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Eco-Friendly Treatment of Green Banana Fiber in Compared to Chemical Treatment

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Abstract

Recently, environmental considerations are becoming vital issues during the selection of consumer goods including textiles. Banana fiber is a biodegradable and recyclable natural fiber that provides certain advantages such as low cost, low density, non-toxicity, comparable strength, and minimum waste disposal problems. This article gives an overall view of banana fibers inter behavior in case of chemical and eco-friendly treatment. Various banana fiber samples were grouped into four bundles according to their treatment variation and apply textile wet processing method which were 100% chemically treated (100%CT), 100% natural treated (100%NT), 75% natural and 25% chemical treated (75NT:25CT), and 50% natural and 50% chemical treated (50NT:50CT). The treated samples were allowed to different physico-chemical and physico-mechanical testing. Finally, the testing results were compared based on their chemical and natural treatment and found that the naturally treated banana fiber is suitable for using in textile applications in compared to chemically treated fiber. It is also found that the eco-friendly banana fiber ash is an effective alternative chemical-scouring agent.

1. Introduction

It is well known that scouring is the most important wet process applied to textile materials. Unexpected oils, fats, waxes, solid dirts, soluble and natural impurities are removed in this cleaning process. Effective scouring is considered as the foundation of good dyeing, printing, and finishing process [1]. Different types of synthetic scouring chemicals have been used in the textile industries e.g., NaOH, $NaCO_3$, $Ca(OH)_2$ etc. The scouring conditions depend on the quality of scoured fabric required. For example, conventional chemical scouring has been carried out in hot (90 °C-100 °C) NaOH solution for 45-60 minutes [2].

Researcher were looking forward to having ecofriendly and sustainable textile processes because the use of extremely toxic chemicals increases the volume of effluents that causes environmental pollution. Subsequently, the effluents may cause alteration of the physical, chemical, and biological properties of aquatic environment that is harmful to public health, livestock, wildlife, fish, and other biodiversity [3]. From the above point of view, researchers concentrated on enzymatic scouring process. Generally, enzymes act in low temperature with first-rate efficacy. It saves high cost of energy consumption compared to conventional process. However, conventional alkaline scouring give better results in compare to enzymatic scourings [4]. For these reasons, researchers started to make the overall process eco-friendly to implement the natural resources and to set example of Green textile. Nature has ornamented this unique world with many marvelous resources. Banana plant were investigated as a remarkable resource of nature. Banana tree trunk ash or natural ash is substance, which used sometimes in our rural areas of Bangladesh to wash the heavy fabrics and other clothes as an alternative to the regular detergent or washing soap. This natural ash has an excellent property to make the fabrics clean. Natural ash obtained from the banana tree and this ash is extremely low cost and environment friendly. Different chronic diseases like bronchitis, dysentery, ulcers, diabetics, and plant sap in cases of hysteria, epilepsy, leprosy, fevers, hemorrhages, actue dysentery, and diarrhea were declared as a treated by banana flower [5]. Banana plant has made significant contribution in the textile sector besides as in the medical sector. In Ghana, a research was carried out to analyse the potential of banana sap as a dye for the Adinkra industry [6]. In addition, antimicrobial properties of banana ash and antibacterial and UV protective properties of banana peel, antioxidant were explored. The properties of banana fiber reinforced composites were also studied, and the variation in the mechanical properties were also analyzed [7-9].

Natural fibres give a lot of benefit over synthetic fiber due to their biodegradability, recyclability, renewability, low cost, high specific mechanical properties and low density [10-14]. Banana fiber is one of the most important natural fiber. Banana is a central fruit crop of the tropical and subtropical regions of the world grown on about 8.8 million hectares [15]. The total production of banana in Bangladesh was 800840 metric tons and the cultivated area was about 130589 acres in 2010-2011 [16]. Banana pseudostem has been used in many countries to develop important bio-products such as fibre to make yarn, fabric, apparel as well as fertilizer, fish feed, bio-chemicals, paper, handicrafts, pickles, candy, etc. whilst it is used as hazardous waste in Bangladesh [17]. After the fruits are harvested, a lot of banana trunks or stems will be wasted. Consequently, it is seen that huge portion of banana plants are just dumped as waste causing environment hazards and making ecosystem imbalance. Nowadays, most of the farmers are facing huge troubles in disposing the accumulated banana pseudostem because millions tones of banana pseudostem are dumped in our country as waste. Such waste gives available sources of fibers, which leads to the reduction of other natural and synthetic fibers production. Hence, the reducing this environmental problem by extraction of fibre and production of many essential food products, fertilizer, bio-chemicals, papers, etc. from banana waste pseudostem can be proposed.

