Comparison of Wood Veneer-Based Composite Characteristics Made of Jabon Wood (*Neolamarckia cadamba*) and Sengon Wood (*Falcataria moluccana*)

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The shift of wood raw material sources from natural forests to community forests opens opportunities for West Java Province Indonesia as a source of wood raw materials because it has a large area of community forests. One type of plant grown in community forests is the jabon tree (*Neolamarckia cadamba*). This study will investigate whether jabon wood can be utilized as raw material for wood composite, such as laminated veneer lumber (LVL), laminated veneer board (LVB), and plywood, from the aspect of physical and mechanical characteristics, such as moisture content, density, bending strength, hardness, delamination, and formaldehyde emission. Another will find out the economic consideration of jabon compared with sengon wood. Results showed that based on the physical, mechanical, delamination, and formaldehyde emission characteristics, the tested jabon wood can be used as a raw material for wood veneer-based composite with better characteristics compared to sengon wood. However, the availability of jabon wood is lower than sengon wood and the price of jabon wood was higher than sengon wood. These factors may limit jabon utilization.

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Keyword: Jabon; Sengon; Mechanical characteristics; Physical characteristics; Raw material; Wood composite

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INTRODUCTION

Indonesia is one of the leading producers of composite wood, boasting a significant industry. According to data from the Central Statistics Agency (BPS), composite wood production reached 1.4 million cubic meters in 2021. Given this high figure, it is essential to source wood without relying on natural forests, as this would harm the environment (Wali and Soamole 2015). In the early 2000s, there was a shift in the source of raw materials for composite wood from natural forests to community forests (Susetyo 2021). This phenomenon of shifting the source of wood materials from natural forests to community forests in Indonesia has opened opportunities for the West Java province, which has an area of private forests reaching 600 hectares, to serve as a source of wood raw materials. This can certainly become a source of income for the community in West Java province.

There are two types of wood species that can be cultivated, namely Jabon (*Neolamarckia cadamba*) and Sengon (*Falcataria moluccana*) (Krisnawati *et al.* 2011; Ismail *et al.* 2015). Both are fast-growing species that can be harvested when they reach an age of 5 years (Iwanaga and Masuda 2013; Dirgantara 2019). The distinguishing factor between the two is their utilization. Sengon wood is now commonly used by the wood veneer-based composite industry as a raw material because of their huge potential number. In contrast, the utilization of jabon wood remains unclear. Previous study on the utilization of jabon wood for glue laminated wood was reported by Lestari ASRD *et al.* (2018), while studies on the utilization of sengon wood for LVL was reported by Setyowati *et al.* (2013) and Basuki *et al.* (2015). Sengon for plywood was reported by Rizky T *et al.* (2022). Considering its potential, it is unfortunate if jabon wood is not extensively utilized, especially for LVL and LVB, as a composite raw material that can provide income for society. This article will discuss the potential of jabon wood as a raw material for composite wood, especially in LVL and LVB panels. Such usage can be an alternative to the current usage in plywood. Sengon wood is commonly used in plywood due to its favorable characteristics. The objective of this study was to investigate the characteristics of LVL, LVB, and plywood composite panels made of jabon wood, to identify the best composite panels made of jabon wood, and to investigate the limitations of the jabon wood utilization considering the economic factor.

Wood veneer-based composite is a wood panel composed of layers of veneers. Some examples of wood panels included in composite wood are laminated veneer lumber (LVL), laminated veneer board (LVB), and plywood. The LVL is a composite wood product made of layers of veneers glued together with the wood fibers aligned. This orientation increases its adhesion strength and flexural strength, making it suitable for structural applications. The LVB is like LVL, but it has a unique design where the direction of the veneer in the middle layer crosses the length of the panel. This modification aims to improve dimensional stability, especially in the width direction, while maintaining structural integrity (Alamsyah *et al.* 2023), while plywood is a panel consisting of veneers orientation perpendicular in each layer.

LVB, as a modified product of LVL, still needs development because research on LVL products is more advanced than LVB products. Several studies on LVL have been carried out for a long time starting from aspects of wood raw materials, aspects of types of wood adhesives, LVL design and manufacturing and analyzing its physical and mechanical characteristics (Arabi *et al.* 2024; Liu *et al.* 2022; Zhang *et al.* 2022; Esen *et al*. 2022).

