Fibre Morphological Properties of Kelempayan *(Neomalarckia cadamba sp.)* Wood

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ABSTRACT

Fibre morphological properties are important factors that influence the strength properties of paper produced. The main objective of the study is to determine the fibre morphological properties (fibre length, fibre diameter and slenderness ratio or length to diameter ratio (L/D ratio)) of Kelempayan, with diameter of breast height ranging between 35cm and 41cm. Three Kelempayan trees were harvested from UiTM Pahang forest and each of them was cut into three portions (bottom, middle and top). Samples were taken from each portion and along the distance of the stem (near pith, middle and near bark). The greatest fibre properties of Kelempayan according to the height level were found to be middle portion, followed by top and bottom portion. Along the distance, it was showed that fibre morphological properties were highest at near bark followed by middle and near pith except for fibre diameter. From the study, significant differences in fibre morphology of Kelempayan according to portion were found only in the fibre length and slenderness ratio (L/D ratio), while according to distance, all fibre properties were statistically significant.

Keywords: *Kelempayan, Neomalarckia cadamba, fibre morphological properties, fibre length, fibre diameter, slenderness ratio (L/D ratio).*

Introduction

Fibre can be described as a wood cell which remains in the wood pulp. In softwood, majority of wood cells consist of tracheids and as for hardwood, it consist of fibrous cells such as longer vessel elements, fibre tracheids, tracheids and libriform fibres (Panshin & Zeeuw, 1970). Fibre morphological properties are believed to be the great factor in determining the paper strength produced (Horn, 1978; Muneri & Raymond, 2001). In fibre morphology point of view, both physical and mechanical properties of the material itself are associated with fibre properties especially fibre length and generally related with the toughness, durability and workability of the wood material. As in pulp and paper production, fibre length is one of the most important factors that control the strength properties of paper. This is due to the fact that the number of bonding site provided for fibre-to-fibre bonding to be successful is mainly determined by the length of individual fibre present. This will also assure that the stress applied during the production to be spread evenly over the entire area of the paper sheet (Abd. Latif et al., 1992; Panshin & Zeeuw, 1970). The objectives of this study are to determine the fibre morphological properties of Kelempayan wood according to portion (bottom, middle and top) and along the distance of the tree (near pith, middle and near bark) and to study the correlation of tree height and distance along the radial direction to its fibre morphological properties.

Materials and methods

Three samples were used in this study with each represent the position on the trunk (bottom, middle and top) and then, each portion was further divided into three equal distance (near pith, middle and near bark). The maceration of fibres was carried out using a method outlined by Wilson (1954). The macerated fibres then were dyed with safranin. After that, a slide consisting of 5 individual fibres was prepared. 100 of fibres for each portion and distance were measured. The measurement of fibre dimension (fibre length, fibre diameter) was carried out using a Motic System Microscope (B1 Series) connected to a computer. The measurement for fibre length was done under 4x and 10x object lense while measurement for fibre diameter was carried out under 40x object lens. From the fibre length and fibre diameter, the Felting Power or L/D factor was calculated as follows;

Felting Power or L/D ratio : $\frac{L}{D}$

Where:

L = fibre length (mm)

D = fibre width (μm)

Results and Discussions

Table 1 shows the average values of fibre length, fibre diameter and slenderness ratio or length to diameter ratio (L/D ratio) according to tree portion and distance. The highest and lowest value for fibre length was 1.80 mm at near bark of middle portion and 1.29 mm at near pith of bottom portion respectively. As for fibre diameter, the highest and lowest value was at middle of bottom portion (38.16 mm) and near pith of bottom portion (29.20 mm). The highest value of L/D ratio was 51.17 mm at near bark of middle portion while the lowest was 40.44 mm at near pith of middle potion. Fibre length, fibre diameter and L/D ratio values increase from bottom to middle and they slightly decrease at the top. Along the tree distance, fibre length and L/D ratio were the only properties that showed an increment from near pith to near bark while for fibre diameter, the value increased from near pith to middle and it slightly decreased as it reached the near bark. The results of the DMRT and correlation analysis are shown in Figure 1, Figure 2 and Table 3, respectively.

