Cell Proportion and Dimension of Sukun (Breadfruit) (*Artocarpus communis* FORST) Wood: “A Potential Multipurpose Tree Species”

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Abstract

Sukun (*Artocarpus communis* FORST), also known as breadfruit, is a multipurpose tree and is mostly grown in community forest. In an effort to increase the added value of Sukun trees grown in community forest, a study on the cell proportion and dimension of the wood was conducted by using Sukun trees grown on Karangmojo Village, Bantul Regency, Yogyakarta. Samples for the study were taken from pith to bark in the north direction of the stem. Cell proportion as well as fiber dimension were then observed. The properties observed were analyzed by analysis of variance using a Completely Randomized Design. The result shows that the wood was composed of fiber of only 37.91%, while its rays, parenchyma, and vessel are of 26.60%, 23.85% and 11.61% respectively. The wood had a rather long average fiber length that is 1.65 mm and fiber diameter of 42.48 μm , lumen diameter of 37.28 μm and cell-wall thickness of 2.60 μm .

Key words: Sukun, bread fruit tree, cell proportion, fiber dimension.

Introduction

The declining potentiality of natural forest in supplying commercial wood has led people to considering alternative resources which is in fact quite a lot in Indonesia. Utilization of lesser known species, establishment of Industrial Plantation Forest, and utilization of wood from community forest are among the possibilities.

A lot of wood species are actually available in the community forest. Many of them such as jackfruit (*Artocarpus* sp) and Durian (*Durio zibenthus*) trees are initially grown for the purpose of their fruits but when the trees are getting old and their productivities in producing fruits become less, the trees are then felled for regeneration/replanting.

Sukun (*Artocarpus communis* FORST) tree is also a kind of wood species which is able to grow in many type of soil and is mostly cultivated for the production of its edible fruit. The gum of the tree is usually used for adhesive and medicine. Many of these trees are able to produce fruits when they reach only 2 to 3 years old but the productivity in producing fruit is declining when the tree reach of about 25 years old. Trees of this age are usually felled for regeneration but the wood is only used for fuelwood (Heyne 1987), a condition which can no longer be tolerated.

The effort for utilizing the wood thus can be initiated by firstly studying its properties particularly its basic properties such as cell proportion and fiber dimension. Since the formation of wood in the stem is determined by the meristem apical and cambium of different times while time is known as having a strong effect on the growth of a tree, the effect of the position of wood in the stem on the properties observed is also considered important to be studied.

Materials and Methods

Three healthy trees of Sukun (*Artocarpus communis* FORST) wood grown on community forest at Karangmojo Village in Bantul Regency, Yogyakarta Province were randomly selected and harvested for the observation in this study. They were of average diameter at breast height (dbh) of 37 cm, 35 cm, and 38 cm and of height of 16 m, 19 m, and 18 m respectively. The site where the trees grow is on the altitudinal of 40 m and of 7°40' 50" South latitude and 110°20' 30' East Longitude.

Free branch trunk of each tree was initially divided into three different parts of proportionally equal length i.e. bottom (butt end), middle, and top part. A disk of 2 cm was then cut from each of the boles. Each disk was stripped radially to yield small block of 1 cm thick across the pith. All the small blocks were cut into the matching sample length for cell proportion and fiber dimension of 1 cm longitudinal length. All of those various testing were conducted on wood samples of three different radial position in the northern cardinal direction of the standing tree i.e. 10% (R_1), 50% (R_2) and 90% from pith (R_3), or near the pith, intermediate point, and outer most or near the bark respectively. In the axial position, cell proportion and fiber dimension were also observed at three different heights that were bottom (A_1), middle (A_2) and top (A_3).

Observation on cell proportion and dimension was prepared by using H_2O_2 (hydrogen peroxide) and acetic acid, safranin, xylol, Canada Balsam and sliding microtome. They were observed in an object and deck glasses by using fibroscope, curvimeter and microscope (Bradbury 1973).

