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TEXTILE TECHNOLOGY

Cotton/Kenaf Fabrics: a Viable Natural Fabric

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INTERPRETIVE SUMMARY

Kenaf fibers are produced when the core of the kenaf is separated from the fibrous outer layers. Kenaf fibers tend to be stiff because of the lignin content. In order to convert kenaf fibers into a fiber for valuable textile products, they must be either chemically or bacterially retted. The retted kenaf fiber is blended with cotton and can be carded and spun into yarns that can be made into woven or knitted fabrics. Kenaf fibers, produced by carding the chemically or enzymatically retted kenaf ribbons, were used in the yarns and fabrics in this study.

Kenaf fibers produced from different retting techniques were blended with cotton and evaluated. When fiber separation techniques (mechanical, chemical, or bacterial) were considered, mechanically separated fibers were deemed too stiff for processing into yarns, thus chemical and bacterial retting were compared. Bacterially retted fibers, degummed with 1% NaOH, produced the smoothest fabrics before finishing.

Cotton/kenaf fabrics can be further improved in softness and hand. The effects of different fabric treatments such as enzymes, bleaching, and mercerization were compared and measured for softness of hand. Two types of fabrics were treated, a light weight plain weave and a heavy weight twill. Mercerization dramatically improved the softness and hand for both fabrics. This research has shown that blending cotton fibers with kenaf fibers, with the proper fabric treatments, can result in a higher value end product, making kenaf a viable textile fashion fiber.

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ABSTRACT

By blending kenaf (*Hibiscus cannabinus* L.) with cotton (*Gossypium hirsutum* L.), new high-end uses for kenaf have been identified. Kenaf fibers, bast fibers similar to jute, are typically separated by mechanical, chemical, or bacterial means. Mechanically separated fibers are usually too stiff to be blended with cotton and cannot be made into good yarns. Fibers processed chemically and bacterially were blended with cotton and made into fabrics and evaluated. The retted kenaf ribbons were carded to produce straightened fibers which were cut into uniform lengths, blended with cotton, converted into yarns which were then made into fabrics to compare the retting treatments' effects on fabric hand and appearance. In order to further improve the hand of the retted kenaf/cotton blend fabrics, the fabric needed to be softened with routine finishes used in the textile industry. The effects of different fabric treatments such as enzymes, bleaching and mercerization on blended light weight and heavy weight cotton/kenaf fabrics were compared and measured for softness of hand. This collaborative effort resulted in cotton/kenaf blend fabrics that were aesthetically appealing and had a soft hand. The light weight blend fabrics had a linen look and, after treatment, were suitable for use in apparel without any type of lining. Mercerization was an adequate means to improve hand and appearance of the heavy weight fabrics, resulting in excellent examples of upholstery fabrics. Cotton enhanced the kenaf fibers and resulted in a higher value end product.

Cotton blend fabrics have been increasing in popularity in recent years because they combine the best properties of each of the components. Cotton has been the major substrate lending its quality to increase the value and use of alternative materials. Natural fibers have become more prevalent in fashion over the last 10 years. Fibers new to fashion such as ramie, a bast fiber, have found acceptance. Blending cotton with milkweed fibers produces a fabric that has high moisture regain rendering the fabric more comfortable for apparel and, if dewaxed, the fabric is more absorbent (Louis and Andrews, 1987). Bast fibers, such as linen and ramie, are typically blended with cotton to improve fabric hand (Cheek and Roussel, 1989). Mercerization affects ramie, flax, and cotton differently (Cheek and Roussel, 1989). Thus, it is important to evaluate the finished fabric to identify the optimum treatment.

Kenaf is an annual crop that is generally separated into two components, the core and its bast. The core is very absorbent and one of its many uses as an absorbent is to clean up oil spills. The core is also used for insulation panels, animal bedding, and potting media (Chen et al., 1995). The fibrous outer layer is used for rope, twine, carpet backing, and burlap. Kenaf has a good potential of becoming an excellent source of fiber in the manufacturing of pulp, paper, and other textile products (Ramaswamy et al., 1995). Conceptually, kenaf should have potential in the textile industry in manufacturing fabrics similar to the ramie/cotton blends (Ramaswamy and Easter, 1997).

Mechanically separated kenaf fibers, while much more economical to produce, are too stiff to produce quality yarns on the cotton system for apparel or upholstery fabrics. The other means of separating kenaf fibers are chemical and bacterial retting. Retting is a wet process by which the bundles of cells in the outer layers of the stalk are separated from nonfibrous matter by the removal of pectins and other gummy substances. Then the fibers can be easily separated into strands by carding. Bacterial retting uses microorganisms under controlled water temperature and flow that produces pollutants. Chemical retting has traditionally used alkali solutions (Morrison III et al., 1996).

Several treatments (mechanical, chemical, and enzymatic) have been developed to duplicate the effects of wear on denim to attain a worn look, softness, and comfort. Enzymes are being used instead of stones in stonewashing of denim fabrics to impart abrasion to duplicate the effects of prewashing (Olson, 1988). Enzyme treatments have been successful in softening cotton fabrics and theoretically may be effective on fabrics with kenaf fibers. Treatments to soften 50% cotton / 50% kenaf blend fabrics were evaluated using two types of enzymes, xylanase (a hemicellulase) and laccase (a peroxidase), both from Novo Nordisk (Franklington, NC; Niels Krebs Lange of Novo's Enzyme Development and Applications Staff recommended these enzymes for our application).