EXPERIMENTAL

Manufacture of Wood Composite

In this study, the manufacturing process of wood composite (LVL, LVB, and plywood) and some testing procedures used the procedure previously conducted by Alamsyah *et al.* (2024). The wood used in this study came from Cibugel Village, District Sumedang, West Java Province, Indonesia. The age of the jabon wood and sengon wood used was 10 years. Tests on aspects of composite wood characteristics from jabon wood or sengon wood were carried out by making wood of three types of wood composite, as follows: 1. Laminated Veneer Lumber (LVL); 2. Laminated Veneer Board (LVB), 3. plywood. The production of LVL, LVB, and plywood panels consisted of 9 layers of veneer with the thick of each veneer was 2.2 mm (Table 1 and Fig. 1). The final target of each panel's thickness was 18 mm. Panels were formed using phenol formaldehyde (PF) type 1 as adhesive with a weight of 250 g/m^2 assisted by a glue spreader machine. After that, the veneer was put into a cold press with a pressure of 8 kgf/cm^2 for 18 min, and then into a hot press at 110 °C with a pressure of 8 kgf/cm^3 for 15 min. The veneer arrangement is then called a panel. After that, the panel is trimmed to smooth the edges.

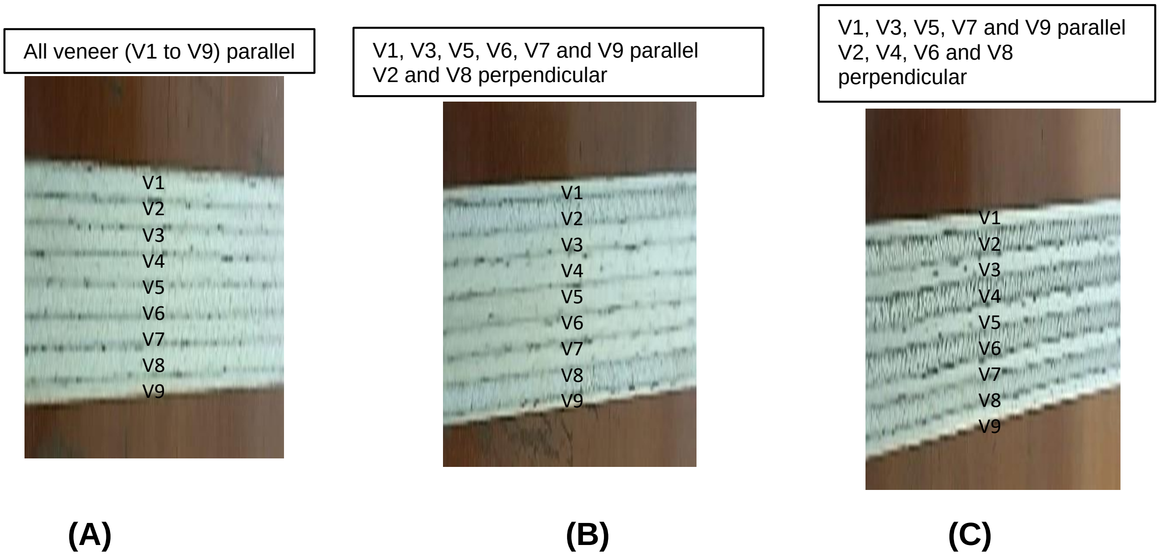


Fig. 1. Appearance of veneer direction of wood composite panels of LVL (A), LVB (B), and Plywood (C)

Table 1. Illustration of Veneer Fiber Directional Arrangement in Various Wood Composite Type

Wood Composite Type	Layer								
	1st	2nd	3th	4th	5th	6th	7th	8th	9th
LVL	//	//	//	//	//	//	//	//	//
LVB	//	⊥	//	//	//	//	//	⊥	//
Plywood	//	⊥	//	⊥	//	⊥	//	⊥	//

