Wood Properties of Kayu Manis (Cinnamomum sp.)

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Wood Properties of Kayu Manis (*Cinnamomum* sp.) Planted in South Kalimantan, Indonesia

インドネシア南カリマンタンに植栽されたカユマニス（*Cinamomum* sp.）の木材性質

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1. Introduction

Besides palm and rubber trees, kayu manis (*Cinnamomum* sp.) is a common plantation species in South Kalimantan, Indonesia (Fig. 1). Kayu manis trees are harvested for the essential oils present in the bark (Fig. 2), which are used in cosmetics, medicines, and as insect repellents[13)]. Recently, the plantation area of this species has increased in South Kalimantan, Indonesia, because the trees grow rapidly[10)]. After harvesting the bark, the remaining wood of the kayu manis tree is typically only used for firewood. Research on the wood properties of this species is required to determine the utility of the wood for other purposes.

The objective of this study is to determine general information on basic wood properties of plantation-grown kayu manis, which will aid in the discovery of alternate uses of the wood.

2. Materials and methods

The trees of kayu manis (*Cinnamomum* sp.) were planted in Loksado, South Kalimantan, Indonesia (2° 29′ S–2° 56′ S and 114° 51′ E–115° 36′ E). A log (*ca*. 150 mm in diameter and *ca*. 200 mm in length) was collected from 1 m above the ground of a tree after harvesting for collecting the bark by local people.

A disc with 30 mm in thickness was obtained from the log for measuring the physical properties and anatomical

Fig. 1. Plantation of kayu manis in Loksado, South Kalimantan, Indonesia.

Fig. 2. Harvested bark of kayu manis in Loksado, South Kalimantan, Indonesia.
Note: In Loksado, South Kalimantan, Indonesia, local people harvested bark of kayu manis at about 7 years after planting. After harvesting, the bark was air-dried and then it was sold for local market.

characteristics. Due to indistinct growth ring in the sample, the radial variation of wood properties was analyzed at 1 cm intervals from pith to bark.

The strip from pith to bark (20 mm in width) was collected and then small blocks were obtained at 1 cm interval from pith. Basic density was calculated as the ratio of oven-dry weight and green volume determined by water displacement method [1].

Transverse sections (20 µm in thickness) were obtained by sliding microtome (REM710; Yamato Kouki). Slide was prepared according to method described previously[7]. Digital images were obtained by digital camera (E-P3; Olympus) equipped with microscope (BX51; Olympus) for measuring the diameter and frequency of vessels, and diameter and cell wall thickness of wood fibers. These anatomical characteristics were determined by using ImageJ software (National Institute of Health).

Small sticks were prepared at 1 cm interval from pith and were macerated for measuring the length of vessel elements and wood fibers. Macerated samples were projected on screen (V-12B; Nikon) and the length was measured by digital calipers (CD-15CX; Mitutoyo). All vessel and wood fiber morphologies were measured 30 and 50 individual cells in each radial position, respectively.

Air-drying specimens (20 x 20 x 20 mm) were prepared at 20 mm interval from pith to bark. Five specimens were obtained in each radial position. Radial and tangential directions were measured by screw meter (MDC-25M; Mitutoyo) at air- and oven-dried conditions. Shrinkage per 1% moisture content in radial and tangential directions was calculated according to previous paper [8].

Static bending test specimens (10 (R) x 10 (T) x 160 (L) mm) were prepared from 1 cm interval from pith. Total 17 specimens were prepared. Static bending test was conducted by universal testing machine (MSC-5/500-2; Tokyo Testing Machine) with 140 mm of span. The load was applied to the center of specimen with 3 mm/min. From obtained load-deflection diagrams, modulus of elasticity (MOE) and modulus of rupture (MOR) was calculated. After bending test, small specimens (*ca*. 10 x 10 x 10 mm) were obtained from bending specimens for determining the air-dry density and moisture content. The mean moisture content determined by oven-drying method was 12.0%.

Wood meals (42 to 82 mesh) were prepared for determining the chemical components (hot-water extract, 1% NaOH extract, ethanol-toluene (1:2, v:v) extract, holocellulose, $\alpha-$, $\beta-$, and $\gamma-$ cellulose, Klason lignin, acid soluble lignin, and ash). The chemical components were determined according to ordinary methods [2,5,14]. Each component was determined at three times and mean values were calculated.