The banana fibers are good moisture absorbent, highly breathable, quickly dry with high tensile strength. The fiber length varies greatly depending on the precise source and treatment of the fiber during fiber extraction. If the fiber is removed from the full length of the sheaths, the average length ranges from 3 to 15 ft. Compared to cotton fibre the moisture regain percentage of banana fibre is high of about 11-15%. The banana fibers have higher water absorbency and water release properties compared to other fibers like cotton, jute and flax, and lower crystallinity (19-24%) in the fiber structure. [14, 18, 19].

Several factors depend on the mechanical properties of the plant fibre like the source, age, the species, processing parameters and the internal structure [11]. The mechanical properties of the fibres with an increase in the diameter of the range investigated 50 to 250 μm have no appreciable change. The iniitial modulus gradual decrease with an increase in diameter of the fibres in the range of 100 to 450 μm. On the other hand, the ultimate tensile strength and breaking strain increased up to 200 μm diameter after which they remain constant [11,13].

Banana fiber used primarily for making items like ropes, mats, and some other composite materials and had a very limited application in the recent past. The applications of the banana fiber is increasing in other fields such as apparel garments and home furnishings because of the increasing environmental awareness and growing importance of eco-friendly fabrics. It is being used for making traditional dresses like kimono, and kamishimo since the Edo period (1600-1868) in Japan [20]. It is preferred by people there as summer wear due to its being lightweight and comfortable to wear. Different types of fine cushion covers, Neckties, bags, table cloths, curtains etc. are also made from Banana fibe. In addition, Rugs are very popular world over that made by banana silk yarn fibers.

To the best of our knowledge, there have been no reports on pretreatment of banana fiber with banana tree trunk ash. This naturally occurring compound is being used here in replace of conventional chemical compounds, which was enormously being used in the textile industries all over the world. In this work, a comparison was carried out between chemically and naturally treated banana fiber, to analysis the comparison different physico-mechanical test and dyeability test also carried out. Thus, we used this natural ash as the textile pretreatment ingredients which will be replace as chemical scouring agent and finally that's replacement will reduce the chemical dependency of textile pretreatment in textile industry.

2. Materials and Methods

2.1 Materials

Banana pseudostem was collected local market of Rajshahi, Bangladesh to prepare banana fiber and ash. Caustic soda and Jet (Detergent) used as scouring agent were supplied by Merck (India) and Kohinoor Chemicals Bangladesh Ltd., respectively. The bleaching agent hydrogen peroxide and sodium silicate were also purchased from Merck (India). The direct red 81 purchased from Sigma-Aldrich.

2.2 Extraction of banana fiber

Scrapping, the most common method of extraction of banana fiber from the pseudostem was used. Here, we used hand scrapping to scrap the stem with blunt metal edge. In this method, after harvesting the banana fruits, the plants were cut down. Then, the trunk was peeled and brown-green skin was ~~is~~ thrown away retaining the cleaner or white portion which processed into knotted fibers. The pseudostem was cut at the bottom at an angle, and its sheaths were removed to extract the fiber. After that, the fibers extracted through hand scrapping by either serrated or non serrated knives. The non-fibrous materials were removed by using wood plank and knife. The extracted fibers were sun-dried which whitens the fiber. Each fiber was separated according to fiber sizes and grouped and knotted to the end of another fiber manually. Then, this fiber stored for further processing.

2.3 Banana tree trunk ash preparation

The banana tree truck were collected from surrounding and chopped it into small pieces. Then, these small pieces were dried by sunlight in order to remove moisture and can be easily made ash. These dried banana tree trucks were burnt in a fire chamber and sieve the primary ashes with a bolter which removing unnecessary ingredients from it and make fresh banana tree trunk ashes for fabrics pretreatment. Then, these ashes were kept in a clean polyethylene bags for further processing. The photograph of banana tree truck ash is shown in Fig.1 (a).