Note: // = parallel; ⊥ = perpendicular

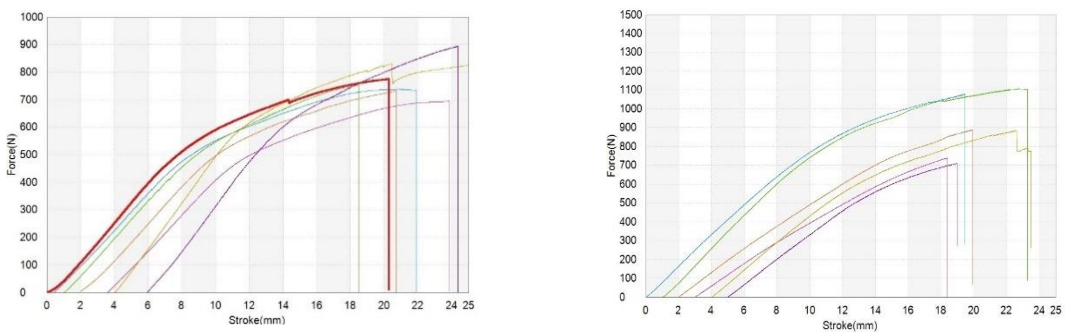
Testing

For simplified terms, jabon wood-based composite will be referred to as jabon wood composite and sengon wood-based composite will be referred to as sengon wood composite. Prior to testing, the boards were conditioned at a relative humidity (RH) of 65% and temperature of 25 °C for a week. The three types of wood composite were observed for their flexural strength modulus of elasticity (MOE) and modulus of rupture (MOR), shear strength and janka hardness test. To collect the MOE and MOR data, the flatwise bending test was carried out using UTM. The test is said to be complete when the sample is broken or has cracks (Fig 2).

(A) **(B)**

Fig. 2. Bending test apparatus UTM (A) and the appearance of sample after tested (B)

In the flat bending test, it was clear that the relationship between load (force) and deflection (stroke) was initially linear. As an example, an initially linear part can be seen in the relationship between load and deflection of each solid wood and plywood of jabon, as shown in Fig. 3.



(A) **(B)**

Fig. 3. Relationship between load and deflection in Jabon solid wood (A) and plywood (B)

In addition, the physical properties of the panels were tested for moisture content and density. Table 2 lists the test standards that were used.

Table 2. Physical and Mechanical Test Standard for Composite Wood Characteristics

No.	Parameter	Testing Standards	Sample Size
1	Moisture Content	JIS 701 (2008)	5 x 5 x 1.8 cm^3
2	Density	ASTM D2395 (1996)	5 x 5 x 1.8 cm^3
3	Bending strength (MOE/MOR)	JIS 701 (2008)	42 x 2 x 1.8 cm^3
4	Shear strength	JIS 701 (2008)	2 x 2 x 1.8 cm^3
5	Hardness	ASTM D143 (2003)	5 x 5 x 1.8 cm^3

The delamination test was conducted according to JIS 701 (2008) standard, sample size 24 x 7 x 1.8 cm^3. The sample was boiled at 100 °C for 4 h. Then, the sample was drained and put into the oven for 20 h at 60 °C. The sample was observed with the naked eye on the open adhesive part.

Formaldehyde emission test was conducted according to JIS A 1460 (2001), with a sample size of 15 x 5 x 1.8 cm^3. The sample was dipped in melted wax at the tip and then left until the wax hardened. The sample was then stored in a desiccator together with 20 mL of water for 24 h at a temperature of 20 °C. After 24 h, 10 mL of water was taken from the desiccator and put into an Erlenmeyer flask containing 10 mL of acetyl acetone ammonium acetate (A4) solution. The Erlenmeyer flask was then closed and put into hot water for 10 min. Then, the mixture was put into the spectrometer (UV 1800; Shimadzu, Tokyo, Japan).

Data Analysis

The test of each parameter and wood composite type was repeated three times. In addition to the three types of wood composite, tests were also carried out on solid wood from jabon wood and sengon wood. Wood characteristics testing was carried out using a universal testing machine (UTM; AG-IS 50Kn, Shimadzu, Tokyo, Japan). An analysis of variance (ANOVA) statistical analysis (SPSS; IBM Corp., 25.0.0.2, Armonk, NY, USA) was used to see the significance of differences in mechanical and physical properties between jabon and sengon wood.

RESULTS AND DISCUSSION

Wood Composite Characteristics

Physical properties

From the test, the characteristic values of wood composites made of jabon wood and sengon wood were obtained.

