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Characterization of *Triumfetta Tomentosa B.* a bast fiber growing wildly in Kenya

J.I.Mwasiagi[1,2]*, T.Phologolo[1], C.W.Yu[1], E.Kamalha[1], L.Kinuthia[3], Lusweti Kituyi[4]

[1]College of Textiles, 2999, North Renmin Road, Shanghai-201620, (CHINA)

[2]iOTEX, Bahir Dar University, PO Box 26, Bahir Dar, (ETHIOPIA)

[3]Egerton University, P.O Box 536 Egerton-Njoro, (KENYA)

[4]School of Science, Chepkoilel University College, Po Box 1125, Eldoret, (KENYA)

E-mail: igadwa@gmail.com

ABSTRACT

Triumfetta Tomentosa B(*TTB*) is one of the plants that grow naturally in the Kenyan forested regions of Mt. Kenya, Aberdares ranges, Kakamega and the Mau forest. Traditionally *TTB* leaves have been used as food, the bark is used to make ropes or weave baskets and the stem is used as firewood. Among the farmers living in the Mt. Kenya region, the *TTB* bark is normally treatment with a bleaching agent (used for general laundry purposes), with an aim of getting a stronger fiber. The objectives of this research work included the study the properties of *TTB* bast fibers. Comparison with jute fibers was also undertaken to gauge its suitability for use as grain (maize) packing material. *TTB* stems were harvested from Mount Kenya region, step retted and then characterized. Surface and chemical characterization of the *TTB* fibers was undertaken using modern equipments such as FT-IR, SEM, XRD and tensile property measurement equipments. The chemical ingredients of the fibers were also determined. The results obtained in this research work using the XRD equipment indicated that *TTB* fibers have cellulose I structure, which is common with most bast fibers. Comparison of the chemical ingredients of *TTB* and jute fibers revealed that the raw *TTB* fibers contained higher percentages of lignin and lower levels of hemicellulose. The treated *TTB* fibers contained higher levels of cellulose and reduced levels of lignin and hemicellulose. Treated *TTB* fibers exhibited finer count and higher tensile strength when compared to the raw fibers.

KEYWORDS

Triumfetta Tomentosa B. (*TTB*);
Bast;
Fiber;
Characterization.

INTRODUCTION

Kenya is a third world country that has launched vision 2030 to enable it move from an agricultural to a highly industrialized nation[1]. In order to achieve its goals in vision 2030, Kenya plans to improve the economic situation of the country, by adapting wealth creation strategies. While there are many opportunities for wealth creation, Kenya can make rapid strides towards economic empowerment of its people by harnessing its

natural resources. Kenya is situated in the tropical regions and has pleasant climate. The Kenyan climate can allow the growth of a variety of plants, which includes exotic and indigenous trees. One type of shrubs which grows wildly in the Kenyan forested regions is *Triumfetta Tomentosa B.* (*TTB*). This plant (*TTB*) also grows in many other sub-Saharan countries[2]. In Kenya *TTB* grows naturally in forested regions which includes, Karura forest, Mt. Kenya Forest, Mau Hills, Kakamega Forest and the Aberdare ranges. Traditionally, Kenyans have used *TTB* leaves as food, the bark is used to make ropes or weave baskets and the stem is used as firewood. Among the farmers leaving in the Mount Kenya region, the *TTB* bark is normally treatment with a bleaching agent (used for general laundry purposes), with an aim of getting a stronger fiber. Unpublished reports indicate that TTB is rich in nutrients needed by animals and is therefore feed to domestic animals like goats. This could be true given that *TTB* leaves have been reported to be one of the important dietary ingredients for gorillas living in mountainous region covering Uganda, Rwanda and Congo[3].