2.4 Scouring of banana fiber

Scouring is the process by which all natural and adventitious impurities such as oil, wax, fat etc. are removed to produce hydrophilic and clean textile materials. The banana fibers were scoured using four different types of solution. In the case of first type, the raw banana fibers were treated with only natural banana tree trunk ashes solution (100% NT) instead of chemicals. In the second type, the raw banana fibers were treated with the mixture of 50% natural banana tree trunk ashes and 50% caustic soda chemicals (50NT:50C). The raw banana fibers were treated with the third type of solution of 75% natural banana tree trunk ashes and 25% chemical (75NT:25C) mixture.

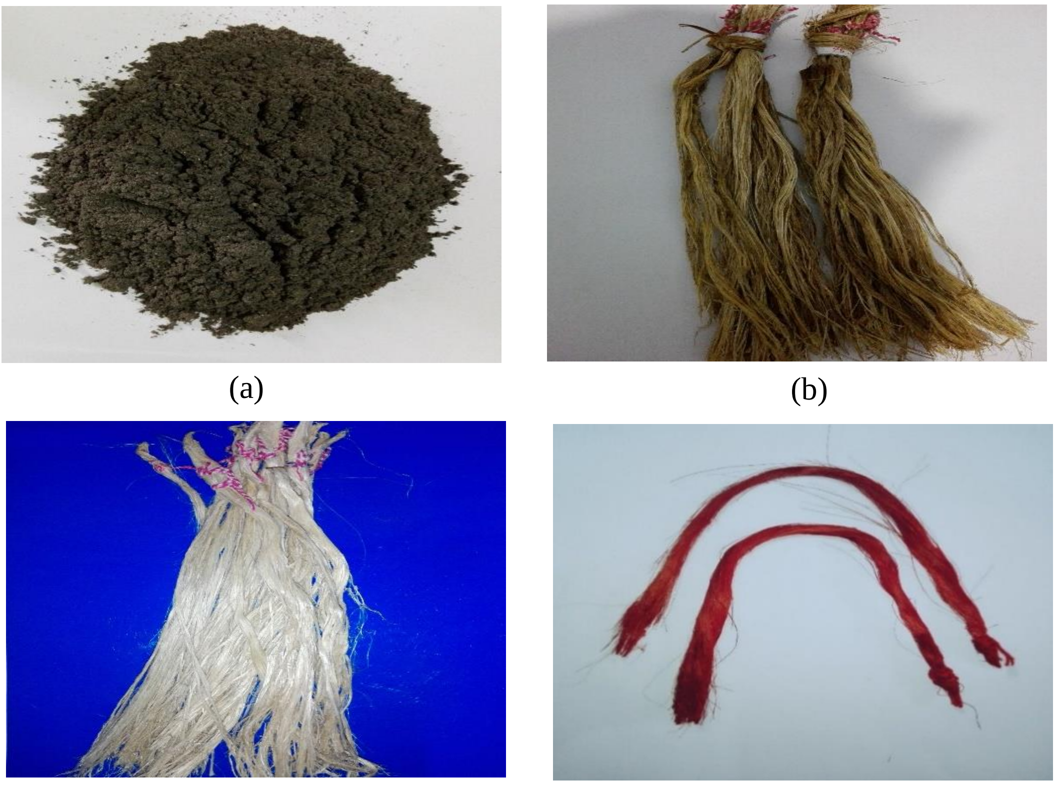

Figure 1 Photographs of (a) Banana tree trunk ash (b) Scoured banana fiber (c) Bleached banana fiber and (d) Dyed banana fiber.

In the fourth type, the raw banana fibers were treated with 100% chemical solution (100% CT) instead of banana tree trunk ashes. To remove dirty substances, the banana fibers were scoured in a solution containing 10 gm of natural banana tree trunk ashes and caustic soda, detergent (according to their respective percentage in four types of solution) per liter at 75°C for 30 minutes in a beaker in the fiber liquor ratio 1:50, followed by washing of fiber with water and then drying in air [21]. The photograph of scoured banana fiber is shown in Fig.1 (b). During scouring textile fibers loss a remarkable amount of impurities (Oil, fats, waxes etc.). Thus, the textile goods loss weight with respect to removed impurities. The scouring effect can be evaluated based on this weight loss of fiber. Usually, it is calculated from the difference of un-scoured and scoured sample weight at the same moisture content, and then it is measured in percentage [22, 23].

