A preliminary study of kenaf fiber bundles and their composite cells

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ABSTRACT

Only the bark of the kenaf stalk is fibrous. It has fiber bundles bound by lignin and other natural binders. The fiber bundles have single kenaf fibers of varying lengths and widths. Fiber dimensions are critical for textile preparation, nonwoven processing, and pulp and papermaking. This study examined the characteristics of single kenaf fibers by treating bundles with a mixture of glacial acetic acid and hydrogen peroxide. Examining the structure of kenaf bundles and individual fibers by light and by scanning electron microscopy provided an average length for a single fiber of 2.72 mm and an average width of 12.5 microns.

Application:

Determination of the ideal length of kenaf fibers will allow breeders to grow material for specific uses.

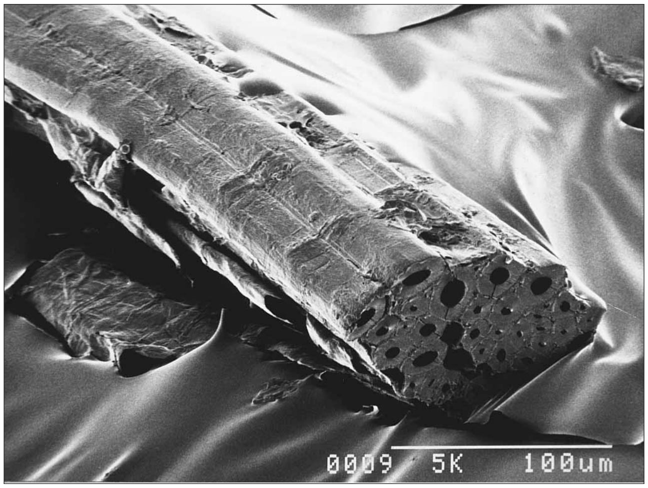
KENAF BAST FIBERS COME FROM *Hibiscus cannabinis L.,* an annual plant with a single, straight stem consisting of an outer fibrous bark and an inner woody core. It can annually yield approximately 6–10 tons of dry fiber per acre—nine times the yield of wood *(1)*. Many varieties are available varying in form, leaf color, shape and size, stem, and flower and seed appearance. Each variety responds differently to geographical conditions giving different quality and yields of kenaf fiber. Kenaf fibers offer the advantages of being renewable, potentially inexpensive, biodegradable, environmentally safe, and easily grown in many southern states. These fibers have found traditional use in the production of cordage, coarse yarns, canvas, and sacking *(2)*. Kenaf could also be an alternative fiber crop for paper making *(3, 4)*. Kenaf has recently received considerable attention as a potential natural fiber source for nonwoven textiles and fiber-reinforced composites *(5–9)*.

Figure 1 shows a bundle of single fibers bound by lignin and pectins comprising kenaf bark fiber. Various chemical treatments can remove lignin and separate fiber bundles *(5, 8–12)*. Knowledge of fiber dimensions is critical for textile preparation, nonwoven processing, and pulp and papermaking. Many researchers have reported measurements of lengths and widths of individual fibers *(12–19)*. The results usually only provide an average number with no detailed description of the data gathering methods. The results obtained by the different researchers also show varying results *(12–18)*. The intent of this research was to study the structure of the kenaf fiber, accurately determine the lengths and widths of individual fibers, and compare the results with the findings of others.