While Kenya is endowed with such plants like *TTB* it however has to import grain packaging material, such as jute fibers from Asian countries due to lack of research of the potential of locally available natural fibers. If properly harnessed and commercialized the bast fiber obtained from the *TTB* shrub could be used to supply raw material for the grain packaging industry. Considering one of the important grains in Kenya as an example, Kenya produces over 3 million metric tonnes (3 billion kg) of maize[4]. This translates to approximately 33 million bags of 90 kg. Since most of the maize crop is rain fed, more bags will be needed to store the maize to cater for emergencies which might include crop failure due to drought. Given that there is a policy by most African countries to increase food reserves[5] the need for more storage facilities and is bound to increase. In Kenya like in many other Africa countries maize is packed in jute or polypropylene (pp) bags. While jute was the main maize packing material in 1970s pp bags have dominated the grain packing industry due to the mere fact that pp bags are comparatively cheaper[6]. However for grains that need to be stored for more than three months the use of pp bags may lead to aflotoxins poisoning. Reports by several researchers[7-11] have proven beyond any reasonable doubt that the use of pp bags for storage of grains leads to grain damage. Grain storage in Africa is a complicated issue, affected by the poverty level, Government policies and social-economic factors. For example most farmers prefer storing their own grains instead of the use of large silos as is the case in Asia and western countries. There is a new trend reported by Mutambuki[12], where farmers prefer to store their own seeds on the farm for planting in the next season. This will definitely increase the need of storage bags, and could be one of the reasons jute exporting countries are predicting an increase in the use of jute bags in African countries like Kenya[13]. Therefore the need for the use of natural bags for the storage of grains in African countries cannot be overemphasized. In fact the commercialization of the growing of jute-like fibers in Kenya could lead to improvement of the economic status of some of the peasant farmers.

Apart from the afore-mentioned advantages of natural fibers when used for grain storage, natural fibers have another advantage over synthetic fibers; they are eco-friendly. Like all plants, natural fibers use up carbon dioxide as a way of making sugars, and produce oxygen. Studies have shown that the carbon dioxide assimilation of kenaf (a jute like fiber) is much higher than that of other plants like trees[14]. If Kenya could identify a local jute like fiber and commercialize it for use in grain storage and packing industry, it will also contribute to carbon dioxide assimilation, and this will be in line with Kenyan Vision 2030 which also emphasis sustainable eco-friendly development. Considering the possible potential of the TTB bark fiber and the problem of grain storage currently experienced in Kenya, this research work aimed at studying the properties of *TTB* bast fibers. A comparison of the *TTB* with jute fibers was also undertaken.

MATERIALS AND METHODS

Materials

The fibers used in this research work were obtained from freshly cut stems of the TTB shrubs growing wildly in the Mount Kenya forest (see Figure 1). Freshly cut stems, which exhibited a basal of approximately 7 cm, were retted for two weeks after which the barks were scraped off and washed in running water. *TTB* fibers were extracted using a mechanical method from the retted barks. The extracted fibers were dried under the

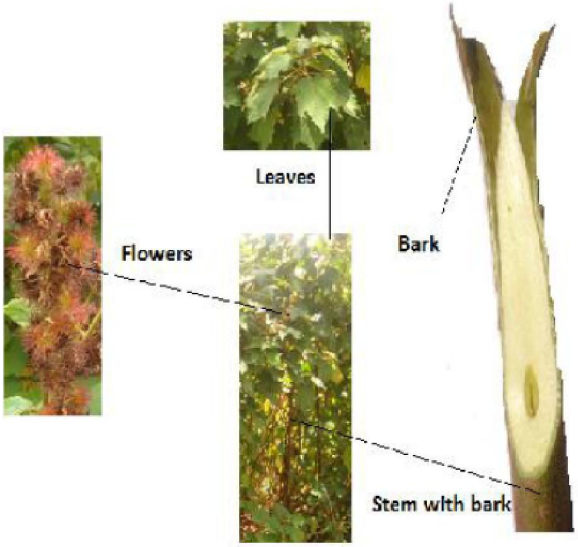


Figure 1 : The *TTB* plant (flowers, leaves and stem enlarged)

shade and divided into two main samples. One of the samples was not treated and hence code named raw fiber, while the second sample was treated using a domestic laundry bleaching powder, according to the procedure adapted by the local farmers. This sample was code named treated fiber. The raw and the treated fibers were characterized.

Methods

The fiber samples were characterized using several instruments which included FT-IR, SEM, XRD and tensile property measurement equipments. The chemical ingredients of *TTB* fibers were also determined. This section presents a brief descriptions of the methods used.

(a) Fiber morphology

Scanning electron microscope (Hitachi TM1000) was used to observe the morphology of the fibers. The longitudinal and cross-sectional views were considered. The testing was done after the samples had been acclimatized to standard testing condition of 20^0C and 65% relative humidity. The SEM voltage was set at 15KV.