Weight loss percent of the sample $= \frac{Wi - Wf}{Wi} \times 100\%$

Where, W_i is the initial weight of the fiber and W_f is the final weight after scouring. The criteria of weight loss were measured by the weight loss percent of the sample. The standard weight loss scoured sample is 4-8% (sometimes 9%). When the weight loss percentage is less than 4%, then it is considered that the sample is not well scoured which is not acceptable. In addition, if the weight loss percentage is more than 8%, then it considered that the sample is damaged due to over scoured which is also not acceptable.

2.5 Bleaching of banana fiber

The banana scoured fiber was bleached with 1% (v/v) of hydrogen peroxide using 2g/L of sodium silicate as stabilizer maintaining the fiber liquor ratio 1:50. The fiber was treated in this solution for 45 minutes at 60°C. Then samples were neutralized using dilute acetic acid. Here, the four types of scoured banana fibers (100% NT, 50NT:50C, 75NT:25C and 100% CT) were bleached in four different bath in the same bleached solution. The photograph of bleached banana fiber is shown in Fig.1 (c).

2.6 Dyeing of banana fiber

Direct red 81 dye solutions were prepared by making paste with cold water and then by adding boiling water, the dye baths were prepared by taking required percentage of dye and electrolyte (Sodium Chloride). The banana fiber liquor ratio was maintained at 1:30. Before immersing the banana fiber in the dyebath it was treated well in distilled water and squeezed for even absorption of dye particles. Dyeing was carried out at 90 minutes at 90°C temperature control water baths with occasionally stirring with a glass rod and then allows for further 30 minutes for cool down. During dyeing boiling distilled water was added to the dyebaths in order to maintain the fiber liquor ratio 1:30. After dyeing the fibers were squeezed over dyebath so that not a single drop of exhausted dye liquor was lost, rinsed in cold distilled water and dried at room temperature. The rinsed water was added to the exhausted dyebath [24-28]. The photograph of dyed banana fiber is shown in Fig.1 (d). In order to measure the dyeability, as well as percentage of dye absorption of banana fibre samples were examined in a Spectronic 20(colorimeter):

$$\text{Absorption of dye percentage} = \frac{\boldsymbol{Do-De}}{\boldsymbol{Do}} \times \mathbf{100}\%$$

Where, D_0 and D_e are the original and exhausted dye bath concentration, respectively [29].

2.7 Wicking Test of banana fiber

It is a very reliable test for measuring the scouring effect. Equal length and weight of the samples and a standard dye solution (0.1% direct dye) is taken to perform the test. A mark is drawn at 1cm above from the sample. Then the sample is hung from a stick and immerses the sample in the dye solution up to the 1cm mark. Hold the sample five minutes in the position. The dye solution is absorbed by the sample and climb upward direction [23, 30]. The schematic illustration of the experimental setup of wicking test is shown in Fig. 2. The criteria for wicking test depend on the acceptable absorbing length. The acceptable absorbing length is 30-50 mm. The acceptable lower limit of scouring is 30mm absorbing length. If the absorbing length is 40-45mm, it means very good scouring and above 50mm, absorbing length means excellent scouring.

2.8 Water intake or absorption test of banana fiber

Water intake or absorption was performed according to ASTM Designation C 67-91. The test specimen was cut in a size length ≈ 10.4cm, width = 0.9-1.00 cm. Samples were immersed in a static water bath at 250 C for time interval of a 5 hr. (up to 30 hr.). After certain periods of time, samples were taken out from the bath and wiped using tissue paper and weighted again [31]. Then the amount of water intake was calculated by the following equation:

$$\text{Water intake (\%)} = \frac{Wf - Wi}{Wf} \times 100\%$$

Where, W_i and W_f are the weight of the fiber before immersion and after immersion respectively.