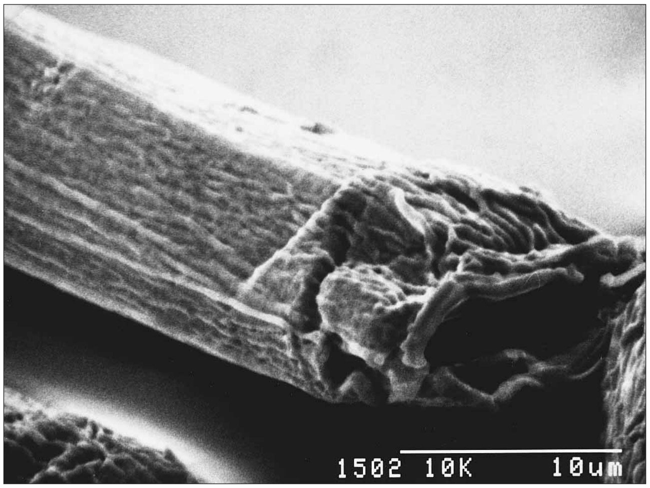
MATERIALS AND METHODS

Agro-Fibers, Inc., Angiola, CA, supplied the kenaf fibers used for this work. The company could not identify the kenaf variety they supplied but stated that all plants harvested exhibited similar physical characteristics—leaf shape, color and size, etc. The fibers were mechanically processed through a Rando Cleaner to remove core material and to provide approximately 5000 g of cleaned kenaf bark fibers. Five samples of approximately 10 g each were drawn randomly from various locations and hand blended. Five samples of 1 g each were drawn randomly from the 50 g previously blended. This material was also hand blended. Samples of mechanically cleaned kenaf fibers from the blended lot weighing 1 g were placed into Erlenmeyer flasks containing a mixture of equal parts of glacial acetic acid and 20% hydrogen peroxide for each extraction *(12)*. The samples were heated in a water bath at 98°C for 7 h. The fiber samples were then transferred to deionized water in another flask and left overnight. The flasks were next gently hand shaken to help the fiber bundles separate into their individual fibers. The fibers were mounted on microscope slides and stubs for microscopical examination.

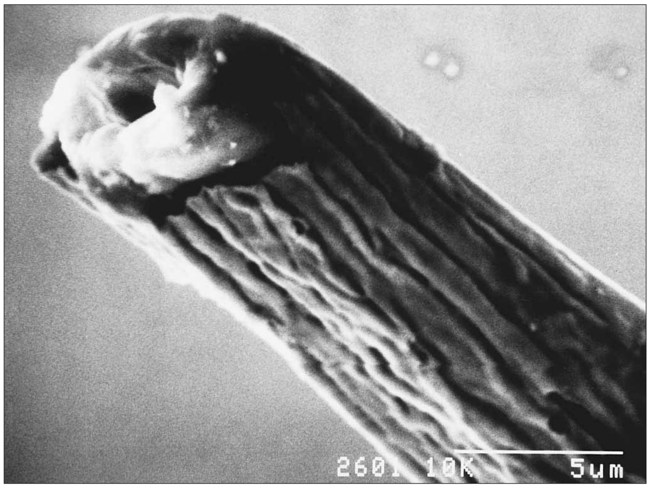
The kenaf fiber bundles and single fibers were examined using an Olympus Optical Zoom Stereo Microscope, model SZH. The samples were also examined using a Hitachi model S-510 Scanning Electron Microscope (SEM). The kenaf fiber specimens were mounted on the stubs and sputter coated with gold and palladium for SEM observation. The stubs on which the fiber specimens were mounted could be tilted and rotated in all directions to examine any point on the exposed fiber. The longitudinal and end cross section surfaces of bundles and single fibers were examined. Images of fiber areas revealing important structural details were observed and recorded. Kenaf individual fiber dimensions were determined from the resulting photomicrographs. About 50 individual fibers were measured.