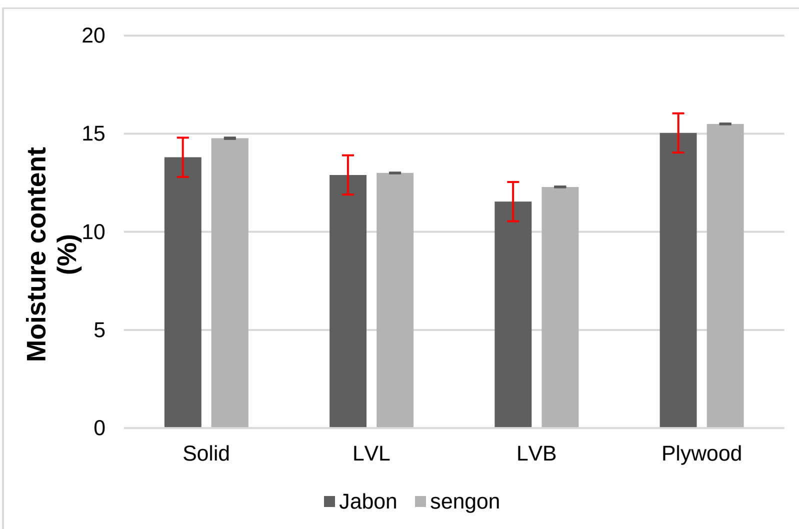


Fig. 4. Moisture content of solid and composite wood

The moisture content was not significantly different in LVL, LVB, and solid panels, while the plywood panel was significantly different with a significance value of 0. 001. This can happen because in the process of making wood panels, for LVL, LVB, and plywood there is a standardized hot press process, so that the results are relatively the same. The plywood panel has a higher moisture content value (Fig. 4). This can occur due to different conditioning processes. The plywood panel had a shorter conditioning time. The results of the statistical analysis test showed that the orientation of the veneer fibers was not significantly different from the percentage of moisture content of the panel board. Meanwhile, for each treatment, the results showed no significant difference in the percentage of moisture content of the panel boards. This is because the orientation of the veneer fibers has a more significant effect on the mechanical and structural properties of the wood panel. Research by Shukla and Kamdem (2008) shows that the physical properties of LVL panels made from two different hardwood species are influenced by the physical properties of the solid wood species but are not influenced by the fiber orientation of the panels made.

The moisture content test results were highly dependent on the drying or conditioning process of the panel, so the standard value could be achieved with a longer drying process. According to the JIS 701 (2008) standard, the moisture content of good wood composite is below 14%. Therefore, the moisture content test data is not representative of the wood composite manufacturing process. However, moisture content has a correlation with the density of wood, so moisture content testing is intended to determine the density value under certain moisture content conditions. For example, in solid wood, the density of wood is 0.32 g/cm^3 when the moisture content is 13.8% (Gartner and Meinzer 2005; Přívětivý and Samonil 2021). The varying moisture content values of panel board can be caused by varying initial moisture content of the veneer. The variation in moisture content values is thought to occur due to the influence of temperature and humidity around the veneer storage area. This is caused by the hygroscopic nature of wood, which can release and attract water content (moisture) in response to changes in temperature and humidity in the surrounding air (Bahanawan *et al.* 2020). In conditions of high air humidity during storage, wood veneer will absorb water content (moisture) from the surrounding environment. It is necessary to pay more attention to environmental conditions, especially humidity so that it does not have much influence on the moisture content.