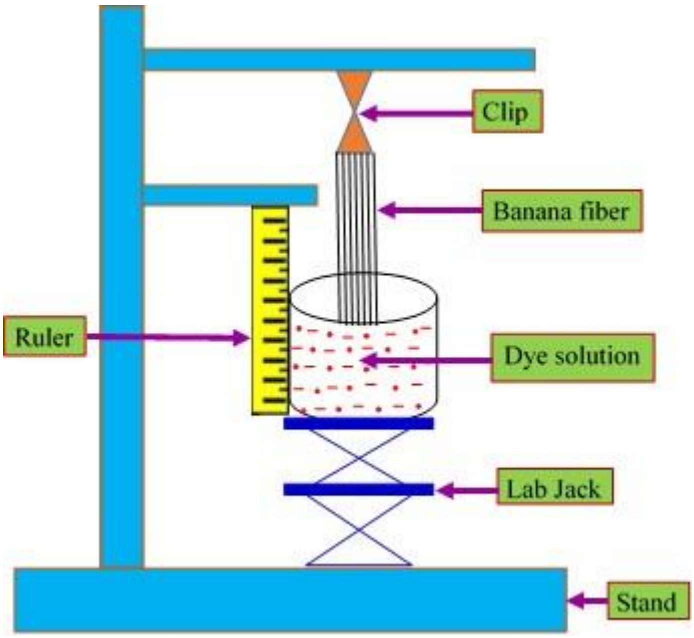

Figure 2 Schematic illustration of the experimental setup of wicking test of banana fiber.

2.9 Tensile Strength

The fiber sample was cut into equal pieces of length 15cm and the length of each specimen between the jaws of machine was maintained 10cm. One twist per 2cm was given along the length of the fiber between the jaws of the machine. The breaking load was gradually increased after starting the machine and at a particular point the specimen was broken down. The machine was stopped at the point of break. The breaking load was shown that on the scale of the tensile tester in Kg. In this process the breaking strength of scoured, bleached and dyed sample were measured [32]. Tensile strength was estimated by the following formula

$$\mathbf{TS} = \frac{\mathbf{Fmax}}{A}$$

Where, F_{max} is the maximum load applied to the sample and A is the cross sectional area of the sample.

Elongation at Break

Percent of elongation at break was obtained by the following relation

$$\mathbf{EB\ (\%)} = \frac{\Delta \mathbf{Lb}}{\mathbf{L0}} \times 100\%$$

Where, ΔLb is the extension at break point of the sample and L_0 is the Gage length or original length of the sample.

3. Results and Discussion

3.1 Weight Loss Analysis

The percentage of weight loss of various treated banana fiber samples is shown in Table 1. The results were taken weight of the banana fiber sample before and after of scouring. In this test, the 100% NT banana fiber gives 7.75% weight loss, which is near to 100% CT fiber gives weight loss of 8.05%. On the other hand, 75NT:25CT and 50NT:50CT samples exhibit weight loss of 6.25% and 6.70%, respectively. The weight loss percentage of various treated banana fiber samples also shown in Fig. 3.

Table 1. Weight loss Percent of various banana fiber sample.

No.	Sample Name	Weight Before Treatment	Weight After Treatment	Average Final Weight	% Weight Loss
01	100% CT	2gm	1.8377	1.839	8.05%
			1.839		
			1.842		
02	100% NT	2gm	1.846	1.845	7.75%
			1.852		
			1.839		
03	75NT :25CT	2gm	1.881	1.875	6.25%
			1.872		
			1.874		
04	50NT :50CT	2gm	1.868	1.866	6.70%
			1.859		
			1.870		

