ASIAN JOURNAL OF FORESTRY
Volume 9, Number 2, December 2025
Pages: 372-380

E-ISSN: 2580-2844
DOI: 10.13057/asianjfor/r090218

Diversity of color and chemical properties of the resins of Indonesian *Styrax* spp.

RIDWANSYAH[1,2], TITI CANDRA SUNARTI[1,♥], KHASWAR SYAMSU[1], FARAH FAHMA[1], ELISA JULIANTI[2], BELLADINI LOVELY[3]

[1]Department of Agroindustrial Technology, Faculty of Agricultural Engineering and Technology, Institut Pertanian Bogor. Jl. Raya Dramaga, IPB Dramaga Campus, Bogor 16680, West Java, Indonesia. Tel.: +62-251-8622642, ♥email: titi-cs@apps.ipb.ac.id

[2]Department of Food Technology, Faculty of Agriculture, Universitas Sumatera Utara. Jl. Dr A. Sofyan No. 3 USU Padang Bulan Campus, Medan 20155, North Sumatera, Indonesia

[3]Research Center for Biomass and Bioproducts, National Research and Innovation Agency. Jl. Raya Bogor Km. 46, Bogor 16911, West Java, Indonesia

Manuscript received: 28 July 2025. Revision accepted: 21 November 2025.

Abstract. *Ridwansyah, Sunarti TC, Syamsu K, Fahma F, Julianti E, Lovely B. 2025. Diversity of color and chemical properties of the resins of Indonesian* Styrax *spp. Asian J For 9: 372-380. Styrax* is a native Indonesian plant that grows in northern Sumatra and produces resin, locally known as kemenyan, as a valuable non-timber forest product widely used in perfumery, cosmetics, and traditional medicine. The present study aimed to analyze the color, chemical, and phytochemical profiles of resin from three Indonesian *Styrax* species, namely *S. sumatrana*, *S. benzoin* var. *hiliferum*, and *S. benzoin*. Color was assessed by the CIE Lab system, while chemical properties, including cinnamic and benzoic acids, were measured using ultraviolet-visible (UV-Vis) spectrophotometry. Phytochemical screening and Fourier Transform Infrared (FTIR) spectroscopy were performed to identify bioactive constituents and functional groups. The results revealed that *S. sumatrana* has the highest cinnamic acid content (32.65%) and the lowest benzoic acid level (16.08%), along with superior color parameters (L, a*, b*), qualifying it as Grade A under the Indonesian National Standard (SNI 7940:2013). FTIR spectra also indicated higher concentrations of phenolic compounds and terpenoids in *S. sumatrana* than in other species. The *toba* resin showed the most complex and abundant aromatic and resinous group spectrum, followed by *bulu*. *Durame* showed abundant carbonyl compounds and fewer aromatic structures, suggesting compositional differences between them. These findings highlight the superior quality of *S. sumatrana* resin, which contains a higher level of cinnamic acid and a brighter color than *S. benzoin.*

Keywords: Benzoic acid, cinnamic acid, color, phytochemical, resin

INTRODUCTION

The *Styrax* genus is one of the largest groups in the Styracaceae family, consisting of woody trees native to subtropical and tropical forests in Asia and the Americas (Son et al. 2021). Indonesia, especially northern Sumatra, is a major distribution center. These trees produce benzoin resin (kemenyan), a culturally, economically, and medically important non-timber product. Globally, the resin is valued in fragrances and cosmetics (Kholibrina and Aswandi 2021), while traditional medicine uses it to treat respiratory problems, skin inflammation, and microbial infections (Pasa 2023).

In Sumatra, three primary varieties of resin-producing *Styrax* are recognized: *toba* (*S. sumatrana*), *durame* (*S. benzoin* Dryand), and *bulu* (*S. benzoin* var. *hiliferum* Steenis) (Mustikasari et al. 2022; Rahmawaty et al. 2024). These species provide livelihoods for many local communities engaged in resin tapping, collection, and trade, thereby playing a critical role in the rural economy of North Sumatra. Resin from Indonesian *Styrax* is exported globally to countries such as India, China, Malaysia, Vietnam, Cambodia, Thailand, the United States, Mexico, and Brazil, where it is used in diverse cultural and industrial applications (Paparella et al. 2025). Notably, each of these resin types is believed to have distinct physical and chemical properties, including differences in resin color, texture, phytochemical compositions, and functional groups, which collectively influence quality and market classification.

Scientific investigations into *Styrax* species worldwide have demonstrated a considerable diversity of chemical profiles. For instance, studies have documented the presence of styrene, α-pinane, and β-caryophyllene in the resin, along with triterpenes and lignans from *S. tonkinensis* leaves (Hu et al. 2019). Beyond phytochemical characterization, experimental research has revealed promising pharmacological activities of *Styrax* derivatives. Extracts of *S. tonkinensis* and *S. japonica* have exhibited antiproliferative, antibacterial, antifungal, analgesic, cytotoxic, and anti-complement effects (Xia et al. 2023; Verešová et al. 2024). Furthermore, various plant parts of *S. japonicus*—including resin, leaves, and flowers—have been used in folk remedies as immune boosters and treatments for cough, bronchitis, laryngitis, inflammation, paralysis, and oral infections (He et al. 2022; Ren et al. 2024). Phytochemical markers such as phenylpropanoids from *S. suberifolium* also serve as chemotaxonomic indicators, highlighting the taxonomic and pharmacological importance of this genus (Liu et al. 2018).

Research by Kiswandono et al. (2016) found that the *bulu* resin contained 15.4% cinnamic acid, 12.8% ash content, 22.1% insoluble acetone impurities, and 15.0% methanol-soluble components. In contrast, Hidayat et al. (2018) conducted phytochemical screening of *toba* resin, identifying its bioactive components. Although the two resins share several chemical constituents, they exhibit clear differences in their phytochemical profiles and overall composition. Bulu resin generally contains higher ash and impurity levels, indicating lower purity and possible environmental influences, while Toba resin has been more extensively examined for its bioactive compounds, giving it a distinct chemical fingerprint. Existing research also highlights the limited comparative studies on Indonesian *Styrax* varieties in terms of color, phytochemical screening, and chemical composition, emphasizing the need for deeper investigation. This study characterizes resins from three native Indonesian varieties (toba, bulu, and durame), through CIE-Lab color measurements; analysis of cinnamic and benzoic acids; ash, moisture, and impurity levels; solubility in methanol and acetone; and FTIR spectroscopy to estimate compound components. The findings show that incense quality is determined not only by color but also by its chemical makeup, particularly cinnamic and benzoic acid content.

