Relationship Between Wood Properties and Drying Qualities at Three Age Groups of Mindi (*Melia azedarah* L.) Tree for Furnitur Materials

Saefudin, Efrida Basri, and Rohmah Pari

Abstract

All wood based products should have been dried to ensure their stable dimension. Indicators of stable dimension can be figured-out from wood's physical properties, especially the ratio of tangential shrinkage to radial shrinkage (T/R ratio) and wood drying properties at high temperatures. From those two indicators could be predicted the drying quality of wood as basic to determine the minimum – maximum drying temperature. This research aimed to look-into the relationship between wood properties of wood and the drying quality of mindi (*Melia azedarach* L.) wood at their 5, 9, and 13 year-old trees. The preparation of test samples, and testing methods on wood's physical properties covered moisture content, air-dry density, and shrinkage in a tangential and radial direction, which referred to the BS 1957. Meanwhile, drying properties followed the modified Terazawa's method. Five classes of wood drying qualities could be derived from the analysis of the T/R ratio and drying property at each tree age group. Results revealed that wood density ranged from about 0.46 – 0.58 g/cm^3. The drying quality of each wood (except the portion near the pith) belongs to B (good) for 13 years old, C (fair) for 9 years, and D (poor) for 5 years old. Related to the drying quality, the minimum – maximum temperature for 13 years mindi wood was 55 – 85 °C; for 9 years was 50 – 80 °C; and for 5 years was 40 – 65 °C. Supported by the performance of wood surfaces, especially at 13 years old, mindi wood was suitable for wooden furniture.

Keywords: Density, T/R ratio, drying property, drying quality, minimum-maximum, temperature of drying.

Introduction

Local wood species which so far have been utilized as raw materials for furniture and crafting products comprise teak (*Tectona grandis*), mahoni (*Swietenia* sp.), pine (*Pinus merkusii*), trembesi (*Samania saman*), and sungkai (*Peronema canescen*). Unfortunately, since the pandemic outbreak, Indonesia's furniture manufactures have suffered from the lack of wood materials, thereby necessitating the imported wood, such as oak, walnut, cherry, pine, and yellow poplar from Europe in considerable quantity, reaching 20% of their needs to cope with the deficit of raw materials (HIMKI 2022).

Mindi (*Melia azedarach* L.) tree belongs to the family Meliaceae. In Indonesia, these trees grow well in Java, Bali, East Nusa Tenggara (Martawijaya *et al*. 2014). In natural forests mindi trees in height can reach 40 m with a diameter at breast height (dbh) of 185 cm (Martawijaya *et al*. 2014). In plantation forest, the growth of Mindi trees reaches 20-25 m high (including the canopy) or 8-20 m (as branch-free trunk) with the dbh's diameter of 60-80 (Dishut Jatim 2023). The Forest Products Research and Development Center reported that mindi wood belonged to class II as Fancy Commercial Trade Wood based on the criteria of consecutively wood beauty, specific gravity/density, and durability class (Djarwanto *et al*. 2017). The wood resembles oak wood, because its surface texture is relatively smooth and decoratively valued, the fibers are closely arranged, resistant to the termite and fungi attacks, the density is categorized as fairly compact. Referring to the SAW (Simple Additive Weighting) method, which is a method to identify wood species for furniture material based on wood properties, strength class, and texture, wood mindi was classified as the 3rd best for furniture materials, after teak and mahoni woods, with preference value at 0.84 (Novyanto and Nurraharjo 2022). Referring to those two references (Djarwanto *et al.* 2017; Novyanto and Nurraharjo 2022), this wood was proved suitable for furniture products.

Other factors that deserve consideration in wood processing for furniture products are the dryness of the wood (Basri *et al*. 2020). This is because it is related to the wood-dimensional stability in order not to undergo swelling-shrinkage when the wood has already been converted to finished products. Such dimensional instability could be recognized, especially from the ratio of tangential to radial shrinkage (R/T ratio) in wood (Yuniarti and Basri 2017; Basri and Saefudin 2021; Basri *et al*. 2021). The instability of wood dimensions is common in fast-growing wood species, where their portion of juvenile wood is still relatively high (Darmawan *et al.* 2015, 2018; Basri *et al.* 2021). Nevertheless, as the tree ages, the properties of the wood become superior, due to the larger portion of mature wood, higher wood strength, and low fibril angles (Basri and Wahyudi 2013; Barrios *et al.* 2017). Relevantly, this paper presents the relationship between wood properties of mindi (*Melia azedarah* L.) and wood-drying qualities at three wood age groups (5, 9, and 13 years) for furniture materials. The properties scrutinized in this research covered physical, drying properties, and performance of the wood to obtain the mindi wood that meets the requirements of SNI-01-0608 (2017) as furniture wood raw materials.