Analysis of variance (ANOVA) was carried out to identify the sources of variation. The method of analysis used for all the values was a factorial experiment in Completely Randomized Design. Statistically significant result was at the 95% confidence level. A necessary further analysis was conducted by using HSD test.

Results and Discussion

Macroscopic Features

The trees exude white latex as seen inside the inner bark of the periphery of the log (Figure 1). The sapwood is light yellow or straw colour and the heartwood is yellow to pale yellowish-brown. The texture is coarse and the grain is interlocked or occasionally irregular.

Figure 1. Cross section of Sukun wood

Notes:

B: Bark

L: Latex (white colour)

S: Sapwood

H: Heartwood

P: Pith

Wood Structure and Anatomy

Structure and anatomy at three different surfaces i.e. cross section, tangential and radial surfaces of sukun wood are shown in Figure 2, 3, and 4. Sukun shows a diffuse porous wood. Vessels are solitary and in radial multiples of 2 ~ 3 but these vessels are mostly solitary with a generally rounded and oval shape with tangential diameter of 273 (246 ~ 347) μm which is a bigger tangential vessel diameter than that of jackfruit (*Artocarpus heterophyllus*) wood of $191 \pm 45 \mu\text{m}$ (Kim 2013). Rays are 1 ~ 5 seriate while axial parenchyma is vasicentric and aliform.

Figure 2. Transverse surface (x) of sukun wood.

Figure 3. Tangential surface (t) of sukun wood.

Figure 4. Radial surface (r) of sukun wood.

Notes :

a : Vessels

b : Fiber

c : Rays

d : Parenchyma

Cell Proportion

Sukun wood botanically belongs to hardwood group. Hardwood is known as having rather complex morphology since it is composed of fiber, vessel elements, ray, and parenchyma cells (Bowyer *et al.* 2007; Panshin and de Zeeuw 1980; Biermann 1996; Smook 1994). Cell (Tissue) proportion is crucial in determining the properties of timber and the functioning of xylem in living trees (Baas and Wheeler 2000). Proportion of various tissues of Sukun wood grown on the community forest in Bantul Regency of three different axial positions and three different radial positions are presented in Table 1. The wood had a rather small proportion of average vessel element of 11.63% since hardwood is commonly composed of vessel elements of 20 ~ 55% (Biermann 1996) or 20 ~ 60% (Bowyer *et al.* 2007). Such small proportion is not unusual because although vessel volume in the hardwoods in the United States and Canada is reported as approximately 30 percent but they are in the range from 6.5 to 55 percents (Panshin and de Zeeuw 1980).

A different trend of tissue proportion from the butt end (bottom) to the top part of the tree was found in the trunk of Sukun trees. Average vessel tissue proportion of 11.63% showed an increasing trend from 9.27 % at the butt end to 13.31% to the top. Average fiber proportion of 37.91% decreased from the butt end to the middle and then increased to the top, average ray proportion of 28.46% showed a continuous decrease from 28.46% at the butt end to 23.89% at the top, while average parenchyma proportion of 23.85% increased from the butt end to the middle height but then decreased toward the top of the tree trunk.

A statistical analysis in Table 1 indicates that interaction between axial and radial positions seemed to have no significant effect on any of the cell proportions. Axial position also did not significantly affect almost all the cell proportion except for vessel proportion whose effect is highly significant. A further statistical analysis (HSD test)

result as shown by the small letter (the same letter indicates a non significant difference) behind the number in Table 1 indicates that vessel proportion increased significantly from butt end to the middle height, and showed a significant difference between wood from butt end and top positions, while the increase of vessel proportion from the middle height toward the top position was not significantly different. Although a higher vessel proportion of 17% in the wood of *Azadirachta excelsa* (Jack) Jacobs was reported by Sahri *et al.* (2000), it is interesting to note that the wood shows a similar increasing trend of vessel proportion to the sukun wood.