Table 1: Average value for fibre length, fibre diameter and L/D ratio of Kelempayan *(Neomalarckia cadamba)* wood according to its portion and distance on the tree

Portion	Distance	Fibre length (mm)	Fibre diameter (μm)	L/D ratio
Bottom	NP	1.29	29.20	44.32
	M	1.55	38.16	40.72
	NB	1.65	36.65	46.14
Middle	NP	1.33	31.85	40.44
	M	1.72	35.83	48.27
	NB	1.80	35.81	51.17
Top	NP	1.36	31.39	44.80
	M	1.62	35.53	45.93
	NB	1.71	35.07	48.15

Note: NP: Near pith , M : Middle, NB : Near bark

The analysis of variance (ANOVA) for fibre properties of Kelempayan wood is summarized in the Table 2. It shows that fibre properties value of Kelempayan wood according to portion was statistically different except for fibre diameter. However, the radial position gives a significant effect on all fibre properties value. As for their interaction of Portion x Distance, it showed a significant difference to all fibre properties.

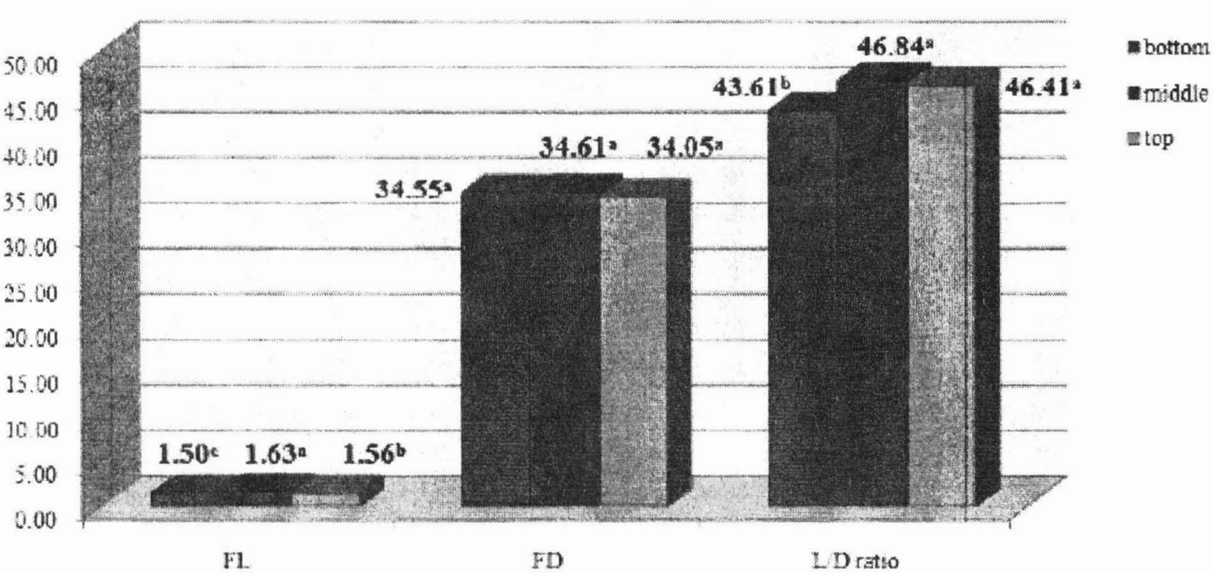
Table 2: Summary of ANOVA on the fibre properties of Kelempayan (*Neomalarckia cadamba*) wood

Source of variation	Fibre length (mm)	Fibre diameter (μm)	L/D ratio
Portion	53.424*	1.768 ns	31.650*
Distance	625.254*	221.833*	87.357*
Portion x distance	8.333*	17.400*	37.099*

Note: * shows F value significance at P value < 0.05
ns shows F value not significance at P value < 0.05