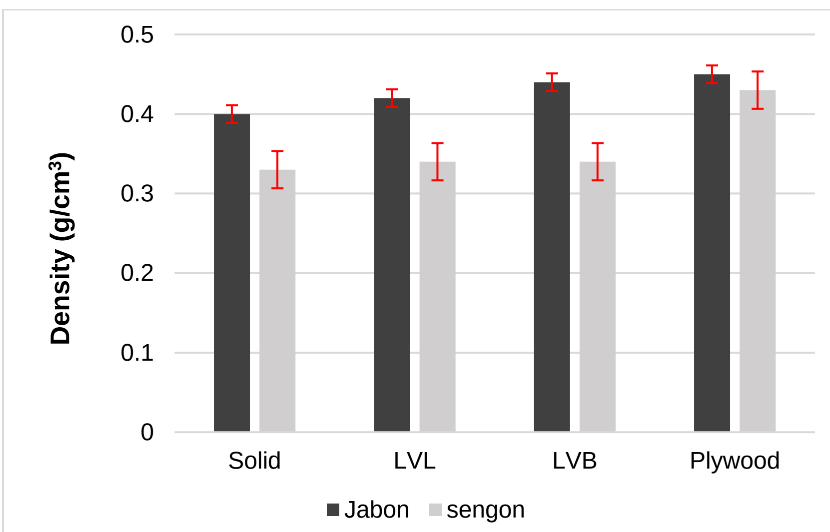


Fig. 5. Density of solid and composite wood

The density test results showed that jabon wood composites had a greater density than sengon wood composites. It can be seen in the solid panel that the density of jabon wood was higher compared to solid panel of sengon wood. When it had been processed into wood composites of LVL, LVB, and plywood, the density value of jabon wood composite panels became higher than that of sengon wood composites, as shown in Fig. 5.

The difference in density between jabon wood composite and sengon wood composite can occur because in its solid form, jabon wood tends to have a higher density than sengon wood (Richter and Dallwitz 2000). According to Ross (2010) there is a correlation between density and hardness. Wood with higher density tends to have better strength. Another reason is that sengon wood has higher moisture content compared to jabon wood. This may be a factor contributing to its lower strength compared to the jabon wood.

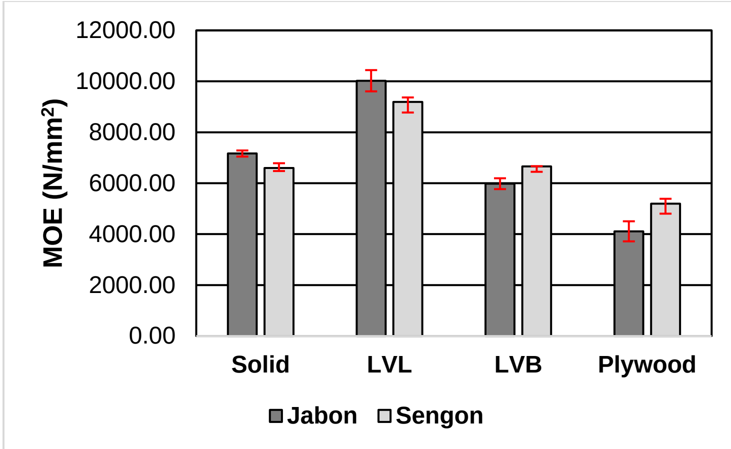
Processing jabon wood into wood composite panels increased the density of wood from 0.40 g/cm^3 to 0.42 g/cm^3 for LVL, 0.44 g/cm^3 for LVB, and 0.46 g/cm^3 for plywood. In the case of sengon wood, processing into composites resulted in increases from 0.33 g/cm^3 to 0.34 g/cm^3 for LVL, 0.34 g/cm^3 for LVB, and 0.43 g/cm^3 for plywood. This is because in the manufacturing process there is a compression process that can increase density. In contrast, the wood composite manufacturing process requires glue. The addition of glue to the veneer increases the mass of the wood so that the density increases (Luan *et al.* 2021).

Tenorio *et al.* (2011) showed an increase in the density value after becoming an artificial board with a density value for LVL of 0.523 g/cm^3 and for plywood (LVB) of 0.516 g/cm^3. The increase in the density value of the panel board was influenced by the presence of an adhesive layer that fills the empty cavities and compaction occurs when pressing the panel board (Supriadi *et al.* 2020). Using the same raw materials and the same manufacturing conditions, the difference in fiber orientation of LVL and LVB panels was not significantly different in terms of density values. The factors that influence the value of wood density include the type of wood (wood density), the amount of compression pressure during the compression process, the number of constituent layers, adhesive content, and other additional materials (Kelly 1977).

