



Full Length Research Article

Physical and Mechanical Properties of Oriented Strand Board from Three Species of Plantation Forests at Various Resin Contents

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ABSTRACT

The objective of this study was to determine the physical and mechanical properties of oriented strand board (OSB) from three wood species of plantation forests, i.e., Afrika (*Maesopsis eminii*), mangium (*Acacia mangium*), and sengon (*Paraserianthes falcataria*) at various resin contents. OSB was made with a shelling ratio (face:core:back) of 1:2:1 and a target density of 0.6 g/cm³. Methylene diphenyl di-isocyanate (MDI) adhesive was used with 3%, 5%, and 7% resin contents. The physical and mechanical properties were evaluated based on JIS A 5908:2003 standard and the values were compared with CSA 0437.0 (Grade O-1) standard. The results show that the physical and mechanical properties of the OSB were improved as the resin content increased for all wood species. OSB prepared from Afrika and mangium wood strands with 7% resin content showed better physical and mechanical properties than the other OSBs. Thickness swelling of OSB prepared from three wood species had met the CSA 0437.0 (Grade O-1) standard. All OSBs produced in this experiment met the standard for MOR parallel and perpendicular to the grain. OSB from three wood species with a 5% and 7% resin content met the standard for MOE perpendicular to the grain. Only mangium OSB with a resin content of 7% met the standards for MOE parallel to the grain. Afrika OSB with 5% and 7% resin content, mangium OSB with 5% resin content, and sengon OSB with 3% and 7% resin content met the standard for the internal bond.

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1. Introduction

The productivity of natural forests in Indonesia is currently declining. According to the [Ministry of Environmental and Forestry \(2021\)](#), natural forest wood production in 2018 was 7.02 million m³ and in 2019 decreased to 6.39 million m³. Increasing the development of plantation forests can be a solution to meet the supply of wood raw materials through the Timber Utilization License in Plantation Forest (IUPHHK-HT) ([Kusumaningrum 2015](#)). [Statistics Indonesia \(2020a\)](#)

reported that the number of IUPHHK-HT companies reached up to 42.97% (318 companies) of the total forestry companies in Indonesia. [Ministry of Environmental and Forestry \(2021\)](#) also reported that timber production in plantation forests in Indonesia is 39.4 million m³ and tends to increase due to high public interest in plantation forest development. According to the analysis conducted by [Benyamin et al. \(2019\)](#), the target for total timber production in plantation forests is estimated to reach 269.05 million m³ by 2045.

Wood species planted in plantation forests dominated by Afrika (*Maesopsis eminii*), mangium (*Acacia mangium*), sengon (*Paraserianthes falcataria*) woods. According to [Statistics Indonesia \(2020b\)](#), mangium and sengon woods are the first and third-largest total production in 2019, 32.69 million m³ and 5.47 million m³, respectively. Meanwhile, there is no information about the national production of Afrika wood in Indonesia. However, [Ismail et al. \(2015\)](#) reported that Afrika wood production in Majalengka Regency, West Java reached 1,352 m³ per month. These three wood species belong to fast-growing species. Fast-growing wood species have the characteristics of small diameter, low quality, and contain many juvenile woods, resulting in low wood yield ([Cahyono et al. 2017](#); [Suri et al. 2021](#)). Afrika wood has a specific gravity of 0.37 ([Kim et al. 2012, 2014](#)), strength class of IV ([Karlinasari et al. 2021](#)), and durability class of IV ([Febrianto et al. 2015](#)). Mangium wood has a specific gravity of 0.46-0.52, strength class of III ([Somadona et al. 2020](#)), and durability class of IV ([Febrianto et al. 2015a](#)). Sengon wood has an average specific gravity of 0.29 ([Bahanawan et al. 2020](#)), strength class of IV-V, and durability class of IV-V ([Febrianto et al. 2013](#)). These characteristics indicate that these three wood species are unsuitable when used as solid wood. These three wood species are commonly used for non-structural purposes and have low added value ([Marwanto et al. 2018](#)).