From Figure 1, fibre length showed a significant variation from bottom to top portion which increased from bottom to middle and decreased slightly at the top portion and it was positively correlated with r = 0.140 (Table 3). Fibre length is one of the most important factors that influence the strength properties of paper. Paper made from long-fibred wood will tend to have good characteristics as desired as they give high L/D ratio (Horn, 1978; Abd. Latif et al., 1992). Longer fibre will provide more bonding area between other individual fibres thus, the stress will be applied evenly through the entire area of the sheet produced. Paper made from short fibre is easy to tear apart due to its low resistance toward tensile strength. However, each portion of trees tends to have a wide range of fibre lengths, not only longer fibres but also shorter ones, thus this will influence the significant importance of longer fibres in determining the characteristics of paper produced. Therefore, wood with many short fibres is also included in the paper making production (Panshin & Zeeuw, 1970). Horn (1978) also added that in the past, fibre length was believed to be the only factor that determined the characteristics of paper. However, after much research was done, that belief has changed. The fact that must be kept in mind is that the length of fibre in paper produced is not the actual length of cells in a tree but the length that remains in the former or pulp during the completion of the process. The result obtained from this study is different to the previous study by Jorge et al, (2000); it was found that fibre length in wood of *Eucalyptus globulus* decreased from bottom to top. In contrast, Muneri and Raymond (2001) found that fibre length in *E. globulus* increased from bottom at first, then plateaued before it decreased to a minimum length as it reached the top, about 70% of height level. However, the most general longitudinal trend reported for fibre length in eucalyptus is fibre length increasing form bottom until to a point somewhere up the stem and decreasing as it reaches the top of the tree (Muneri & Raymond, 2001; Jorge et al, 2000). Muneri and Raymond (2001) reported that there was no exact trend of fibre length according to tree portion. The decrease of fibre length with height was associated with a decrease in a length of fusiform initials in the vascular cambium. However, the variation was small. Generally, the fibrous cells in the tree are shorter at the top portion than any other parts (Panshin & Zeeuw, 1970). They also explained that along the tree height, fibre length increasd from the base to the maximum height up the trunk, before decreasing rapidly beyond this level. But somehow, some hardwoods and conifers do not follow the pattern mentioned above, especially for hardwoods which are heterogeneous in cell types (Horn, 1978; Panshin & Zeeuw, 1970). Panshin and Zeeuw (1970) also proved that a minimal tracheid length in white fir (*Abies concolor*) occurred insignificantly at stump height, not at the top and in young-growth *Pinus ponderosa* which showed no changes in tracheid length above 5-foot stem height. This could be the reason why middle portion was found to be the highest fibre length in this study.

Figure 1: Duncan Multiple Range test on the effects of tree portion on the fibre properties of Kelempayan *(Neomalarckia cadamba)* wood



Note : FL – fibre length
: FD – fibre diameter
: L/D ratio – length over diameter ratio

Note: Values with the same alphabetical superscript in each column indicates groups that are not statically different according to Duncan's multiple range tests at P < 0.05

Fibre diameter showed a non significant difference according to tree portion (Figure 1); increased from bottom to middle and decreased slightly as it reached near bark with a negative correlation (r = -0.050), as shown in Table 3. Fibre diameter is one of the new features related with incremental growth of a tree. In hardwoods, variation in fibre diameter is related to both early wood and late wood (Panshin & Zeeuw, 1970). In softwood, rapid growth in the trees may be a reason why fibre diameter in many wood species decreases. Same quadratic pattern of fibre diameter in this study was also found in fast-growth plantations of *Gmelia arborea* (Roque, et al., 2007).

Table 3: Correlation coefficients of fibre properties of Kelempayan (*Neomalarckia cadamba*) wood with portion of the tree