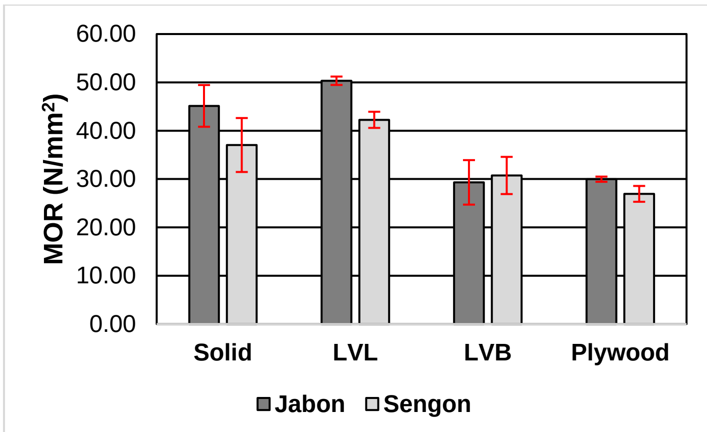
Mechanical Properties

From the test results (Fig. 6), jabon wood had higher values in solid wood and LVL types. Statistically, the difference in MOE value in LVL between jabon wood and sengon wood was significantly different, while in LVB and plywood types, sengon wood had a better value. From the statistical test results, it can be said that sengon wood had a significantly better value in LVB and plywood compared to the jabon wood. This can happen because in the cases of LVB and plywood there are cross-oriented veneers. This shows that in cross orientation sengon wood has better bending strength than jabon. The explanation behind this phenomenon is still unexplained, but it is possible that the tangential bending strength of sengon wood is better than jabon wood.

Basically, one of the factors affecting the MOE and MOR values of solid wood is its fiber length (Thumm and Dickson 2013; Madyan *et al.* 2020). The fibers jabon wood are longer than those of sengon wood. Jabon wood has a fiber length of 1980 µm, while sengon wood is 1500 µm (Richter and Dallwitz 2000). Additionally, the percentage of cellulose affects its strength. The more cellulose in the cell wall, the stronger the mechanical characteristics will be (Xi 2018; Augustina *et al.* 2021). According to Latib *et al.* (2014) the holocellulose content of jabon wood ranges from 83% while according to Ramadhan *et al.* (2018) the holocellulose content of sengon wood is 77%. This may explain why the elastic strength of jabon wood is better than that of sengon wood.



(A)



(B)

Fig. 6. MOE test results (A) and MOR test results (B)

In general, when comparisons were made on the type of wood panel alone, the MOE and MOR values of LVL panels were higher than the corresponding values for LVB and plywood. This is because the orientation of the veneer preparation also affects the MOE and MOR values. The longitudinal direction of the wood fibers is the longitudinal direction of the wood. This fiber orientation direction is the strongest wood orientation direction compared to the widened/tangential fiber orientation direction (Lundmark and Olsson 2015; Arriaga *et al.* 2023). The longitudinal direction can be represented by long-cut veneers (parallel veneers), while the widened or tangential direction is represented by the cross-cut veneers. This causes LVL to have higher MOE and MOR test values compared to LVB and plywood. (Sun *et al.* 2022). This is because LVL panel has 9 veneers with long-cut direction while LVB has only 7 long-cut veneers and plywood has only 5 long-cut veneer.

The results of mechanical properties testing showed that LVL manufacturing increases MOE and MOR values while LVB and plywood manufacturing decreases MOE and MOR values compared to solid wood. This is due to the different veneer fiber direction between the three.

From the test results (Fig.7), the average shear strength value of the LVL, LVB, and plywood panels was better than the shear strength of solid wood in both jabon and sengon. The LVL panel had a higher shear strength compared to LVB and plywood for both jabon and sengon. The difference in value between LVL and LVB can be attributed to the parallel strength of the fiber direction having better strength compared to the perpendicular one. In LVL, all veneers are parallel, while in LVB there are two veneers arranged perpendicularly so that the bonding value is smaller (Cristescu 2006).