Extensive research on *Styrax* species worldwide generally focuses on resin yield or broad uses, while information on the color, chemical properties, and phytochemical composition of Indonesian *Styrax* remains limited. These gaps are important because such traits underpin quality assessments like the Indonesian National Standard (SNI 7940:2013) and influence pharmacological and industrial applications. As Indonesia is the natural habitat of *S. sumatrana* and other benzoin-producing species, comprehensive characterization is essential to distinguish its varieties from those sourced elsewhere. This need has grown alongside global demand for natural products, which requires scientific validation to support sustainable utilization and added value. Natural resins are increasingly recognized for their therapeutic potential, aligning with trends in plant-based health products. Therefore, this study analyzes the characteristics of three key Indonesian *Styrax* types (toba, durame, and bulu), through CIE Lab color profiling, chemical analysis of cinnamic and benzoic acids, phytochemical screening, and FTIR functional group assessment to support broader applications and sustainable management.

MATERIALS AND METHODS

Sampling location

Styrax samples were collected from the Siborong-borong Sub-district, North Tapanuli District, North Sumatra Province, Indonesia (Figure 1). The selection of Siborong-borong was primarily due to its location along the resin distribution route in North Sumatra, where resin-producing trees are naturally abundant. The collected samples were *toba* (*S. sumatrana*), *durame* (*S. benzoine*), and *bulu* (*S. benzoine* var. *hiliferum*) resins. Resin samples were obtained from local farmers without regard to sample size or the number of trees. One kilogram of fresh resin was collected from farmers. The number of replicates was 6 times for all analyses except FTIR and phytochemical screening.

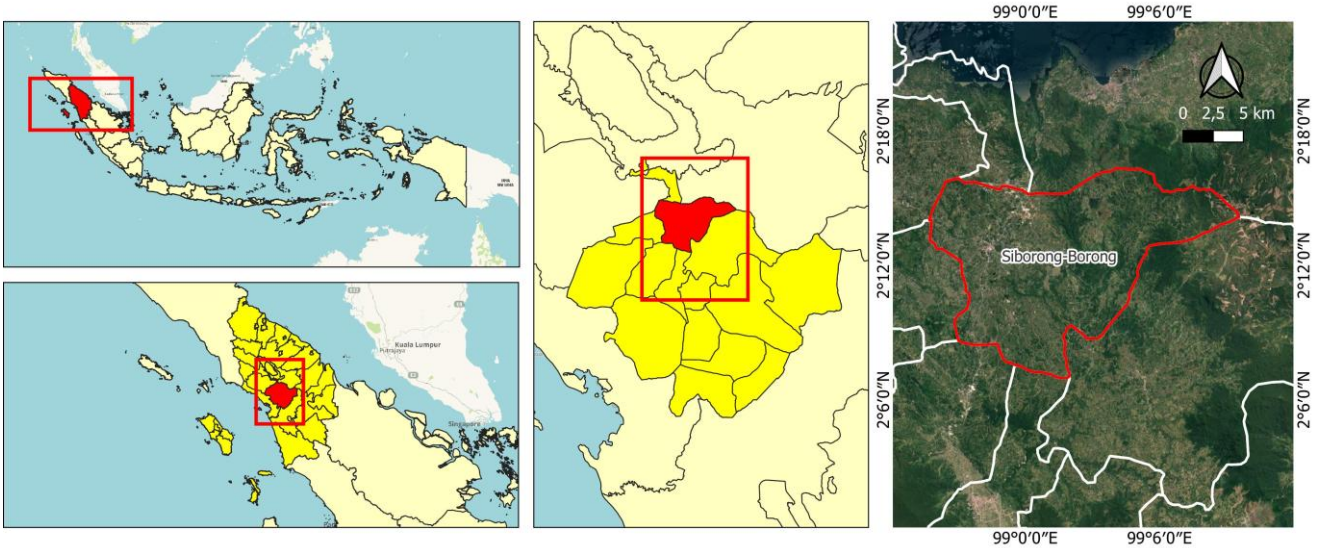

Figure 1. Sampling location of Indonesian *Styrax*: Siborong-borong Sub-district, North Tapanuli District, North Sumatra, Indonesia

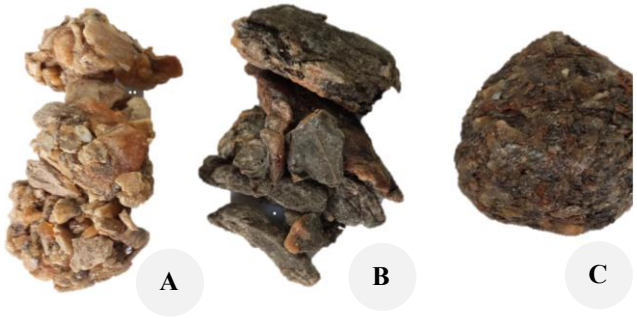

Figure 2. Gum resin of Indonesian *Styrax*: A. *S. sumatrana* (*toba*); B. *S. benzoin* var. *hiliferum* (*bulu*); C. *S. benzoin* (*durame*)

Color analysis

Figure 2 illustrates the variation of Indonesian *Styrax*. Gum resin collected from *Styrax* trees was analyzed using a colorimeter (Colour Tech PCM/PSM, China) equipped with a CIE Lab System. This system facilitated color analysis through the utilization of L*, a*, b* values, Chroma (C*), as well as °Hue angle (h*). The CIE Lab coordinates (L*, a*, b*) were obtained directly. The CIE Lab uniform space was defined by the measurement of two colour coordinates, a* and b*, along with a psychometric index of lightness, L*. The parameter a* assumes positive values for reddish hues and negative values for greenish tones, while b* takes on positive values for yellowish shades and negative values for bluish tints. L* serves as an approximate measurement of luminosity, a property that allows each color to be viewed as a counterpart within the greyscale spectrum, ranging from black to white. Chroma is a measure of the purity or intensity of a color, indicating the extent to which a color diverges from a shade of gray of equivalent lightness. An elevated C* value indicates a purer or more saturated color, whereas a diminished C* value suggests it is nearer to gray. Chroma was calculated by Equation 1 (Pathare et al. 2012).