Mercerization is known to swell cotton fiber as well as improve fabric strength. Mercerization was used in this research to enhance strength and as a control to compare the different enzyme treatments. Heavy weight woven twill fabrics with a cotton warp and a cotton/ kenaf blend filling were treated with enzymes and then mercerized and bleached.

The overall objective of this study was to answer the question, "Does kenaf fiber have the potential to ultimately produce yarns and fabrics for apparel or upholstery applications? The objectives of this study were twofold: (i) to evaluate the effects of retting on yarn quality and fabric hand; and (ii) to evaluate chemical and enzyme treatments for improving the softness and hand of the fabrics produced.

MATERIALS AND METHODS

General

Control yarns and fabrics were made from 100% pima cotton. The cotton had a 4.13 micronaire, and an average length of 32.3 mm (1.27 inches). This cotton was also used in the blended cotton/kenaf knit and plain weave fabrics.

Kenaf variety Everglades 41 (E41) was decorticated in the separator at Mississippi State University's Department of Agricultural and Biological Engineering. The decorticated green, fibrous ribbons were processed in the Textile Laboratory in the School of Human Sciences, Mississippi State University, according to the procedure described by Ramaswamy et al. (1994). The decorticated kenaf stalks were retted by bacterial and chemical processes as shown in Table 1.

Bacterial retting was done in troughs at a temperature of 30°C±2. After 10 days of bacterial retting, the stalks were washed in hot water, air-dried, and hand carded with a soft nylon brush. Chemical retting was done by boiling stalks in 7% sodium hydroxide for 1 hour, after which they were washed under tap water, neutralized in 0.2% acetic acid, washed, air-dried, and carded. The various extraction processes for the decorticated green ribbons are outlined in Table 1.

Table 1. Fiber extraction processing.

ID	Retting method	Processing	Softening
C-0	Chemically retted (7% NaOH)	Boiled 1 hour then washed and neutralized in 0.2% acetic acid	None
C-1	Chemically retted (7% NaOH)	Boiled 1 hour then washed and neutralized in 0.2% acetic acid	Novo Nordisk Enzyme 1% cellulase
B-0	Bacterially retted	10 days of bacterial retting @ 30°C±2. and degummed (1% NaOH).	None
B-1	Bacterially retted	10 days of bacterial retting @ 30°C±2. and degummed (1% NaOH).	Novo Nordisk Enzyme 1% cellulase
BA-0	Bacterially retted	10 days of bacterial retting @ 30°C±2. & degummed (7% NaOH).	None
BA-l	Bacterially retted	10 days of bacterial retting @ 30°C±2. & degummed (7% NaOH).	Novo Nordisk Enzyme 1% cellulase

The kenaf ribbon was held by one end while a card wire brush was used to separate the fibers. The straightened fibers were then bundled and cut to lengths approximately 45 to 51 mm (1.75 to 2 inches) to produce staple. These processes were aimed at preserving fiber bundle strength, fiber flexibility, and reducing gum content. Gum refers to alkali-soluble residues, including hemicelluloses, lignin, waxes, pectins, and cellular contents (Ramaswamy et al., 1994). Chemical retting reduces the gum content so that later degumming does not reduce gum levels (Ramaswamy et al., 1995).

Mini-Spinning

The Southern Regional Research Center of USDA-ARS operates a Mini-Spinning Laboratory that contains unique miniature textile machinery that can process much smaller (50 g) quantities of fiber than conventional textile mills. The facility provides a quick method for evaluation of cotton or cotton blended with other fibers. The 50-gram spinning test (Landstreet, et.al., 1962) was modified to handle the kenaf/cotton blend. Instead of using the miniature opener, the retted and cut kenaf fibers were opened in the Spinlab no. 338 opener/blender (Special Instruments Laboratory Inc., Knoxville, TN), which separated the clumps of bast fiber while minimizing fiber breakage, and then blended with cotton for a 80% cotton / 20% kenaf blend. The kenaf was processed twice in the opener.

The cotton was hand blended with the opened kenaf and run through the opener on low speed. The blended fibers were then processed on the mini-spinning system in 50 g quantities. (Landstreet et al., 1962). The control yarn and fabric was made from 100% pima cotton. Six experimental 49.2 Tex [12's (12 cotton count)] yarns were spun using the six different kenaf fibers blended with cotton fibers (Table 1). The cotton/kenaf blend yarns were made using 40 g of the control pima cotton and 12 g of kenaf. Because of losses in processing, the final yarns were approximately 20% kenaf and 80% cotton. The 100% cotton yarn and the six cotton/kenaf blend yarns were knitted into plain jersey fabrics.

The yarns were tested as directed in ASTM Method D-1425-8196 (ASTM, 1998) on an evenness tester (Zellweger Uster, Inc., Charlotte, NC) for 5 min @ 22.9 m min^{-1} (25 yd./min.). The average value of evenness obtained was reported as CV%, where the lower the CV%, the smoother or more uniform the yarn. Yarn strength and elongation of one full skein were tested as per ASTM D-1578-8893 (ASTM, 1998) on a Scott tester (Henry L. Scott Test Co., Providence, RI), and as per ASTM D-2256-8897 (ASTM, 1998) 100 single strand breaks on a Tensorapid (Zellweger Uster, Inc., Charlotte, NC). The jersey fabrics were analyzed on the Kawabata evaluation system for surface roughness and coefficient of friction. Small samples of plain weave fabrics were also made using a common pima warp with 12's filling yarns approximately 30% kenaf (Table 1, B-1, bacterially retted and softened with cellulase enzyme (Novo Nordisk, Franklington, NC)) and 70% cotton.

