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Anatomical Structures and Fiber Morphology of New Kenaf Varieties

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Abstract: Kenaf plant is claimed as one of the fast-growing herbaceous plants with the high potential as a fiber material or lignocellulosic material. Nine kenaf varieties i.e., Q-Ping, KK60, V12, V19, V36, V132 and NS V133 and TK were introduced recently by Taman Pertanian Universiti, Universiti Putra Malaysia as one of the potential plant to replace tobacco plantation. Since, these nine kenaf varieties are new to Malaysia, therefore, there is a need to study their anatomical structures and fiber morphology as well as microscopic appearances to understand their different and similarity. Cell morphology and anatomical appearances were observed and evaluated under the image analysis system (Leitz DMRB). From the results, V19 and V12 had the wider ray among the nine varieties, whereas other varieties in their microscopic appearance were almost similar to those observed in many diffuse-porous hardwoods. The longest fiber length was observed in variety TK (2.96 mm) followed by V36. Q-ping showed the widest fiber diameter and lumen diameter amongst the nine varieties, with value of 28.64 μm in bast fiber and 28.06 μm in core diameter. However, Q-ping had the thinnest core cell wall with the thickness of 3.34 μm. In term of fiber length, all the kenaf varieties bast fiber has longer fiber than core fiber. The kenaf core of nine varieties has wider fiber diameter and fiber lumen diameter than the bast fiber. Conclusively, although kenaf exhibit similarity in some fiber morphology and anatomical structures, however, there still some distinction that can be used to differentiate these kenaf variety.

Key words: Kenaf varieties, anatomical structure, fiber morphology

INTRODUCTION

Kenaf (*Hibiscus cannabinus* L., Malvaceae) is one of the fast-growing plants classified taxonomically in the *Fucaria* section of *Hibiscus*, with heights of 5 to 6 m in about 4-5 month (Alexopoulou *et al*., 2000; Amaducci *et al*., 2000; Webber and Bledsoe, 2002). As an herbaceous plant, kenaf has a high potential as the fiber materials or lignocellulosic material. The stalk of the kenaf plant consists of two distinct fiber types. Fiber derived from the plant originates from the stalk itself; relatively long fiber aggregates from bark known as bast and shortest wood fiber from the central part of the stem as core.

Kenaf known as the future crop is a source of cellulose fiber and is potential crop for the production of pulp and paper, ropes, twine, coarse, burlap and fiberboard (Webber and Bledsoe, 1993; Petrini *et al*., 1994; Yu and Yu, 2007). To use kenaf most effectively, it requires a knowledge of not only the amounts of various substances that make up kenaf, but also how those substances are distributed in the cell walls. The knowledge that mentioned can

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be gained by studying their anatomical structure. The anatomical structure play an important role in selecting the right kenaf varieties for particular usage because its affects strength properties, appearance, resistance to penetration by water and chemicals, resistance to decay, pulp quality and the chemical reactivity of fiber. The various forms of anatomical structure may produce different properties in different kenaf varieties.

In Malaysia, extensive research on Kenaf plants had been carried out by MARDI and Institute of Tropical Forestry and Forest Products (INTROP). Seventeen varieties of selected kenaf germplasm were introduced and planted in MARDI Serdang Station trial plots, Malaysia. The kenaf varieties with intermediate flowering that have been planted are namely V4, V12, V21, V23, V25, V33, V34, V36, V40, V41, V72, Sabdariffa Keewyai. The early flowering varieties which were planted are V13, V19 (green stem), V19 (red stem), Khon Kaen 60, Q-Ping and Tainung 2. There are also four late flowering kenaf namely TK, V133, KB-6 and K114-2 planted in MARDI Serdang trial plots.

There are nine kenaf varieties i.e., Q-Ping, KK60, V12, V19, V36, V132 and NS V133 and TK were identified by INTROP as potential to be planted commercially in Malaysia. Q-Ping and KK60 are early flowering kenaf varieties where they start flowering within two months after planting. The intermediate flowering plant namely V 12; V 19; V36; V132 and NS starts flowering between 64 to 93 days after planting. While V 133 and TK are grouped in the late flowering because of their 1st flower initiation on 80 to 100 days after planting (Aini *et al.*, 2009).