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad [1]$$

The hue angle quantifies a color's identity or family, depicted as an angle on a color wheel or axis. It begins at a reference point, such as red (0°), and advances through yellow (90°), green (180°), and blue (270°). It aided in evaluating color consistency by computing delta (Δ) as a measure of color variation. A higher hue angle indicates a reduced yellow character in the assays. The hue was determined by Equation 2 (Pathare et al. 2012).

$$h^* = \text{Tan}^{-1}\left(\frac{a^{*2}}{b^{*2}}\right) \quad [2]$$

The whiteness index, yellowness index, and browning index were determined by Equations 3, 4, and 5, respectively (Pathare et al. 2012; Eldin et al. 2020). Whiteness Indices (WI) are extensively quantified to produce figures that closely align with consumer preferences for white hues. It integrates lightness and yellow–blue into a unified mathematical expression. The WI serves as a measure of the overall whiteness of food products and may reflect the degree of discoloration that occurs during drying. Furthermore, Yellowness Indices (YI) primarily measure these forms of degradation using a singular value. These methods are applicable for assessing transparent, nearly colorless liquids or solids in transmission, as well as for evaluating near-white, opaque solids in reflectance. The Browning Index (BI) captures this variation in a single index related to brown colour.

$$\text{Whiteness Index (WI)} = 100 - \sqrt{(100 - L^{*2}) + a^{*2} + b^{*2}} \quad [3]$$

$$\text{Yellowness Index (YI)} = \frac{142.86\, x\, b^*}{L^*} \quad [4]$$

$$\text{Browning Index (BI)} = 100 \times \left(\frac{X - 0.31}{0.17}\right),$$

$$\text{Where X} = \frac{(a^* + 1.75L^*)a^*}{(5.645L^* + a^* - 3.012b^*)} \quad [5]$$

Chemical characterization

The resin undergoes air-drying for 3 days, after which the larger chunks are fragmented into smaller pieces. The dried fragments were subsequently pulverized with a blender and immediately filtered through a 60-mesh screen. The resin powder was used as a sample for analysis of moisture, ash, cinnamic acid, benzoate, and impurities.

The moisture and ash content were measured by gravimetric analysis. Five g (a) of resin powder were dried in an oven at 105°C for a minimum of 2 hours, ensuring the attainment of a constant weight (b). The experiment was conducted in triplicate. The moisture content was determined by Equation 6.

$$\%\ \text{Moisture content (MC)} = \frac{a - b}{a} x100\% \quad [6]$$

Ash content was determined by placing 5 g of resin into a furnace set at 600°C for 6 hours, followed by measuring the mass of the residual ash (b). The ash content was calculated by Equation 7.

$$\%\ \text{Ash content (AC)} = \frac{b}{a} x\ 100\% \quad [7]$$

The determination of cinnamic acid and benzoic acid was carried out using an ultraviolet-visible (UV-VIS) spectrophotometer (Thermo Fisher Scientific, Aquamate UV-VIS 840-240000, United States). The samples were prepared according to the method of El-Masry (1979). An amount of 0.5 g of resin powder was refluxed with 10 mL of alcohol and 0.5 N potassium hydroxide (KOH) for 1 hour, after which the alcohol was evaporated. The residual substance was removed by washing with 20 mL of hot water and left to cool. Subsequently, 30 mL of distilled water and 20 mL of 3% magnesium sulfate ($MgSO_4$) were incorporated, mixed, and permitted to rest for 10 minutes. The filtrate was passed through filter paper, and the residue was rinsed with 10 mL of distilled water. The filtrate was diluted with 100 mL of distilled water. A 10 mL dilution was performed to achieve a total volume of 100 mL using 0.5 N hydrochloric acid (HCl). The resulting solution was diluted to 100 mL with 5 mL of 0.5 N HCl. The absorbance of the final solution was measured alongside the reference solutions of cinnamic acid and benzoic acid in a 1 cm

cuvette at their respective maximum wavelengths of 229 nm and 279 nm, utilizing an appropriate spectrophotometer, with 0.5 N HCl as a blank. The concentrations of benzoic acid and cinnamic acid were then calculated using Equations 8 and 9.

$$\text{Benzoic acid } \left(\frac{g}{100g}\right) = \frac{(143 \times A1 \times 12{,}8 \times A2)}{12855.96} \times 200 \times \{(100/0.5)/10\} \quad [8]$$

$$\text{Cinnamic acid } \left(\frac{g}{100g}\right) = \frac{(90.6 \times A1 \times 7.8 \times A2)}{12855.96} 200 \times \{(100/0.5)/10\} \quad [9]$$

Where: A1 is the absorbance of the final solution at 229 nm, and A2 is the absorbance of the final solution at 279 nm. The numbers 143, 12.8, 90.6, and 7.8 are the specific absorptivity coefficients of each acid at a particular wavelength. Furthermore, the numeric 12855.96 is a conversion factor that includes the molecular weight and dilution factor, and the last numeric in the formula (200 × {(100 / 0.5) / 10} is the volume factor of the filtrate and dilution from the experimental procedure.

The determination of impurity content was carried out in accordance with the Indonesian National Standard (SNI 7940:2013). The impurity content is defined as a resin substance that is insoluble in acetone and methanol. A 5 g sample of resin powder was dissolved in 25 mL of a methanol/chloroform mixture. The mixture was then filtered through Whatman no. 1 paper and rinsed with methanol/acetone. The insoluble residue was dried in an oven at 105°C until a stable weight was reached. The dry matter was measured as a proportion of the residual material insoluble in acetone/methanol.

Phytochemical screening

The extraction method developed by Susanti et al. (2023) was employed for phytochemical screening. The extraction procedure involved macerating the resin powder for 72 hours, with the ethanol solvent being refreshed every 24 hours. The solvent renewal process used a 400-mesh nylon filter to ensure that the resin powder remained unfiltered. The resin-to-ethanol solvent ratio was 1:2. After a 72-hour maceration period, the extract was filtered under vacuum and concentrated using a rotary evaporator.

The resin extract obtained was subjected to phytochemical characterization. It involves the methodologies outlined by Harborne (1998) and Hidayat et al. (2018), which encompass tests for alkaloids, phenols, flavonoids, saponins, tannins, and steroids/triterpenoids. The presence of phenolics and tannins was determined by analyzing a 70% ethanol extract added with $FeCl_3$. The formation of a green color indicated the presence of tannins. The determination of flavonoids involved adding magnesium and hydrochloric acid until a magenta-red precipitate was observed. Alkaloids were analyzed utilizing Mayer and Wagner reagents. The presence of steroids in resin extract was determined by adding anhydrous acetic acid and sulfuric acid. Terpenoids were identified through the addition of sulfuric acid. The determination of saponins involved adding a small amount of dimethyl sulfoxide (DMSO) and hot water.

Fourier Transform Infrared (FTIR)

The resin powder extract was mixed with KBr Pellet, using a mortar and pestle, and compressed into a thin pellet. FTIR spectroscopy was performed at room temperature (approximately 25°C), using an FTIR-4200 spectrophotometer (8201PC-Shimadzu, Tokyo, Japan) and the KBr pellet method to determine the assignment of absorbance bands to specific functional groups. The spectroscopic results were obtained using an FTIR spectrometer, with a scan range of 4000-400 cm^{-1}.

Classification standard

The quality of resin was compared to the grades in accordance with the Indonesian National Standard (SNI 7940:2013). Table 1 presents the quality parameters for Grades A, B, and C of resin.

