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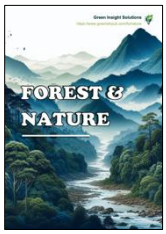

RESEARCH ARTICLE

Variation of Chemical Components in Bintangur (*Callophyllum inophyllum*) Wood along Stem Position and Its Potential Industrial Uses

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ABSTRACT

This study investigates the axial variation of major chemical constituents in bintangur wood (*Calophyllum inophyllum*), a species native to Indonesian peat forests, with emphasis on its industrial applicability. Wood samples were collected from three stem positions—base, middle, and top—to quantify extractives, holocellulose, alpha-cellulose, hemicellulose, and lignin content using the Technical Association of the Pulp and Paper Industry (TAPPI) standard methods. The results revealed a notable chemical gradient along the tree axis. Holocellulose (65.76–72.28%) and alpha-cellulose (44.56–49.61%) increased toward the upper stem, indicating enhanced suitability for pulp, paper, and bioethanol conversion at the tip region. In contrast, ethanol-benzene extractives peaked at the middle (7.26%) and declined at the tip (4.52%), while lignin exhibited a non-linear pattern, ranging between 25.47–28.64%. The moderate lignin content supports potential applications for charcoal, adhesives, phenolic derivatives, vanillin synthesis, and engineered wood products. Meanwhile, the relatively high extractive fraction suggests additional prospects for natural preservatives, essential oils, dye sources, and marine-grade timber. Overall, the distinct axial variability in chemical composition highlights the importance of stem-position-based processing optimization and demonstrates the feasibility of bintangur as a versatile raw material for biorefinery-based utilization. These findings provide baseline knowledge supporting future industrial development and valorization strategies for this under-exploited tropical hardwood.

1. Introduction

Wood is a raw material that plays a crucial role in human survival, particularly in the construction of housing and the manufacture of household appliances. The use of wood has increased over time, in line with technological advances. This is evident in the rapid growth of the wood industry worldwide, including in Indonesia. Consequently, the need for building materials and other industrial raw materials is also increasing. This further encourages the wood industry to strive to meet the demand for raw materials of sufficient quality and ready for use (Pramasari et al., 2021).

Each type of wood has unique characteristics, such as strength, hardness, resistance to weather and pest attacks, and load-bearing capacity (Neneng et al., 2021). Therefore, wood quality requires a wealth of information, including its basic properties suitable for industrial use, such as its chemical properties. The chemical properties of wood, along with its basic properties, influence other properties, such as its physical properties, durability, and strength. Meanwhile, physical and mechanical properties are often closely tied to the strength of lignocellulosic materials used as raw materials for the resulting products (Pramasari et al., 2021). Chemical indicators determine wood permeability, durability, and the suitability of wood adhesives for various applications, including sawing, machining, and finishing. Furthermore, lignin is used in the production of artificial boards; the lignin-to-cellulose ratio determines the wood's suitability for pulp and paper production (Wu, 2016).

Wood properties vary both within the same species and between different species, and even within the same tree. These differences in wood properties are not only the result of interactions among environmental factors that modify physiological processes, but also of the genotypic characteristics of the species, so their use is tailored to the wood's quality (Hastuti et al., 2017). Differences in wood properties can be observed in their chemical, physical, mechanical, and anatomical properties.

To optimize the use of wood, information on its characteristics is required. Several basic properties play a crucial role in utilizing wood as a raw material. One of these is the chemical component, which consists of cellulose, hemicellulose, lignin, and extractives (Iswanto et al., 2021). The chemical properties are also important and should be considered, as they are associated with various applications. In terms of cellulose content, these properties serve as a reference for the utilization of wood as a bioethanol feedstock and as a pulp and paper material (Yanti et al., 2018; Yanti et al., 2019). The chemical properties of cellulose and lignin, as well as their content, affect the heating value of wood (Lee et al., 2019). Furthermore, cellulose is used as a material for capacitor production (Li et al., 2018), replacing the use of ink on plastics with colored films (Tzeng et al., 2015), and as a raw material for 3D printing ink (Mietner et al., 2021). The lignin can be utilized for raw material in wastewater treatment (Fatriasari et al., 2020; Maulina et al., 2020; Xiao et al., 2019), biomedicine (Siddiqui et al., 2018), biorefinery (Liu et al., 2019; Yang et al., 2019), paint and coating (Zikeli et al., 2019), and packaging (Xing et al., 2019). One type of wood whose chemical properties remain unknown is bintangur wood (*Callophyllum soulattri*), which affects its utilization.