One of the alternatives to increase their efficiency and improve their added value is to use them as raw material for composite boards such as oriented strand board. Oriented strand board (OSB) is a structural composite board made of long, thin, and wide strands whose layers are arranged or oriented perpendicularly and bonded with a waterproof adhesive through hot pressing and pressure ([APA 2017](#)). OSB can be used for various structural applications, including floor coverings, underfloor cladding, roof cladding, wall cladding, and exterior siding ([Febrianto et al. 2017](#)). OSB can be a more efficient substitute for plywood because it can utilize fast-growing wood, small diameter wood, low-quality wood, and defective wood with low economic value ([Aisyah et al. 2021](#); [Febrianto et al. 2010](#); [Hidayat et al. 2011](#); [Iswanto et al. 2010](#)). Afrika, mangium, and sengon wood meet these criteria for making OSB.

OSB quality can be influenced by several factors, including pre-treatment, strand quality, strand size, particle orientation, layer structure, moisture content, board density, density profile ([Febrianto et al. 2017](#); [Maulana et al. 2019a](#)), adhesive type, resin content ([Lubis et al. 2020](#)), and wood species ([Maulana et al. 2019b](#)). Wood species with high density can improve the quality of OSB ([Dumitrascu et al. 2020](#); [Hidayat et al. 2013](#); [Lunguleasa et al. 2021](#)). Variations in the density of raw materials affect the quality and consumption of adhesives in OSB ([Febrianto et al. 2015b](#)). Due to their availability, high prospect, and a wide variety of specific gravity, it is necessary to study the effect of resin content on the physical and mechanical properties of OSB of three fast-growing wood species.

2. Materials and Methods

2.1. Strand Preparation

Afrika (*Maesopsis eminii*), mangium (*Acacia mangium*), and sengon (*Paraserianthes falcataria*) logs from Bogor, West Java, were converted into tangential boards with a length of 120-140 cm and a width of 18-23 cm. The boards were then cut to a length of 7 cm to produce strands. Strands were made using a disk flaker with a length of about 7 cm, a width of 2.5 cm, and a thickness between 0.06-0.08 cm. Strands were air-dried and then oven-dried at a temperature of 60°C for approximately seven days until they reached a moisture content of less than 10%.

2.2. Oriented Strand Board Manufacturing

The oriented strand board (OSB) was made by mixing strands with MDI adhesive with 3%, 5%, and 7% resin content using a rotating drum blender and spray gun. The board size (length × width × thickness) was 30 × 30 × 0.9 cm³ and the target density was 0.6 g/cm³. The layer ratio of face, core, and back was 1:2:1. Strands were then hot pressed with a pressure of 2.45 MPa and a temperature of 170°C for 7 minutes. After hot-pressed, OSBs were conditioned by stacked indoors for 14 days at room temperature and relative humidity of 60% to release residual stresses and reach equilibrium moisture content.

2.3. Testing Procedures

The parameters for testing the physical and mechanical properties of OSB refer to the standard JIS A 5908:2003 (JSA 2003). The physical properties tested included density, water absorption, and thickness swelling. Meanwhile, the mechanical properties tested were modulus of elasticity, modulus of rupture, internal bond, and screw holding power. The physical and mechanical properties test results were compared to the commercial OSB standard CSA 0437.0 (Grade O-1) (SBA 2005). The physical and mechanical testing methods are described briefly below.

2.3.1. Density

Standardized OSB samples were measured in an air-dried state to obtain its volume (V_a). The samples were then weighed to obtain air-dried weight (W_a). The density (D) value of the sample was calculated by dividing the W_a with V_a .

2.3.2. Water absorption

Standardized OSB samples were weighed (W_1) and then immersed in water for 24 h. After that, the samples were drained and weighed again (W_2). The water absorption (WA) value of the sample was calculated by dividing the sample weigh gain ($W_2 - W_1$) with the initial weight (W_1) and times by 100%.

2.3.3. Thickness swelling

Standardized OSB samples were measured for their average thickness (T_1) and then immersed for 24 h. After immersing, samples were drained, and the average thickness was measured again (T_2). The thickness swelling (TS) value of the sample was calculated by dividing

the additional thickness of OSB after immersion test (T_2-T_1) with the initial thickness of OSB (T_1) and times 100%.

2.3.4. Modulus of elasticity

Standardized OSB samples in both parallel and perpendicular to the grain directions were used in the modulus of elasticity (MOE) measurement. The test was carried out using Universal Testing Machine (UTM, Instron, United States) with a load speed of 10 mm/min and a span length of 15 cm. The MOE value of the sample was calculated according to the standard JIS A 5908:2003 (JSA 2003).

2.3.5. Modulus of rupture

Standardized OSB samples were used for the modulus of rupture (MOR) testing. The test was carried similar to the MOE measurement. The loading was continued until the sample reached the maximum load (P). The MOR value of the sample was calculated according to the standard JIS A 5908:2003 (JSA 2003).