(b) Studying the chemical groups in TTB fibers

Fourier transform infrared spectrophotometry (FT-IR), Nicolet 8700 was employed to determine chemical groups in the fiber samples, using a range of 4000 to 400 cm^{-1}. Spectra outputs were recorded in the absorbance mode as a function of wave number.

(c) Testing for the degree of orientation using XRD

X-ray diffraction meter (D /MAX -2550 PC) set at 18kW, 30mA and scanning rate of 2^0 min^{-1} was used to study the crystallinity of the fibers. The scanning range was 5^0 to 60^0.

(d) Physical properties

The tensile properties of the fibers were tested using a single fiber tensile testing equipment model LLY-06, following ASTM D-5035 standards, while the fiber fineness was determined using Chinese standard GB/T12411.3.

(e) Study of the chemical ingredients in TTB fibers

The chemical ingredients of the *TTB* fibers were determined by using the Chinese standard GB/5889-86 for bast fibers, where the percentages of wax, water soluble matter, pectin, hemicelluloses and cellulose present in the fiber were recorded. The procedure is given in the appendix.

RESULTS AND DISCUSSIONS

Fiber surface morphology

The use of SEM to study the surface morphology of the *TTB* fiber as discussed in the materials and methods section yielded the images given in Figure 2. The cross-sectional SEM images indicated that the fibers were clustered together. This is a phenomena observed in many other bast fibers like jute and hemp[15].

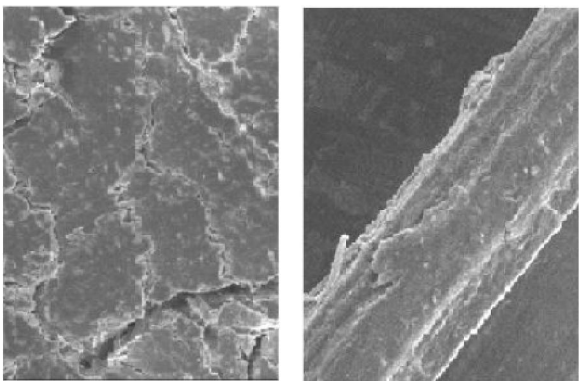
The longitudinal view of the raw fiber indicate that the fiber is covered by some gummy like material. The gummy like material appears to have been reduced by the treatment done to the fiber as it can be seen in the longitudinal view of the treated fiber.

(a) The chemical ingredients of TTB fibers

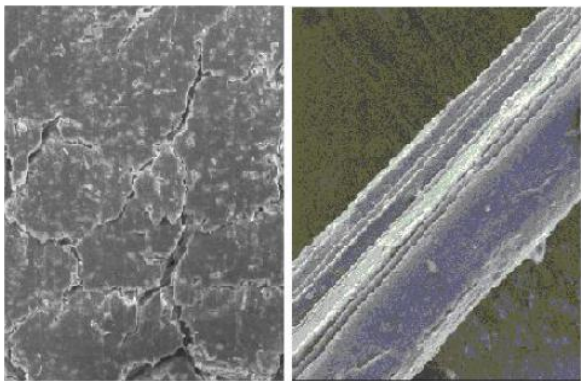
The chemical ingredients in *TTB* fibers were determined as explained in the material and methods sections are given in TABLE 1. The treated fibers exhibited an increase in the amount of cellulose and hemicellulose, and a reduction in the amount of lignin. Comparing the chemical ingredients of jute reported by several researchers and presented by Rowell and Stout[16] (cellulose (63-72%), hemicellulose (13-22%) and lignin (13-14.35%)) the raw *TTB* fibers can be adjudged to contain higher percentages of lignin and lower levels of hemicellulose. Higher levels of lignin will render the raw *TTB* fibers to exhibit a harsher handle when compared to jute. The treated *TTB* fibers reported higher

levels of cellulose and reduced levels of lignin.