Bintangur wood (*Callophyllum inophyllum*) is a native plant species of peat forests. Currently, bintangur has not been widely developed as an industrial forest plantation. Bintangur wood comprises approximately 190 species, with its distribution center located in Kalimantan. Bintangur wood is fairly hard and has a light to medium weight. Its density ranges from 450 to 850 kg/m³ at a 15% moisture content, with an average value of 680 kg/m³. The wood grain direction is combined, twisted or wavy; the wood texture is quite coarse to rough and uneven. Economically, bintangur has high utility value and can be used as a raw material for bioenergy and pulp and paper (Darwo and Bogidarmanti, 2016).

Generally, bintangur has many uses, including as a shipbuilder, beams, piles, and floorboards (Kaliky et al., 2020). However, information on the basic properties of bintangur wood based on trunk height remains limited. Limited data are found regarding the physical properties of bintangur wood (*Callophyllum soulattri*), as reported by Kaliky et al. (2020), and regarding the effect of standing tree preservation on the chemical and mechanical properties of bintangur (*C. soulattri*), as reported by Pramasari et al. (2021). This research is useful for developing bintangur wood as a woody plant with the potential to meet the wood needs of plants with a long growth cycle. To more effectively utilize bintangur wood, we must analyze its properties. For this reason, it is necessary to research the variation in the chemical composition of bintangur wood along the stem and its potential industrial applications. The purpose of this study is to analyze the levels of extractive substances, including benzene, ethanol, holocellulose, cellulose, hemicellulose, and lignin, in bintangur wood by stem position and to assess their potential industrial uses.

2. Materials and Methods

Research on the chemical characteristics of bintangur wood and its potential uses was conducted at the Forest Products Chemistry Laboratory, Faculty of Forestry, Tanjungpura University. This research was conducted over a period of 6 months, from material preparation to data processing (**Fig. 1**).

2.1. Research Materials and Tools

The main material used is bintangur wood from the peat forest. The tools used in this study include chemical component testing tools according to standards, including a circular saw, drying oven, cover glass, analytical balance, water bath, desiccator, Soxhlet extractor for extracting extractive substances, acid-resistant glass reactor for lignin analysis, petri dish, pipette, test tube, camera, and pH meter.

2.2. Material Preparation

The bintangur stem (base, middle, and top) was cut into chips. Differences in stem height play a crucial role in determining the diversity of wood chemical components. Then, it was air-dried until

reaching equilibrium moisture content. The three parts of the bintangur trunk were then ground into powder using a Willey mill. The three parts were passed through a 40–60 mesh screen and then air-dried.

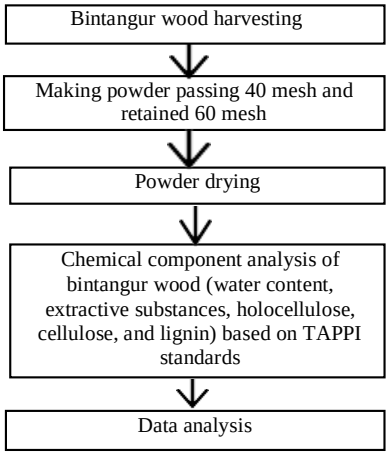

Fig. 1. Research flowchart.

2.3. Chemical Component Analysis of Bintangur Wood

The chemical component analysis in this study, namely the extractive content of benzene ethanol (1:2), lignin content, holocellulose content, and alpha (α) cellulose content, was determined using the Technical Association of the Pulp and Paper Industry (TAPPI) standard procedures: TAPPI T 204 om–88, TAPPI T 222 om–88, and TAPPI T9m–54.

2.3.1. Extractive content in ethanol-benzene

The ethanol-benzene extractive content was measured using the standard (TAPPI T 207 om–88). A 2 g sample was placed in a lead paper tube of known weight. The sample was placed in a Soxhlet flask and extracted with a 1:2 ethanol-benzene solution for 6–8 hours. The sample was washed with ethanol and air-dried. The sample was dried at 103 ± 2°C until its weight was constant. Once the extractive content is obtained, it can be calculated using Equation 1 (TAPPI T 207 om–88).

$$Extractive = 1 - \frac{ODW\ (1+WC)}{IDW} \times 100 \quad (1)$$

where *ODW* is the oven dry weight (g), *IDW* is the initial dry weight (g), and *WC* is the water content.