2.3.6. Internal bonding strength

Standardized OSB samples were glued to two wooden blocks with epoxy adhesive and allowed to dry for 24 h. The two blocks are pulled perpendicular to the surface of the sample at a load speed of 2 mm/min until the maximum load. The internal bonding (IB) strength of the sample was calculated according to the standard JIS A 5908:2003 (JSA 2003).

2.3.7. Screw holding power

The screws of 2.7 mm in diameter and 16 mm long were inserted standardized OSB samples were until 8 mm depth. The screw holding power (SHP) value is expressed by the maximum load achieved in kg.

2.4. Data Analysis

The data analysis used a factorial completely randomized design with two factors, including wood species (Afrika, mangium, and sengon woods) and resin content (3%, 5%, and 7%). The analysis of variance was tested at a 95% confidence interval. Then Duncan's multiple range test was carried out to determine the significantly different levels. All data analyses were carried out using IBM SPSS Statistics 22 Software.

3. Results and Discussion

3.1. Density

The density of the OSB from three wood species ranged from 0.56 to 0.64 g/cm³ (Fig. 1). The highest density (0.64 g/cm³) was found in mangium OSB with 7% resin content, and the lowest density (0.56 g/cm³) was found in sengon OSB with 3% resin content. Afrika OSB with 3% resin content and sengon OSB with 3% and 5% resin content did not meet the target density. The same phenomenon also happened in previous studies due to the presence of spring back effects as an effort to relieve pressure during conditioning so that the desired final thickness of the board

before testing did not match the target density (Adrin et al. 2013; Bufalino et al. 2012). Analysis of variance showed that only the wood species significantly affect OSB density. Duncan’s multiple range test results showed that the mangium and sengon wood species had significantly different values at each level. The density of the board is highly dependent on the density of the material used (Febrianto et al. 2017; Kartika et al. 2013). The specific gravity of sengon wood is lower than Afrika and mangium woods. It caused the sengon OSB to have a slightly lower density, followed by Afrika and mangium OSB. The higher the wood specific gravity, the higher the density of the resulting board. Moreover, the difference between the board density can be caused by the uneven distribution of strands (Febrianto et al. 2017).

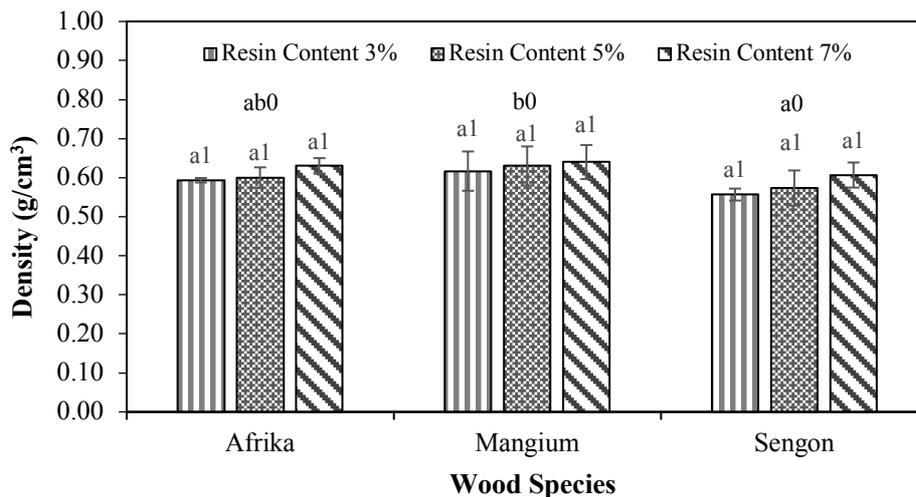


Fig. 1. Density of OSB from three wood species at various resin contents (different letters showed a significant difference; 0: wood species, 1: resin content).

3.2. Water Absorption

The value of 24 h water absorption (WA) of OSB from three wood species ranged from 29.66–101.29% (Fig. 2). The highest WA value (101.29%) was achieved in sengon OSB with 3% resin content, and the lowest (29.66%) was shown in mangium OSB with 7% resin content. Analysis of variance showed that the interaction of wood species and resin content had a significant difference in WA.