The 67 x 41 thread count fabric was 164 g m^{-2} (5.24 ounces per square yard). This fabric was treated as outlined in section 2.4. Fabric strength and elongation were tested as per ASTM D-5035-95 (ASTM, 1998), flex abrasion resistance ASTM D-3885-92 (ASTM, 1998), and air permeability per ASTM D-737-96 (ASTM, 1998).The fabrics were significantly improved (visibly and to the touch) with the treatments. There was not enough fabric available to perform the Kawabata evaluation system test with replicates. Consequently, the heavy weight fabrics in section 2.3, which have a much higher kenaf content, were treated and then evaluated (five replicates).

Table 2. Fabric treatments for cotton/kenaf blended upholstery fabrics (fabric weight 22 g) 80:1 liquor ratio based on the weight of the fabric (wof), and prechem (0.1% weight of water, wow).

	Enzyme treatments (wof)		Mercerization and bleaching treatments (wow)				
ID	Xylanase 5%	Laccase 10%	NaClO Sol. 0.5%	NaSi 1.5%	H_2O_2 0.9% or 1.8%	Prechem 0.1%	NaOH 20%
T 1	--	--	440 mL	6.75 g	13.5 g	0.45 g	90 g
T 2	1.065 g	--	440 mL	6.75 g	13.5 g	0.45 g	90 g
T 3	--	2.2 g	440 mL	6.75 g	13.5 g	0.45 g	90 g
T 4	--	2.2 g	440 mL	6.75 g	27 g	0.45 g	90 g

Heavy Weight Fabrics

A heavy weight fabric was made for potential upholstery fabrics. The chemically retted kenaf (Table 1, C-1, chemically retted and softened with cellulase enzyme from Novo Nordisk) was blended 50/50 with cotton and processed on standard cotton processing machinery, producing 4.5's open-end yarns. The kenaf/cotton filling yarns were woven into a 100% cotton warp (12's), resulting in a 9.9 ounces per square yard twill weave fabric (Ramaswamy and Easter, 1997). The chemically retted kenaf was selected for this phase of the study since it has less processing time and would therefore be more suitable for industry. These fibers produced rougher fabrics than the others, but the fabric treatments were expected to soften them.

Fabric Treatments

The kenaf/cotton upholstery fabrics were treated with three enzyme treatments and one control treatment using an Atlas LP2 launderometer (Atlas Electric Devices Co., Chicago, IL). Mechanical action increases the effectiveness of the enzymes and a jet beck is generally used for these treatments. Because of the size of our samples, we chose the stainless steel balls with the launderometer to simulate mechanical action. The initial fabrics were woven loosely, much like a burlap, and the treatments were expected to compact the weave by shrinkage to produce a heavier upholstery type fabric.

Two commercial enzymes from Novo Nordisk, xylanase and laccase, were used (based on the weight of the fabric). Novo reports the enzyme activity as follows: the xylanase contains 600 EXU/g (endoxylanase units/g), the laccase is mixed with a surfactant and mediator and contains 500 DLPU (denilite performance units/g). The treatments were administered in two parts, the enzyme treatment followed by mercerization with bleaching.

For the enzyme treatment phase, the enzyme was placed in deionized water at a 80:1 liquor ratio based on the weight of the fabric and Prechem (0.1% weight of water). Fifty stainless steel balls were used to assist with the agitation. The samples were placed in the launderometer for a run time of 60 minutes at a temperature of 50°C. To denature the enzyme, the temperature was raised to 75°C for 15 minutes. The fabrics were then brought through a cool down stage at 25°C for 15 minutes. The fabrics were then rinsed, and the enzyme solution discarded.

The mercerization phase consisted of 0.5% sodium hypochlorite, peroxide (0.9% peroxide for treatments 1, 2, and 3, and 1.8% for treatment 4), 20% sodium hydroxide, and 1.5% sodium silicate. All of these values were based on weight of water. The mercerization phase was carried out in an identical fashion to the enzyme phase: 50°C for 60 minutes, 75°C for 15 minutes, and 25°C for 15 minutes. Mercerization at elevated temperatures resulted in better yarn penetration because the NaOH solution was much less viscous. Once the yarns were penetrated with NaOH, the solution was cooled down to 25°C, which resulted in a more uniform treatment (Boylston and Hebert, 1975). Fifty stainless steel balls were used to assist with the agitation. The treatments were replicated three times.

For this research on relatively small samples treated in batches, slack mercerization was necessary because tension mercerization was impractical. However, for future research at pilot plant scale, tension mercerization would be the method of choice. To make the mechanical exposure the same for all samples, the control was treatment 1 (mercerization and bleaching only) which used only deionized water and Prechem for the enzyme phase. In the second phase of treatment 1, the mercerization phase, the kenaf/cotton blend fabric was only bleached and mercerized.