2.3.2. Holocellulose content

The holocellulose content was determined according to TAPPI T–203 standard. Two grams of extractive-free durian peel powder was placed in a 250 ml erlenmeyer flask, followed by 100 ml of distilled water, 1 g of $NaClO_2$, and 1 ml of acetic acid, respectively. The sample was then heated in a water bath at 70–80°C, with 1 g of $NaClO_2$ and 0.2 mL of acetic acid added every hour (four additions) over one hour. Once the residue turned whitish, the sample was filtered and rinsed with 500 mL of distilled water and 25 mL of 10% acetic acid. It was then dried in an oven at 103 ± 0.2°C for 24 hours until a constant weight was reached, and then weighed. The holocellulose content was calculated using Equation 2 (TAPPI T–203).

$$Holocellulose\ content\ (\%) = \frac{Oven\text{–}dry\ weight}{Initial\ powder\ weight} \times 100 \quad (1)$$

2.3.3. Alpha-cellulose content

The method for determining alpha-cellulose content is based on the TAPPI T203 cm–99 standard. A 1 g holocellulose sample was placed in an Erlenmeyer flask, then 10 mL of 17.5% NaOH was added at 20°C. At 5-minute intervals, 5 mL of 17.5% NaOH was added three times, resulting in a total volume of 25 mL of 17.5% NaOH. The sample was allowed to stand for 30 minutes at 25 ± 0.2°C. Afterward, 33 mL of distilled water was added to the sample and allowed to stand for 60 minutes. The sample was

filtered and rinsed with 100 mL of 8.3% NaOH. Rinsing was continued with hot distilled water. Afterward, the sample was rinsed again with 10% acetic acid, followed by hot distilled water until it was acid-free. The sample was oven-dried at 103 ± 2°C for 24 hours and then weighed until a constant weight was reached. Once the alpha-cellulose content is obtained, the calculation is based on Equation 3 (TAPPI T–203).

$$\textit{Alpha-cellulose content (\%)} = \frac{Oven\ dry\ weight}{Initial\ powder\ weight} \times 100 \quad (3)$$

2.3.4. Hemicellulose content

The hemicellulose content is determined as the difference between the holocellulose content and the Alpha-cellulose content, and is calculated using the following Equation 4 (TAPPI T–203).

$$\textit{Hemicellulose content (\%)} = A - B \quad (4)$$

where *A* is the holocellulose content (%), and *B* is the alpha-cellulose content (%).

2.3.5. Lignin content

Lignin content was measured using the TAPPI T–222 om 88 standard (TAPPI 2002b). A 0.5 g sample free of extractives was hydrolyzed with 5 mL of 72% sulfuric acid for 3 hours at room temperature, with stirring every 15 minutes. The solution was diluted to a sulfuric acid concentration of 3%. Hydrolysis was continued at a sulfuric acid concentration of 3% at 121°C for 30 minutes in an autoclave. The lignin was precipitated, filtered, and washed with hot distilled water until acid-free. Then, it was dried at 103 ± 2°C to a constant weight. Lignin content was calculated using Equation 5 (TAPPI T 222 om–88).

$$\textit{Lignin content (\%)} = \frac{Oven\text{–}dry\ weight}{Initial\ powder\ weight} \times 100 \quad (5)$$

2.4. Data Analysis

The experimental design for analyzing the chemical components of bintagur wood based on stem position used a completely randomized design (CRD) with five replications. Thus, the total sample analyzed was 15 units. An analysis of variance (ANOVA) test at a 95% confidence interval was performed to determine whether this treatment significantly affected the chemical component parameters tested. If the treatment had an effect, a further test, namely the honestly significant difference (HSD) test, was conducted.

3. Results and Discussion

3.1. Extractive Content and Ethanol-Benzene Soluble Content

Extractives are organic components that can be extracted from wood using solvents of varying polarity without significantly altering the cell structure (Prabawa, 2017). Extractive compounds are distributed throughout the resin canals and ray parenchyma cells, while smaller amounts are found in the middle lamella, intercellular spaces, tracheid cell walls, and libriform fibers. Types of organic compounds found in extractives include terpenes, lignans, stilbenes, flavonoids, other aromatic compounds, fats, waxes, fatty acids, alcohols, steroids, and higher hydrocarbons (Darwo and Bogidarmanti, 2016). The average values of extractives from the analysis of 1:2 ethanol-benzene soluble extractives are presented in **Fig. 2**.