This study was carried out to examine the nine kenaf varieties microscopic appearance and fiber morphology because the reliable identification of these varieties is not available. Furthermore, the study of fiber morphology will provide some basic information on the fiber quality of kenaf for pulp production.

MATERIALS AND METHODS

Nine Kenaf varieties with different flowering period were selected for this study. Q-Ping, KK60, V12, V19, V36, V132 and NS V133 and TK were planted in January 2007 and harvested in July 2007 from Taman Pertanian Universiti, Universiti Putra Malaysia (UPM). Three sample discs with the length of two cm were obtained from the middle half of bole height from each kenaf variety. The sample discs from all the kenaf varieties were soften in an autoclave at temperature of 121°C for 30 min prior to sectioning and maceration process.

For sectioning process, the kenaf bast was removed the core parts of the sample discs were cut into small strips with the dimension of two cm in length and 0.5-1 cm in width. Cross sections with the thickness of 20-30 μm were slice using the sliding microtome. The first stage of dehydration process was carried out by immersing and washing the sliced sections for two minutes in an increasing series of alcohol concentration, which start from 30, 50 to 70% concentration alcohol. Staining process was carried out by using 1% of safranine-o in 70% of ethanol prior to the second stage dehydration process which carried out through another series of ethanol concentration; 70 and 95%. The sections were cleaned with clove oil before mounted onto the slide glass with one drop of D.P.X. (Neutral mounting medium) and were dried for 7 days. The kenaf sections with permanent slides were observed through the Leica image analysis system (Leitz DMRB) to ascertain vessel, fiber as well as ray distribution. The detailed examinations of the sections were carried out using the microscopic magnification of 100X.

The maceration process is according to the Technical Association of Pulp and Paper Industry (TAPPI) Standard T233-Su-64 (Smook, 2003). The process involves splitting of core and bast separately into matchstick size of two mm in width and 10-20 mm in length. This followed by adding 25 mL distilled water with 1.5 g sodium chlorite and 8 drops of acetic acid into each test tubes. The test tubes were boiled in water bath for 24 h. Subsequently, the core and bast were washed gently using distilled water and shaken in distilled water to get the individual fibers. One drop of safranine-o was dropped into the fibers and stained for fifteen minutes. A small amount of fibers were then transferred onto a slide. The measurement of kenaf core and bast for their fiber morphology were carried out using the Leitz DMRB with microscopic magnification of 400X. Fiber morphology such as fiber length, fiber diameter and fiber lumen diameter as well as fiber cell wall thickness were evaluated. Thirty fibers were measured from each maceration slide to obtain the average value of fiber length, fiber diameter and fiber lumen diameter.

RESULTS

Cross Section of Kenaf under Microscopic Observation

The cross sections near pith and near bark of kenaf varieties observed under microscopic magnification of 100X were shown from Fig. 1a, b-3a, b. Most of the kenaf varieties except V19 and V12 exhibit similarity of microscopic structures as shown in Fig. 1.

The microscopic features of different kenaf varieties showed similar distribution of the tissues such as vessels, ray parenchyma and fibers size. The wood is diffuse-porous, consisting of fibres, vessel members and typically rectangular fines ray parenchyma. There