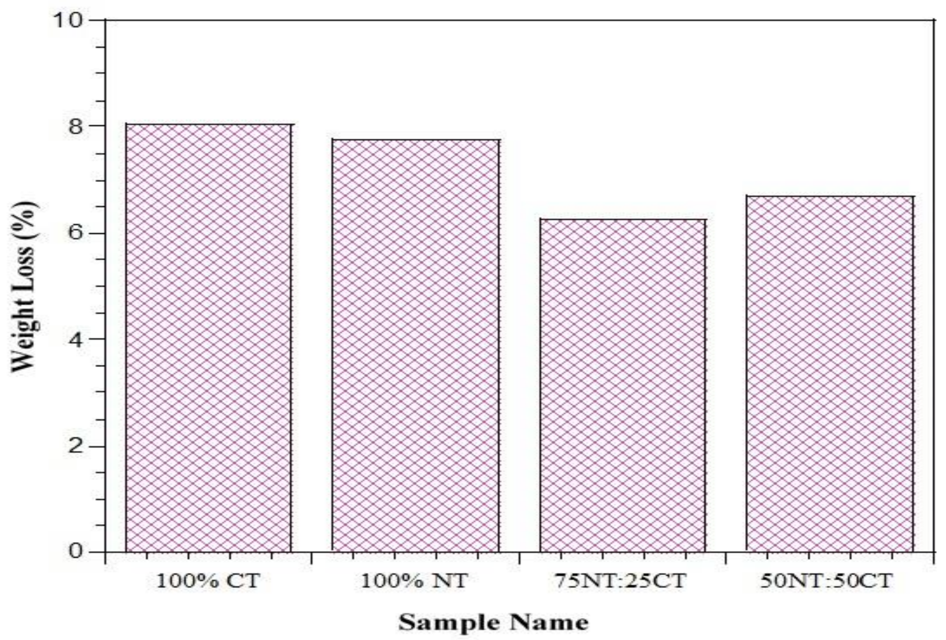

Figure 3 The percentage of weight loss of 100% CT, 100% NT, 75NT:25CT, and 50NT:50CT banana fiber.

As we know from the textile wet processing technology that in scouring section the chemical scouring agents removing the redundant attaching objects from the fiber surface with the accumulate chemical action, that's why the materials loss its raw weight after scouring. Here, the naturally treated fibers loss its weight in a certain range which is closely to the conventional chemical treated samples. It means that the raw banana fibers were well scoured with the aid of natural ash treatment. Therefore, it may be expected that the banana fiber can be treated with natural ash, which will give results same as chemically treated samples in the bulk production.

3.2 Wicking Test Analysis

The wicking properties of 100%CT, 100%NT, 75NT:25CT and 50NT:50CT banana fiber are shown in Table 2. It can be seen that the 100%CT sample traveled maximum distance of 44.50mm than any other samples. Thus, these type banana fibers possess excellent wicking properties. Nearly similar wicking properties shows 100NT banana fiber of 41.05mm, and 75NT:25CT and 50NT:50CT banana fiber also provided pleasantry wicking behaviour of 33.25 and 37.50, respectively. The Wicking properties of various banana fiber sample are also shown in Fig. 4. According to the above wicking test analysis, it can be seen that the banana tree trunk ash can be capable of treating banana fiber in textile wet processing technology and obtained results nearly similar to those conventional chemically treated banana fiber samples.

Table 2 Wicking properties of various treated banana fiber sample.

No.	Sample Name	Experiment Time (minutes)	Travel of Water (mm)	Average Travel (mm)
01	100% CT	10	44.35	44.50
			45.15	
			44.00	
02	100% NT	10	40.05	41.05
			43.25	
			41.20	
03	75NT: 25CT	10	33.40	33.25
			34.05	
			32.35	
04	50NT : 50CT	10	37.15	37.5
			37.10	
			38.35	

3.3 Water Intake or Absorption Test Analysis

The water absorption of 100%CT, 100%NT, 75NT:25CT and 50NT:50CT banana fiber are shown in Fig. 5. The 100%CT sample shows maximum absorbency of 31.15% at 30 hours than any other samples and it posses excellent water absorbency characteristics. Nearly similar maximum absorbency shows 100%NT sample of 28.25% at 30 hours. The 75NT:25CT and 50NT:50CT samples show maximum water absorbency of 25.54% and 26.87%, respectively at 30 hours. This can be explained in such way that the Banana fibre is hydrophilic due to the presence of hydroxyl groups.

