Properties of Ligno-Cellulosic Bilayered Vegetable Fabric from Ridge Gourd

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ABSTRACT: The two layers of bilayered vegetable fabric from ridge gourd were analyzed by FTIR, chemical, X-ray, and thermogravimetric methods before and after alkali treatment. The morphology of the fabrics in the two layers, before and after alkali treatment, was also studied using SEM technique. The FTIR and chemical analyses indicated lowering of lignin and hemicellulose content by alkali treatment in the fabric of both layers. Further, the X-ray diffraction revealed increase in crystallinity of the fabric by alkali treatment. The thermal stability of the fabric was also found to increase by alkali treatment. © 2006 Wiley Periodicals, Inc. J Appl Polym Sci 102: 2338–2342, 2006

Key words: ligno-cellulose; bi-layered vegetable fabric; ridge gourd; FTIR; thermogravimetric; morphology; crystallinity; hemicellulose

INTRODUCTION

As the synthetic polymers and their composites with nondegradable conventional reinforcements are posing environmental problems, the trend is slowly shifting towards using natural fibers as reinforcements. The composites prepared using natural fiber reinforcements are known as "green composites." In this direction, some green composites were developed by several workers.[1–11] To identify new natural fibers and fabrics as reinforcement, their properties have to be studied. In the present work, the authors studied the properties of the bilayered vegetable fabric from ridge gourd. The botanical name of this vegetable is *Luffa acutangula* (L.) Roxb, which belongs to the family of Cucurbitaceae. It is a tropical high yielding annual tendril climber plant. The fabric from this vegetable is widely used as natural body scrubber in many parts of Asia. This edible vegetable also has many medicinal values. As data are not available on this fabric/fiber, the authors studied some of its properties such as chemical composition, thermal stability, XRD, and spectral analysis and morphology. The authors studied these properties before and after alkali treatment.

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MATERIALS AND METHODS

Extraction of the fabric from the vegetable

The tubular vegetables belonging to the ridge gourd family were dried in the sun for several days and were gently crushed to remove the dried powder matter. The dried tubular vegetables having the fabric alone were slit open to yield rectangular bilayered fabric. Some of the fabric samples were treated with 5% aq. NaOH solution and were dried before analysis.

FTIR spectral analysis

The fibers from both layers were separated and in each case they were cryogenically cooled and powdered. These powders were diluted to 1%, using KBr and pellets were prepared. The FTIR spectra of the untreated and alkali-treated samples in both layers were recorded in 4000–500 cm^{-1} region on a PerkinElmer 16PC FTIR instrument with 32 scans in each case at a resolution of 4 cm^{-1}.

Chemical analysis

The chemical analysis of the fibers from both layers, before and after alkali treatment, was carried as per the standard procedure.[12] In this analysis, the percentage of α-cellulose, hemicellulose, and lignin were determined. In each case, five samples were used and the average values were reported.