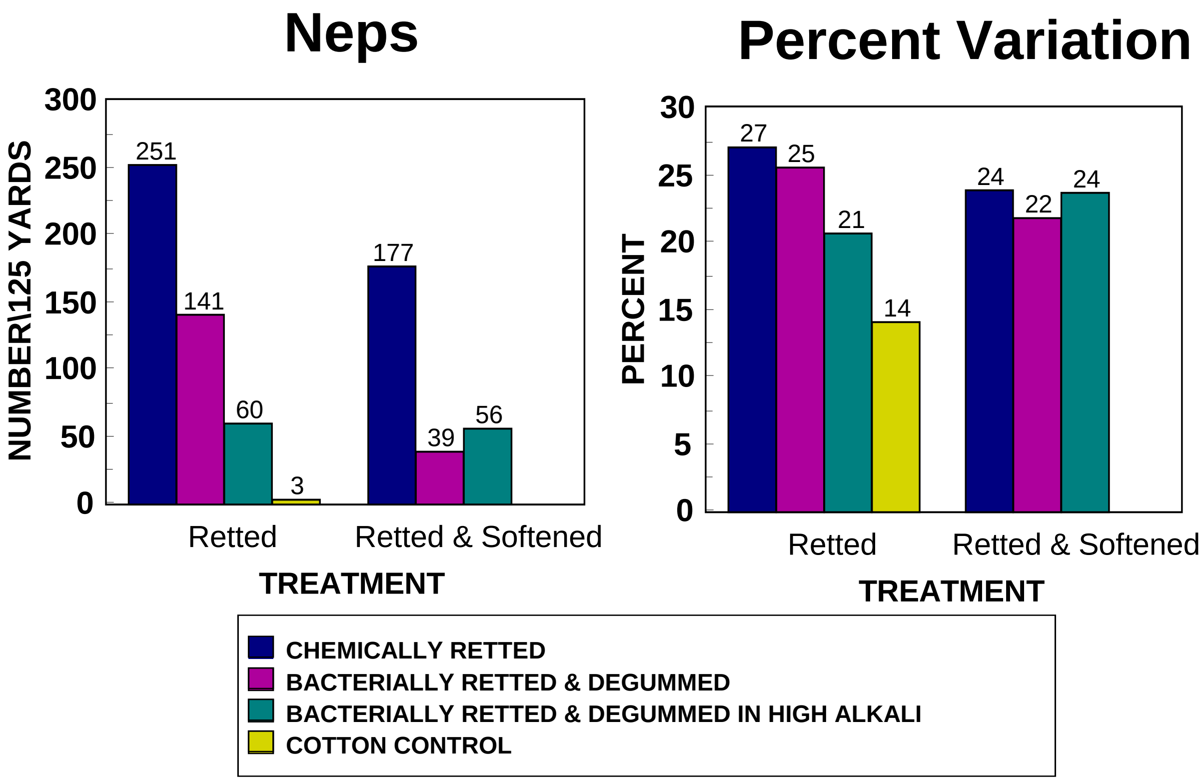


Figure 1. Yarn uniformity as measured with evenness tester from Zellweger Uster.

Treatments 2, 3, and 4 included enzymes treatments followed by mercerization (Table 2). Additional peroxide was used in treatment 4 to further soften the fibers.

Scanning Electron Microscopy

Photomicrographs were taken using a Hitachi S-510 scanning electron microscope (Nissei Sangyo America Ltd., Mountainview, CA) to study the surfaces of the fabrics at 100x and 1000x magnification. This analysis provided the opportunity to study the surface effects of the treatments on the kenaf fibers.

Kawabata Fabric Evaluation

The Kawabata system (instruments to quantify the drape of a fabric) was used to test compression and surface roughness. Samples for the tests were 10 cm square.The fabrics were tested with five replicates each. The Kawabata evaluation system data were generated from graphs produced during the testing. Because of the thickness and texture of the cotton/kenaf blended twill fabrics, the typical settings were not appropriate and needed to be changed accordingly. Therefore, the values presented are relative and can only be used for comparisons between these fabrics.

RESULTS AND DISCUSSION

Chemical vs. Bacterial Retting

Figures 1 and 2 show that the 100% cotton control yarn is superior to the kenaf blend yarns, as expected. Softening the fibers lowers the nep count for the chemically and bacterially retted samples, and improved yarn uniformity for the bacterially retted samples as seen in Fig. 1. The most uniform 80% cotton / 20% kenaf yarns were produced from BA-0 fibers, followed by B-l (Fig.1). The chemically retted fibers produced stronger yarns (Fig. 2), but the bacterially retted samples were more uniform and softer to the touch (Fig. 1).

The fabric surface roughness and fabric surface friction (Fig. 3) for the unsoftened fibers showed