Statistical analysis

This study used a non-factorial Completely Randomized Design (CRD) to analyze the color and chemical characteristics of *kemenyan* resin. All analyses were performed in six replications. Statistical analysis was conducted using one-way ANOVA followed by Duncan's Multiple Range Test (DMRT), and differences were considered significant at $p<0.05$.

RESULTS AND DISCUSSION

Color analysis

The colors of *Styrax* resin are of significant visual importance as a quality indicator and affect its applicability. Color factors were analyzed using various indices; therefore, color standardization was required to ensure product marketability and compliance with specifications (Pathare et al. 2012).

Table 1. Classification and quality parameters for resin based on SNI 7940:2013

Parameter	Unit	SNI 7940:2013's grades		
		A	B	C
Color (visual observation)	-	Clear white	Brownish-white (50% white, 50% brown)	Whitish-brown (25% white, 75% brown)
Impurities content	%	< 1	< 1	>1 - <5
Ash content	%	< 1	< 1	>1 - <2
Cinnamic acid content	%	> 30	21-29	<20

Table 2 compares the variation in color traits across aspects between the three Indonesian *Styrax* species. The resin luminosity was represented by the L values (lightness): L* = 0 (black) and L* = 100 (white). The L* value in Table 1 indicated that *toba* resin exhibited greater brightness than *bulu* and *durame.* The characteristics of *bulu* and *durame* resin were attributable to enzymatic activity and the slightly adhesive quality of these varieties due to the inclusion of bark, litter, and other debris during harvest, resulting in a darker °Hue (L) relative to the *toba* resin. According to SNI 7940:2013, the *toba* resin was classified as grade A, while *bulu* and *durame* were classified as grade C. Color variations were affected by several factors, including tree species, resin age, and processing method (Ding et al. 2025), and plant species.

The a* value represented the intensity of redness or greenness in resin. A positive a* number (100) signified red, whereas a negative a* value (-80) denoted that green is the predominant color. Table 1 indicates that the *toba* possessed a superior a* value compared to *durame* and *bulu*. It noted that the *toba* variant exhibited a greater degree of redness. The b* value represented the extent of yellowness or blueness. A positive b* number (-70) signified a predominant yellow hue, whereas a negative b* value (-80) denoted an intense blue hue. *Toba* displayed a more pronounced yellow hue than the *bulu* and *durame*. The whiteness, browning, and yellowness indices were derived from the L*, a*, and b* values obtained by colorimeter measurements. *Toba* demonstrated superior whiteness, browning, and yellowness index values compared to *bulu* and *durame*, as indicated by its elevated L*, a*, and b* values.

The physicochemical characteristics

The physicochemical composition of three species of Indonesian *Styrax* is presented in Table 3. The *toba* exhibited higher cinnamic acid than *bulu* and *durame*; however, the *durame* demonstrated higher benzoic acid than *bulu* and *toba*. The elevated levels of cinnamic acid in the *toba* suggested its classification as grade A. In contrast, *durame* and *bulu* are categorized as grade C. Waluyo et al. (2006) previously analyzed various resin qualities, including the cinnamic acid content in grade A resin. Variation in the chemical composition of resin is due to geographic growth location and climatic conditions (Akhtar and Alam 2022; Heng et al. 2023). Conversely, Nurwahyuni et al. (2020) found that *S. benzoin* contained 12-21% cinnamic acid, was classified as grade B, and was thought to be *S. benzoin* var. *hiliferum* (*bulu*), which aligns with the results of this study.

The antibacterial properties of cinnamic acid indicate that it can inhibit the growth of various bacteria, including *Streptococcus aureus* and *Escherichia coli* (Annuur et al. 2024). Additionally, benzoic acid has antioxidant properties, with a strong ability to scavenge free radicals. This antioxidant activity contributes to potential health benefits, particularly in protecting against oxidative stress and related diseases (Bułakowska et al. 2023; Halpani and Mishra 2024). Benzoic acid is also known for its antibacterial properties (Synowiec et al. 2021). It is a food and non-food preservative widely used for its broad-spectrum antimicrobial activity, including inhibition of the growth of various pathogenic microorganisms such as *S. aureus* and *E. coli* (Faisal et al. 2023).

The SNI does not mandate the use of benzoic acid as a quality indicator for resin; however, its inclusion should be considered. The benzoic acid content was 16.08%, 24.20%, and 36.73% for the *toba*, *bulu*, and *durame* resin variants, respectively. Sormin et al. (2021) discovered a benzoic acid content of 5.29% in resin collected from the North Tapanuli District; however, the resin variety was not specified. Meanwhile, Pangoloi et al. (2023) isolated a highly pure benzoic acid of 99.27% from *S. benzoin*. Susanti et al. (2023) used ethanol as the solvent to extract benzoic acid from *S. benzoin*, yielding 14.01%, which was lower than the amount reported in this study. The significant variations and discrepancies in benzoic acid content were affected by species, geographic and growth conditions, genetic factors, solvent type, and extraction method.

Furthermore, Aswandi and Kholibrina (2020) introduced a novel classification system for evaluating the quality of *toba* resin, comprising four distinct, physical classifications (Table 4). The moisture content of *toba*, *bulu*, and *durame* resin was categorized as grade I, IV, and II, respectively. Furthermore, the ash content of *toba* and *durame* was classified as grade II, whereas that of *bulu* was classified as grade III. Unfortunately, based on the impurity content, all resin was included in grade IV. The moisture level in the resin affects the amount of debris. Increasing water content could increase the impurity concentrations. The *toba* variety had lower impurity levels in methanol and acetone than other varieties, as evidenced by the impurities that remained insoluble in acetone at 7.17% and in methanol at 6.61%. Table 3 shows that the resin solubility in methanol is higher than that in acetone, suggesting the presence of more semipolar compounds relative to polar compounds. The findings from Kiswandono et al. (2016) indicated that the insoluble residues in acetone and methanol were 22.1% and 15%, respectively. The differences are due to variations in the composition. The insoluble impurities in acetone and methanol, including fibers associated with or adhering to sap, such as tree bark, litter, and others that remained insoluble in these solvents (Kiswandono et al. 2016).