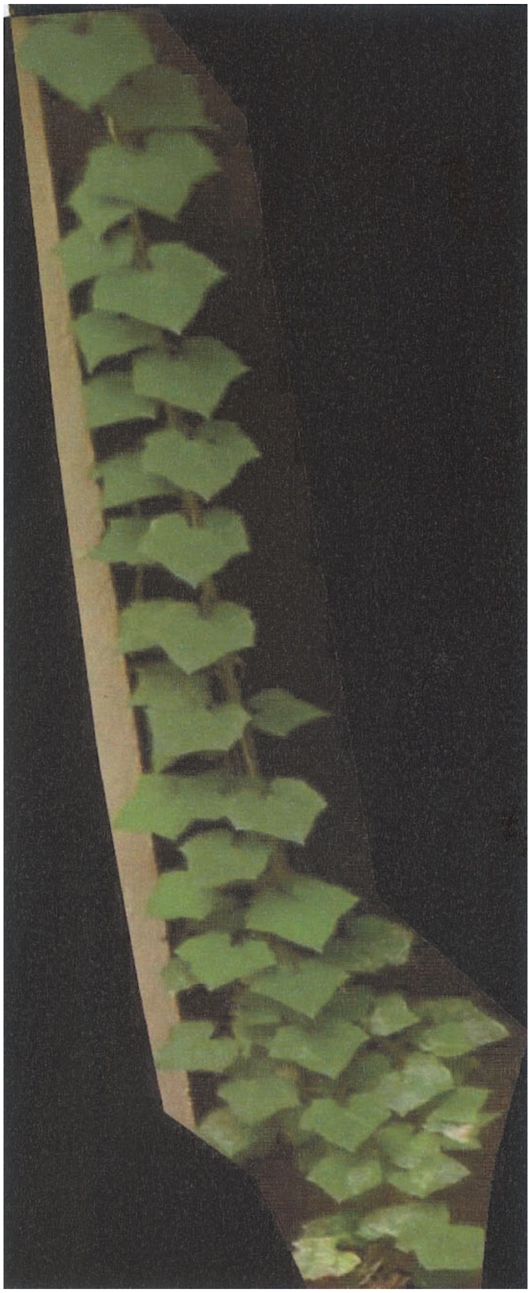

Figure 1 Photograph of ridge gourd creeper plant. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Thermogravimetric analysis

The thermograms of the fibers from both the layers, before and after alkali treatment, were recorded on a PerkinElmer TGA-7 instrument in nitrogen atmosphere at a heating rate of 10°C/min. Using the primary thermograms, the thermal parameters—initial degradation temperature, final degradation temperature, inflection point, and the integral procedural degradation temperature (IPDT)—were calculated using Doyle[13] method.

X-ray analysis

The X-ray analysis of powdered fabric samples was carried out on a Rigaku Dmax 2500 instrument.

Morphology

The scanning electron micrograms of the fabric in the two layers before and after alkali treatment were recorded on a JOEL JSM 820 microscope. The fabric samples were gold-coated before recording the micrograms.

RESULTS AND DISCUSSION

The ridge gourd creeper plant is shown in Figure 1. This is a high yielding variety and grows very well in tropical areas. The photographs of the tubular vegetable fabric, rectangular fabric in the top and bottom layers, are shown in Figure 2. The morphology of the fabric in both layers before and after alkali treatment is shown in Figure 3. From Figure 3, it is clearly evident that the covering layer having probably hemicellulose and lignin is considerably removed by alkali treatment in both layers. Further, it is evident that the surface of the fibers becomes rough on alkali treatment. Similar observation was made in the case of lingocellulose fabric *Hildegardia populifolia*.[14]

The FTIR spectra of the fibers from the fabric samples in both layers, before and after alkali treatment, are presented in Figure 4. The band positions and possible assignment are presented in Table I. From Figure 4, it is evident that well-defined bands at around 3440, 1630, 1260, 1105, 1060 cm^{-1} are present in the spectra. But in the case of untreated fabric, an additional band at around 1740 cm^{-1} is also present, which corresponds to hemicellulose. On alkali treatment, this band is found to decrease in intensity indicating the elimination of hemicellulose on alkali treatment to a considerable extent. Of the bands identified, the band around 3440 cm^{-1} belongs to α-cellulose, whereas the remaining bands correspond to lignin in the fibers. From the spectra, it is also evident that the intensity of the bands corresponding to lignin from the fibers of both the layers has also decreased on alkali treatment, indicating the lowering of lignin content on alkali treatment. Because of this process, the intensity of the bands belonging to α-cellulose has increased. The FTIR analysis of the fibers from both the layers is further supported by chemical analysis (Table II). From Table II, it is also evident that the chemical composition of the untreated fibers from the top and bottom layer is almost similar. In the case of the fibers from both layers treated by alkali, the hemicellulose and lignin content decreased, whereas the α-cellulose content increased. Here also, the chemical