Chemical Groups of *TTB* fibers A study of the chemical groups undertaken using FT-IR as explained in the Materials and Methods sections are given in Figures 3 and 4. For the raw *TTB* fibers the peaks were more or less similar to the peaks exhibited by jute fibers[15]. The peaks at 3342 cm^{-1} and 1034 cm^{-1} could be attributed



(a) Raw fiber



(b) Treated fiber

Figure 2: Cross-sectional and longitudinal SEM for *TTB* fiber

TABLE 1 : Chemical contents of TTB fibers

Ingredients	*TTB*-raw (%)	*TTB*-Treated (%)
Cellulose	69.65	78.37
Lignin	17.9142	6.6169
Hemi-cellulose	6.61	8.59
Pectin	2.27	2.14
Wax	0.9	0.36
Water soluble	2.65	3.92

to the O-H stretching and bending groups respectively. The vibration peaks at 1612 cm^{-1} could be attributed to C=C stretching, while the vibration peak at 1246 cm^{-1} could be attributed to C-O stretching vibrations. According to Favaro et al[17], peaks at around 1242 cm^{-1} could be attributed to hemicelluloses present in natural fibers. Other peaks at 2920 cm^{-1} and 1317 cm^{-1}, could be attributed to C-H stretching and bending vibrations respectively.

The FT-IR spectra for the treated *TTB* fibers showed that the raw and treated fibers have minor differences. The peak at 1246 is less prominent in the treated fibers. This could be due to the reduced amount of lignin as shown in TABLE 1.

(b) The crystalline structure of TTB fibers

The XRD patterns for the *TTB* fibers given in Figure 5, showed two major peaks at around 16^0 and 22^0. The peak around 16^0 is however split into two (see TABLE 2,) with the raw fiber having 15.15^0 and 16.497^0 peaks and the treated fiber having 15.057^0 and 16.26^0 peaks respectively. This is close (but not the same) to the XRD for jute patterns given by Wang et al[18]. This pattern is slightly different from the three peak pattern of 14^0, 16^0 and 22^0 for cellulose 1 crystalline structure. As reported by Wang YP et al[19], the splitting of the peak at around 16^0, can be adjudged to be due to the overlapping of the 14^0 and 16^0 peaks. Therefore the *TTB* fibers can be considered to possess cellulose I structure.

The degree of crystallinity for the raw and treated fibers was 66.42% and 69.46% respectively. This is higher than that of jute (53.8%) but lower than that of ramie (72.2%) another bast fiber commonly grown in China[19]. Higher degree of crystalline could lead to higher fiber strength. The reduction of the percentage of lignin (amorphous) content in the treated fiber could have contributed to the increase in the level of the crystallinity.

(c) Fiber tensile properties and fineness

The fiber tensile properties and fineness were tested as discussed earlier in the materials sections are given in TABLE 3. The reported fiber strength for *TTB* fiber is lower than that of jute. The treated of the fiber with the domestic laundry bleaching powder managed to increase the tensile strength of the treated fiber. This could be due to the increase of the amount of cellulose as reported earlier in TABLE 1, and the reduction of lignin which is amorphous in nature. The increase in fiber strength in the treated fiber could also be supported by the increase in fiber crystallinity. As reported earlier the treated fiber recorded higher fiber crystallinity, hence a higher tensile strength could be expected.