Table 2. Color variation of Indonesian *Styrax*

Color resin description	Indonesian *Styrax*		
	Toba	***Bulu***	***Durame***
	White-cream	**Brownish-yellow**	**Brown**
L*	56.01±3.96[a]	38.41±5.39[b]	34.39±1.47[b]
a*	10.38±1.15[a]	7.39±0.67[b]	8.53±0.28[b]
b*	21.46±0.82[a]	9.66±1.52[b]	8.97±1.44[b]
c*	23.89±0.71[a]	12.33±0.93[b]	12.43±1.12[b]
h*	64.14±2.94[a]	51.62±6.64[b]	46.03±4.52[b]
WI	49.92±3.38[a]	37.18±5.11[b]	33.22±1.29[b]
BI	61.39±5.06[a]	42.87±326[b]	47.75±4.44[b]
YI	54.87±2.72[a]	35.90±2.25[b]	37.15±4.82[b]
Aroma	Balsamic	Balsamic	Balsamic
Texture	Hard	Soft-hard	Soft-hard

Note: WI: Whiteness Index, BI: Browning Index, YI: Yellowness Index. Different letters following numbers in the same row indicate a significant level (P<0.05) by Duncan Multiple Range Test

The ash content of all resin samples complied with the ash content requirements specified in the SNI. Meanwhile, according to classification by Aswandi and Kholibrina (2020), *toba*, *bulu*, and *durame* resins were categorized as grade II, III, and II, respectively. The ash content of *Styrax* resin indicates the inorganic residue that remains after combustion, which is non-combustible. Ash content could serve as a quality indicator: the lower the ash content, the greater the purity and overall quality. The findings showed that ash content also significantly affected color; lower ash content resulted in a brighter hue. The L value in Table 2 illustrated this point: *Toba* resin had the lowest ash content and the highest brightness value, indicating its superior whiteness. Furthermore, a decrease in ash content correlates with a reduction in water content, which affects the quality of the resin (Abduh et al. 2022).

Phytochemical characteristics

Phytochemical screening (Table 4) showed the absence of alkaloids, as evidenced by the lack of brown or red precipitate formation. Hidayat et al. (2018) previously reported that there is no alkaloid content. However, Kiswandono et al. (2016) and Susanti et al. (2023) reported the presence of alkaloids in resin extracts. Environmental conditions, such as soil type, climate, and geographic features, strongly influence the presence or absence of alkaloids in resin extracts (Debnath et al. 2022).

Functional groups

The FTIR spectrum analysis of *toba* resin, as shown in Figure 3 and Table 5, identified characteristic functional groups, including hydroxy (-OH), carbonyl (C=O), aromatic (C=C), ether, and ester groups. Notably, the *toba* resin exhibited numerous minor peaks in the 1500-1000 cm^{-1} range, which indicate a variety of polar compounds with complex functional groups. The higher absorption in the O-H and C-H stretching regions in *toba* resin compared to others suggests a high concentration of hydrocarbons and polar compounds. These specific functional groups, especially the hydroxyl (-OH), carbonyl (C=O), and aromatic (C=C) groups, are known to confer significant bioactivities. Hydroxyl and carbonyl groups are commonly involved in antioxidant activity by donating hydrogen atoms or electrons to neutralize free radicals. Aromatic compounds and other polar groups can disrupt microbial cell membranes or inhibit pathogen functions, leading to antimicrobial effects. Therefore, the presence and abundance of these functional groups, which are linked to bioactive compounds in *toba* resin, explain its potential antimicrobial and antioxidant activities. The complex mix of polar and hydrocarbon compounds identified in the FTIR spectrum reflects the chemical basis for these biological properties, as supported by earlier studies showing *toba* resin's inhibitory effects on microbes and its free radical scavenging ability. The absorption intensity in the C=O region near 1700 cm^{-1} observed for the *bulu* resin is indicative of a higher carbonyl content typically associated with non-polar ester compounds. Carbonyl groups, which show a strong and sharp peak between 1670 and 1780 cm^{-1} in FTIR spectra, are key functional groups found in aldehydes, ketones, esters, and carboxylic acids. The ester carbonyl peak often appears around 1735-1750 cm^{-1}. Higher absorption intensity at this wavelength suggests a significant amount of these ester carbonyl compounds. Esters and similar non-polar compounds generally exhibit antiseptic properties, often by disrupting microbial membranes or interfering with microbial enzymes. Aromatic esters can also contribute aromaticity, influencing fragrance and bioactivity.

In contrast, antioxidant activity is usually associated with polar hydroxyl, phenolic, or flavonoid groups rather than with predominantly non-polar esters. Therefore, while *bulu* resin's high carbonyl (ester) content suggests strong antiseptic or aromatic properties, it may have less pronounced antioxidant properties than resins richer in polar compounds, such as hydroxy or phenolic groups (Bujok et al. 2019). This functional group profile explains the distinct bioactivity potential of *bulu* resin compared to *toba* resin, which showed greater complex polarity and antioxidant activity. Meanwhile, *durame* had the potential to serve as a natural antiseptic and fragrance due to its balanced spectrum of hydroxyl, carbonyl, and aromatic groups (Suharso et al. 2017).

Table 3. The physicochemical properties of Indonesian *Styrax* compared to the standards set by SNI 7940:2013 and the classification by Aswandi and Kholibrina (2020)

Physicochemical characteristics	Species/variant of Indonesian *Styrax*			SNI 7940:2013's grades			Aswandi and Kholibrina's grades			
	Toba	*Bulu*	*Durame*	A	B	C	I	II	III	IV
Moisture content (%)	2.06±0.13^{b}	2.59±0.17^{a}	2.27±0.22^{b}				2.24	2.29	2.46	3.10
Ash content (%)	0.160±0.03^{c}	0.328±0.05^{a}	0.223+ 0.02^{b}	≤1	≤1	>1 - >2	0.08	0.25	0.59	1.66
Cinnamic acid (% w/w)	32.65±0.77^{a}	13.74±0.74^{b}	4.19±1.01^{c}	≥30	21-29	≤20				
Benzoic acid (% w/w)	16.08±0.95^{c}	24.20±2.34^{b}	36.73±1.61^{a}	-	-	-				
Impurity contents:										
Methanol (%)	6.61±0.93^{b}	8.71±1.11^{a}	8.56±0.82^{a}	-	-	-				
Aceton (%)	7.17±0.81^{b}	11.01±1.33^{a}	9.81±1.57^{a}	≤1	≤1	>1 - >5	3.43	3.97	5.41	11.47

Note: Different letters following numbers in the same row indicate a significant level (P<0.05)

Toba's absorption bands were more complex and robust across nearly all wavelength ranges. It indicated a higher concentration of bioactive compounds, particularly phenolics, carbonyls, and terpenoids. *Toba* resin was comparable to *durame*, which exhibited an intermediate spectrum. However, the O-H and C=O groups were slightly weaker. Low absorption intensity indicated the lowest bioactive content in *bulu.* The three varieties of resin exhibited comparable primary functional groups, albeit with differing intensities. The *toba* exhibited the most diverse range of aromatic and resin groups, followed by *durame*. *Bulu* showed a higher concentration of carbonyl compounds and a lower concentration of aromatic compounds. A previous study by Suharso et al. (2017) on *bulu* resin showed that it has a broad absorption band at 3200-3387 cm^{-1}, characterized by high intensity, indicating the adsorption of alcohol O-H. The absorption region suggested the existence of carboxylic O-H groups from cinnamic and benzoic acids. The absorption band appeared in the range of 1512-1450 cm^{-1}, with a sharp, vigorous intensity, and was intensified in the 3000 cm^{-1} region. The functional groups identified in *bulu* resin extract included benzoic acid, cinnamic acid, and isovanillin.