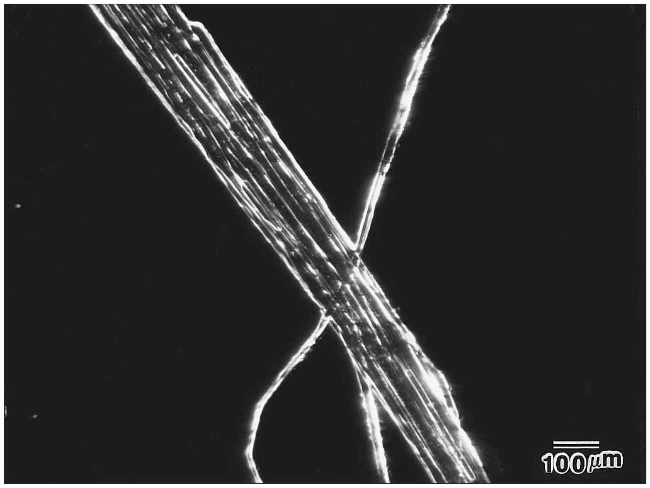
1. A kenaf fiber bundle



2. A single kenaf fiber cell with a wide lumen and a thin wall



3. A single kenaf fiber cell with a narrow lumen and a thick wall



4. Comparison between a fiber bundle and a single cell

RESULTS AND DISCUSSION

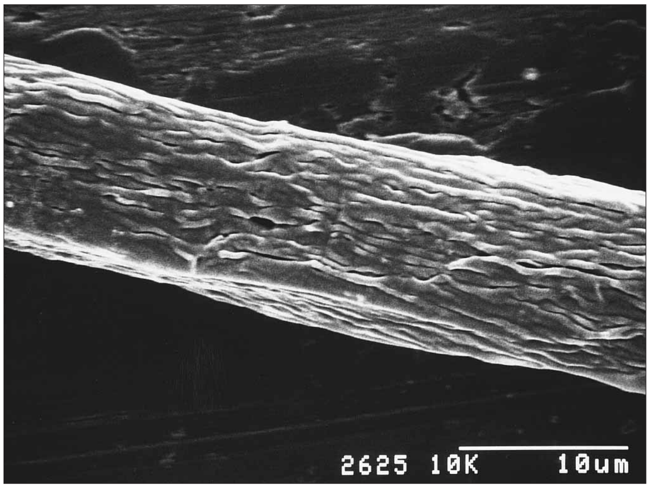
Kenaf usually occurs as a bundle of single fibers bound by lignin and pectins. Most lignin is probably present between the single fibers. Some research has shown that lignin may be imbedded in the primary cell wall of the kenaf fibers *(20, 21)*. We plan to examine lignin content and location thoroughly in subsequent work. In any case, as much lignin as possible must undergo chemical or enzymatic degradation and extraction to permit separation of fiber bundles and to obtain kenaf single fibers.

Figure 1 shows a kenaf bundle comprising approximately 30 single fibers. It is approximately 100 microns in diameter. Kenaf fiber bundles are usually coarse. The single fibers examined were either circular or rounded polygonal structures that had either thick or thin walls. The fiber bundles contain single fibers with both wide and narrow lumina.

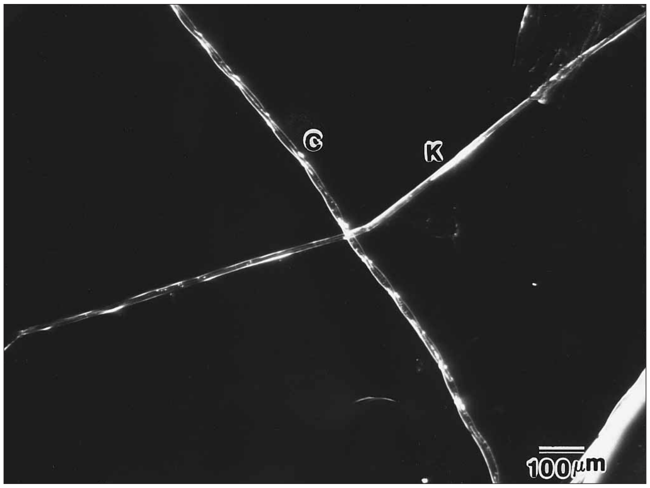
Figure 2 shows a kenaf single fiber. This fiber is approximately 11 microns wide. It has a wide lumen and a thin wall. Note that the single fiber in **Fig. 3** is approximately 8 microns wide and has a narrow lumen and a thick wall. This is typical of most clusters of kenaf fiber specimens. They contain single fibers with thick and thin walls, wide and narrow lumina, and different fiber widths.