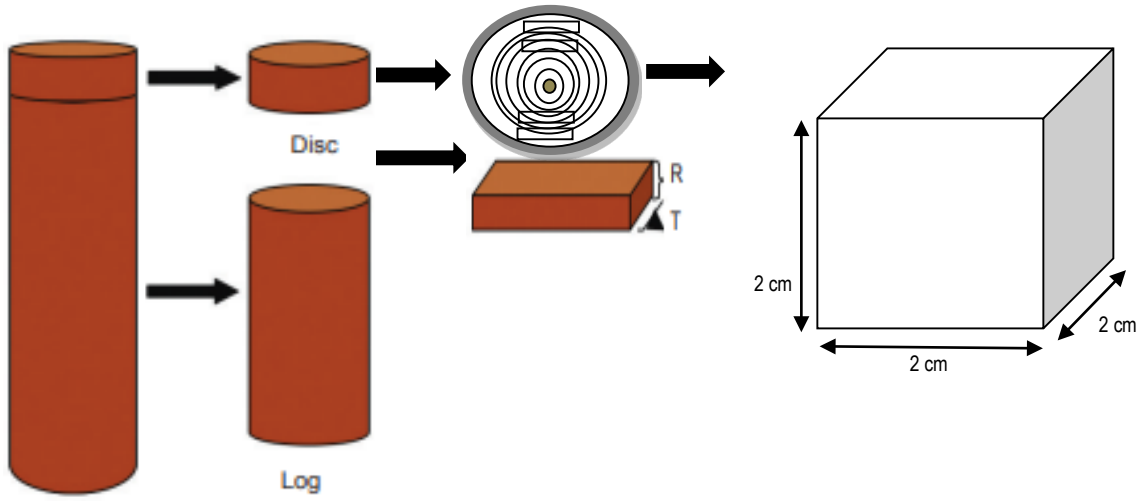

Figure 1. Sample preparation for physical and drying properties.

Materials and Methods

Sample Preparation

Three age groups of mindi wood (5, 9, and 13 years) were taken from the private forest in Kaliurang Regency (DI Yogyakarta, Indonesia). For each group, the studied were consecutively at nearing the pith, in the middle between the pith and bark, and nearing the bark. Furthermore, 5 cm thick wood discs were extracted from each tree at breast height for testing physical properties (i.e. green/initial moisture content, air-dry density, and wood shrinkages from green to air dry). The dimensions of each sample for physical properties testing are 2 cm (radial/thickness) by 2 cm (tangential/wide) by 2 cm (length). Meanwhile, the samples for examining drying properties were prepared on board sheet from also the breast-height stem (Figure 1), measuring 2 cm (radial) by 10 cm (tangential) by 20 cm (longitudinal).

Testing Mehods

Physical properties, namely green/initial moisture content, air-dry density, and wood shrinkages from green to air dry were measured according to British Standard 373 (1957). The measurement formula for calculate green moisture content (MC_g), air-dry density (ρ) and air-dry shrinkage (S_{ad}) are as follows:

$$MC_g\ (\%) = \frac{W_g - W_{od}}{W_{od}} \times 100 \qquad (1)$$

$$\rho\ (g/cm^3) = W_{ad} / V_{ad} \qquad (2)$$

$$S_{ad}\ (\%) = \frac{D_g - D_{ad}}{D_g} \times 100\% \qquad (3)$$

Where:

W_g = green weight (g)
W_{od} = oven-dry weight (g)
W_{ad} = air-dry weight (g)
B_{kt} = oven-dry weight (g) at temperature 103±2 °C
V_{ad} = air-dry volume (cm^3)
D_g = green dimension (in radial, or tangential) [cm]
D_{ad} = air-dry dimension (in radial, or tangential) [cm]

Preparing the sample and testing drying properties followed the Terazawa's method modified for young-aged wood (Basri *et al*. 2020). The drying properties of mindi woods were tested based on one or more than three types of the least severe drying defects or the worst defect that occurred in the samples. Based on kinds of defects and degree of wood damage, then the drying properties could be determined. A set of criteria were used to assess three types of defect. Size and number of defects taking place on the surface of the dried lumber were scored using a scaled set of values which ranged from 1 to 7 for initial checks as well as deformation, and from 1 to 6 for honeycomb defect. The lower of the values means the less of the defects while the higher of the values, the more severe the defects.