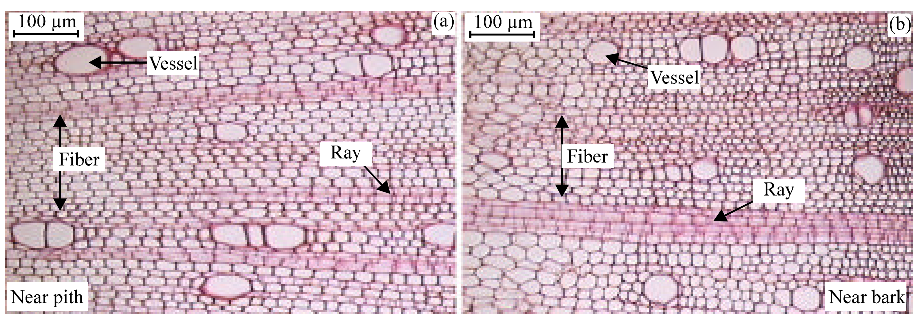

Fig. 1: Q-ping cross sections (a) near pith and (b) near bark under microscopic magnification of 100X

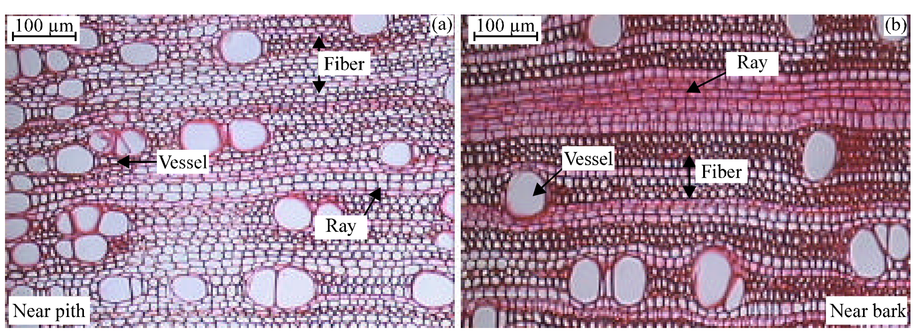

Fig. 2: V19 cross sections (a) near pith and (b) near bark under microscopic magnification of 100X

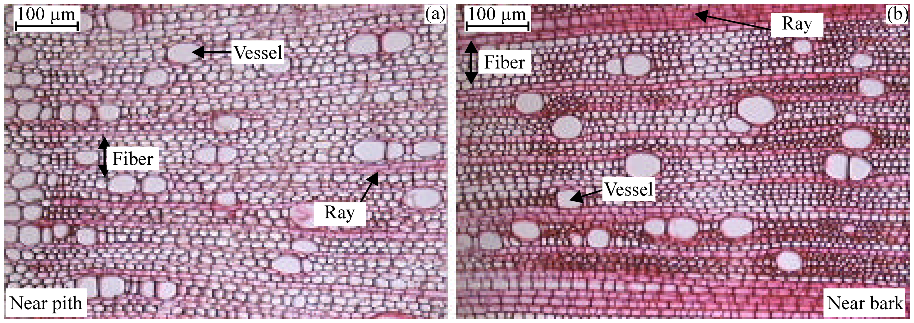

Fig. 3: V12 cross sections (a) near pith and (b) near bark under microscopic magnification of 100X

Table 1: Mean value of fiber length, fiber diameter and fiber lumen diameter and the fiber cell wall thickness of nine kenaf varieties