The analysis results show that the middle section has the highest extractive content compared to the base and tip sections. This result is suspected because the extractive substances are relatively more easily degraded or released in the middle section. This statement is supported by Kristy et al. (2022), stating that when parenchyma cells in the wood die, the base of the parenchyma cells disrupts their physiological function, leading to the formation of heartwood, whose constituent cells undergo lignification. A similar finding was reported in the Guring (2017) study, which showed that the extractive content of benzene alcohol in *Memecylon garcinioides* wood was highest in the middle section (3.39%) and lowest at the tip (1.77%).

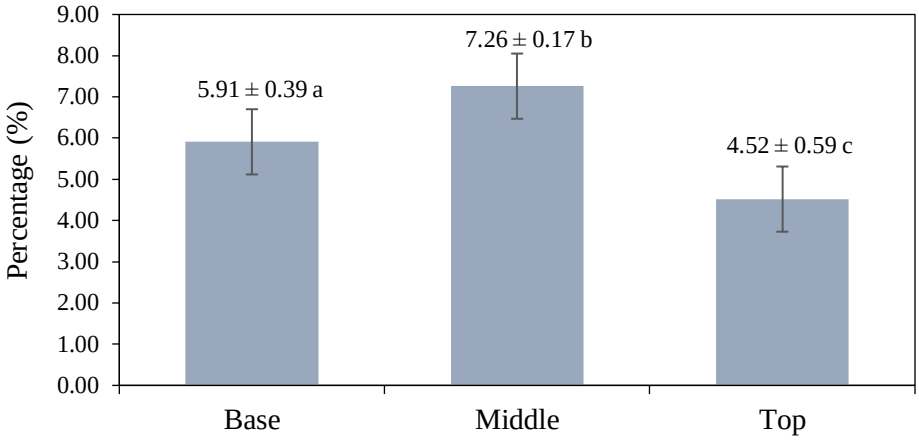

Fig. 2. Results of analysis of 1:2 ethanol-benzene extractive content in bintangur wood.

The solubility of the 1:2 benzene ethanol extractive substance in bintangur wood is classified as high, based on the classification of the chemical components of Indonesian broadleaf wood (> 4%). In general, extractive content originating from temperate regions ranges from 4% to 10%, and in tropical regions, it can reach up to 20% (Putra et al., 2018). High extractive content will inhibit the penetration of cooking chemicals into the wood's cellular structure and cavities during the wood-pulp cooking process. Consequently, the extractives negatively impact the pulping process, ultimately affecting the quality of the resulting paper (Istikowati et al., 2016). For structural uses such as wood for carpentry, higher extractives often impart beneficial traits (durability, colour, resistance to decay), but for pulping purposes, high extractive content is an issue because it can negatively influence pulp quality (Lehr et al., 2021). Extractives influence color, durability, and adhesive properties. They also influence pulp processing through chemical processes.

Results of the variance analysis showed that the stem section significantly affected the benzene ethanol extractive content. The variance analysis of benzene ethanol extractive content is presented in **Table 1**.

Table 1. Results of the variance analysis of ethanol-benzene extractive content

Analysis of variance	Degrees of freedom	Sum of squares	Means square	F-calc	F-table	
					5%	1%
Treatment	2	11.37	5.68	18.46*	9.55	30.82
Error	3	0.92	0.31			
Total	5	12.29	5.99			

Notes: nse = no significant effect; * significant effect.

The results of the analysis of variance in **Table 1** indicate that the stem position of bintangur wood has a significant effect on the ethanol-benzene-soluble extractives content at the 5% level. This can be seen from the calculated F-value of 18.46, which is greater than the F-table value at the 5% level (9.55) and smaller than the F-table value at the 1% level (30.82). Furthermore, to determine the treatment that influences the levels of benzene ethanol extractives, a further test was carried out using honestly significant difference (HSD) (**Fig. 2**). The results of the HSD test show that the base to the middle part is significantly different, and the base to the top part is significantly different. In contrast, the middle to the top part is very significantly different.

3.2. Holocellulose Content

All carbohydrates in wood are known as holocellulose, which is the primary component of wood. Holocellulose is a combination of cellulose (40–45%) and hemicellulose (15–25%). Holocellulose in wood is generally 65–70% by dry weight (Purwita et al., 2020). A high holocellulose content indicates a high pulp yield from the wood cooking process. The distribution of holocellulose in bintangur wood,

including the base, middle, and tips, tends to increase. The highest holocellulose content is found at the tops. The analysis data are presented in **Fig. 3**.