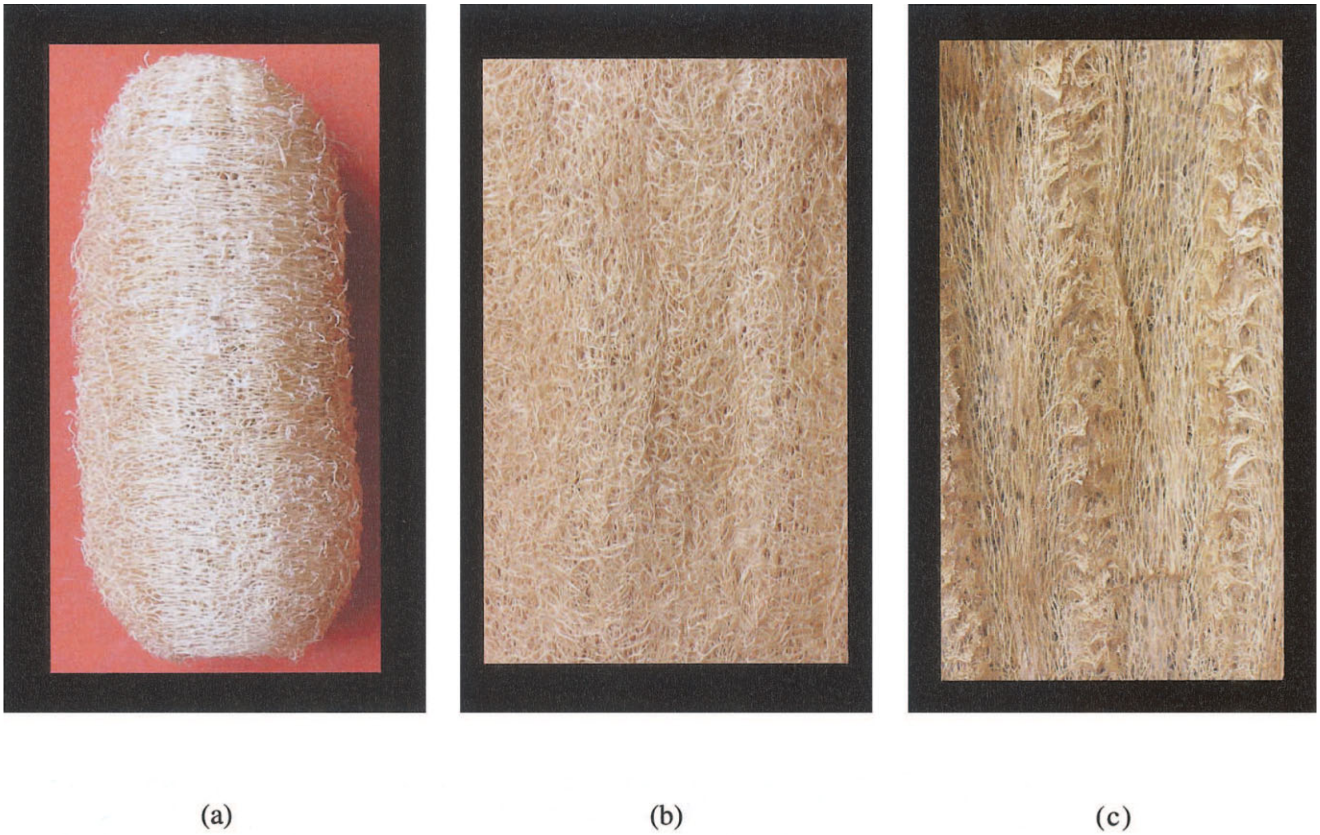

Figure 2 Photographs of (a) tubular, (b) rectangular top layer, and (c) rectangular bottom layer fabric. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

composition of the alkali-treated fibers from both layers is found to be similar.

The X-ray diffractograms of the fibers from both the layers, before and after alkali treatment, are presented in Figure 5. From Figure 5, it is clearly evident that the crystallinity of the fibers from both the layers increased on alkali treatment. This is understandable as the crystalline α-cellulose content is increased, whereas the amorphous hemicellulose and lignin content decreased on alkali treatment. This is in conformity with the FTIR and chemical analyses.

The primary thermograms of the fibers from both layers, before and after alkali treatment, are presented in Figure 6. The thermal parameters calculated from the primary thermograms—the initial degradation temperature, the final degradation temperature, the inflection point and the IPDT—are presented in Table III. From the thermograms and the tables, it is evident that the thermal stability of the alkali treated fibers is higher, when compared to that of untreated fibers from both the layers. This may be attributed to the increased crystallinity of the fibers by alkali treatment. These parameters indicate that the fibers from ridge gourd vegetable can be utilized as reinforcement not only in thermosetts but also in thermoplastics with a melting temperature less than 250°C.