Prospects in antibacterial potential applications

This study extends beyond discussing the prospects of antibacterial applications for Styrax resins by including actual analyses of their antibacterial activity. Previous research, such as by Mashael et al. (2020), demonstrated that benzoin resin smoke could significantly reduce microbial populations in indoor air and hospital environments, indicating its potential to purify air and inhibit bacterial growth. The FTIR analysis in this study revealed distinct chemical features in the resins, including the presence of cinnamic acid, known for its antibacterial and antimicrobial properties.

Cinnamic acid displayed notable antibacterial and antimicrobial properties. Cinnamic acid, a natural compound commonly found in resins, has been widely reported to inhibit the growth of various bacterial and fungal species. Previous studies have shown that cinnamic acid exhibits antibacterial activity against both Gram-positive and Gram-negative bacteria. However, its efficacy tends to be more potent against Gram-positive strains, such as *S. aureus,* and weaker against Gram-negative bacteria, such as *E. coli,* due to their protective outer membranes. Additionally, cinnamic acid has demonstrated antifungal activity against species like *Aspergillus* and *Candida*. Research highlights its role in disrupting microbial growth and biofilm formation, and in enhancing the effectiveness of some antibiotics (Guzman et al. 2014; Annuur et al. 2024).

Table 4. Phytochemical compounds of Indonesian *Styrax*

Phytochemical compounds	Indonesian *Styrax* species/variant		
	Toba	***Bulu***	***Durame***
Phenolic	+ (green)	+ (green)	+ (green)
Flavonoid	+ (orange)	+ (red)	+ (red)
Tannin	+ (green)	+ (green)	+ (blue)
Steroids	+ (green)	+ (green)	+ (green)
terpenes	+ (yellow)	+ (yellow)	+ (yellow)
Saponin	+ (foam)	+ (foam)	+(foam)
Alkaloid	-	-	-

Note: +: Presence, -: Absence

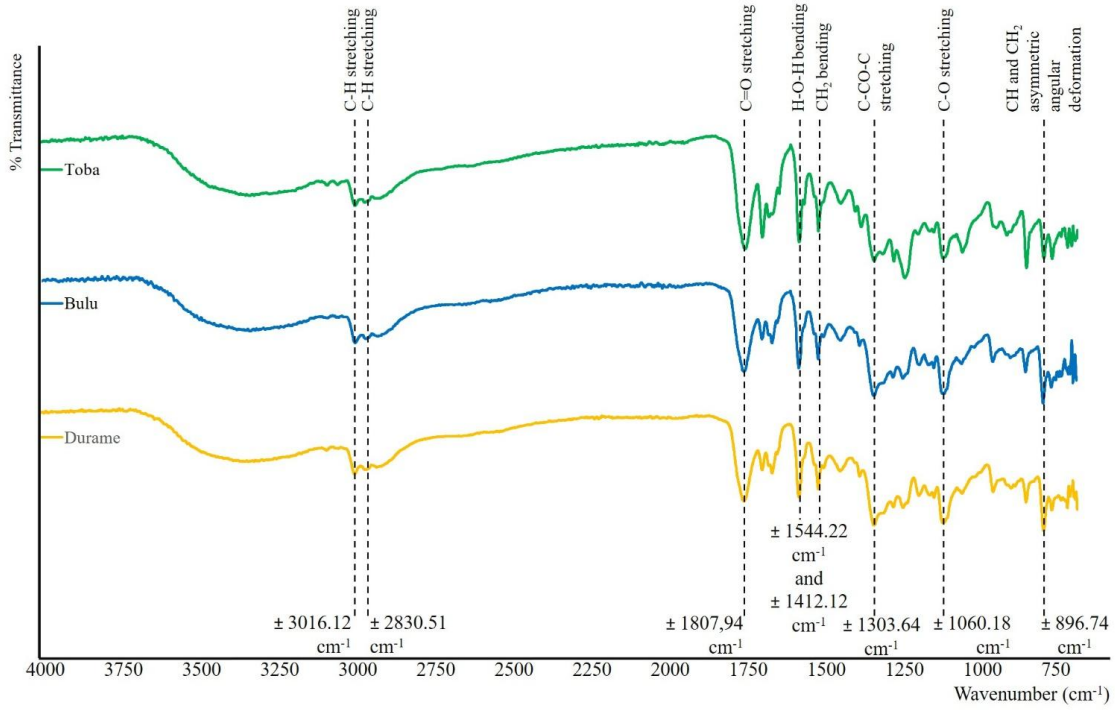

Figure 3. FTIR spectra of Indonesian *Styrax*

Table 5. Functional group identification of Indonesian *Styrax* based on FTIR spectrum

Wavelength (cm^{-1})	Functional groups	Compound types	Interpretation
3200-3315	O–H, stretching (wide)	Alcohol/phenol	Highest phenolic/alcohol content in *S. sumatrana*
3016-2830	C–H, stretching (aliphatic)	CH_3 and CH_2 (terpenoids)	The highest aliphatic hydrocarbon and terpenoid content in *S. sumatrana* and *S. benzoin*
1808	C=O, stretching	Carbonyl (ester, ketone, acid)	*S. sumatrana* contained many triterpenoid compounds
1700	C=O stretching (carboxylate/aromatic)	Benzoic acid, sinamic acid, Aromatic ester	characteristic peak of aromatic carbonyl; confirms the presence of benzoic and cinnamic acids in all *S. sumatran* *S. benzoin* and *S. benzoine* var. *hiliferum*
1544	O–H, bending / C=C, aromatic	Phenolic aromatic	Complex aromatic structures in *S. sumatrana.*
1412	CH_2, bending	Aliphatic	Aliphatic content in almost all species
1304	C–O, stretching	Alcohol, ester, carboxylic acid	Polar compounds, such as glycosides and resins
1060	C–O–C, stretching	Ether or polysaccharide	Polar complex structures in *S. sumatrana* and *S. benzoin*
897	C–H, deformation	Aromatic substitution	Complex aromatic structure or aromatic ring of *S. sumatrana.*

A study by Mingoia et al. (2022) indicated that cinnamic acid has antibacterial activity against *S. aureus* with the Minimum Inhibitory Concentration (MIC) range of 16-64 µg/mL, and the studies by Zawiła et al. (2024, 2025) and indicated that cinnamic acid effectively inhibits the formation of biofilm on both *S. aureus* and *S. epidermidis*. The antibacterial activity against *E. coli* was lower than that against *S. aureus*, due to the outer membrane of Gram-negative bacteria hindering the penetration of phenolic compounds, with the MIC value of approximately 1,017 µg/mL. The increased levels of benzoic acid in the *durame* offer promising opportunities for its use as a preservative in both the food and pharmaceutical industries.