3. Results and discussion

Table 1 shows the mean values of wood properties of kayu manis. Basic density, air-dry density, radial, and tangential shrinkage per 1% moisture content values were 0.53, 0.62 g/cm^3, 0.15, and 0.28%, respectively. The mean value of modulus of elasticity (MOE) and modulus of rupture (MOR) were 9.60 GPa and 106.2 MPa, respectively. Significant positive correlations between air-dry density and MOE and between air-dry density and MOR were found, suggesting that mechanical properties of kayu manis can be predicted by air-dry density. Nugroho *et al*.[11] reported that the range of wood density of *Acacia mangium* growing in Indonesia from 0.34 to 0.66 g/cm^3 and in our previous research[8], we found the range of basic density in medang wood (*Neolitsea latofolia*) growing in Indonesia was 0.48 to 0.58 g/cm^3. In the present research, basic density of kayu manis is in the basic density range value of *A. mangium* and Medang. In general, it is well known that wood density positively correlates with the mechanical properties of wood [3,9]. From the obtained result we can say that might be this species has similar mechanical properties with *A. mangium* and Medang wood.

The mean value of organic solvent extracts, Klason lignin, and holocelluloce contents was 2.9, 19.0, and 80.3%, respectively. Pinto *et al*.[12] reported that the mean value of organic solvent extracts, Klason lignin, and holocelluloce contents in *A. mangium* was 4.5, 27.1, and 70.9%, respectively. Organic solvent extracts and Klason lignin in kayu manis wood lower than that contents in *A. mangium* while holocellulose content in kayu manis wood higher than that content in *A. mangium*.

Figure 3 shows photomicrographs of transverse, radial, and tangential sections of kayu manis. In *Cinamomum* spp., Lemmens *et al*.[10] reported that growth rings presented but indistinct to vague. Wood was diffuse-porous and vessels were solitary and radial multiples of 2 to 3 rows. Perforations were predominantly simple, and tyloses and oil cells presented [10]. Our results were similar to the results obtained by Lemmens *et al*.[10].

The statistical values of anatomical characteristics were listed in Table 1. The mean value of vessel diameter, cell wall thickness of wood fiber, wood fiber length, and vessel frequency in this species were 75.1 µm, 2.5 µm, 1.13 mm, and 39.0 no./mm^2, respectively (Table 1).

Radial variation of cell length was shown in Fig. 4. Vessel element length increased from the pith to the bark. This pattern is similar with another species, *Casuarina equisetifolia* growing in Bangladesh[4]. While, Honjo *et al*.[6] reported if vessel element length in *A. mangium* was almost constant across the stem. Fiber length gradually increased from pith to bark (Fig. 4). Some reports also found the same pattern with this present study [4,6,15]. Vessel diameter strongly increased from the pith, and then slightly increased with little fluctuation to the bark (Fig. 4). A similar pattern was observed in *A. mangium* from Indonesia and *Eucalyptus camaldulensis* from Thailand, wherein vessel diameter increased from pith to bark[11,15].

Table 2 shows the correlation coefficient between

Table 1. Mean values of wood properties of kayu manis

Property	*n*	Mean	SD
Basic density (g/cm^3)	6	0.53	0.02
Air-dry density (g/cm^3)	6	0.62	0.02
MOE (GPa)	17	9.60	1.28
MOR (MPa)	17	106.2	7.1
RS per 1% change in MC (%)	15	0.15	0.02
TS per 1% change in MC (%)	15	0.28	0.02
VD (μm)	7	75.1	17.1
VF (no./mm^2)	7	39.0	7.2
WFCWT (μm)	7	2.5	0.5
WFD (μm)	7	15.0	0.5
VEL (mm)	7	0.53	0.07
WFL (mm)	7	1.13	0.19
Hot water extract (%)	3	6.6	0.5
1% NaOH extract (%)	3	17.9	0.3
Organic solvent extract (%)	3	2.9	0.1
Klason lignin (%)	3	19.0	2.9
Acid soluble lignin (%)	3	0.6	0.1
Total lignin (%)	3	19.6	2.9
Holocellulose (%)	3	80.3	0.1
α-Cellulose (%)	3	45.1	0.3
β -Cellulose (%)	3	3.6	2.1
γ-Cellulose (%)	3	30.3	2.0
Ash (%)	3	0.3	0.2

Note: *n*, sample number; SD, standard deviation; MOE, modulus of elasticity; MOR, modulus of rupture; RS, radial shrinkage; TS, tangential shrinkage; VD, vessel diameter; VF, vessel frequency; WFCWT, cell wall thickness of wood fiber; WFD, wood fiber diameter; VEL, vessel element length; WFL, wood fiber length. Sample number in anatomical characteristics, basic density, and air-dry density is that of radial position. MOE, MOR, RS, and TS were obtained from samples at different radial positions. Chemical components were determined in triplicates.