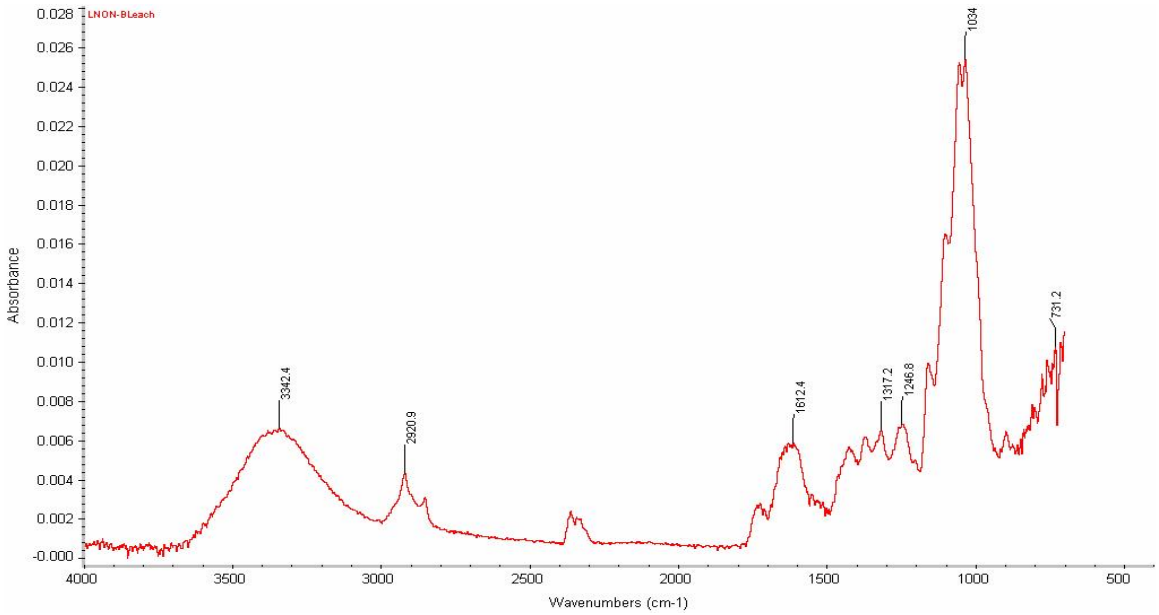


Figure 3 : FT-IR spectra for raw *TTB* fibers

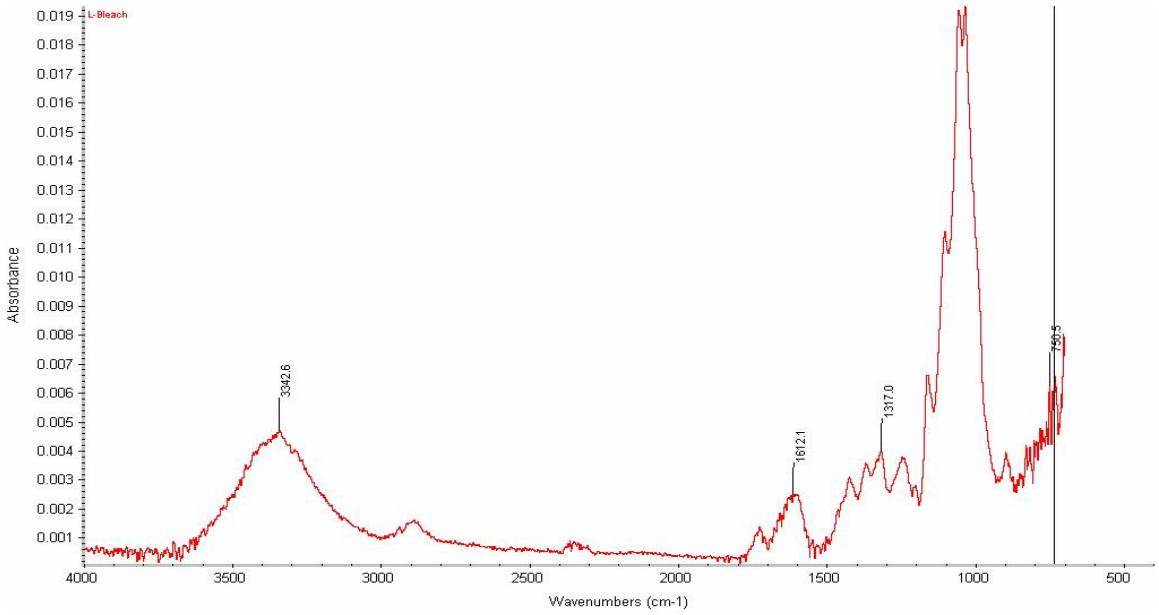


Figure 4 : FT-IR spectra for treated *TTB* fibers

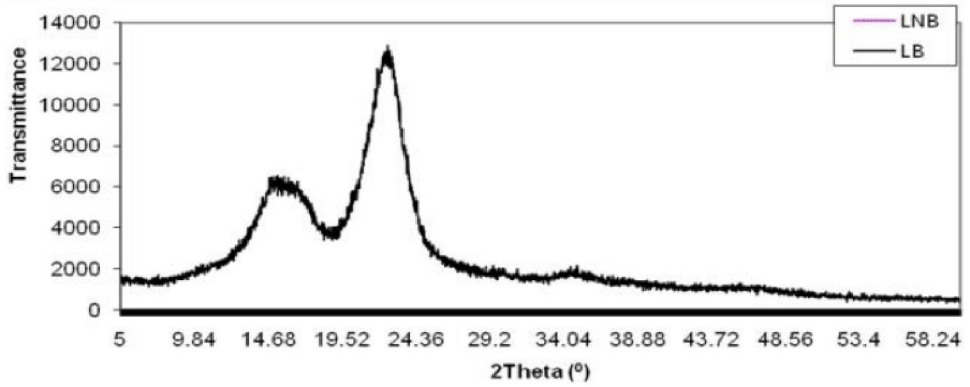


Figure 5 : The XRD pattern for raw and bleached *TTB* fibers

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Considering the fiber fineness as given in TABLE 2 the treated fiber exhibited finer when compared to the raw fiber. This could be due to the fact that the domestic bleaching powder could have removed some of the gummy like material holding the fibers together, hence reducing the overall fiber diameter.