Figure 4 compares a kenaf fiber bundle and a single fiber. The bound single fibers comprise a fiber bundle that is typically approximately 100–200 microns in diameter. **Figures 5 and 6** show that the single fibers are very fine—typically approximately 10–15 microns wide. During study under the microscope, we carefully excluded the multiple fibers from width determination. Figure 5 is a SEM photomicrograph showing surface structure and width of a single fiber. The image shows striations on the fiber surface like ramie fiber *(22)*. This single fiber is approximately 11 microns wide. We determined fiber widths by linear measurement adjusted according to magnification.

Figure 6 is a light photomicrograph comparing the width of a cotton fiber (c) and a kenaf single fiber (k). One can quickly recognize the

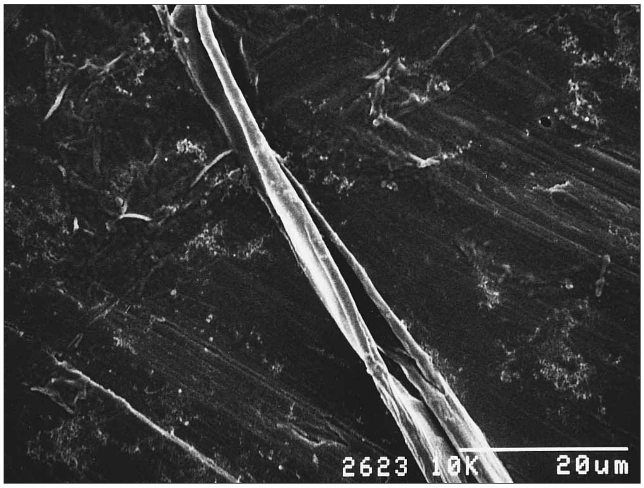


5. Longitudinal surface of a kenaf fiber cell



6. Comparison between a kenaf fiber cell (k) and a cotton fiber (c)

7. Kenaf fiber cells with different lengths

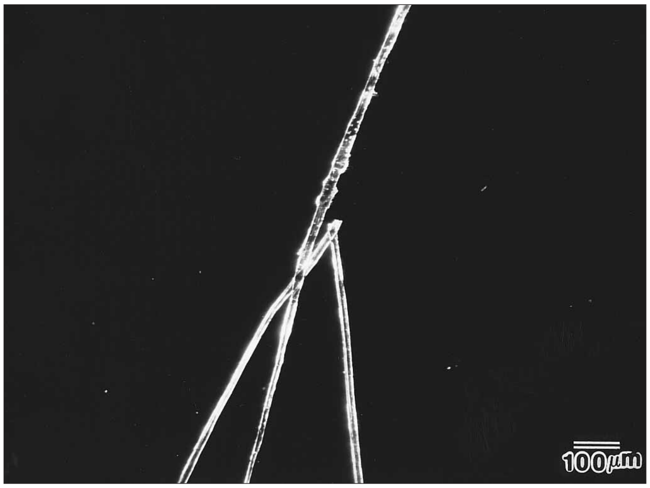


8. A kenaf fiber cell end

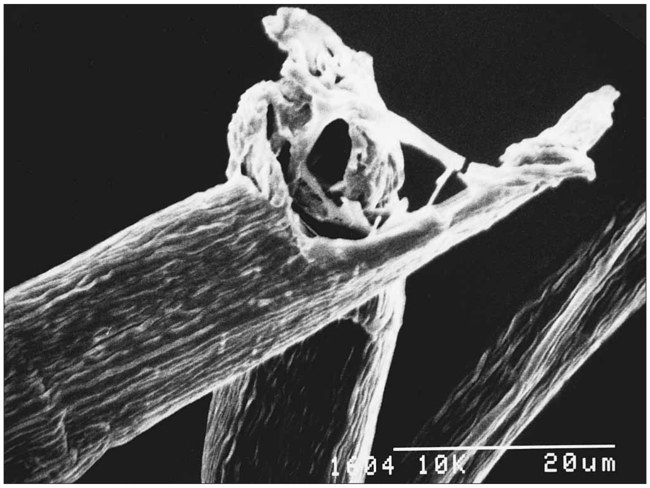
fiber with the unique twist as typical cotton fiber. Note that the widths are in the same range. Although the kenaf single fibers are as fine as cotton fibers, they are very short as **Fig. 7** shows. Kenaf single fibers are only 2–4 mm long. Cotton fibers are usually 25–30 mm long. Fiber lengths less than 15 mm are usually too short to process on conventional textile equipment. Kenaf single fibers are obviously too short for textile processing.