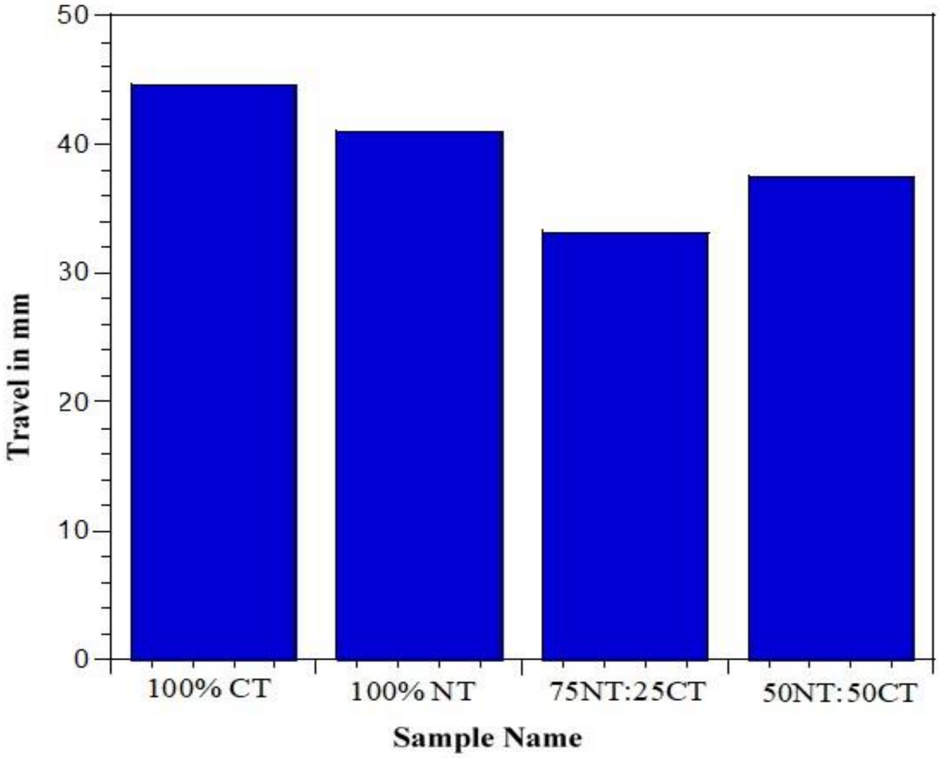

Figure 4 Wicking properties of 100% CT, 100% NT, 75NT:25CT, and 50NT:50CT banana fiber.

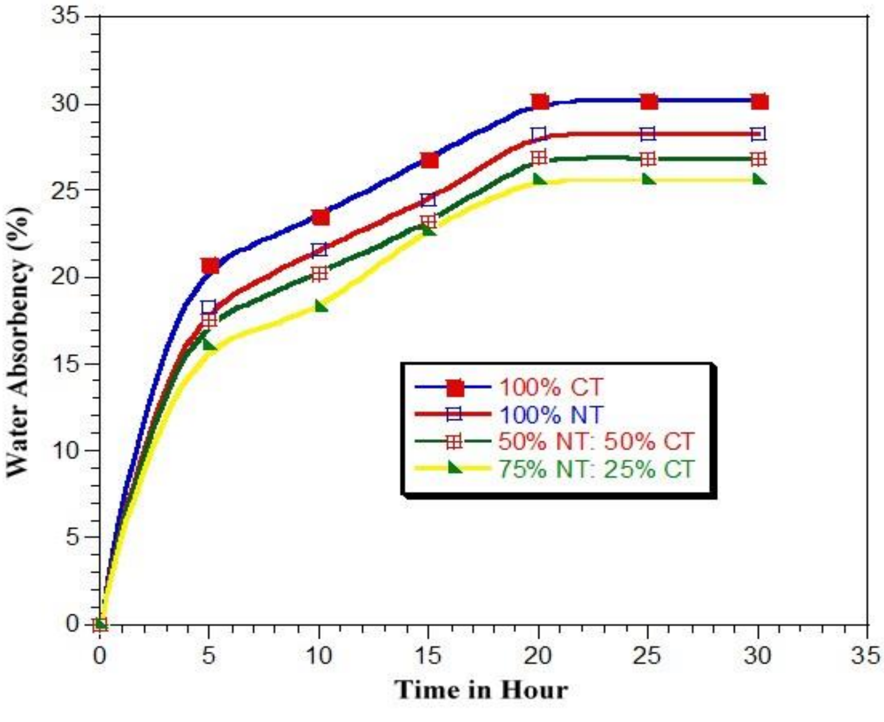

Figure 5 Plots of water absorption vs time of 100%CT, 100%NT, 75NT:25CT and 50NT:50CT

Moreover, it is possible in case of chemical treatment that the hydrophilicity may reduce with NaOH by decreasing the hydroxyl groups in the fibers [32]. However, in case of natural treatment there were no such probability of reducing hydroxyl group in the fibers. So according to the above analysis, it can be anticipated that the banana fiber treated with natural ash that is a part of eco-friendly treatment may compete with other natural textile fibre in textile industry.