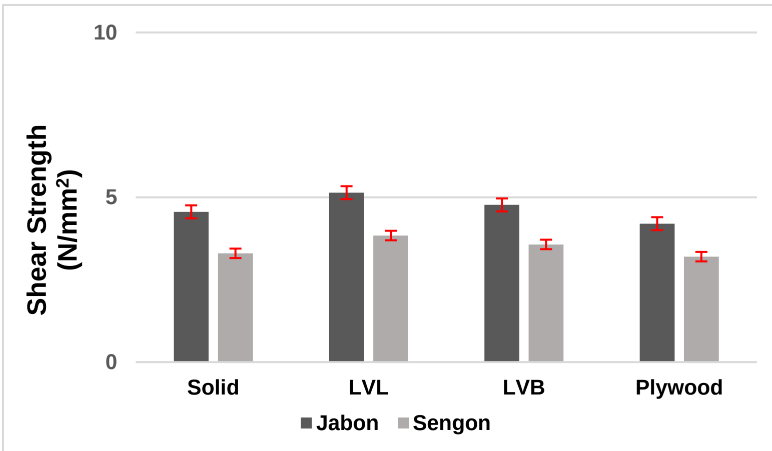


Fig. 7. Shear strength of solid and composite wood

From the hardness test results (Fig. 8), jabon wood exhibited a higher value than sengon wood in all four panel types. This is because jabon wood has more crystalline content (29.0%) compared to sengon wood (24%) so the hardness is higher (Prihatini *et al.* 2020; Rahayu *et al.* 2021). According to research by Li *et al.* (2021), one of the factors that affects the hardness of wood is its crystallinity or the amount of crystalline area in the wood. The higher the crystalline area, the better the mechanical strength of the wood. In addition, jabon wood also had a higher density according to the results of the density test (Fig. 2), making it harder than sengon wood. When viewed from its chemical composition, the hardness of a type of wood can be influenced by the amount of lignin (Xi 2018).

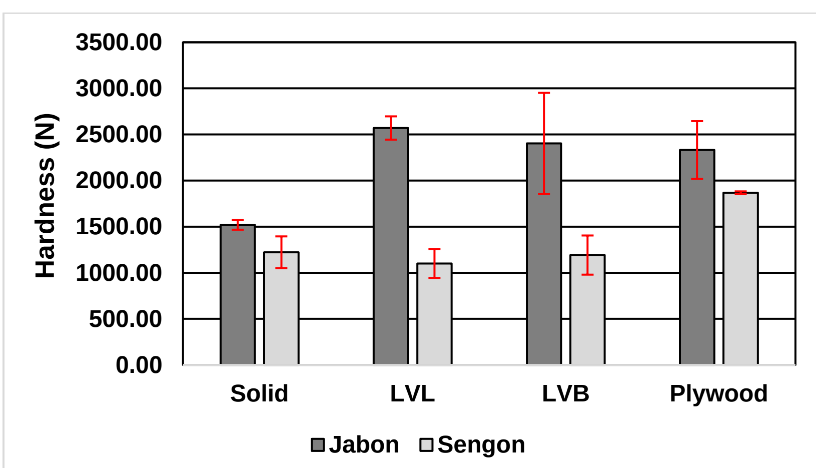


Fig. 8. Hardness of solid and composite wood

Delamination

The results of the delamination percentage test on the jabon wood composites and sengon wood composites panels are in Fig. 9. In jabon wood, all composites were 0% delamination and passed the standard. In sengon wood, LVB and plywood were 0% delamination and LVL was 3% delaminated, but overall, they passed the standard. Delamination in this panel board sample could be caused by the adhesive curing process in the middle of the veneer layer being difficult to achieve. Based on the JIS 701 (2008) standard for LVL panels, the standard percentage of passing the test was < 10%, so that all composites made of jabon and sengon passed the delamination test. According to Ekawati 1968, factors that influence the delamination value of artificial boards include the shear plane, type of adhesive, and their interactions. Delamination in this panel board sample could be caused by the adhesive curing process in the middle of the veneer layer being difficult to achieve due to the large number of layers, resulting in less than optimal interaction between the adhesive and the veneer surface (Iskandar and Supriadi 2017).

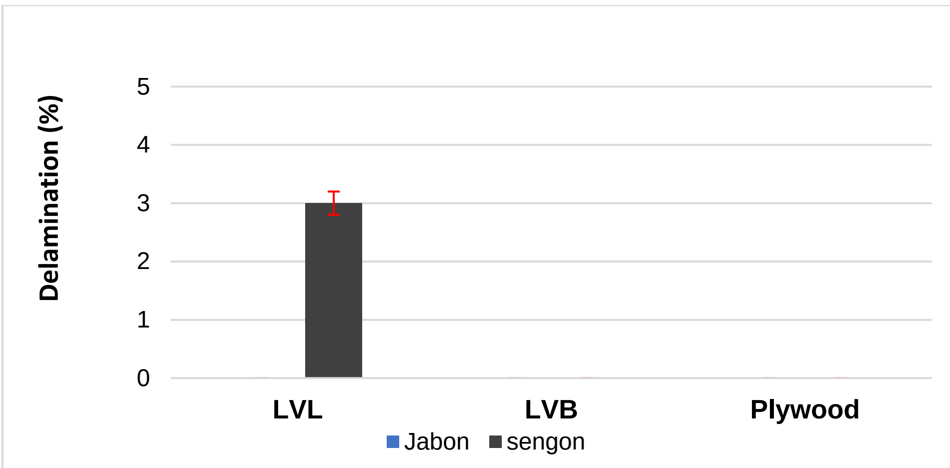


Fig. 9. Percentage of delamination of composite wood

Formaldehyde Emissions

The formaldehyde emission test results from the wood composite panels are in Fig. 10. Based on the test results, it was found that all wood composites made of jabon and sengon wood were classified in the F**** classification.