Figure 8 shows the single fiber ends that are tapering and rounded. One can recognize these unbroken single fiber ends by the presence of a sharp point at the end of the fiber structure with no blunt or jagged terminal structure. Some single fibers have obviously broken during extraction. We excluded these broken fibers from length determination. A single fiber end that is flat probably indicates breaking or fracturing as **Fig. 9** shows. **Figure 10** is a SEM photomicrograph showing fiber rupture. In **Fig. 11**, the two shorter, single fibers have one flat end that was probably broken. The others are tapering and rounded, and they vary greatly in fiber length. **Figure 12** compares the structural differences of a single fiber end and the midsections of other single fibers. Note that thin walls near single fiber tips cause rolling. When determining fiber widths, we therefore did not measure the widths near fiber ends.

We determined lengths of kenaf individual fibers from light photomicrographs and fiber widths from SEM photomicrographs. **Tables I and II** show these measurements, respectively. For comparison, the tables also show the dimensions determined by previous researchers. **Figures 13 and 14** are the histograms for length and width, respectively. The histograms resulted by analyzing the data with Microsoft Excel. The average length of a single fiber determined from our work was 2.72 mm. This is consistent with the findings of previous studies *(12–17)*. The average width determined from this study was 12.5 microns. That value is smaller than those reported in previous studies *(12–17)*. Contrary to the

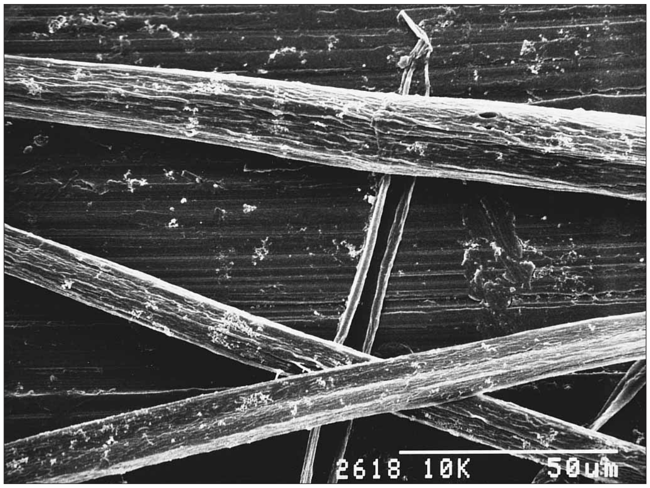


9. A broken fiber cell



10. SEM image of a broken fiber cell

11. Broken and unbroken fiber cells



12. Comparison between a fiber cell end and several cell midsections

wide range of fiber widths reported in previous studies—7.19–34.52 microns *(12)*, this work also found a much narrower range of fiber widths from 8–18.5 microns. The differences are probably because we excluded fiber ends and multiple fibers from measurement in this study. Another probable cause for observed differences in width is that we conducted all our research on kenaf bark and fibers from only one kenaf variety.

The physical dimensions of kenaf individual fibers are similar to those of wood fibers. The fiber length of softwoods is 3.3–6.1 mm and of hardwoods is 1.04–.85 mm. Fiber diameter of softwoods is 25–65 microns, and the diameter of hardwoods is 10–40 microns *(23)*. These data show that kenaf fiber length is similar to the fiber length found in softwoods and that kenaf fiber width is near that of hardwoods.