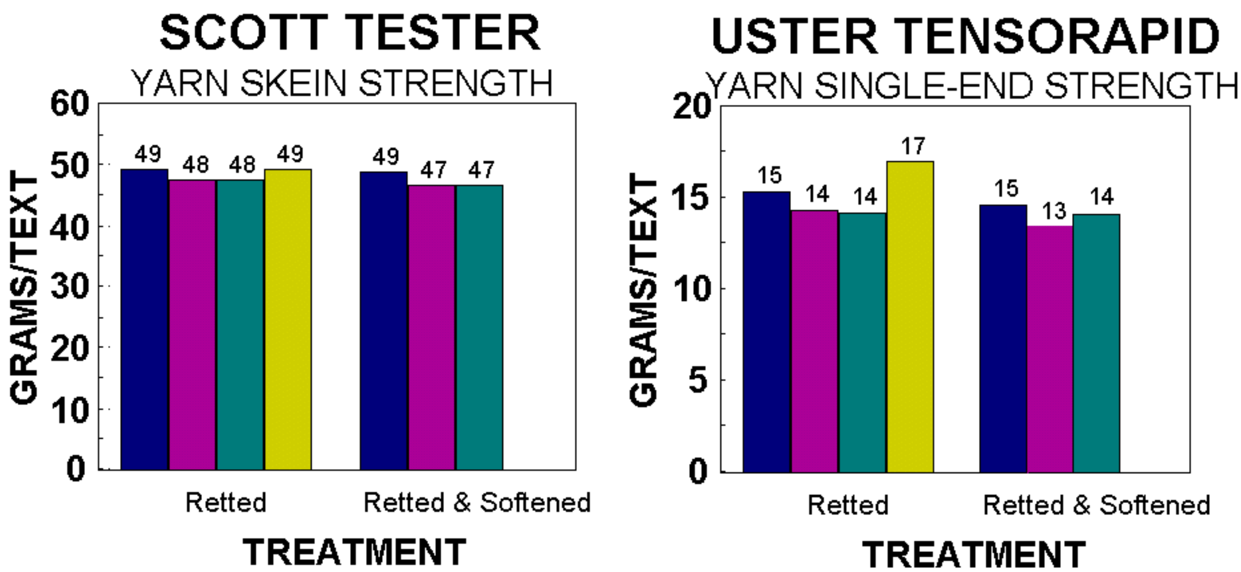


Figure 2. Yarn strength as measured with strength tester (Scott) and Tensorapid (Zellweger Uster).

the chemically retted as the highest (most rough), followed by the bacterially retted, and the bacterially retted with high alkali as the smoothest. The softener improved the fabric surface roughness for both of the bacterially retted fibers. The kenaf that was bacterially retted and softened with the enzyme produced the most aesthetically pleasing fabrics for apparel use of the initial six knitted fabrics. These fabrics were very attractive, but would need lining to be used as apparel fabrics.

The bend in the loops of the knit fabrics tended to make the stiffer kenaf fibers stick out from the surface of the fabrics, which added to the surface roughness. To minimize this problem, the next set of fabrics produced were woven. The fabric properties for the experimental blend 30% kenaf (B-1, bacterially retted and softened) and 70% cotton plain weave fabric 164 g m^{-2} (5.24 oz/yd^2) and 100% cotton plain weave control fabric 176 g m^{-2} (5.69 oz/yd^2) are in Table 3. This initial woven cotton/kenaf fabric had an aesthetically pleasing look. Although the hand was improved over the knit fabrics, it was still harsh for apparel quality fabric. It did however have good abrasion resistance and low air permeability, but was lower in strength than the 100% cotton fabric. The cotton/kenaf blend fabric was divided into four panels and then treated with treatments 1 through 4. All four treatments significantly improved the softness of the fabrics and were very similar according to panelists. There was not enough fabric sample to test in replicate for hand, so the finishing procedures were run in replicate on the upholstery fabrics.

Fabric Finishing Treatments

The heavier weight upholstery type fabric (50% kenaf in the filling yarns) was very rough with a look and feel similar to burlap, not a viable upholstery fabric. After treatments, as outlined in Table 2, the fabrics' hand and appearance were remarkably enhanced and met industry standards for strength (22.67 kg or 50 lbf minimum) as indicated in ASTM Method D-3597-95a (1998). Table 4 displays the average values of the pertinent parameters for each of the fabrics. During the treatments it was noted that the fabrics shrunk after the enzyme treatments, as expected, but no

Table 3. Fabric properties of the experimental cotton/kenaf blend and cotton control plain weave fabrics.

Fabric properties	30% Kenaf/ 70% cotton	Standard deviation	100% Cotton control	Standard deviation
Breaking load (kg)	27.45	3.50	44.00	3.65
Flex abrasion (cycles)	762.4	81.6	469.2	78.6
Air permeability (m^3/s/m^2)	0.68	0.02	4.06	0.07

Table 4. Properties of the cotton kenaf blend twill fabrics (tested in filling direction).

	Treatment				
Property	**Control**	**1**	**2**	**3**	**4**
KES Thickness (mm)	2.04	2.43	2.54	2.52	2.38
Standard deviation	0.140	0.209	0.093	0.149	0.182
KES (miu) Coefficient of friction	0.3235	0.3224	0.2445	0.326	0.307
Standard deviation	0.022	0.047	0.019	0.054	0.061
KES (smd) Surface roughness, (mm)	18.59	14.548	15.039	14.377	15.65
Standard deviation	1.896	3.061	3.491	2.31	2.889
Fiber diam. (mm) *bundle size	88.9*	14.4	15.8	14.4	12.8
Standard deviation	9.6	1.6	1.5	1.6	1.0
Air permeability ($m^3/s/m^2$)	0.62	0.29	0.26	0.27	0.31
Standard deviation	0.03	0.007	0.002	0.008	0.008
Shrinkage (%)		34.314	31.127	31.373	32.360
Standard deviation		0.662	1.070	2.773	1.376
Softness rank	5	3	1- Softest	4	2
Standard deviation	0	0	0	0	0
Strip elongation, peak strain (%)	18.44	57.02	65.76	61.33	48.7
Standard deviation	0.34	3.6	6.22	4.49	3.04
Strip strength, peak load (kg)	41.76	30.45	37.92	30.48	27.08
Standard deviation	1.61	1.88	3.83	3.80	0.80
Flex abrasion (cycles)	1834	361	601	218	180

measurements were taken at the wet stage before slack mercerization. After slack mercerization the fabrics were rinsed, air-dried, then pressed. The fabrics shrunk on average of 26.3% in the warp direction and 32.3% in the filling direction.