	Fiber length (mm)		Fiber diameter (µm)		Fiber lumen diameter (µm)		Fiber cell wall thickness (µm)	
Variation	Bast	Core	Bast	Core	Bast	Core	Bast	Core
TK	2.96 ± 0.61^{a}	0.78 ± 0.13^{bc}	24.16 ± 4.86^{b}	26.66 ± 4.76^{ab}	10.70 ± 1.35^{c}	15.53 ± 2.28^{d}	6.73 ± 1.79^{abc}	5.56 ± 1.23^{a}
V36	2.89 ± 0.60^{ab}	0.89 ± 0.17^{a}	24.09 ± 4.41^{b}	26.38 ± 5.58^{b}	11.74 ± 1.83^{b}	17.43 ± 3.32^{b}	6.18 ± 1.02^{c}	4.47 ± 0.73^{d}
V 12	2.83 ± 0.67^{abc}	0.66 ± 0.17^{e}	23.33 ± 4.17^{b}	25.20 ± 5.06^{bc}	9.50 ± 1.73^{d}	15.39 ± 2.00^{d}	6.91 ± 1.00^{a}	4.91 ± 0.67^{bc}
Q-ping	2.80 ± 0.63^{abc}	0.74 ± 0.14^{cd}	28.64 ± 4.82^{a}	28.06 ± 4.36^{a}	15.69 ± 2.72^{a}	21.37 ± 3.86^{a}	6.47 ± 0.94^{abc}	3.34 ± 0.54^{e}
KK60	2.75 ± 0.53^{bcd}	0.86 ± 0.18^{a}	22.72 ± 4.40^{bc}	25.96 ± 4.78^{bc}	9.31 ± 1.53^{d}	17.06 ± 1.85^{bc}	6.71 ± 1.08^{abc}	4.45 ± 0.66^{d}
V133	2.65 ± 0.50^{cd}	0.83 ± 0.17^{ab}	21.26 ± 3.75^{c}	21.59 ± 3.86^{d}	7.99 ± 0.76^{e}	12.18 ± 1.88^{ef}	6.64 ± 1.20^{abc}	4.70 ± 0.80^{cd}
NS	2.59 ± 0.45^{d}	0.67 ± 0.13^{e}	23.90 ± 4.91^{b}	24.49 ± 4.80^{c}	11.45 ± 1.54^{bc}	15.75 ± 2.60^{cd}	6.23 ± 1.18^{bc}	4.37 ± 0.80^{d}
V132	2.58 ± 0.50^{d}	0.71 ± 0.14^{be}	22.53 ± 3.68^{bc}	22.63 ± 4.20^{d}	8.98 ± 1.72^{de}	12.76 ± 2.36^{e}	6.78 ± 0.87^{ab}	4.93 ± 0.75^{bc}
V 19	2.28 ± 0.43^{c}	0.84 ± 0.14^{ab}	24.07 ± 4.70^{b}	21.41 ± 5.02^{d}	11.49 ± 2.41^{bc}	10.89 ± 2.15^{f}	6.29 ± 1.11^{bc}	5.26 ± 1.07^{ab}

Data are ecpressed as Mean±SD based on 50 measurements. [1]Means followed by the same superscripted letter(s) the same column are not significantly different at $p\leq0.05$

are bundle of vessels near the pith compare to cross section near the bark. The vessels appearances are almost the same shape as oval or round feature; simple perforation; moderately large; majority in solitary and in multiples of two or three. The microscopic appearances of kenaf in this study showing similar patterns with that observed by Voulgaridis *et al*. (2000). He found that kenaf planted in Greece had fines ray and wood is diffuse-porous, consisting of fibres, vessel members and typically rectangular ray parenchyma. One of the major different between kenaf and tropical hardwood species is the vessels in kenaf denser near the pith and lesser near the bark, whereas, the vessels in tropical hardwood arranged in no specific pattern.

In this study, one of the particular difference in structures of nine varieties was on the width of ray. From the microscopic appearance, V19 and V12 had broader ray amongst the nine varieties. While the rest showed fine rays. Width of ray is one of distinguish features to identify the variety amongst same species. Ilic (2002) in his research found that width of ray can be used as one of the identical features for certain varieties of Eucalyptus species.

Fiber Morphology

Table 1 shows the ANOVA result for the mean value of fiber dimension of the middle position of the kenaf block. The fiber length, fiber diameter and fiber lumen diameter and the fiber cell wall thickness of nine kenaf varieties were found significantly different at $p<0.05$.