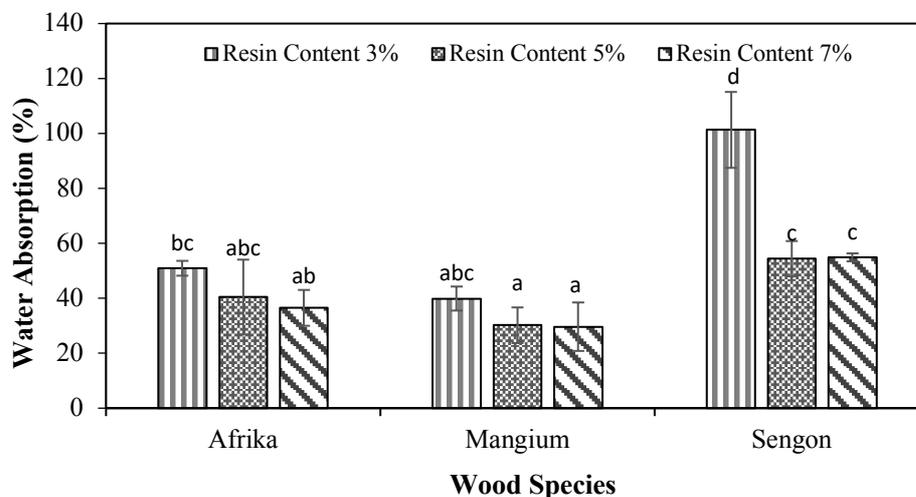


Fig. 2. Water absorption of OSB from three wood species at various resin contents (different letters showed a significant difference).

Duncan's multiple range test results showed that each level of resin content on Afrika and mangium OSB resulted in no significant difference on WA. However, sengon OSB with 3% resin content was significantly different from 5% and 7% resin contents. The results of this study are in accordance with previous studies that increased resin content decreased the WA value (Febrianto et al. 2015b; Hariz et al. 2021; Maulana et al. 2019a). It might be due to the adhesive behavior that fills the space on the OSB (Barbuta et al. 2011). The WA value of sengon OSB was the highest, followed by Afrika and mangium OSB. Because sengon wood has a low specific gravity, where the cell cavity is large, it quickly absorbs water. According to Barbuta et al. (2011) and Febrianto et al. (2017), WA increased because the water was easier to enter and fill voids and wood cell walls on boards with low resin content. The higher wood specific gravity, the lower value of WA. The higher the resin content, the lower the value of WA. It was probably due to the hydrophobic nature of the MDI adhesive that prevents the water from penetrating the board (Adrin et al. 2013).

3.3. Thickness Swelling

The value of 24 h thickness swelling (TS) of OSB from three wood species ranged from 11.39–44.33% (Fig. 3). The highest TS value (44.33%) was achieved in sengon OSB with 3% resin content, and the lowest (11.39%) was shown in Afrika OSB with 7% resin content. The TS value of Afrika OSB with 5% and 7% resin content and mangium OSB with 7% resin content met the CSA 0437.0 (Grade O-1) standard. Analysis of variance showed that the interaction of wood species and resin content had a significant difference in TS. Duncan's multiple range test results showed that mangium OSB had a TS value that did not differ at each level of resin content. The TS value of Afrika OSB with 3% resin content was significantly different with 5% and 7% resin content. Meanwhile, the TS value of sengon OSB was significantly different at each level. The results of this study were in accordance with previous studies, showing the increase of resin content resulted in a decrease in TS values (Febrianto et al. 2015; Hariz et al. 2021; Maulana et al. 2019b). The TS value in all OSB decreased as the resin content increased. It might be due to the adhesive being evenly distributed on the particles to stick to each other in the pressing process (Barbuta et al. 2011; Febrianto et al. 2017). The TS value is also related to the WA value. It is supported by Adrin et al. (2013), stating that the high value of TS in OSB can be influenced by WA and the density of the solid wood.