The thickness measurements determined by the Kawabata compression tests indicated an average increase in thickness of the treated fabrics, when compared to the untreated fabric, of 21.1%. This corresponds to the shrinkage of the fabrics. The resulting tighter fabrics also had much higher resistance to airflow than the untreated fabric.

The twill fabrics were rated for softness by a panel of three people. Fabrics were placed in order of softness with the softest fabric being rated 1, the next softest rated 2, and so on. All agreed that

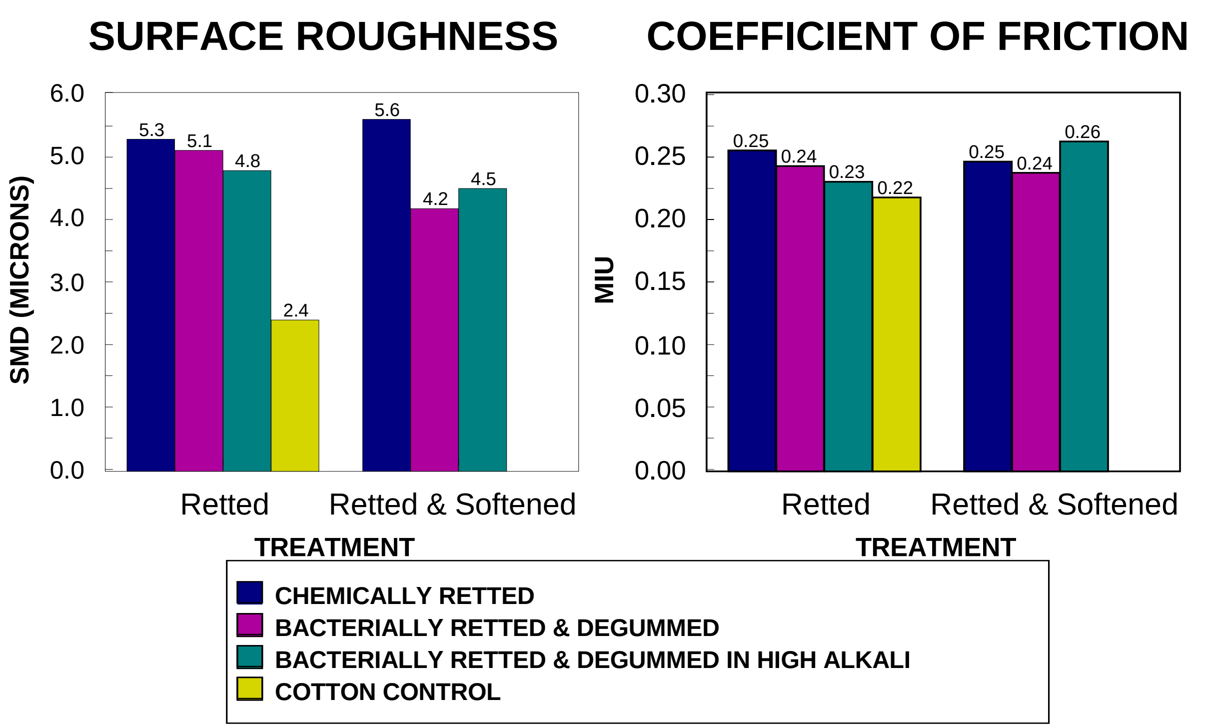
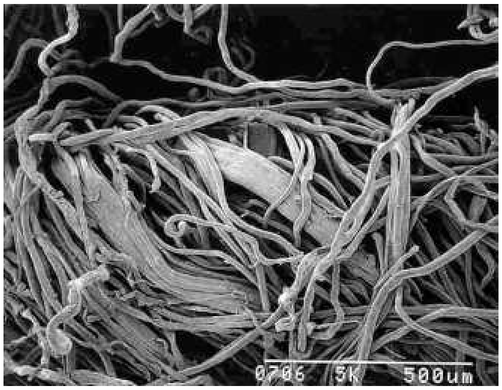
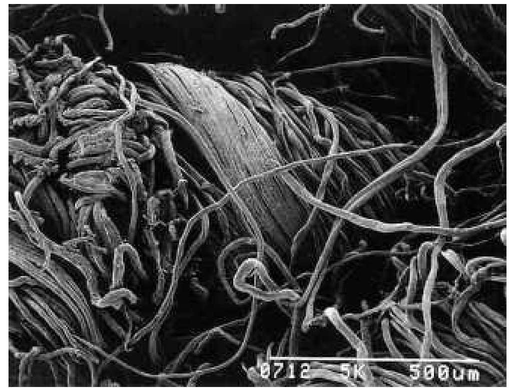


Figure 3. Fabric surface friction as evaluated with the Kawabata system.

Figure 4. Scanning electron micrographs at low magnification of yarns of upholstery fabrics.