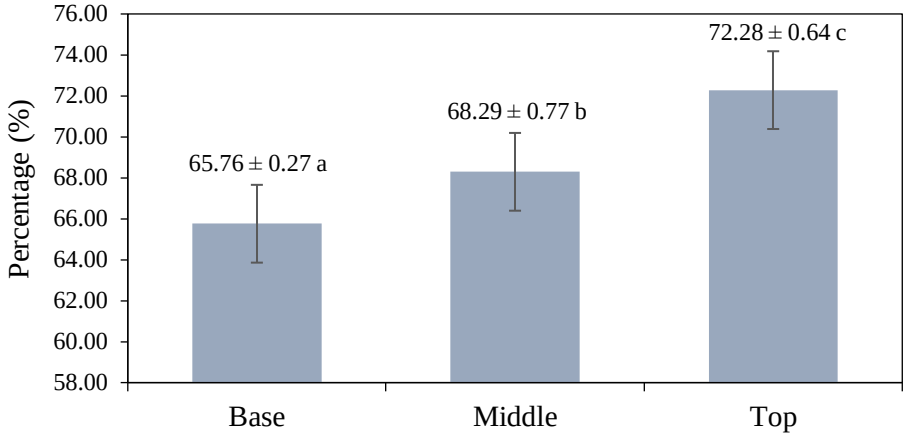

Fig. 3. Results of analysis of holocellulose content in bintangur wood.

The distribution of holocellulose is higher at the tips than at the base or middle. This is because the chemical composition of wood varies not only between different wood species but also within the wood of a single tree. Holocellulose levels in wood can vary from top to bottom. This is due to differences in the development of wood cells from top to bottom, which are typically related to variations in the age and maturity of the wood cells within the tree. Variations in chemical components from the base to the tip of the tree result in holocellulose levels ranging from 40% to 80% (Hou et al., 2016).

The results of this study align with those of Hermawan et al. (2014), who reported that the distribution of holocellulose in oil palm trunks, both axially and radially, tends to decrease. The tips of trees are typically younger and more actively growing, thus containing more cellulose still in the developmental stage. Meanwhile, at the base of the tree, the wood tends to be older and has grown more. Wood cells in this area have undergone thickening of their cell walls over time and lignin accumulation, resulting in a relatively lower holocellulose content than in the tree tips.

The high holocellulose content is generally due to its composition of cellulose and hemicellulose (Ramawat and Ahuja, 2016). The increase in holocellulose content at the base is due to the low alpha-cellulose content in this area and the high hemicellulose content. Palasing et al. (2021) stated that the hemicellulose content decreases from the base to the tip. Based on wood property requirements for pulp raw materials (Park et al., 2017), bintangur wood is considered good as a pulp raw material with a holocellulose content of more than 60%. Holocellulose is a combination of cellulose (40–45%) and hemicellulose (15–25%).

The analysis of variance indicates that the stem section has a highly significant effect on holocellulose content. The analysis of variance for holocellulose content is shown in **Table 2**.

Table 2. Results of the variance analysis of holocellulose content

Analysis of variance	Degrees of freedom	Sum of squares	Means square	F-calc	F-table	
					5%	1%
Treatment	2	16.69	8.34	59.55**	9.55	30.82
Error	3	0.42	0.14			
Total	5					

Notes: nse = no significant effect; * significant effect.

The results of the analysis of variance in **Table 2** indicate that the stem position of bintangur wood has a highly significant effect at the 1% level on the holocellulose content. This can be seen from the calculated F-value of 59.55, which is greater than the F-table value both at the 5% level (9.55) and smaller than the F-table value at the 1% level (30.82). Furthermore, to determine the treatment that affects the holocellulose content, a further test was carried out using honestly significant difference (HSD) (**Fig. 3**). The results of the HSD test show that the base to the middle part is significantly different,

and the base to the top part is very significantly different. In contrast, the middle to the top part is very significantly different.

3.3. Alpha-Cellulose Content

The distribution of cellulose content in bintangur wood is highest at the top, middle, and base, with the highest alpha-cellulose content at the top (49.61%). The results of the alpha-cellulose content calculation are shown in **Fig. 4**. The increase in alpha-cellulose content in the tops may occur in response to various environmental and growth factors. Several factors that can influence the increase in alpha-cellulose content in plant tops include cell maturation. Generally, tops contain younger, less differentiated cells than older plant parts. Younger cells tend to have thinner cell walls and a higher cellulose content. As cells grow and develop, their walls can become air-filled with cellulose, leading to an increase in alpha-cellulose content. In wood, alpha-cellulose content varies not only with the wood species but also with the wood's position within the tree. According to the Directorate General of Forestry (1976), the alpha-cellulose content of bintangur wood is categorized as high (> 45%).