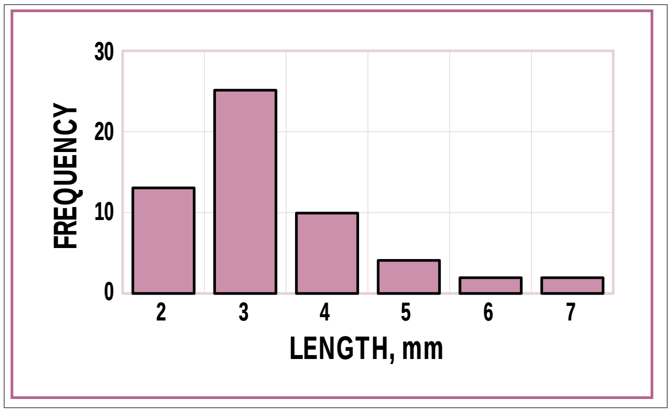
We plan to expand this work soon to study single fiber dimensions from bark obtained from several kenaf varieties. Fiber dimensions also will be measured by Kajaani FS-200 in collaboration with another research laboratory. We will compare measurements from different instruments. Before reaching any rigid conclusions, we must first complete this proposed varietal work. Four kenaf varieties planted in the Southern Regional Research Center experimental plot in New Orleans, LA, in 1996 and 1997 will be the subject of the work.

KEYWORDS

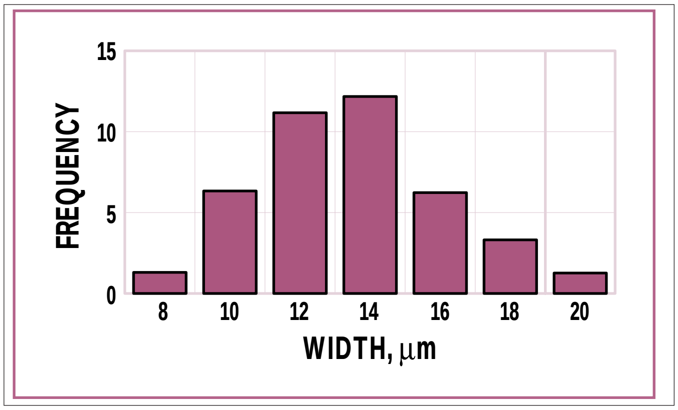
Composites, fiber diameter, fiber dimensions, fiber length, fiber structure, kenaf, lignins, nonwovens, scanning electron microscopy, textiles.

SUMMARY AND FUTURE WORK

We obtained single kenaf fibers from kenaf bark supplied by Agro-Fibers, Inc. The fiber bundles were separated into single fibers by treatment with a mixture of glacial acetic acid



13. Histogram of fiber cell length



14. Histogram of fiber cell width

Species	Hanausek (1907)	Matthews (1931)	von Wiesner (1867, 1927)	Kirby (1963)	Catling and Grayson (1982)	This work
Hibiscus cannabinus	up to 6	2-6	1.5-2.75	1.5-11	range 1.0-7.0	range 1.03-6.25
			frequently 2-2.2	mean 2.4	mean 2.94	mean 2.72

I. Lengths of fiber cells, mm

Species	Hanausek (1907)	Kirby (1963)	von Wiesner (1867, 1927)	Catling and Grayson (1982)	This work
Hibiscus cannabinus	14-16	12-36	21-41	range 7.19-34.52	range 8-18.4
		mean 20		mean 25	mean 12.5

II. Widths of fiber cells, microns

and hydrogen peroxide followed by gentle hand shaking. The structures and dimensions of bundles and single fibers were examined with both a SEM and a light microscope. Four varieties of kenaf have been planted in the experimental plot at the Southern Regional Research Center. Further studies on kenaf single fiber dimensions are planned when these varieties of kenaf are harvested. **TJ**

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