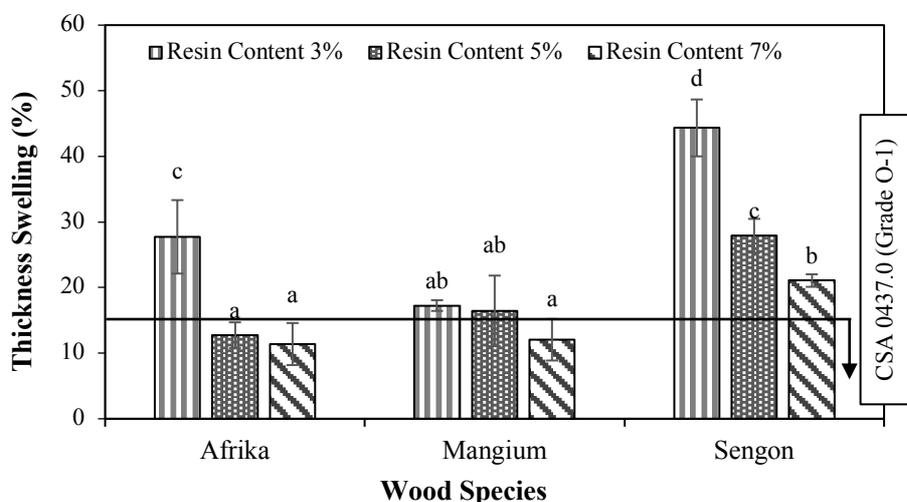


Fig. 3. Thickness swelling of OSB from three wood species at various resin contents (different letters showed a significant difference).

3.4. Modulus of Elasticity

The modulus of elasticity (MOE) parallel to grain ranged from 1909–5555 MPa (**Fig. 4**), and the MOE perpendicular to grain ranged from 1135–1731 MPa (**Fig. 5**). The highest MOE parallel to grain value was shown in mangium OSB with 5% resin content, and the lowest was exhibited in sengon OSB with 3% resin content. In addition, the highest MOE perpendicular to the grain was shown in Afrika OSB with 7% resin content, and the lowest was achieved in Afrika OSB with 3% resin content.

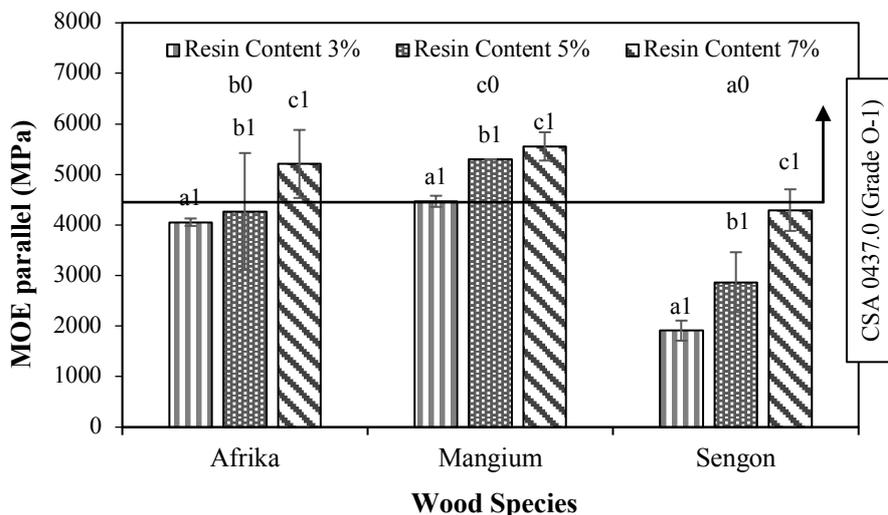


Fig. 4. Modulus of elasticity parallel to the grain of OSB from three wood species at various resin contents (different letters showed a significant difference; 0: wood species, 1: resin content).

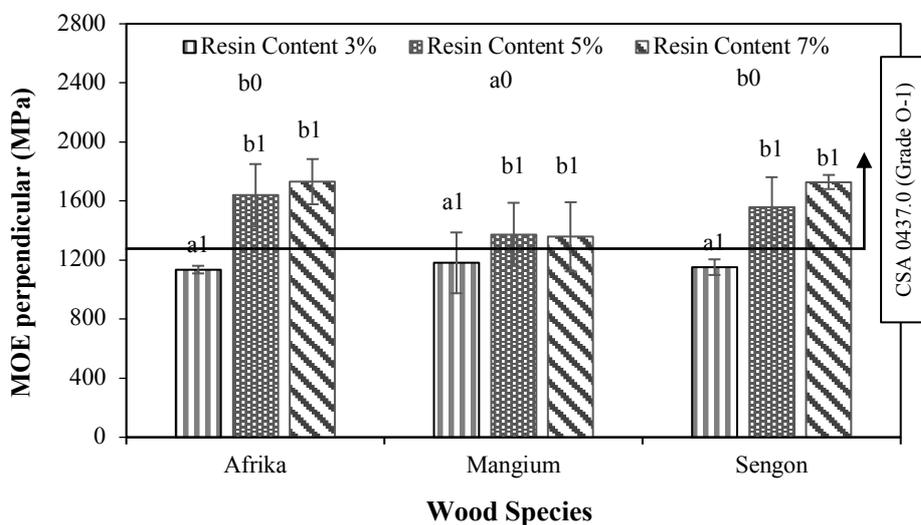


Fig. 5. Modulus of elasticity perpendicular to the grain of OSB from three wood species at various resin contents (different letters showed a significant difference; 0: wood species, 1: resin content).