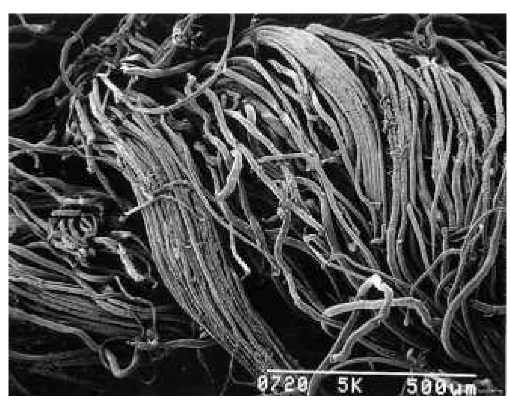
Treatment 1 exposed fabric to mercerization and bleaching only.



Treatment 2 exposed fabric to xylanase, mercerization and bleaching.

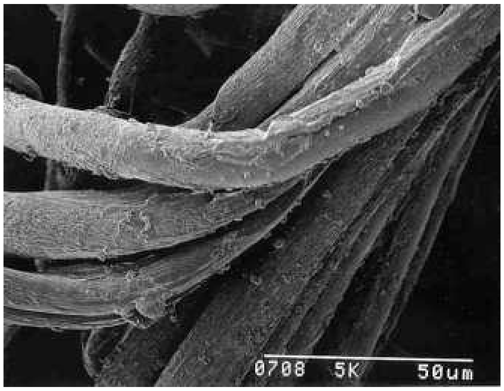
Untreated control fabric.

Treatment 3 exposed fabric to laccase, mercerization and bleaching.

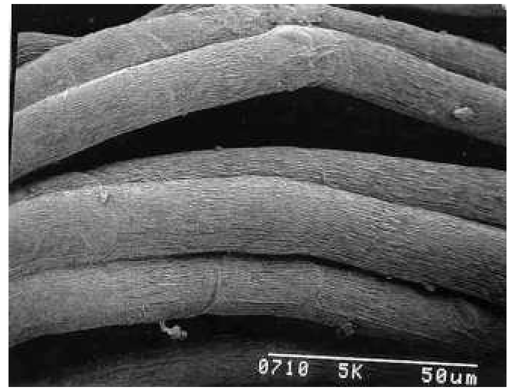


Treatment 4 exposed fabric to laccase, mercerization and bleaching with extra peroxide.

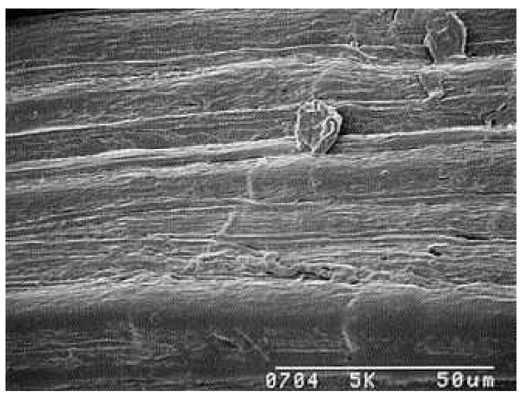
Figure 5. Scanning electron micrographs at high magnification of yarns of upholstery fabrics.



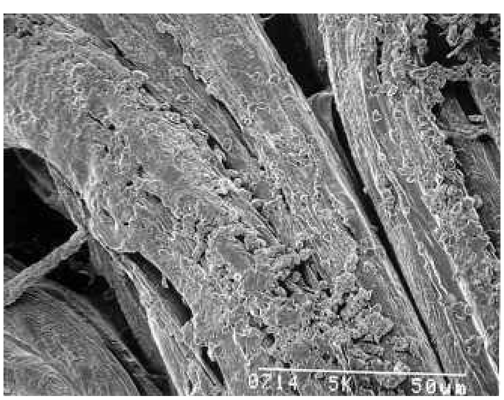
Treatment 1 exposed fabric to mercerization and bleaching only.



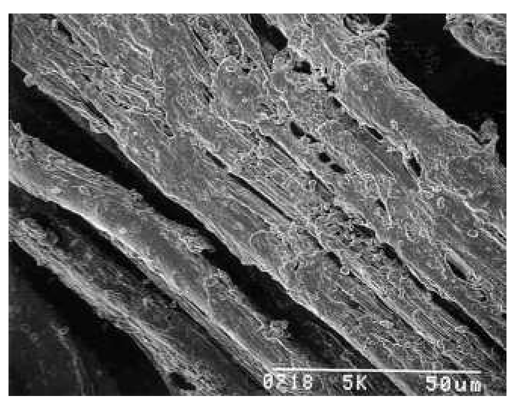
Treatment 2 exposed fabric to xylanase, mercerization and bleaching.



Untreated control fabric.



Treatment 3 exposed fabric to laccase, mercerization and bleaching.



Treatment 4 exposed fabric to laccase, mercerization and bleaching with extra peroxide.

treatment 2 (xylanase, mercerization, and bleaching) provided the softest feeling fabric, followed by treatment 4 (laccase, mercerization, and bleaching with extra peroxide) as the next softest. Treatments 1 (mercerization and bleaching only) and 3 (laccase, mercerization, and bleaching) followed. All panelists agreed that these treatments provided very similar softness and were far superior to the untreated fabric.

The surface roughness was determined by the measurement of the rises and depressions in the fabrics. The surface roughness values from the Kawabata evaluation system data (Table 4) indicated that the four treated fabrics had statistically similar surface roughness and were all smoother than the untreated fabric, as indicated by the panelists. However, the differences between fabrics were not as dramatic as the panel's ranking indicates.