TABLE I
Peak Positions and Assignments of Chemical Groups in the Treated and Untreated Ridge Gourd Fabric

Wavenumber (cm^{-1})	Assignments
3421	OH-stretching of α-cellulose
1740	CO stretching of hemicellulose
1631	CO stretching of lignin
1262	
1160	Asymmetric C—O—C stretching of lignin
1106	
1058	Symmetric CO stretching of lignin

TABLE II
Chemical Analysis of Untreated and Alkali Treated Ridge Gourd Fibers from the Top and Bottom Layers of the Fabric

	Dewaxed untreated		Dewaxed alkali treated	
Chemical component	Top layer	Bottom layer	Top layer	Bottom layer
α-Cellulose	57.2	60.0	73.0	72.7
Hemicellulose	14.0	14.1	12.5	12.3
Lignin	27.7	25.9	14.4	14.96

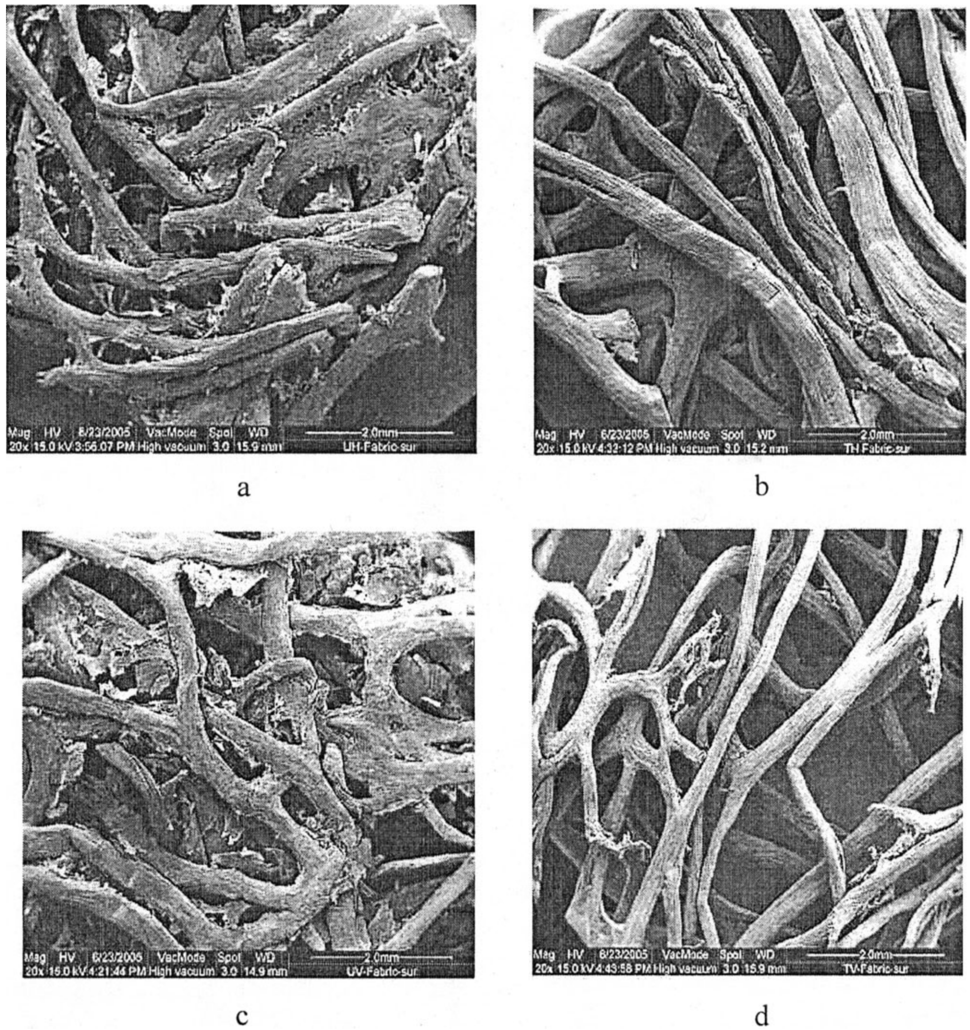

Figure 3 Scanning electron micrograms of ridge gourd fabric: (a) untreated top layer, (b) alkali treated top layer, (c) untreated bottom layer, and (d) alkali treated bottom layer.