Analysis of variance showed that the wood species and resin content significantly influenced MOE in parallel to grain and perpendicular to the grain. Duncan’s multiple range test results showed that the wood species and resin content had significantly different values to the MOE parallel to grain at each level. Afrika and sengon OSB have no significantly different values in the

MOE perpendicular to the grain. Only OSB with 3% resin content has a significant difference to the MOE perpendicular to the grain. In general, the MOE parallel and perpendicular to grain values in the three wood species tended to increase with increasing resin content. The higher the resin content used resulted in the higher the MOE value produced (Febrianto et al. 2015; Oh and Kim 2015; Sulastiningsih et al. 2017). Therefore, the MOE value parallel to grain tends to have higher values than MOE perpendicular to the grain. It is in accordance with Febrianto et al. (2009), stating that the MOE value parallel to the grain is higher than the MOE perpendicular to the grain. At the testing time, the face and back layers withstand the highest loads in the direction parallel to the sample length. Therefore, the MOE parallel to the grain in which the strand in the face and back layers arrangement is parallel to the sample length has a higher value than the MOE perpendicular to the grain. The MOE value can be influenced by several factors, namely density, wood species, strand orientation, strand quality, pressing procedure, strand dimensions, adhesive type and content, and moisture content (Abdurachman and Hadjib 2011; Valarelli et al. 2014; Widyorini 2014). Mangium OSB with 7% resin content met the CSA 0437.0 (Grade O-1) standard for the MOE parallel to the grain. The OSB of three wood species with 3% resin content did not meet the CSA 0437.0 (Grade O-1) standard for MOE perpendicular to the grain.

3.5. Modulus of Rupture

The modulus of rupture (MOR) parallel to the grain ranged from 30 to 47 MPa (Fig. 6), and the MOR perpendicular to the grain ranged from 17 to 31 MPa (Fig. 7). The highest MOR parallel to grain (47 MPa) was achieved in Afrika OSB with 7% resin content, and the lowest (30 MPa) was exhibited in sengon OSB with 3% resin content. Meanwhile, the highest MOR perpendicular to the grain (31 MPa) was achieved in sengon OSB with 7% resin content, and the lowest (17 MPa) was shown in Afrika OSB with 3% resin content. The MOR parallel and perpendicular to the grain of all OSBs met the CSA 0437.0 (Grade O-1) standard.

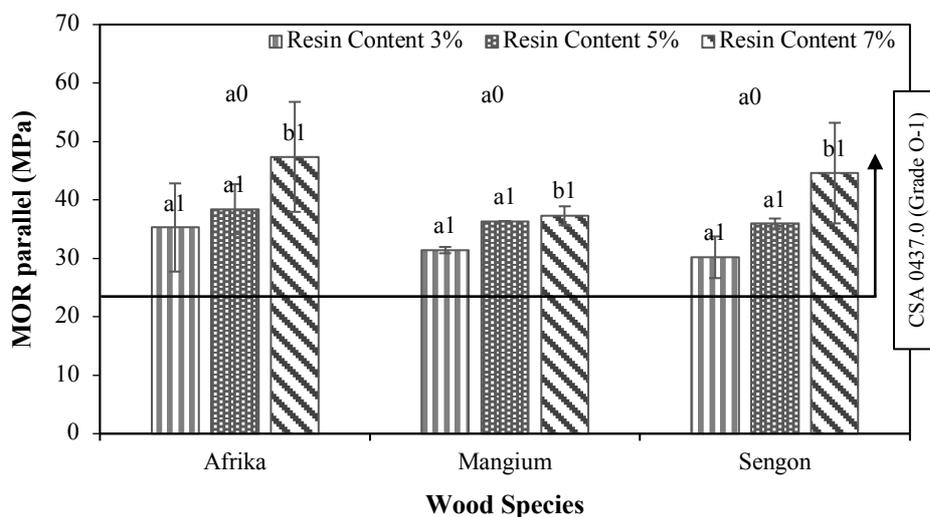


Fig. 6. Modulus of rupture parallel to the grain of OSB from three wood species at various resin contents (different letters showed a significant difference; 0: wood species, 1: resin content).