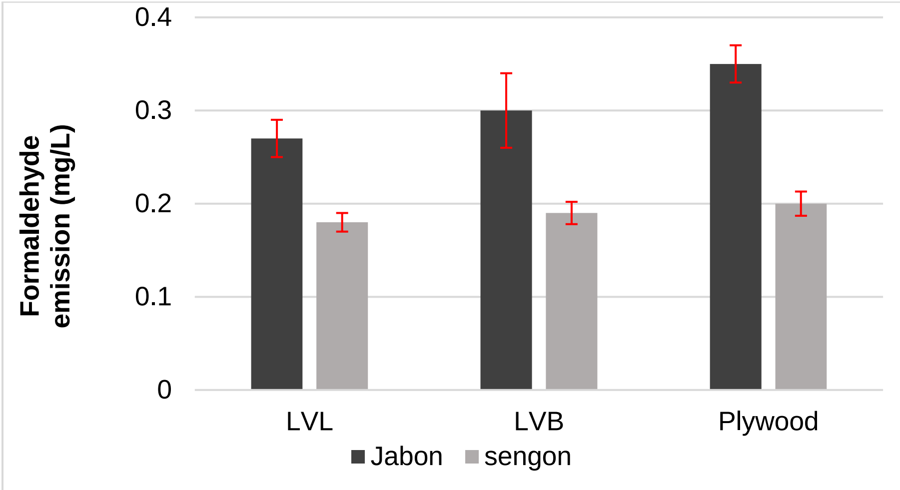


Fig. 10. Formaldehyde emission of composite wood

The results obtained were in accordance with the JIS A 1460 (2001) standard for LVL with the average and maximum values, respectively, of 0.3 mg/L and 0.4 mg/L, so that all wood composite panels were classed as safe to use. This good formaldehyde emission test result was obtained because the type of adhesive used in making wood panels uses phenol formaldehyde (PF) adhesive, which has a low formaldehyde emission level (Liang *et al*. 2021).

Based on statistical tests, the orientation of the fibers in the panel board is not significantly different from the amount of formaldehyde emissions.

Economic Consideration

The price of wood to produce the wood composite panels become one of the interest aspects to know more.

Table 3. Price of Wood to Produce One Cubic Meter of Output

Description	Jabon	Sengon
Price of Jabon wood per m^3 (logs)	Rp 550,000.00	Rp 400,000.00
Rendemen (%)	47%	43%
Need (%)	100%	100%
The price of wood (logs) per-m^3 needs to be made into composite wood	Rp 1,170,212.77	Rp 930,232.56

Source: Abdullah A,F (2024)

Table 3 shows that the cost of jabon wood raw materials to produce one cubic meter of composite wood is around 1.1 million rupiahs. The cost of raw materials for sengon wood to produce 1 cubic meter of wood panels is 930 thousand rupiahs. It is clear that jabon wood is more expensive compared to sengon wood that was became one of limitation factors in the jabon wood utilization.

Data from the Central Statistics Agency (2021) shows that the production of jabon tool wood is 2,901 m^3 while the production of sengon tool wood is 42,000 m^3. This shows that the availability of jabon wood is still very low compared to sengon wood, which has an impact on its price and potential use.

CONCLUSIONS

1. From the results of the physical, mechanical, delamination, and formaldehyde emission tests, jabon wood can be use as raw material for wood veneer-based composite with the better characteristics compare to the sengon wood.
2. Among wood composite types produced, jabon wood most recommended for laminated veneer lumber (LVL) production rather than laminated veneer board (LVB) and plywood.
3. From an economic consideration, jabon wood presently is more expensive compared to sengon wood, which is a limiting factor in its utilization.

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Conflict of Interest

The authors state no conflict of interest.

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