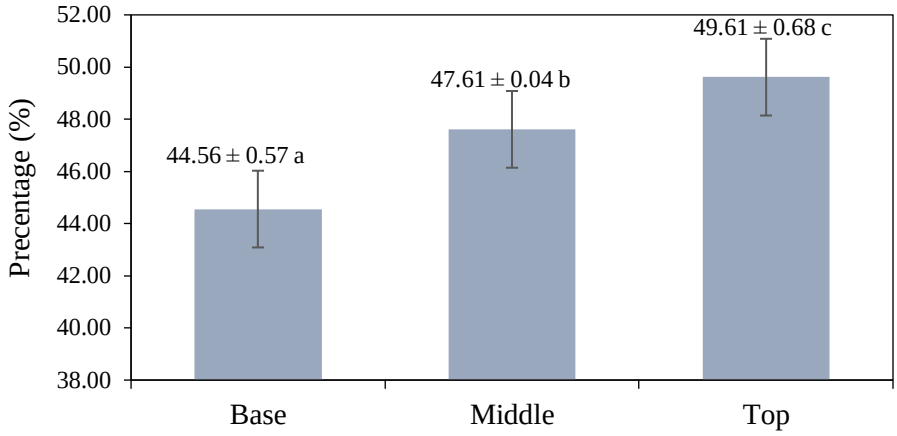

Fig. 4. Results of analysis of alpha-cellulose content in bintangur wood.

Galiwango et al. (2019) stated that alpha-cellulose content is generally determined by tree species and primarily by the isolation and determination method. Cellulose purity is expressed as the percentage of alpha-cellulose. The higher the cellulose content, the better the quality of the material, even if it is not pure cellulose (Marinho, 2025). Alpha-cellulose content is required for the manufacture of Whatman filter paper, which is sourced from cellulose of high purity (Sunardia et al., 2019). According to Mangurai and Munadian (2024), cellulose content in wood can be used to estimate pulp yield during pulping. The higher the cellulose content, the higher the pulp yield.

In pulping processes, particularly chemical pulping, cellulose is the main remaining chemical component found in the fibers. Therefore, cellulose is a key determinant of pulp and paper properties, particularly the final fiber strength, fiber bonding, and sheet characteristics. Przybysz et al. (2016) suggested that the mechanical properties of pulp or paper sheets are determined by the fiber bonds and hydrogen bonds (OH groups) in cellulose, which interact with each other or with O-, N-, and S groups. Based on research results, bintangur wood has great potential as a raw material for pulp and paper, due to its α-cellulose content exceeding 34% (Istikowatia et al., 2022), and as a potential raw material for bioethanol (Yanti et al., 2018; 2019).

The results of the variance analysis showed that the stem section significantly affected the alpha-cellulose content. The analysis of variance for alpha cellulose content is presented in **Table 3**. The results of the analysis of variance in **Table 3** show that the stem position of bintangur wood has a highly significant effect on the alpha-cellulose content at the 1% level. This can be seen from the calculated F-value of 49.26, which is greater than the F-table value both at the 5% level (9.55) and smaller than the F-table value at the 1% level (30.82). Furthermore, to determine the treatment that affects the alpha-cellulose content, a further test was carried out using honestly significant difference (HSD) (**Fig. 4**). The results of the HSD test show that the base to the middle part is significantly different, and the base to the top part is very significantly different. In contrast, the middle to the top part is significantly different.

Table 3. Results of the variance analysis of alpha-cellulose content

Analysis of variance	Degrees of freedom	Sum of squares	Means square	F-calc	F-table	
					5%	1%
Treatment	2	8.56	4.28	49.26**	9.55	30.82
Error	3	0.26	0.09			
Total	5					

Notes: nse = no significant effect; * significant effect.

3.4. Hemicellulose Content

Theoretically, the difference between the holocellulose and alpha-cellulose content is referred to as the hemicellulose content. Hemicellulose is a low-molecular-weight polysaccharide found in cell walls. Hemicellulose differs from cellulose in that it has shorter, more branched molecular chains. The highest hemicellulose content in sengon wood is distributed across the base, middle, and top sections (**Fig. 5**).