In three radial positions (from pith (10%) to bark (90%)) as shown in Table 1, vessel element, ray, and parenchyma cell proportions, all increased from pith (10% position) to middle (50% position) but then when it was close to the bark (90% position) the proportion decreased. In *Shorea leprosula* and *Shorea parvifolia* as observed by Bosman *et al.* (1994), the vessel proportion increases towards the bark. A statistical analysis in Table 1 shows that among the cell proportions observed, only vessel proportion is affected significantly by radial positions, particularly between vessel proportions of 10% and of 50% from the pith.

Data in Table 1 shows that the fibers make up a high proportion of the volume of sukun wood. Fiber cell proportion showed an opposite trend to the above phenomena of three different cell proportions i.e. fiber proportion decreased to the middle radial position but then increased toward the bark. A statistical analysis in Table 1 shows that radial position affects fiber proportions significantly. A further statistical test result -as indicated by small letter behind the number in Table 1 showed that fiber proportion was significantly different between wood of 10% and 50% from the pith but both of them were not significantly different to the fiber proportion of the wood from 90% of the pith.

Table 1. Axial and Radial Variation of Tissue proportion (%) of *Artocarpus communis* wood.

Cell	Axial (A) position from bottom to top			Radial (R) position (% distance from pith)			Average	Statistical Analysis		
	Bottom	Middle	Top	10	50	90		A vs R	A	R
Vessel	9.27 ^a	12.32 ^b	13.31 ^b	10.14 ^a	12.42 ^b	12.34 ^{a,b}	11.63	ns	**	*
Fiber	38.68	35.43	39.61	41.28 ^a	34.43 ^b	38.01 ^{a,b}	37.91	ns	ns	*
Rays	28.46	27.47	23.89	25.68	27.59	26.54	26.60	ns	ns	ns
Parenchyma	23.59	24.79	23.18	22.90	25.56	23.10	23.85	ns	ns	ns

NS: not significantly different

* : Significantly different at P < 0.05

** : Significantly different at P < 0.01

The same letter behind the number indicates a non significant different.

Fiber Length

Fiber length has an effect upon a number of pulp and paper properties and in most cases, long lengths are desirable (Bowyer *et al.* 2007). Sukun woods used in this study as seen in Table 2 show that they have an average fiber length of 1.65 (1.01 ~ 2.23) mm. For wood of broadleaves, such length is quite long but a longer fiber length of the wood of *Artocarpus spp.* of 1.9 mm (1.2 ~ 2.6 mm) has been reported by Ogata *et al.* (2008). This difference in fiber length is probably due to the fact that the wood observed in this study is of difference species from those reported by Ogata *et al.* (2008). *Artocarpus* is a genus consists of 50 woody species and they are divided into 2 groups i.e. (1) the light-weight and the light-coloured type, and (2) the medium-weight and dark coloured type (Ogata *et al.* 2008). *Artocarpus* (Sukun) used in this study belongs to the first group, while those reported by Ogata *et al.* (2008) is probably belongs to group 2.

As seen in Table 2, fiber length decreases from butt end to the top position, and increases from wood near the pith (10%) to the wood near the bark (90% from the pith), while fiber diameter, lumen diameter, and cell wall thickness from the bottom to the middle height position increase and

then decrease a little bit in the top position but are still higher than that at the butt end position.

Analysis of variance indicated that interaction between axial and radial positions affected fiber length and lumen diameter significantly but did not significantly affect fiber diameter and cell wall thickness. Further statistical analysis on fiber length using HSD test in Figure 5 shows that the increase of fiber length has only caused significant difference between fiber 10% and fiber 90% from the pith in the middle height and in the butt end of the trunk, and between fiber 10% and fiber 50% from the pith in the butt end. Mature fibers of hardwood are commonly double the length of those found near the pith (Dadswell 1958). In the butt end, a fiber length increase of 61% from wood near the pith to those of near the bark was found in this study

Fiber length decreased from the butt end to the upper part of the trunk but a significant decrease was only shown by the fiber in the outer part of the trunk (50% and 90% from the pith). Fibers are longest in wood at 10 ~ 20 ft above the ground (Biermann 1996). The short fiber length in the upper part of the trunk is attributable to the fact that formation of the fiber in that area is still being dominated by apical meristems (Bowyer *et al.* 2007).