Drying qualities could be divided into 5 classes/grades, i.e. A (very good), B (good), C (fair), D (poor), and E (very poor). These classes were determined from the resulting analysis of variance (anova) of the T/R ratio and drying properties at three age groups of mindi wood. The anova used to assess the relationship of age groups with T/R ratio and drying properties was a completely randomized design (CRD), followed with the analysis of regression equation. Afterwards, the drying qualities could be grouped into grades (in such regression equation).

Further, based on wood drying quality could then be determined the minimum-maximum temperature which were allowed for each of the age groups (5, 9, and 13 year old), as follows:

- Quality A (grade 1), minimum-maximum temperature at 70- 95 °C.
- Quality B (grade 2), minimum-maximum temperature at 55- 85 °C.
- Quality C (grade 3), minimum-maximum temperature at 50- 80 °C.
- Quality D (grade 4), minimum-maximum temperature at 40- 65 °C.
- Quality E (grade 5), minimum-maximum temperature at 40- 50 °C.

Data Analysis

Data on the physical properties results of the mindi wood drying samples were studied with a completely randomized design with two factors. These factors were tree ages (A) i.e 5 year (a1), 9 year (a2), and 13 year (a3); and wood portions in transition from the pith to bark (B) i.e nearing the pith (b1), in the middle between the pith and bark (b2), and nearing the bark (b3). There were two replications (two trees) of each combination of factor and treatment. Furthermore, drying qualities, were also examined with a single factor with three replications for each tree ages i.e 5 year (a1), 9 year (a2), and 13 year (a3). The results were then examined by the honest significant difference test (HSD) / Tukey's test (Ott 1994). To examine the relation of tree ages with the physical and drying properties of the mindi wood. Regression analysis in the form of linear regression or quadratic regression equations were done using Statistical Analysis System (Parsad 2014).

Results and Discussion

The growth of mindi tree indigenous from Kaliurang (D.I. Yogyakarta) was regarded as slow. At 13 years old, the tree height until branch-free stems reached only 7-8 m, with diameter of only 33 cm. Compared to the growth of mindi tree at Cimahpar (Bogor, West Java Province) at 10 years, the branch-free stem could reach 10 m high with average diameter 38.2 cm (Rambey *et al*. 2018). Geographically, the growth location of mindi tree in Kaliurang allowed them to grow well, with respect to stem height and diameter. The location had a lot of potential water sources supported by high rainfall (16.35 mm/hh) than Bogor (15.66 mm/hh) and it was situated the slope of Mount Merapi. The slow growth of mindi tree at Kaliurang location could be due to lack of tree nurturing and care, such as thinning and pruning. This was reflected by the appearance of many knots and straight growth of stems upwards which has occurred only a few meters above soil surface. The best sylviculture techniques should be implemented to produce the best quality of wood (Susanto and Mashudi 2017; Rocha *et al.* 2019).

Physical Properties

At Table 1, it disclosed that mindi woods at radial section of their stem, the air-dry wood density tended to increase radially from the near pith wood portion to the near-bark portion. Also, the older the tree age, the greater would be the wood density. The density of mindi wood being investigated ranged about 0.42 – 0.58 g/cm^3, which belonged to fair. Concurrent with the increasing density, the T/R ratio decreased (Table 1). T/R ratio could assess the homogenity in wood shrinkage (in radial/tangential direction) and serve as indicator to determine the wood dimensional stability. The T/R values ≤ 1 indicate that the wood dimension is stable for indoor use, especially solid wood (Basri *et al.* 2015, Shmulsky and Jones 2019; Basri and Pari 2019), and therefore will not cause problems after being processed to finished products. This is because wood products with unstable dimension might undergo deformation, delamination at glued products, the bond failure between the components at the glue-jointed products, and even checking.