Properties	Portion
Fibre length	0.140**
Fibre diameter	-0.050
L/D ratio	0.206**

Note: ** shows value significance at P < 0.05

The DMRT analysis in Figure 1 observed that L/D ratio was highest at the middle, followed by top and bottom with 46.83, 46.41 and 43.61 respectively, with a positive correlation (r = 0.206). The same pattern was observed by Abd. Latif et al. (1992) for *Gigantochloa scortechinii* but with a negative correlation. However, L/D ratio value for *Gigantochloa scortechinii* was reported to be higher (128 – 146) than found in Kelempayan in this study (43.61 – 46.84). Horn (1978) said that fibre with higher L/D ratio will provide better tensile strength. L/D ratio is the second new variable after fibre length showing the most significant influence in determining the strength of paper produced especially in terms of burst strength and tensile strength. That is why apart from fibre length, L/D ratio also plays an important role in determining the quality of paper produced. As for paper made from hardwood species, L/D ratio is the most influential parameter used in determining paper strength characteristics. Panshin & Zeeuw (1970) declared that L/D ratio can affect the properties of paper more than the fibre length alone; both strength properties will respond to the same morphological effects just like softwood, especially for beaten pulp, which is highly dependable on fibre-to-fibre bonding. After beating, the degree of fibre collapse will increase and make the fibre more flexible and conformable. Thus, it will provide more bonding area along with the length of fibre. The lower in L/D ratio at the bottom portion could be due to the highest non-fibrous elements such as parenchyma and vessel, which will lessen the effect of L/D ratio in hardwood pulp (Horn, 1978).

From Figure 2, along the distance of the stem, fibre length was observed to increase rapidly from near pith (1.33) to middle (1.63) before increasing gradually at near bark (1.72) with a positive correlation r = 0.760 (Table 4). The same pattern of variation in fibre length was found in *Eucalyptus globulus* and other species of *Eucalyptus* which increased from pith to near bark. The increase of fibre length from pith to near bark may be due to the increase in cambial initials length as well as xylem mother cells as the tree matured or aged (Jorge et al., 2000; Panshin & Zeeuw, 1970). In any cross section of a trunk or branch in softwood species, it was demonstrated that the tracheids at near pith are initially shorter in length, and then it will increase rapidly along the distance for early years of the growth before leveling off to a constant length as it matures, for example in *Pinus radiata, Pinus densiflora, Eucalyptus regnans* and *Sequoia sempervirens*. A continuous growth of fibre length is also possible as reported in *Pinus ponderosa, Pinus taeda and Thuja plicata* (Panshin & Zeeuw, 1970). Since wood at near pith has the shortest fibre length, it is expected that wood fibre at near pith will produce a poor L/D ratio, resulting in a reduction of tearing resistance dramatically because shorter fibre does not produce a good surface contact in developing a fibre-to-fibre bonding (Ververis et al., 2004).