In conclusion, among the three *Styrax* variants, *S. sumatrana* exhibited the brightest resin color (L* = 56.01) and the highest yellowness index, qualifying it as Grade A, although it contained relatively less benzoic acid. None of the resins contained alkaloids. All three species shared similar major functional groups, but their spectral intensities varied with the extraction method used. The *toba* resin showed the most complex and abundant aromatic and resinous group spectrum, followed by *bulu*. *Durame* showed abundant carbonyl compounds and fewer aromatic structures, suggesting compositional differences between them. Classified as Grade A under SNI 7940:2013, *S. sumatrana* (*toba*) contained the highest cinnamic acid concentration, demonstrating antioxidant and antibacterial properties that support its suitability for high-value applications in pharmaceuticals, cosmetics, and food formulations. Conversely, *S. benzoin* (*durame*) had the greatest benzoic acid concentration among the three, suggesting its potential use as a preservative, particularly in non-food and industrial products.

ACKNOWLEDGEMENTS

We are grateful to the Directorate General of Higher Education, Research, and Technology, Ministry of Education, Culture, Research, and Technology, Indonesia, for funding this research as part of the dissertation grant, Number: 082/E5/PG.02.00.PT/2022, dated 1 May 2022.

REFERENCES

Abduh MY, Rahmanita AT, Maulana ER, Nadhira VF, Indira TI, Manurung R. 2022. Valorization of lower grade resin, bark, and fruit of *Styrax sumatrana*. Intl J Innov Res Sci Stud 5 (1): 30-60. DOI: 10.53894/ijirss.v5i1.349.

Akhtar MS, Alam T. 2022. Chemistry, biological activities, and uses of benzoin resin. In: Murthy HN (eds). Gums, Resins and Latexes of Plant Origin. Reference Series in Phytochemistry. Springer, Cham. DOI: 10.1007/978-3-030-91378-6_26.

Annuur RM, Triana D, Ernawati T, Murai Y, Aswad M, Hashimoto M, Tachrim ZP. 2024. A review of cinnamic acid's skeleton modification: Features for antibacterial-agent-guided derivatives. Molecules 29 (16): 3929. DOI: 10.3390/molecules29163929.

Aswandi A, Kholibrina CR. 2020. The grading classification for *Styrax sumatrana* resins based on physico chemical characteristics using two-step cluster analysis. IOP Conf Ser: Mater Sci Eng 935 (1): 012013. DOI: 10.1088/1757-899X/935/1/012013.

Bujok J, Gąsior-Głogowska M, Marszałek M, Trochanowska-Pauk N, Zigo F, Pavľak A, Komorowska M, Walski T. 2019. Applicability of FTIR-ATR method to measure carbonyls in blood plasma after physical and mental stress. BioMed Res Intl 2019: 2181370. DOI: 10.1155/2019/2181370.

Bułakowska A, Sławiński J, Hałasa R, Hering A, Gucwa M, Ochocka JR, Stefanowicz-Hajduk J. 2023. An in vitro antimicrobial, anticancer and antioxidant Activity of N–[(2–arylmethylthio)phenylsulfonyl]cinnamamide derivatives. Molecules 28 (7): 3087. DOI: 10.3390/molecules28073087.

Debnath S, Nath M, Sarkar A, Roy G, Chakraborty SK, Debnath B. 2022. Phytochemical characterization of *Styrax* benzoin resin extract, molecular docking, ADME, and antibacterial activity study. Nat Prod Res 38 (7): 1263-1268. DOI: 10.1080/14786419.2022.2132244.

Ding Y, Guo X, Yang J, Cheng X, Kang S, Brand E, Zhao Z, Liu Y, Wei F, Ma S. 2025. Study on authenticity identification and quality evaluation of *Styrax* by combining multiple detection methods with scientific characterization of description. Food Res Intl 208: 116217. DOI: 10.1016/j.foodres.2025.116217.

Eldin AK, Alhammadi A, Gharsallaoui A, Hamed F, Ghnimi S. 2020. Physicochemical, rheological, and micro-structural properties of yogurts produced from mixtures of camel and bovine milks. NFS J 19: 26-23. DOI: 10.1016/j.nfs.2020.05.001.

El-Masry S. 1979. Rapid Spectrophotometric method for determination of benzoic and cinnamic acids in balsam tolu. J Assoc Off Anal Chem 62 (1): 82-84. DOI: 10.1093/jaoac/62.1.82.

Faisal S, Sadiq S, Mustafa M, Khan MH, Sadiq M, Iqbal Z, Khan M. 2023. Tailoring the antibacterial and antioxidant activities of iron nanoparticles with amino benzoic acid. RSC Sustain 1 (1): 139-146. DOI: 10.1039/d2su00044j.

Guzman JD. 2014. Natural cinnamic acids, synthetic derivatives and hybrids with antimicrobial activity. Molecules 19 (12): 19292-19349. DOI: 10.3390/molecules191219292.

Halpani CG, Mishra S. 2024. Design, synthesis, characterization of ferulic acid and p-coumaric acid amide derivatives as an

antibacterial/antioxidant agent. Pharm Sci Adv 2: 100023. DOI: 10.1016/j.pscia.2023.100023.

Harborne JB. 1998. Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis. Chapman and Hall, New York, US.

He L, Zhou Y, Wan G, Wang W, Zhang N, Yao L. 2022. Antinociceptive effects of flower extracts and the active fraction from *Styrax japonicus*. J Ethnopharmacol 282: 114779. DOI: 10.1016/j.jep.2021.114779.

Heng MY, Syafni N, Ramsyer J, Thuerig B, Tamm L, Hamberger M, Potterat O. 2023. Qualitative and quantitative secondary metabolite profiles in a larger set of Sumatra benzoin samples. Agric Food Chem 71 (28): 10590-10597. DOI: 10.1021/acs.jafc.3c01861.

Hidayat A, Iswanto AH, Susilowati A, Rahmat HH. 2018. Radical scavenging activity of kemenyan resin produced by an Indonesian native plant, *Styrax sumatrana*. J Korean Wood Sci Technol 46 (4): 346-354. DOI: 10.5658/wood.2018.46.4.346.

Hu WL, Li ZL, Chen QJ, Sun YW, Zhai S, Lu F, Li F, Zhang CF. 2019. Triterpenes and lignans from the leaves of *Styrax tonkinensis.* Biochem Syst Ecol 86: 103891. DOI: 10.1016/j.bse.2019.04.009.

Kholibrina CR, Aswandi A. 2021. The consumer preferences for new *Styrax* based perfume products using a conjoint analysis approach. IOP Conf Ser: Mater Sci Eng 935 (1): 012016. DOI: 10.1088/1757-899X/935/1/012016.