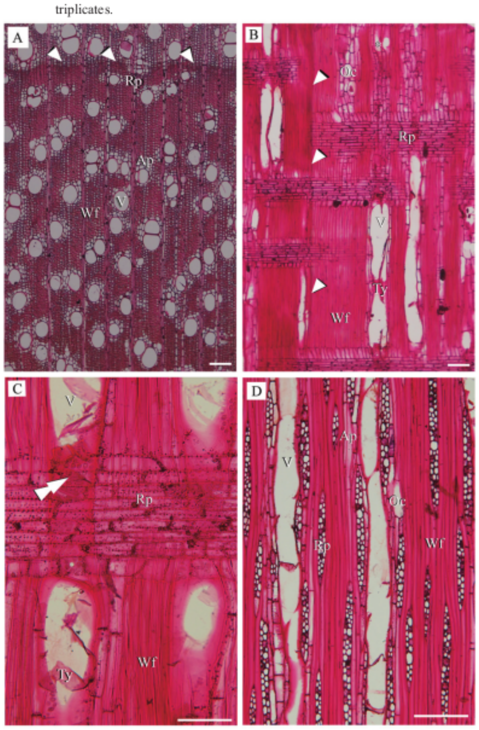

Fig.3. Photomicrographs of transverse, radial, and tangential sections of kayu manis.
Note: A, Transverse section; B, and C, radial sections; D, tangential section. Wf, wood fiber; V, vessel; Ap, axial parenchyma, Rp, ray parenchyma; Ty, tyloses; Oc, oil cell; *, simple perforation. Arrowheads and double arrowhead indicate growth ring and vessel ray pitting, respectively. Scale bar = 100 μm.

Table 2. Correlation coefficients between wood properties and anatomical characteristics

Property	*n*	BD	MOE	MOR	VD	VF	WFCWT	WFD
BD	6	1.000						
MOE	6	0.851*	1.000					
MOR	6	0.875**	0.913*	1.000				
VD	7	0.956**	0.954**	0.931**	1.000			
VF	7	-0.931**	-0.881**	-0.838*	-0.913**	1.000		
WFCWT	7	0.944**	0.891**	0.884**	0.977**	-0.897**	1.000	
WFD	7	0.511	0.548	0.346	0.408	-0.656	0.391	1.000

Note: *n*, number of measured positions from the pith to bark; BD, basic density; MOE, modulus of elasticity; MOR, modulus of rupture; VD, vessel diameter; VF, vessel frequency; WFCWT, cell wall thickness of wood fiber; WFD, wood fiber diameter; *, significant at the 5% level; **, significant at the 1% level.

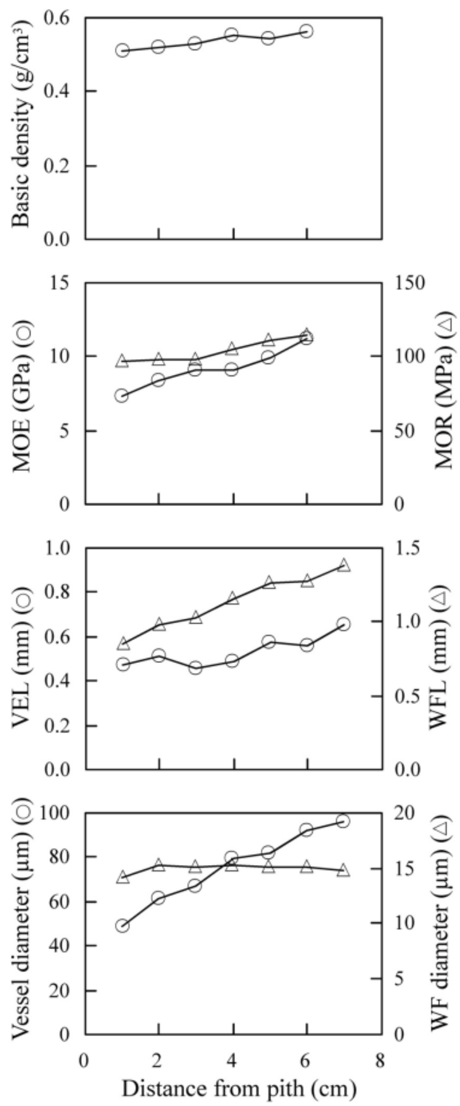

Fig.4. Radial variations of basic density, static bending properties, cell length, and cell diameter in kayu manis.
Note: MOE, modulus of elasticity; MOR, modulus of rupture; VEL, vessel element length; WFL, wood fiber length; WF, wood fiber.

anatomical characteristics and basic density of kayu manis. Basic density was strongly influenced by vessel diameter, cell wall thickness of wood fiber, wood fiber length, and vessel frequency.

4. Conclusion

Wood properties of kayu manis from South Kalimantan were investigated for rational utilization. Basic density, air-dry density, MOE, MOR, radial, and tangential shrinkage per 1% moisture content values were 0.53, 0.62 g/cm^3, 9.60 GPa, 106.2 MPa, 0.15, and 0.28%, respectively. Vessel element and fiber length increased from pith to bark. Vessel diameter strongly increased up to 4 cm from the pith, and then slightly increased to the bark, on the other hand wood fiber diameter increased up to 2 cm from pith and then almost constant to the bark. Organic solvent extracts, total lignin, and holocellulose contents were 2.9, 19.6, and 80.3%, respectively.

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