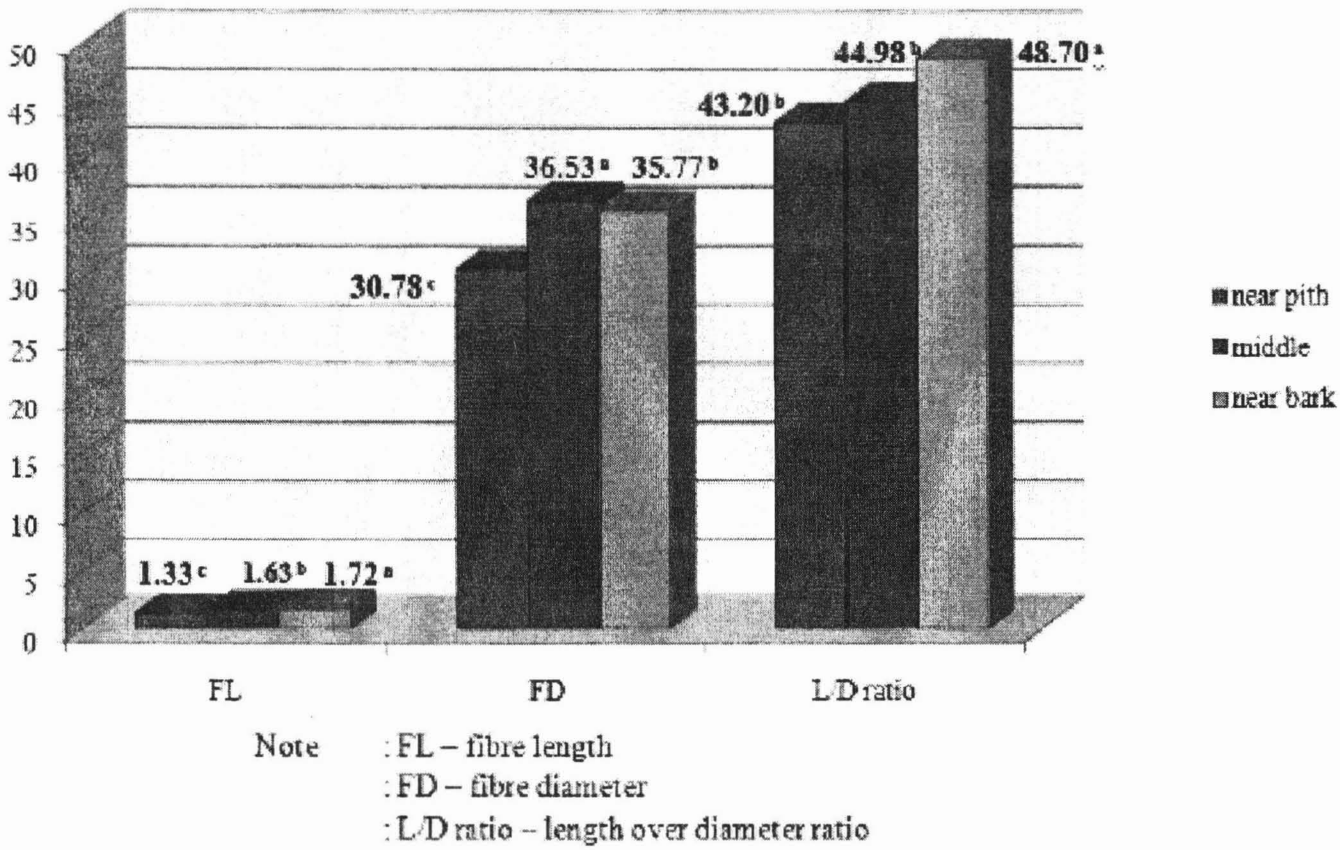


Figure 2: Duncan Multiple Range test on the effects of tree distance on the fibre properties of Kelempayan *(Neomalarckia cadamba)* wood

Note: Values with the same alphabetical superscript in each column indicates groups that are not statically different according to Duncan's multiple range tests at $P < 0.05$.

Fibre diameter of Kelempayan wood also showed a significant difference which increased from near pith (30.78) to middle (36.53) and then, slightly decreased as it reached near bark (35.77). However, the fibre length was positively correlated with $r = 0.519$. A significant difference in fibre diameter of wood fibre in radial direction was also found in *Paraserianthes falcataria* planted in Indonesia by Ishiguri et al., (2009), with the fibre diameter of wood to be almost constant from pith to bark. As for fibre diameter, there was only little information being reported about its trends in radial direction; from pith to bark. In some softwood, fibre diameter in a cross section was observed to increase from pith to the bark, resulting from growth increments.

Table 4: Correlation coefficients of fibre properties of Kelempayan (*Neomalarckia cadamba*) wood with distance of the tree

Properties	Distance
Fibre length	0.760**
Fibre diameter	0.519**
L/D ratio	0.415**

Note: ** shows value significance at $P < 0.05$

Wood portions near the bark have very good derived values (L/D ratio) (48.70) compared to wood portions near pith (43.20) and middle (44.98). This is comparable to such results found in kenaf by Ververis (2004), where kenaf bark is longer in terms of fibre length and it also has higher slenderness ratio at bark. Due to high L/D ratio, wood at near bark will have better tearing resistance, as reported in reed pulps (Shatalov and Pereira, 2002). Therefore, papers made from wood at near bark are expected to have higher mechanical strength which is required for printing, writing as well as for packaging (Ververis, 2004).

Conclusion

The investigation on fibre morphological characteristics (fibre length, fibre diameter and L/D ratio) of Kelempayan (*Neomalarckia cadamba*) wood showed that fibre length and L/D ratio according to portion increased from bottom to middle and it decreased slightly as it reached the top, while fibre diameter according to tree portion decreased from bottom to top. As for fibre length, fibre diameter and L/D ratio according to distance increased from near pith to near bark. Due to low L/D ratio, Kelempayan wood may not be suitable to be used as a raw material for paper making. Since hardwood is known for the heterogeneity of cell types, it is expected for the results to be varied.

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