Kiswandono AA, Iswanto AH, Susilowati A, Lumbangtobing. 2016. Analisis kandungan asam sinamat dan skrining fitokimia getah kemenyan jenis bulu (*Styrax benzoine* var. *hiliferum*) dari Tapanuli Utara. Prosiding Seminar Nasional Kimia-Lombok 2016. [Indonesian]

Liu B, Ding W, Huang S, Sun W, Li Y. 2018. Chemotaxonomic significance of phenylpropanoids from *Styrax suberifolius* Hook. Et Arn. Biochem Syst Ecol 78: 35-38. DOI: 10.1016/j.bse.2018.03.006.

Mashael W. Alruways, Intisar E, Elrayah, Mariam A. 2020. Effect of benzoin resin fumes on indoor environmental microbes. Intl J Med Res Health Sci 9 (12): 52-58.

Mingoia M, Conte C, Di Rienzo A, Dimmito MP, Marinucci L, Magi G, Turkez H, Cufaro MC, Del Boccio P, Di Stefano A, Cacciatore I. 2022. Synthesis and biological evaluation of novel cinnamic acid-based antimicrobials. Pharmaceuticals 15 (2): 228. DOI: 10.3390/ph15020228.

Mustikasari K, Santoso M, Sasanti N, Astuti MD, Komari N, Ersam T. 2022. Perbandingan komposisi kimia ekstrak n-heksana dan minyak atsiri getah kemenyan toba (*Styrax sumatrana*) dari Tobasa Sumatra Utara menggunakan GC-MS serta studi in silico beberapa senyawanya sebagai antiinflamasi. Jurnal Riset Indonesia Hasil Hutan 14 (2): 93-106. DOI: 10.24111/jrihh.v14i2.7220. [Indonesian]

Nurwahyuni I, Nababan B, Pangoloi A, Situmorang M. 2020. Cinnamic acid in resin sap as a criterion for determining the best mother plant for vegetative propagation of *Styrax benzoin* (Sumatra benzoin) in Sumatra, Indonesia. Intl J For Res 2022: 4160241. DOI: 10.1155/2022/4160241.

Pangoloi S, Nurwahyuni I, Situmorang M. 2023. Isolation and identification of benzoic acid from the gum resin of Benzoin Sumatrana (*Styrax benzoin*), North Sumatra. AIP Conf Proc 2673: 060002. DOI: 10.1063/5.0125181.

Paparella A, Serio A, Shaltiel-Harpaz L, Revuru B, Kongala PR, Ibdah M. 2025. *Styrax* spp.: Habitat, phenology, phytochemicals, biological activity and applications. Plants 14 (5): 746. DOI: 10.3390/plants14050746.

Pasa C. 2023. The use of *Styrax officinalis* L. in folk medicine and chemical composition. GSC Adv Res Rev 17 (3): 86-89. DOI: 10.30574/gscarr.2023.17.3.0462.

Pathare PB. Opara UL, Al-Said FAJ. 2012. Colour measurement and analysis in fresh and processed foods: A review. Food Bioproses Technol 6 (1): 36-60, DOI: 10.1007/s11947-012-0867-9.

Rahmawaty, Ginting YA, Batubara R, Rauf A. 2024. The potential for cultivation of *Styrax benzoin* on land suitability evaluation in Pakpak Bharat District, Indonesia. Biodiversitas 25 (3): 1071-1080. DOI: 10.13057/biodiv/d250321.

Ren J, Fang A, Jiao S, Li R, Huang Y, Ni X, Zhang Y, Ma Y, Li S, Li J. 2024. Lignans from the leaves of *Styrax japonicus* and their anti-inflammatory activity. Fitoterapia 172: 105774. DOI: 10.1016/j.fitote.2023.105774.

SNI. 2013. SNI 7940-2013: Kemenyan. Standar Nasional Indonesia. Badan Standarisasi Nasional, Jakarta. [Indonesian]

Son NT, Linh NTT, Tra NT, Ha NTT, Anh LTT, Cham BT, Anh DT, Tuyen NV. 2021. Genus *Styrax*: A resource of bioactive compounds. Stud Nat Prod Chem 69: 299-347. DOI: 10.1016/B978-0-12-819487-4.00008-2.

Sormin E, Harefa N, Purba LSL, Sumiyati, Nadeak B. 2021. Benzoic acid isolation from resin. Adv Soc Sci Educ Humanit Res 2021: 217-221. DOI: 10.2991/assehr.k.210615.043.

Suharso, Sabriania NA, Tugiyono, Buhania, Endaryanto T. 2017. Kemenyan (*Styrax benzoin* Dryand) extract as green inhibitor of calcium carbonate ($CaCO_3$) crystallization. Desalination Water Treat 92: 38-45. DOI: 10.5004/dwt.2017.21478.

Susanti N, Purba J, Nizam M, Br Pakpahan AD, Agnesia C. 2023. Ethanol extract of resin gum (*Styrax* benzoin). Proc 9th Ann Intl Semin Trends Sci Sci Educ 2022: 173-180. DOI: 10.2478/9788367405195-026.

Synowiec A, Żyła K, Gniewosz M, Kieliszek M. 2021. An effect of positional isomerism of benzoic acid derivatives on antibacterial activity against *Escherichia coli*. Open Life Sci 16 (1): 594-601. DOI: 10.1515/biol-2021-0060.

Verešová A, Čmiková N, Vukic M, Ban Z, Elizondo-Luevano JH, Kačániová M. 2024. Antimicrobial activity of *Styrax tonkinensis* essential oil in vitro and in situ. Acta Horticulturae Regiotectureae 27 (2): 131-137. DOI: 10.2478/ahr-2024-0020.

Waluyo TK, Hastoeti P, Prihatiningsih T. 2006. Karakteristik dan sifat fisiko-kimia berbagai kualitas kemenyan di Sumatera Utara. Jurnal Penelitian Hasil Hutan 24 (1): 47-61. DOI: 10.20886/jphh.2006.24.1.47-61. [Indonesian]

Xia D, Han X, Zhang Y, Zhang N. 2023. Chemical constituents and their biological activities from Genus *Styrax*. Pharmaceuticals 16 (7): 1043. DOI: 10.3390/ph16071043.

Zawiła T, Swolana D, Rok J, Rzepka Z, Wojtyczka RD. 2025. Evaluation of the antibacterial activity of cinnamic acid and its derivatives: Synergistic effects with cloxacillin. Molecules 30 (3): 660. DOI: 10.3390/molecules30030660.

Zawiła T, Swolana D, Zawiła M, Wojtyczka RD. 2024. Synergistic interactions between selected β-Lactam antibiotics and cinnamic acid and its chosen derivatives. Antibiotics 13 (8): 710. DOI: 10.3390/antibiotics13080710.