At 5 and 9 years old, the T/R value is still above 2, and the density difference between the inside and outside of the wood is quite large. This has caused the wood when being cut down underwent the so-called split-checking and proceeded until the drying process. This unfavorable situation could appear during the wood drying process, whereby the defects portruding conspiciously at 5 and 9 year old mindi wood (especially 5 years old) consisted mostly of end checking and deformation. These two defects indicate that at 9 years old mindi wood, the mature woods have not yet developed extensively, or the wood portions are made up of mostly juvenile wood. Referring to the related research results, it has found out that the development of mature woods has already commenced after the trees reach 10 – 15 years old (Cahyono *et al*. 2015; Darmawan *et al*. 2015, 2018; Basri and Saefudin 2021; Basri *et al*. 2021). Research results by Vidaurre *et al*. (2018) on *Schizolobium amazonicum* wood at 5 – 11 years old revealed that although the wood density and shrinkage (either in radial or tangential direction) from the bottom upward to the top parts of the stem appeared to be more compact and homogenous, but the wood strengths were still low. In these research results, it turned out that the 13 year old mindi woods afforded T/R ratio ≤ 2 and relatively homogenous density (except at the inside stem near the pith) (Table 1).

Table 1. Physical properties of mindi woods with respect to age groups, and with wood portion arranged in radial direction from near pith to near bark.

Age (years)	Physical property	Radial direction from pith to bark		
		Near pith	Middle	Near bark
5	Green moisture content (%)	62.6	60.5	58.2
	Air-dry density (g/cm^3)	0.42	0.46	0.51
	Ratio of wood shrinkage in tangential to radial direction	3.4	2.7	2.7
9	Green moisture content (%)	56.7	56.2	52.7
	Air-dry density (g/cm^3)	0.48	0.51	0.56
	Ratio of wood shrinkage in tangential to radial direction	2.7	2.4	2.2
13	Green moisture content (%)	52.0	50.4	45.8
	Air-dry density (g/cm^3)	0.49	0.56	0.58
	Ratio of wood shrinkage in tangential to radial direction	2.4	2.0	1.8

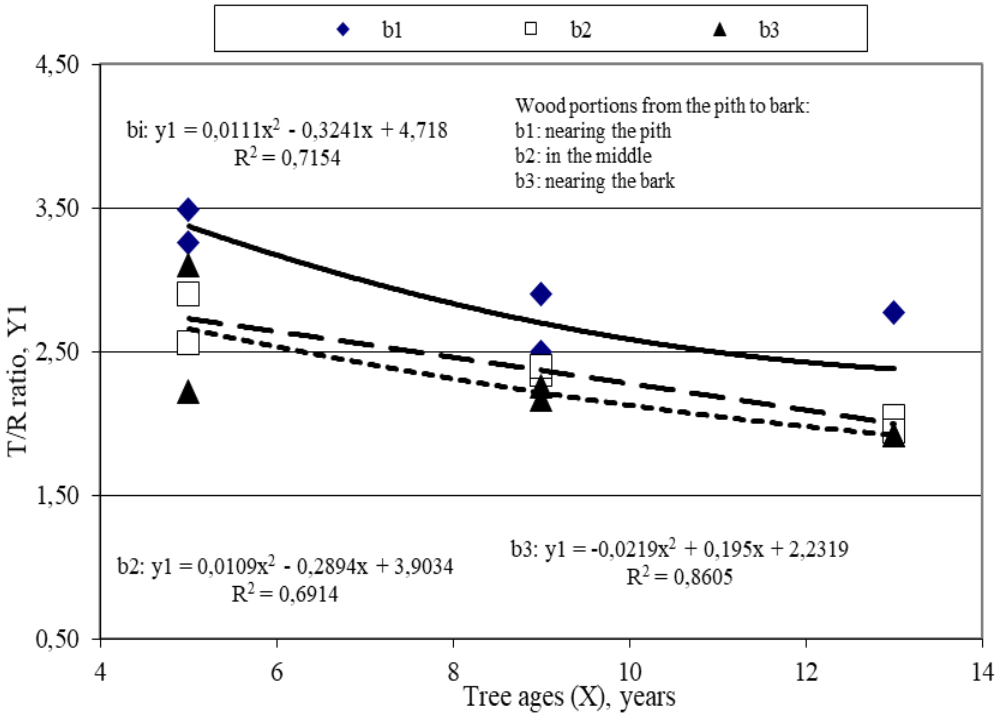

Figure 2. Relationship between ages of trees and T/R ratio of mindi wood.

Drying Properties

The main aim of wood drying is to obtain the dried wood with stable dimension. Meanwhile other aims are to be easily planed, lathed, shaped, sanded, glued, painted, and varnished (as end-finishing). In Table 2, it reveals that drying properties of mindi wood depended especially on tree ages, while position of wood portion in radial direction seemed not affecting the drying. With respect to the kinds of defect and degree of wood damage, then the drying properties of mindi wood at 5 year old could be categorized as class 6 (low), while 9 year old wood belonged to class 4 – 5 (rather low), and 13 year wood as class 3 – 4 (fair to rather good). Further, the older the tree ages, then the better would be the drying properties (Table 2).