Analysis of variance showed that the interaction of wood species and resin content did not significantly affect the MOR parallel and perpendicular to the grain. The wood species factor only significantly affected the MOR perpendicular to the grain. The resin content factor significantly

affects the MOR parallel and perpendicular to the grain. Duncan’s multiple range test results showed that the 7% resin content factor had significantly different values for the MOR parallel to the grain. The 3% resin content factor significantly affected MOR perpendicular to the grain. The results showed that the resin content increased MOR value parallel and perpendicular to the grain. The higher the resin content resulted in higher MOR OSB value (Febrianto et al. 2015; Oh and Kim 2015; Sulastiningsih et al. 2017). The wood species factor affected the MOR perpendicular to the grain due to the differences in the voids in the board so that the MOR value perpendicular to the grain is high (Arifin et al. 2018).

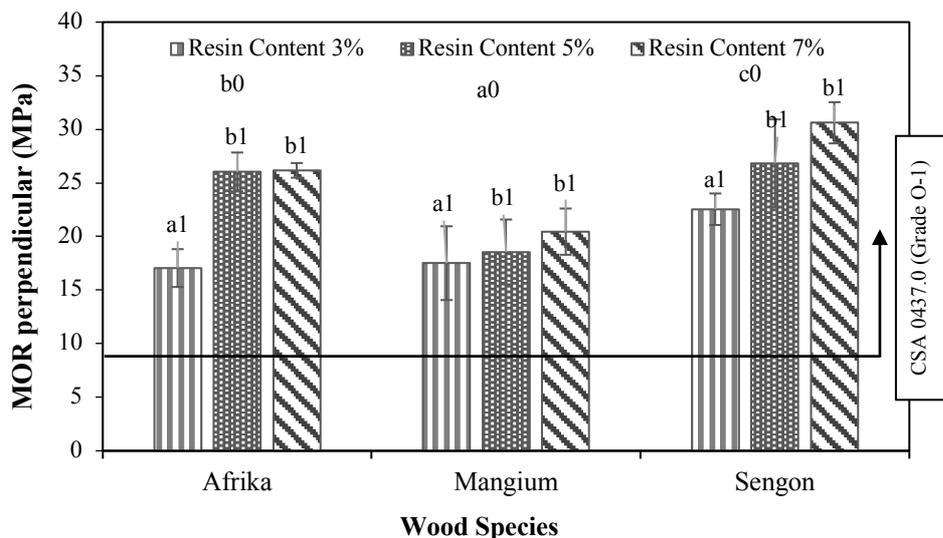


Fig. 7. Modulus of rupture perpendicular to the grain of OSB from three wood species at various resin content (different letters showed a significant difference; 0: wood species, 1: resin content).

3.6. Internal Bonding Strength

The internal bonding (IB) strength of OSB from three wood species ranged from 0.16 to 0.56 MPa (Fig. 8). The highest IB strength (0.58 MPa) was shown in sengon OSB with 7% resin content, and the lowest (0.16 MPa) was exhibited in mangium OSB with 3% resin content.

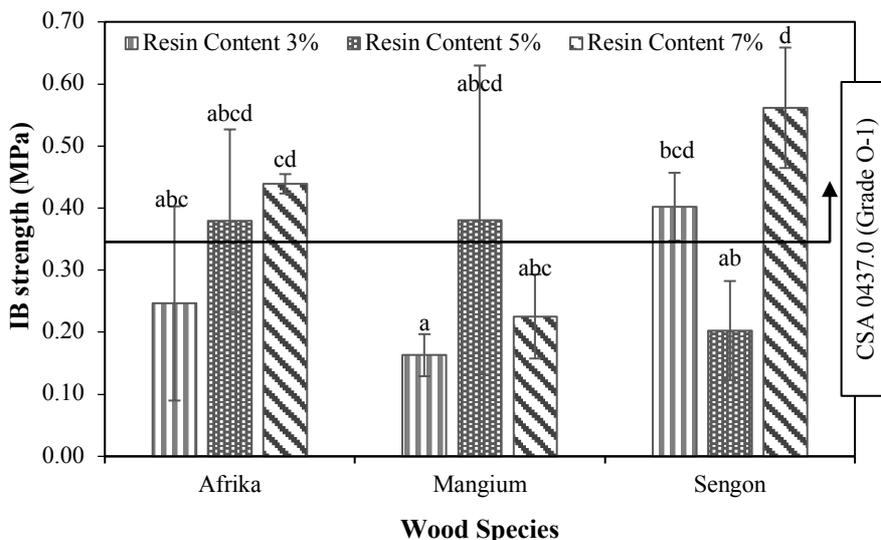


Fig. 8. Internal bonding strength of OSB from three wood species at various resin content (different letters showed a significant difference).