At low magnification (Fig. 4) the photomicrographs revealed that the kenaf fiber in the untreated fabric was very stiff and did not lay down in the yarn with the cotton fibers, which produced a harsh hand. The high magnification (Fig. 5) photomicrographs showed that the lignin binds the individual untreated kenaf fibers into bundles of fibers that cause the stiffness. The stiff kenaf fibers tend to poke out of the yarn, causing the surface to be rough.

High magnification photomicrographs of the treated fabrics (Fig. 5) confirmed that there was some fiber separation and removal of lignin for all treatments. The enzyme and mercerization treatments each removed some level of lignin, pectins, hemicelluloses, and gums, which separated some of the kenaf bundles as confirmed by the high magnification photomicrographs (Fig. 5). The kenaf fibers were more individualized and flexible in the treated fabrics and lay into the yarn (Fig. 4) with the cotton fibers, producing a much softer hand.

Treatment 2 (xylanase, mercerization, and bleaching) did the best job of removing these elements without damaging the kenaf fibers as can be seen in the higher magnification in Fig. 5. Treatment 2 produced the smoothest and most separated of the kenaf fibers, followed by treatment 1 (mercerization and bleaching only), treatment 3 (laccase, mercerization, and bleaching) and treatment 4 (laccase, mercerization, and bleaching with extra peroxide) which show actual fiber damage to the kenaf. In agreement with panelists, treatment 2 (xylanase, mercerization, and bleaching) provided the lowest coefficient of friction (significantly different from the others) which resulted from the separation and smooth surface of the kenaf fibers (Fig. 5). By removing these elements, treatment 2 allowed a more efficient mercerization that also resulted in the highest strength, abrasion resistance, and elongation of the treated fabrics. These values, along with the comments made by panelists, indicate that treatment 2 resulted in the superior fabric.

Instron strip testing as per ASTM D 5035-95 was also done on all fabrics (three reps/treatment, Table 4). The elongation was much higher for the treated fabrics due to the shrinkage of the fabrics. The crimp in the fabric was pulled out during the strip test and this showed up as much higher elongations for the treated fabrics than the untreated fabric. All treatments showed strength loss as compared to the untreated fabric, because of the added strength of the pectins, hemicelluloses, and gums in the untreated fabric and the damage caused by the mechanical action of the steel ball bearings on the treated fabrics.

Treatment 3 (laccase, mercerization, and bleaching) and treatment 1 (mercerization and bleaching only) were similar in most fabric properties except that treatment 1 had better abrasion resistance. Treatment 4 (laccase, mercerization, and bleaching with extra peroxide) had the greatest strength loss. While handling the samples, it was noticed that treatment 4 noticeably reduced the fabric strength. Fibers were visible in the enzyme mercerization and bleaching treatment bath. The samples had to be treated gently so that they would not tear during the final rinse. The damage caused by treatment 4 can be seen in the higher magnification photomicrographs (Fig. 5) and in the kenaf fiber's smaller diameter, and thinner fabric (Table 4) as compared to the other treated fabrics. The surface of the fabric from treatment 4 is irregular due to fiber losses and is easily seen when comparing the thickness graphs generated by Kawabata. The degradation of the fiber by treatment 4 caused poor abrasion resistance, high air permeability, lower strength, and elongation.

CONCLUSIONS

This preliminary study showed that apparel and upholstery quality yarns and fabrics can be made using retted kenaf in blends with cotton. The initial plain weave fabric had the aesthetically pleasing look of linen, but was too scratchy for apparel. The untreated fabrics were too rough, but kenaf's good tensile property and resistance to mildew and rot, may open up markets for industrial textiles. The initial twill fabric (untreated kenaf/cotton) had the look and feel of a loosely woven burlap and was harsh to the touch.

The treated samples were much softer, thicker fabrics with tighter weaves, due to shrinkage, and had the look and feel of heavy upholstery fabrics. The enzyme and mercerization treatments improved the hand of the kenaf/cotton blended fabrics compared to the untreated fabrics. The softness of the fabrics was much improved to the touch. Based on panel judgments, Kawabata data, and photomicrographs, the xylanase enzyme treatment followed by mercerization and bleaching produced the most significant results. With the use of the xylanase enzyme, the kenaf fibers separated and thus conformed with yarn and fabric structure as illuminated by photomicrographs. The laccase, when used in conjunction with the additional peroxide, also offered slight improvement, but with considerable strength loss.

Treatment 1, which only bleached and mercerized the fabric, also had an improved softness, but without the additional cost of enzymes. Even though treatment 2 (xylanase, mercerization, and bleaching) produced a superior fabric, due to the high cost of enzymes (and only a slight difference in hand), treatment 1 (mercerization and bleaching only) was sufficient to create the desired hand with minimal strength loss.

Prior to this research, kenaf was not a viable fiber for apparel and upholstery fabrics. Using cotton as the support system for kenaf, combined with retting and finishing techniques, this research resulted in optimal kenaf/cotton blend fabrics for apparel and upholstery use that are aesthetically appealing and have a soft hand. The light weight fabrics have a linen look and, after treatment, are suitable for apparel without any type of lining. Such cotton/kenaf blends are an inexpensive, natural fiber alternative to linen. The heavy weight twill fabrics are excellent upholstery fabrics that have a soft hand and meet the industry's strength requirements. In both cases this collaborative effort resulted in high value fabrics made with kenaf, an inexpensive fiber.

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