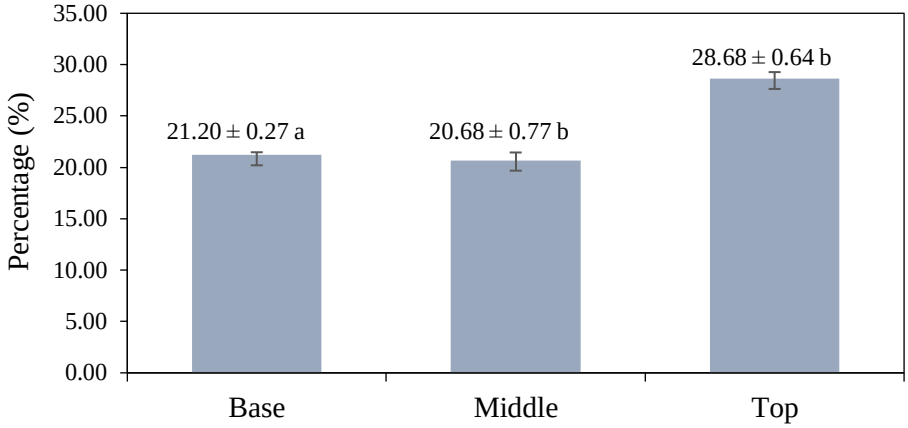

Fig. 5. Results of analysis of hemicellulose content in bintangur wood.

The results of the study showed that the hemicellulose content at the top had a relatively higher value compared to the middle and base of the bintangur tree trunk (**Fig. 5**). The variation in the tendency of hemicellulose content in wood is often relatively small and not the same for each type of hemicellulose. As is known, wood hemicellulose is composed of several types of hemicellulose, such as galactoglumannan and arabinoglucuronoxylan in coniferous wood, or glucuronoxylan, glucomannan in broadleaf wood. In the use of wood fiber for papermaking, hemicellulose serves as a natural adhesive in pulp and paper, enhancing fiber bonding and increasing paper strength. The higher the hemicellulose value, the better the bond between fibers (Han et al., 2023). The results of the variance analysis showed that the stem section significantly affected the hemicellulose content. The analysis of variance for alpha cellulose content is presented in **Table 4**.

Table 4. Results of variance analysis of hemicellulose content

Analysis of variance	Degrees of freedom	Sum of squares	Means square	F-calc	F-table	
					5%	1%
Treatment	2	35.09	17.55	133.11**	9.55	30.82
Error	3	0.40	0.13			
Total	5					

Description: nse = no significant effect; * significant effect.

The results of the analysis of variance in **Table 4** indicate that the stem position of bintangur wood has a highly significant effect on hemicellulose content at the 1% level. This can be seen from the calculated F-value of 133.11, which is greater than the F-table value both at the 5% level (9.55) and smaller than the F-table value at the 1% level (30.82). Furthermore, to determine which treatment affects hemicellulose content, a post hoc test using honestly significant difference (HSD) was carried out (**Fig.**

5). There is a significant difference between the base and the middle and the top, while there is no significant difference between the middle and the top.

3.5. Lignin Content

Lignin is another chemical component that makes up the cell wall. Lignin polyaromatic compounds are found in abundance in the middle lamella of the cell wall, which functions as a fiber adhesive and provides strength to the tree trunk. Lignin can be isolated using a 75% sulfuric acid solution and is readily oxidized (Ponomarenko et al., 2015). The lignin content analysis results range from 25.47% to 28.84% (**Fig. 6**).

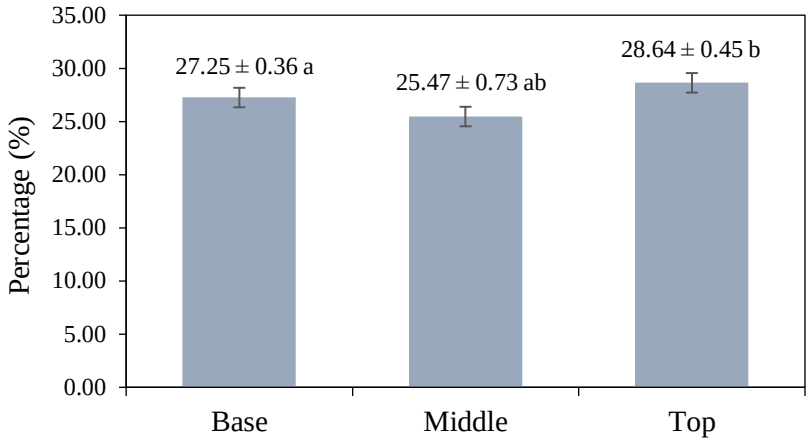

Fig. 6. Results of analysis of lignin content in bintangur wood.