Analysis of variance showed that the interaction of wood species and resin content significantly affected the IB value. Duncan's multiple range test results showed that the Afrika and mangium OSB had no significant difference for each resin content. Meanwhile, the sengon OSB had a significant difference at 7% resin content. Resin content affects the IB value and an increase in resin content resulted in a higher IB value (Budi et al. 2018; Direske et al. 2017; Febrianto et al. 2015; Maulana et al. 2019a). However, the results of the study are not in accordance with the previous study. The IB value could be affected by wood species, wettability, slenderness ratio, board density, and resin content (Arabi et al. 2011; Widyorini et al. 2014). The difference in IB value in this study is presumably due to the difference in surface characteristics and wettability of each wood species (Darmawan et al. 2018, 2020). Afrika OSB with 3% resin content, mangium OSB with 3% and 7% resin content, and sengon OSB with 5% resin content did not meet CSA 0437.0 (Grade O-1) standards.

3.7. Screw Holding Power

The screw holding power (SHP) values ranged from 65 to 122 kg (Fig. 9). The highest SHP value (122 kg) was achieved in Afrika OSB with 5% resin content, and the lowest (65 kg) was shown in Afrika wood OSB with 3% resin content. Analysis of variance showed that the interaction between wood species and resin content significantly affected screw holding power. Duncan's multiple range test results showed that Afrika OSB wood had significantly different values for each resin content. Meanwhile, Afrika OSB with 3% resin content has a significantly different value. According to Rita et al. (2015), the SHP value is influenced by particle size or strand, wood species, and resin content used.

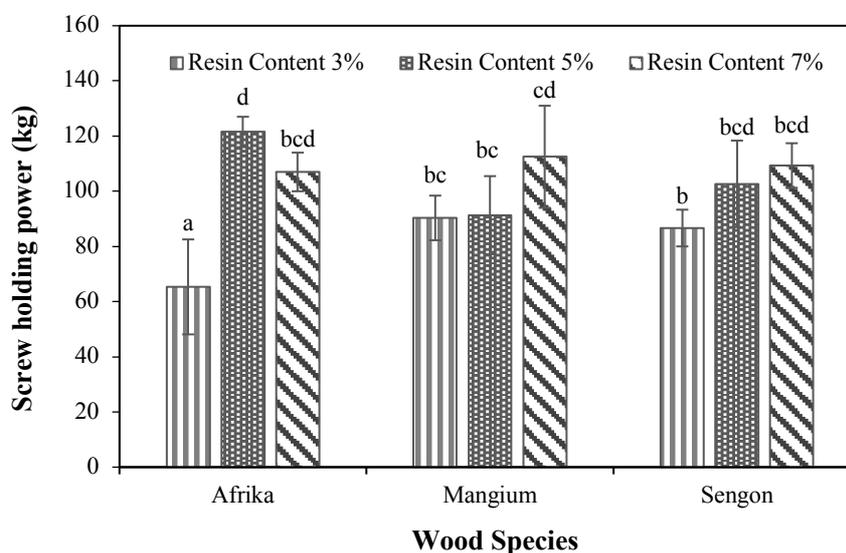


Fig. 9. Screw holding power of OSB from three wood species at various resin contents (different letters showed a significant difference).

4. Conclusions

Wood species and the resin content used in OSB manufacture affected the value of the physical and mechanical properties of OSB. Resin content improved the physical and mechanical properties of all OSBs. OSB from three wood species with 3% resin content could not meet the

CSA 0437.0 (Grade O-1) standard. Almost all parameters of physical and mechanical properties of OSB of the three wood species with 5% and 7% resin content met the CSA 0437.0 (Grade O-1) standard. The physical and mechanical properties of Afrika and Mangium OSB with 7% resin content were better than the other OSBs and could meet most of CSA 0437.0 (Grade O-1) standard parameters.

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