TABLE III
Thermal Degradation Parameters of Untreated and Alkali Treated Ridge Gourd Fibers from the Top and Bottom Layers of the Fabric

	Top layer fabric		Bottom layer fabric	
Degradation Parameter	Untreated (°C)	Alkali treated (°C)	Untreated (°C)	Alkali treated (°C)
Initial degradation temperature	225	260	245	260
Final degradation temperature	355	388	360	377
Inflection point	310	348	330	350
Integral procedural degradation temperature	227	230	234	239

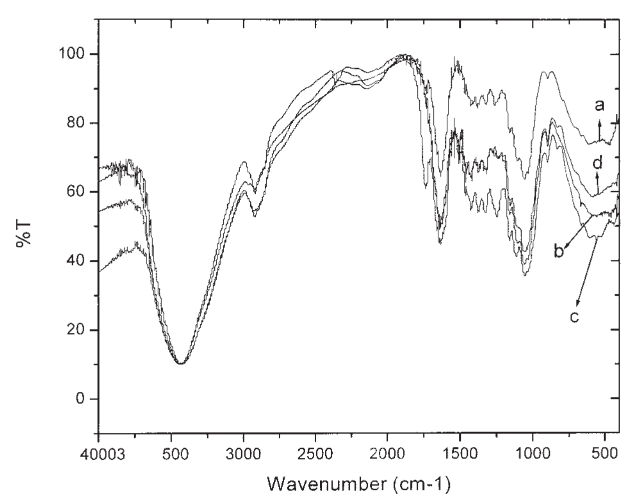

Figure 4 FTIR spectra of ridge gourd fabric: (a) untreated top layer, (b) alkali treated top layer, (c) untreated bottom layer, and (d) alkali treated bottom layer.

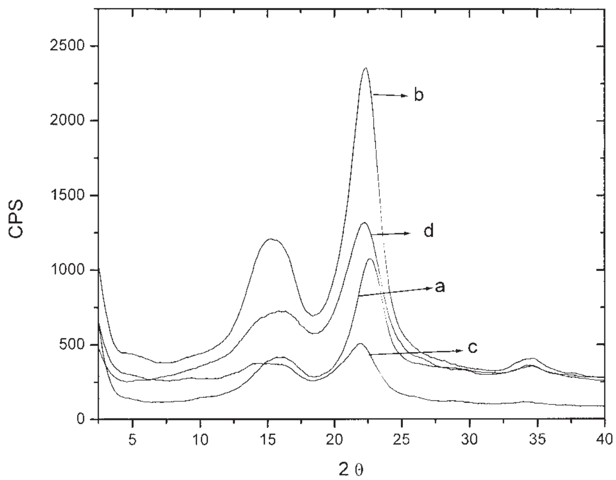

Figure 5 X-ray diffractograms of ridge gourd fabric: (a) untreated top layer, (b) alkali treated top layer, (c) untreated bottom layer, and (d) alkali treated bottom layer.

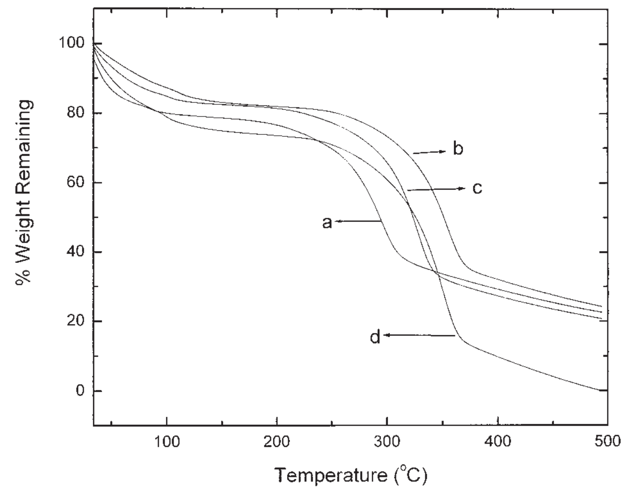

Figure 6 Primary thermograms of ridge gourd fabric: (a) untreated top layer, (b) alkali treated top layer, (c) untreated bottom layer, and (d) alkali treated bottom layer.

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