The high lignin content in the wood tops is attributed to the higher proportion of earlywood, which generally contains more lignin and less cellulose than latewood (Carteni et al., 2018). When the analysis results are linked to the chemical component classification of Indonesian broadleaf wood, the lignin content of bintangur wood falls into the moderate lignin content category (> 18–33%), making bintangur wood suitable for pulp and paper production because pulp production requires a low lignin content. High lignin content can make milling difficult, resulting in stiff, yellow, and low-quality paper. Lignin can also be utilized as a raw material for vanillin production in the food industry, and phenol is produced for various industrial applications when hydrogenated under high pressure and temperature (Ciriminna et al., 2019). Bintangur wood can also be used as a construction material, such as laminated boards, composite boards, and particleboard. This is because the lignin content of bintangur wood is classified as medium (Kaliky et al., 2020).

Lignin compounds are closely related to cellulose, which functions to provide strength to cells because lignin is a compound that makes up wood cell walls or lignocellulosic fibers. Lignin and cellulose in wood are found in each cell wall layer and between cells within the cell wall (Uraki and Koda, 2015; Zhang et al., 2022). The results of this study align with those of Kristy et al. (2022), who reported that the lignin content in jelutung wood is generally classified as moderate, with variations from base to tip ranging from 11.33% to 28.00%. The lignin content is high at the tips, suggesting that the tips contain more early wood. High lignin levels are undesirable in paper pulp processing because they increase the need for cooking chemicals, thereby making the process less economical. Lignin must be removed to facilitate the decomposition of wood cells. The variance analysis showed that the stem section significantly affected lignin content. The analysis of variance for lignin content is presented in **Table 5**.

The results of the analysis of variance in **Table 5** indicate that the stem position of bintangur wood significantly affects lignin content at the 5% level. This can be seen from the calculated F-value of 17.33, which is greater than the F-table value at the 5% level (9.55) and smaller than the F-table value at the 1% level (30.82). Furthermore, to determine which treatment affects the alpha-cellulose content, a post hoc test using honestly significant difference (HSD) was carried out (**Fig. 6**). The base-to-middle and base-to-top parts are very significantly different. In contrast, the middle to the tip part is significantly different.

Table 5. Results of the variance analysis of lignin content

Analysis of variance	Degrees of Freedom	Sum of Squares	Means Square	F-calc	F-table	
					5%	1%
Treatment	2	4.21	2.11	17.33*	9.55	30.82
Error	3	0.36	0.12			
Total	5					

Notes: nse = no significant effect; * significant effect.

3.6. Potential Uses

Cellulose is the main component and reinforcing material in wood, while hemicellulose acts as a binding matrix. The utilization or use of wood is closely related to its main chemical components, namely cellulose, hemicellulose, lignin, and extractive substances. The relative proportions of these chemical components lead to specific applications, both in the form of processed wood and in industrial products. High levels of holocellulose (alpha-cellulose and hemicellulose) indicate potential applications for the pulp and paper industry, bioethanol production, and other chemical products. The hydrolysis of this carbohydrate component can yield various products, including molasses, acetic acid, and furfural, which are used as polishing agents or industrial chemicals (Hastuti et al., 2017).

Lignin is a complex polymer that acts as an adhesive or binder between cellulose and hemicellulose, providing structural strength and rigidity to wood. High lignin content is used as an adhesive, fuel or raw material for charcoal production (energy wood), in aromatic chemicals used in various modern chemical industries, as a raw material for vanillin production for the food industry, various industrial purposes, and construction materials (laminate, composite, and particleboard) (Hastuti et al., 2017).

Extractive substances are non-structural organic compounds (such as tannins, resins, oils, dyes) that give wood its distinctive properties, including color, aroma, and natural durability. The potential use of bintangur wood which has high extractive substances is used as a natural preservative because it provides natural resistance to fungal and insect attacks so that it can be used as a construction material and raw material for shipping, and is also used as a special chemical product where these extractive substances can produce essential oils, natural dyes, or medicinal ingredients (Zalsabila y et al., 2024).

4. Conclusion

This study demonstrates clear axial variation in the chemical composition of bintangur wood, indicating its potential for diversified industrial applications. Holocellulose and alpha-cellulose content increase markedly from the base toward the top of the stem, supporting its suitability for pulp and paper production, bioethanol feedstock, and other cellulose-based bioproducts. In contrast, extractive content peaks in the middle portion of the stem, indicating potential utilization for natural preservatives, essential oils, dyes, and marine or structural timber. The moderate lignin fraction further supports its application in charcoal production, adhesives, aromatic chemicals, composite boards, and vanillin synthesis. Overall, the chemical profile of bintangur wood confirms its promise as a renewable raw material for wood-based industries and emerging biorefinery systems.

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