Table 2. Drying properties at mindi wood, with respect to the tree age groups.

Age (year)	Position in radial direction	Green moisture content (%)	Kinds of defects & degree of wood damages		
			I	II	III
5	a	63.5	7	7	1
	b	60.5	6	6	1
	c	57.0	6	6	1
9	a	58.7	6	6	1
	b	55.6	5	5	1
	c	52.3	5	4	1
13	a	53.0	5	5	1
	b	50.2	4	3	1
	c	48.3	3	3	1

Remarks: **a**. nearing the pith; **b**. middle; **c**. nearing the bark; **I**. End & surface cracks/checks; **II**. Deformation/ collapse; **III**. Honeycombing. Classes of defects: **1** = < 5% (very good); **2** = 5–10% (good); **3** = > 10–20% (quite good); **4** = > 20–40% (fair); **5** = > 40–60% (rather low); **6** = > 60–80% (low); and **7** = > 80% (very low)

Relationship of Tree Ages with Wood Properties and Drying Qualities

The parameters that could be used to determine the drying qualities of a particular wood species are wood properties, commonly the T/R ratio, and drying properties (Basri *et al*. 2020). If the R/T ratios are low (≤ 2) and drying properties good, then the wood would be easily dried without suffering damage, or the degree of damage is low.

Table 3 presents the drying quality of mindi woods in three age groups (5, 9, and 13 years), based on the T/R ratio and drying properties. Analysis of variance (anova) with CRD pattern brought out the quality criteria for 13 year old mindi wood, which belonged to B (good); for 9 year old as C (fair); and 5 year old as D (poor). Further, referring to the drying qualities, then the minimum-maksimum temperature for 13 years old mindi wood was 55 – 85 °C, for 9 years old 50 - 80 °C, and for 5 years old 40 – 65 °C.

Table 3. Average data of physical and drying properties of mindi wood.

Ag	P	Tc	Physical properties			Ag	G	Drying Quality
			T/R	Density	Green Mc.			
5	a	1	3.4	0.46	62.55			
9	b	4	2.7	0.48	56.71	5	V-VI	D
13	c	7	2.4	0.49	51.98			
5	a	2	2.7	0.50	60.50			
9	b	5	2.4	0.51	56.19	9	IV	C
13	c	8	2.0	0.54	50.40			
5	a	3	2.7	0.53	5.23			
9	b	6	2.2	0.56	52.67	13	II-III	B
13	c	9	1.8	0.58	45.83			

Remarks: Ag = ages of mindi trees; P= wood portions from pith to bark (a = nearing the pith, b = in the middle, c = nearing the bark); Tc = treatment combination between factors Ag and P; T= tangential shrinkage; R= radial shrinkage; Mc.=moisture content; G = grades (I, II, III, IV, V, VI); average of three replicates.

Based on the value of air-dry density, dimensional stability, drying quality (Table 3), and wood-surface performance or wood decorative value, especially at 13 - years old mindi wood, could meet the SNI-01-0608 (2017) as furniture's raw material.

Conclusions

The air-dry density of 5 year old mindi wood in the radial direction from the pith to the bark ranged about 0.42 – 0.51 g/cm^3; for 9 year old about 0.48 – 0.56 g/cm^3; while for 13 years old about 0.49 – 0.58 g/cm^3. T/R ratio of 5 year old mindi wood in the radial direction from the pith to the bark ranged about 2.7 – 3.4; for 9 years old, the R/T ratio ranged about 2.2 – 2.7; while for 13 years old, the range was 1.8 – 2.0 (T/R ratio ⩽ 2). Based on the T/R ratio, 13 year old mindi wood was regarded as stable, with T/R value 1.8 – 2.0 (except for nearing the pith).

Drying properties of 5 year mindi wood were regarded as low, while 9 years old as fair, and 13 years old as good. Drying qualities of mindi wood based on T/R ratio and drying properties (except for wood portion near the pith) at 13 years old belonged to B (good) grade; for 9 years and 5 years regarded as consecutively C (fair) and D (poor) grades. The minimum – maximum temperature for 13 year mindi wood was 55 – 85 °C; for 9 year 50 – 80 °C; and for 5 year 40 – 65 °C Technical.

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