the chemical composition of benzoin oil extracted from the resin of three quality grades. Specifically, Grade A oil contains higher concentrations of major aroma compounds compared to Grades B and C, while Grade C displays the lowest levels of these compounds. The data show that the oil's composition varies significantly between grades. This variation, in turn, influences its chemical characteristics and potential uses.

Table 3. The chemical composition and area content of benzoin oil from three grades of resin.

Composition	Compound	Area of Content %		
		Grade A	Grade B	Grade C
Hydrocarbon	D-Limonene, β-Caryophyllene, Humulene	4.27	-	0.14
Alcohol	Endo-Borneol, Caryophyllenyl alcohol	4.66	-	1.18
Ketone	(+)-2-Bornanone (camphor)	-	-	0.12
Phenol	Eugenol	6.10	4.40	5.91
Aldehyde	Vanillin	4.18	3.81	3.79
Carboxylic acid	Benzoic acid, Cinnamic acid, 3,5-Bis(1,1-dimethylethyl) benzoic acid, n-Hexadecanoic acid	55.58	71.10	71.00
Oxide	Caryophyllene oxide,	2.40	-	-
Ester	Benzyl benzoate, Hexadecanoic acid, methyl ester, (Z)-Cinnamyl benzoate, Methyl cinnamate, Cinnamyl cinnamate	22.8	20.01	17.37

Table 3 shows that the carboxylic acid component is the largest fraction in all three grades, with the highest percentages found in Grade B (71.10%) and Grade C (71.00%), while Grade A is slightly lower (55.58%). This indicates that Grade B and C resins have a more dominant carboxylic acid content, which can affect the oil's acidic properties and chemical reactivity. In industry, carboxylic acid is used as a raw material for the manufacture of drugs, food, and cosmetics; however, its use must be cautious because, in concentrated form, it is corrosive and has a pungent odour (Meredith et al., 2000; Samanta et al., 2011).

Furthermore, the ester content in Grade A is the highest (22.8%), followed by a decrease in Grade B (20.01%) and Grade C (17.37%). Esters are important compounds in determining the aroma and properties of the oil; therefore, a decrease in ester content in lower grades may impact the quality of the aroma and its potential applications (Ceccoli et al., 2024; SÁ et al., 2017). Grade A shows the presence of hydrocarbon compounds (4.27%), alcohol (4.66%), and oxide (2.40%), which are quite significant, while these compounds are almost undetectable or very low in Grades B and C. These volatile compounds are crucial for the aroma and biological activity of benzoin oil (Burger et al., 2016; Fernandez et al., 2003; Sadgrove et al., 2022), which gives the highest resin grade an advantage in this aspect.

Phenolic and aldehyde contents were relatively stable across all grades, although Grade A had a slightly higher phenol content (6.10%) than Grade B (4.40%) and Grade C (5.91%). Aldehydes were in a similar range for all three grades (approximately 3.79–4.18%). These compounds contribute to the distinctive aroma and potential pharmacological activity (Kisiriko et al., 2021; Y. Zhang et al., 2022). Ketones were detected only in very small amounts (0.12%) in Grade C, and were not found in

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Grades A or B, indicating that ketones are not a major component and do not play a significant role in the differences in oil quality between grades.

Differences in the chemical composition of benzoin oil from the three resin grades indicate that Grade A has a higher content of volatile compounds, such as hydrocarbons, alcohols, and oxides, which contribute to its superior aroma and potential bioactivity (Burger et al., 2016; Sadgrove et al., 2022). In contrast, Grades B and C are dominated by carboxylic compounds with lower ester contents, which can affect the overall characteristics of the oil (Groza et al., 2024; Meredith et al., 2000). This information is crucial for determining the application of benzoin oil based on grade, particularly for the development of cosmetic and pharmaceutical products that require specific chemical profiles.

Table 4 shows the aromatic and bioactivity profiles of the phytochemical compounds contained in benzoin oil.

Table 4. Aromatic and bioactivity profiles of phytochemical compounds in benzoin oil.