TABLE 2 : The interplanar (XRD) for *TTB* fiber

Raw fiber		Treated fiber	
D(nm)	2Thet(^{0})	d(nm)	2Theta(^{0})
5.879	15.057	5.8429	15.151
5.4468	16.26	5.3689	16.497
3.9718	22.365	3.9798	22.32
3.6448	24.401	2.9976	29.78
2.9645	30.12	2.5859	34.66
2.5787	34.76	1.9549	46.41
2.3547	38.189		
1.96	46.282		

TABLE 3 : Physical properties of *TTB* fiber

Fiber type	Strength (cN/Tex)	Extension (%)	Fineness (Tex)
Raw	24	3.24	4.1
Treated	27	4.46	3.3

APPENDIX

Chinese standard GB/5889-86 gives the procedure for the study of chemical ingredients of hard fibers (leaf and bast fibers). The procedure involves the determination of the percentages of wax, water soluble matter, pectin, hemicelluloses and cellulose present in the fiber. It includes;

(i) Weighing a sample of fiber (about 5 gms) and getting its oven dry weight (W_1)

(ii) Using a mixture of benzene and methanol and boiling together with the fiber for 3 hours. Wax dissolves in the mixture and is therefore removed from the fiber. Once the boiling is over the fiber should be washed in water and oven dried (for 2 hours at a temperature of at 105^{0}C) to get the bone dry weight (W_2). Wax contented can be calculated by using the following expression; Wax content (%) = $(W_1-W_2)*100/W_1$

(iii) Water soluble substances can be obtained by boiling the de-waxed fiber in distilled water for 3 hrs, and thereafter getting the bone dry weight of the fiber (W_3).
Water soluble matter = $(W_1-W_3)*100/W_1$

(iv) Boiling the dewaxed fiber with ammonium oxalate solution for 3 hours (pectin will dissolve in the ammonium solution) and then getting the bone dry weight of the fiber (W_4). The amount of pectin can be calculated by using the following formula;
Pecti (%) = $(W_1-W_4)*100/W_1$

(v) Boiling the fiber from the procedure (iv) above with a solution of Sodium Hydroxide for 3.5 hrs, and getting the bone dry weight of the fiber (W_5), and then calculating the amount of hemicellulose using the following expression; Hemicellulose (%) = $(W_1-W_5)*100/W_1$.

(vi) Determining the amount of lignin in the fiber involves first dewaxing a new set of fiber sample, which has been weighed to have an intial weight of W_{11} and then dewaxed. The dewaxed sample can then be dissolved in concentrated sulphuric acid for 24 hrs, followed by filtration and collection and weighing of the residue (lignin) (W_6). The amount of lignin can then be calculated by using the following expression; Lignin (%) = $(W_{11}-W_6)*100/W_{11}$

CONCLUSION

A study of the properties of the bast fiber obtained from *Triumfetta Tomentosa B.* (*TTB*) a shrub that grows wildly in Kenya, was undertaken. Two main fiber samples; raw and treated fibers were considered. Surface, chemical and physical characterization of the fiber samples were undertaken using modern equipments such as FT-IR, SEM, XRD and fiber tensile property measurement equipments. The chemical ingredients of *TTB* were also analyzed.

The results obtained in this research work indicated that *TTB* fiber has Cellulose I structure and its cross-sectional morphology was typical to other commonly known bast fibers like jute. The treated fibers exhibited higher percentage of fiber crystallinity. Comparison of the chemical ingredients of *TTB* and jute fibers revealed that the raw *TTB* fibers contained higher percentages of lignin and lower levels of hemicellulose. Compared to the raw fibers the treated fibers contained higher levels of cellulose and reduced levels of lignin and hemicellulose. Treated *TTB* fibers exhibited finer count and higher tensile strength when compared to the raw fibers.

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