Table 2. Axial and Radial Variation of Cell Dimension of *Artocarpus communis* wood.

Cell	Average	Axial (A) position from bottom to top			Radial (R) position (% distance from pith)			Statistical Analysis		
		Bottom	Middle	Top	10	50	90	A vs R	A	R
Fiber Length (mm)	1.65	1.84	1.67	1.44	1.32	1.73	1.90	*	**	**
Fiber diameter (µm)	40.48	40.27 ^a	44.42 ^b	42.74 ^{a,b}	46.14 ^a	40.06 ^b	41.23 ^b	ns	**	**
Lumen diameter (µm)	37.28	35.28	38.94	37.61	41.15	34.95	35.73	*	**	**
Cell wall thickness (µm)	2.60	2.49	2.74	2.56	2.50	2.56	2.75	ns	ns	ns

ns not significantly different

* Significantly different at $P < 0.05$

** Significantly different at $P < 0.01$

The same letter behind the number indicates a non significant different.

Figure 5. Fiber length at various radial and axial positions.

Fiber Diameter

Fiber diameter of Sukun wood in this study gave an average value of 40.48 (36.37 ~ 51.30) μm while Ogata *et al.* (2008) in their book mentioned that wood of *Artocarpus* has fiber diameter of 25 ~ 45 μm . It means that fiber of Sukun wood in this study does not only have shorter length but also bigger cell diameter (fatter). Such condition further supports that the wood reported by Ogata *et al.* (2008) was the wood of the same genus but of different species.

A statistical analysis indicates that axial as well as radial position of the wood give a significant effect on the fiber diameter. The result of HSD test as indicated by the letters (the same letter indicates a non significant different) behind the number in Table 2 show that although fiber diameter of the wood increase with the increase of the wood in the axial position but the highest fiber diameter was produced significantly only by the wood from middle height. A higher axial position does not significantly affect the diameter of the fiber. Further statistical analysis for fiber diameter at different radial position resulted in a significant decline for wood 10% to 50% and 90% from the pith but no significant difference between wood from 50% and 90% from the pith.

Lumen Diameter

Sukun wood has an average lumen diameter of 37.28 μm . Wood fiber located 50% from the pith in the butt end of the trunk showed the smallest lumen diameter of 31.78 μm while those located near the pith of middle height of the trunk showed the biggest lumen diameter of 44.75 μm . Although wood fiber of different positions in the trunk showed a different value of lumen diameter, but statistical analysis as shown in Figure 6, indicates that the differences

are only between wood fiber close to the pith (10% from the pith of all axial positions) and those of 50% and 90% from the pith of butt end.

Fiber Wall Thickness

Fiber wall thickness is closely related to wood density (Baas and Wheeler 2000), which in turn is probably the single most important predictor of mechanical properties of the wood (Bowyer *et al.* 2007; Baas and Wheeler 2000; Panshin and de Zeeuw 1980)

Measurement of the fiber (cell) wall thickness of Sukun wood as shown in Table 2 give an average value of 2.60 μm . Axially along the tree trunk, cell wall thickness in the middle height showed the thickest thickness but it was not significantly different with two other height positions of the trunk i.e. fiber in the butt end and top part with thickness of 2.49 μm and 2.56 μm respectively. An opposite trend was reported in *Populus* hybrids (Griffioen 1972) and *Quercus* (Taylor and Wooten 1973).

Across the tree trunk, the wood showed an increased trend of fiber wall thickness from pith (2.50 μm) to bark (2.75 μm) but they were not significantly different too. For the hardwoods, cell wall thickness was reported showing an increased trend radially (Sahri *et al.* 2000).

Conclusions

Based on the data obtained in this study, it can be concluded that Sukun wood composed of fiber of only 37.91%, while its rays, parenchyma, and vessel are of 26.60%, 23.85% and 11.61% respectively. The wood has an average fiber length of 1.65 mm, fiber diameter of 42.48 μm , lumen of 37.28 μm and cell wall thickness of 2.60 μm .

Figure 6. Lumen diameter at various radial and axial positions.

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