Compound	Aroma Profile	Bioactivity	Application			
			Flavour	Fragrance	Cosmetic	Medicine
D-Limonene	citrusy, sweet	Antioxidant, anti-inflammatory, anticancer, antibacterial, and natural solvent of topical drugs (Anandakumar et al., 2021; Lin et al., 2024)	√	√	√	√
Endo-Borneol	Soft, woody, balsamic camphor.	Antibacterial, antiviral, anti-inflammatory, relieves pain and fever (Hu et al., 2024)	-	√	√	√
(+)-2-Bornanone (camphor)	Sharp, refreshing, minty camphor	Topical analgesic, antiseptic, anti-inflammatory, rubefacient - improves blood circulation (Fazmiya et al., 2022; Lee et al., 2022; Singh & Jawaid, 2012)	-	√	√	√
Benzoic acid	It has no distinctive aroma, slightly sweet.	Antimicrobial, antifungal, cosmetic and food preservative (del Olmo et al., 2017; Groza et al., 2024)	√	-	√	√
Eugenol	Spicy, warm, clove-like	Antiseptic, analgesic, anti-inflammatory, anticancer, often used in dentistry (Nisar et al., 2021; Ulanowska & Olas, 2021)	√	-	√	-
Vanillin	Sweet, creamy, classic vanilla	Antioxidant, antimicrobial, neuroprotective, used in food and cosmetics (Kafali et al., 2024; Wang et al., 2024)	√	√	√	-
β-Caryophyllene	Woody, spicy, dry	Anti-inflammatory, analgesic, interaction with CB2 (cannabinoid) receptors, anticancer (Francomano et al., 2019; Scandiffio et al., 2020)	-	√	√	√
Humulene	earthy, woody, slightly spicy	Anti-inflammatory, antibacterial, potential as an anticancer (Dalavaye et al., 2024; Mendes de Lacerda Leite et al., 2021)	-	√	-	-
Cinnamic acid	Sweet, balsamic, cinnamon-like	Antibacterial, anti-inflammatory, antidiabetic, treating cancer, sunscreen and skin lightening product (Freitas et al., 2024; Ruwizhi & Aderibigbe, 2020a, 2020b)	√	-	√	√
Caryophyllenyl alcohol	Woody, slightly floral	Antimicrobial, anti-inflammatory, sedative effects (Bhatia et al., 2008)	-	√	-	√

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Benzyl benzoate	Slightly floral-balsamic	Antiparasitic (scabies, lice), solvent in perfumes and lotions, anti-inflammatory (Claire Fuller & Sunderkötter, 2024; Lajarin-Reinares et al., 2022)	-	-	√	√
Caryophyllene oxide	Woody, spicy, fresh	Antifungal, antioxidant, potential anticancer (Fidyt et al., 2016; Gyrdymova & Rubtsova, 2022)	-	√	-	√
3,5-Bis(1,1-dimethyl-ethyl) benzoic acid	Not typical, neutral	Antioxidant, protective against oxidative stress (Velika & Kron, 2012)	-	-	√	√
Hexadecanoic acid, methyl ester	Slightly waxy or fatty	Anti-inflammatory, emollient, hepatoprotective, UV protective (Elwekeel et al., 2023; Gupta et al., 2023)	-	-	√	-
n-Hexadecanoic acid	fatty, waxy.	Antimicrobial, anti-inflammatory, natural emollient (Aparna et al., 2012; Purushothaman et al., 2025)	-	-	√	√
(Z)-Cinnamyl benzoate	Floral, balsamic, sweet	Mild antimicrobial, used as a fragrance ingredient (Bhatia et al., 2007a)	√	√	-	-
Methyl cinnamate	Sweet, fruity, like strawberries	Antimicrobial, antifungal, anti-inflammatory (Huang et al., 2009)	√	√	√	-
Cinnamyl cinnamate	Warm, balsamic, sweet, spicy	Antioxidant, antimicrobial, fixative in perfume (Bhatia et al., 2007b)	√	√	-	-

The aromatic compounds in Table 4 play a vital role in various industries, including food, perfume, cosmetics, and pharmaceuticals due to their unique aroma characteristics and diverse biological activities. Compounds such as D-limonene, vanillin, eugenol, and methyl cinnamate are widely used in food and beverage products due to their distinctive sweet, fresh, and fruity aromas (Daniel et al., 2009; Huang et al., 2009; Kafali et al., 2024; Lin et al., 2024; Nisar et al., 2021; Ulanowska & Olas, 2021; Wang et al., 2024; Zari et al., 2021). D-limonene, with its citrus aroma, and eugenol, with its clove-like aroma, not only impart flavour but also offer benefits such as antioxidant, anti-inflammatory, and antibacterial properties (Anandakumar et al., 2021; Lin et al., 2024). Vanillin, with its characteristic sweet vanilla aroma, is used not only in flavours and perfumes but also possesses antioxidant and antimicrobial properties that support its use in natural cosmetics (Kafali et al., 2024; Wang et al., 2024). On the other hand, compounds such as camphor and endo-borneol have refreshing aromas and biological effects such as analgesic and anti-inflammatory, which make them important in therapeutic applications, particularly in ointments and balms (Fazmiya et al., 2022; Hu et al., 2024; Lee et al., 2022; Singh & Jawaid, 2012; Tang et al., 2025). In the fragrance industry, compounds such as camphor, endo-borneol, cinnamyl cinnamate, and caryophyllene oxide impart distinctive, strong aromas—ranging from woody to balsamic—and act as fixatives to prolong the longevity of perfume on the skin (Bhatia et al., 2007b; Fazmiya et al., 2022; Gyrdymova & Rubtsova, 2022; Kholibrina & Aswandi, 2021b; Lee et al., 2022).

One compound that stands out is cinnamic acid, both in terms of its applications and its therapeutic potential. Cinnamic acid is an aromatic compound with a mild, sweet-balsamic aroma profile. This compound is used in flavours for its ability to add depth to the sweet-spicy flavours, and in cosmetics as an active agent for skin lightening and UV protection (Gunia-Krzyżak et al., 2018). In the medical field, cinnamic acid exhibits various important biological activities, including anti-inflammatory, antimicrobial, anticancer, antidiabetic, and antioxidant properties (Freitas et al., 2024; Ruwizhi & Aderibigbe, 2020a). Pharmacological studies have demonstrated that cinnamic acid derivatives can inhibit pro-inflammatory enzymes and induce apoptosis in cancer cells, rendering them a promising candidate for the development of natural compound-based drugs.