The longest bast fiber amongst the nine kenaf varieties was observed in TK with the length of 2.96 mm, while V19 had the shortest bast fiber with the length of 2.28 mm. The longest kenaf core fiber was observed in V36 with the length of 0.89 mm. Meanwhile, the

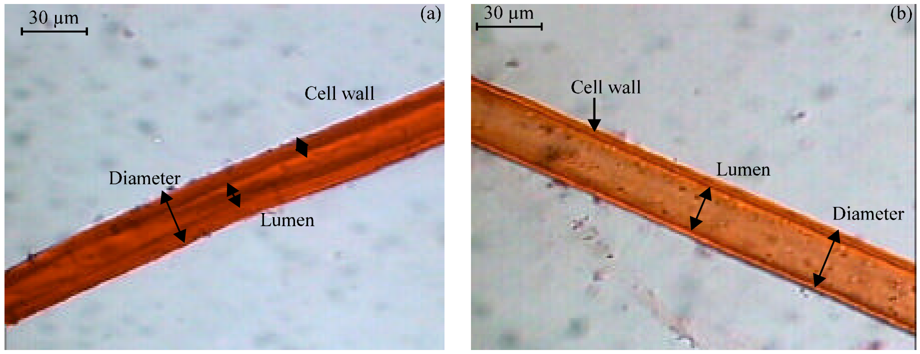

Fig. 4: Q-ping (a) bast fiber and (b) core fiber under microscopic magnification of 400X

shortest fiber was found in variety V12 with the length of 0.66 mm. Tsoumis (1991) and Voulgaridis *et al*. (2000) stated that the difference in fiber length of different variety for the same species is usually due genetically inherited and other external factors (light, water and nutrient). The fiber length may influence the various properties in wood, especially if trees are growing more rapidly due to genetic manipulation, wide spacing, fertilization or irrigation, or are growing on different soils or in different climate zones (Hazandy *et al*., 2009).

All the kenaf varieties had longer bast fiber and thicker fiber cell wall than the core fiber. However, kenaf core of nine varieties had wider fiber diameter and fiber lumen diameter than the bast fiber. Example of the bast and core for fiber diameter, lumen diameter and cell wall thickness of all kenaf varieties are shown from Fig. 4.

From the statistical analysis, Q-ping had significantly widest bast and core fiber and lumen diameter amongst the nine varieties. Most of varieties except V133, V132 and V19 had similar bast and core fiber and lumen diameter. For cell wall thickness, all the varieties except V36, NS and V19 are not significant different in the bast cell wall thickness. TK and V19 showed the highest core cell wall thickness compared to other varieties. The result may be influenced by parent gene tree and other environment condition effect. Genetic strains or provenances of a single species can also respond differently to the same environment (Haarer, 1952).

The fiber morphology of Kenaf is comparison with other fibrous materials as found in study by Ates *et al*. (2008). The average bast and core fibers length of Kenaf are 2.70 and 0.78 mm, respectively. The bast fiber is comparable to that of softwood fibers (2.7-4.6 mm) and longer than the hardwood fibers (0.7-1.6 mm) (Ates *et al*., 2008). However, the core fibers are shorter than softwoods and close to minimum value of hardwood fibers. The fiber diameter of different kenaf varieties in this study was 22 µm in mean and was in normal range when compared to hardwoods fiber with the diameter ranged from 20.0 to 40.0 µm (Ates *et al*., 2008).

The physical dimensions of the fiber are among the most important factors in pulping and other industries. Longer fiber length will produce better fiberboard and paper tensile strength properties. The tensile strength properties of fibreboard and papers were found to positively correlate with the felting coefficient (fiber length/fiber diameter). The felting coefficient should be more than 70 for softwoods and 40 for hardwoods to produce good quality fiberboard and paper (Akgul and Tozluoglu, 2009). The felting coefficient of all the nine Kenaf varieties bast fiber and core fiber in this study was found to be 95 to 124 and 26 to 37, respectively. The result shows that all the kenaf bast fiber suitable for pulp production whereas core fiber was not.

CONCLUSION

All the kenaf varieties had similar microscopic appearance features such as vessel arrangement and type, ray cells and fibre size except V19 and V12 that had broader ray cells. The fiber morphology of all kenaf varieties however proved that there are differences in their length, fiber and lumen diameter. This distinction morphology can be used as a tool to identify the kenaf varieties in this study. Beside that, the kenaf bast fiber can be used to produce high quality paper as they provide high tensile strength compared to core fiber.

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