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In the cosmetic and medical fields, compounds such as benzoic acid, palmitic acid, benzyl benzoate, and cinnamic acid function as active ingredients and natural preservatives due to their antimicrobial and anti-inflammatory activities. The advantage of these compounds and their derivatives lie in their ability to bridge the gap between aesthetic (aroma) and biological (therapeutic) functions, making them highly attractive in the formulation of holistic and functional cosmetics. Some compounds, such as β-caryophyllene, demonstrate further therapeutic potential through their interaction with the body's endocannabinoid system, opening up opportunities for use in modern herbal medicine formulation (Francomano et al., 2019; Gyrdymova & Rubtsova, 2022). Beyond their pleasant aroma, these biological activities make these aromatic compounds not only additives but also functional components in various consumer products.

3. Materials and Methods

3.1. Materials

The benzoin residue used in this study was specifically collected directly from the community benzoin forest in Pollung, Humbang Hasundutan Regency, Province of North Sumatra of Indonesia. Five sample trees were harvested, each with an average diameter of 30 cm and a height of 20 meters. From each sample tree, three grades of resin were collected from 12 tapping points based on the harvest period and the resin's physical characteristics: Grade A, Grade B, and Grade C.

Grade A resin, produced from the first harvest, is larger (3–5 cm), denser, and has a cleaner colour. Resin from the second harvest, taken from the trunk surface, is classified as Grade B. It is smaller (2–3 cm), softer, and has a light yellow-reddish brown colour. Grade C resin, which comes from bark cleaning residue, consists of thin pieces, low-quality fragments, flakes, or the smallest dust-like particles. After cleaning, each sample was weighed to determine its raw weight. Table 5 presents the design for collecting benzoin resin samples.

Table 4. Benzoin resin sampling design.

Tree Sampling	Resin collected (gram)			
	Grade A	Grade B	Grade C	Total
P1				
P2				
P3				
P4				
P5				

3.2. Methods

Each grade of resin from each sample tree (a total of 15 samples) was extracted using 96% ethanol solvent with a ratio of 1:2 (1 gram of benzoin resin to 2 ml of ethanol). During the extraction process, the solution was shaken at 150 rpm. The time required for all the resin to disintegrate and dissolve was recorded. The solution was then thickened using a rotary evaporator, allowing most of the solvent to be removed. Each resin sample that had been extracted into benzoin oil was weighed. The design of the benzoin resin extraction test is outlined in Table 6.

Table 6. Experimental design of extraction of benzoin resin.

Material	Resin Weight (g) M1	Extraction Time (minutes)	Oil Weight (g) M2	Extraction Rate (%) (M2/M1)*100%
Grade A				
A1				
A2				
A3				
A4				
A5				

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Grade B
B1
B2
B3
B4
B5
Grade C
C1
C2
C3
C4
C5

3.3. Analysis Methods

Gas chromatography-mass spectrometry (GC-MS-QP2010) was used to detect benzoin oil components in the injected samples. The obtained samples were then identified for their phytochemical compounds using a Shimazu GC-MS device at the Integrated Laboratory for Bioproducts (i-Lab) BRIN in Cibinong. Since the target compound is an aromatic compound, the column used was Rtx-1 (30m x 0.25mm, thickness 0.25um), with a column temperature of 40-250^{o}C, a temperature rise rate of 20^{o}C/min, a detector temperature of 260^{o}C with a carrier gas of nitrogen at a column rate of 0.72 ml/min and a flow rate of 37.7 ml/min. Identification of phytochemical compounds was carried out by searching the standard spectrum library and the NIST literature. The area of content percentage of each component was calculated using the peak area normalization method.

4. Conclusions

This research demonstrates that the grade of benzoin Sumatra resin has a significant influence on the chemical composition and application potential of the resulting oil. Higher resin quality (Grade A) has a higher content of volatile compounds, alcohols, esters, and oxides, making it suitable for high-value-added applications, particularly in the cosmetics and pharmaceutical industries. Lower resin qualities (Grades B and C) are richer in carboxylic acids such as cinnamic and benzoic acid, which have important biological activities but are better suited for formulations that do not emphasize complex aromas. One key finding is the dominance of cinnamic acid in all grades, making it a key compound in benzoin Sumatra oil, which serves as a functional agent with antioxidant, anti-inflammatory, and antimicrobial properties. The varying phytochemical composition between grades offers opportunities for product development based on resin quality, enhancing the efficiency of natural resource utilization, and promoting the development of high-value natural products. This research lays the groundwork for standardizing benzoin Sumatra resin in the industry and for the sustainable enhancement of the economic value of non-timber forest products.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/doi/s1, Figure S1: title; Table S1: title; Video S1: title.

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