3.4 Direct dye (Red) Exhaustion

Dye exhaustion vs dye concentration of 100%CT, 100%NT, 75NT:25CT and 50NT:50CT banana fiber are shown in the plot of Fig. 6. From the above plot, it is seen that dye absorption of various treated banana fiber sample decreases with the increase of dye concentration in the dye bath. This may be explained that the presence of more dye ions hinder absorption of dye to the fiber whereas rare ions favors it. It can be mention that with the increase of dye concentration, the absolute quantity diminishes [21, 22]. From the above graph, it is also seen that the dye absorbability of 100% NT fiber are nearly similar to that of 100% CT fiber. Therefore, it can be say that the naturally treated banana fiber can be used as textile fabric making fiber and also other textile purposes.

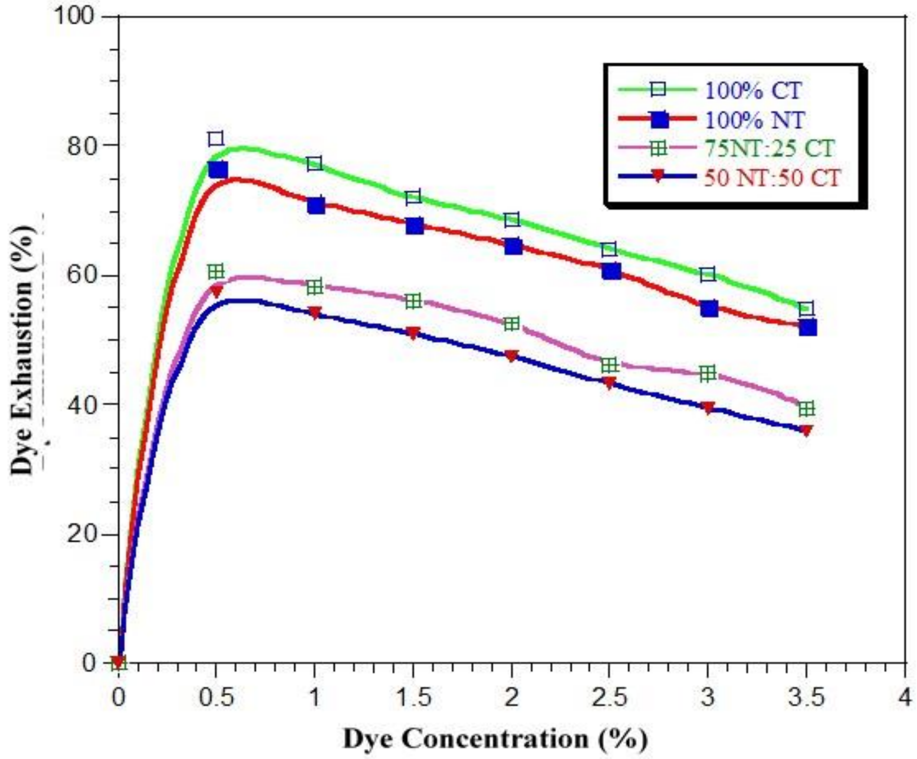

Figure 6 Plots of dye exhaustion vs dye concentration for 100%CT, 100%NT, 75NT:25CT and 50NT:50CT banana fiber.

3.5 Tensile Strength Testing

The tensile properties of Raw, 100%CT, 100%NT, 75NT:25CT and 50NT:50CT banana fiber are shown in the column graph of Fig. 7. It can be seen that the 100%NT sample shows maximum value of 28.74 Kg/Cm2 than 100%CT sample of 24.71 Kg/Cm2. The 75NT:25CT and 50NT:50CT sample show tensile strength of 27.43 Kg/Cm2 and 23.52 Kg/Cm2, respectively. These results can be explained in terms of the internal structure of the fiber, such as cell structure, microfibrillar angle, defects etc., also the effect of scouring agents (both chemical and natural ash). It was observed that the eco-friendly treatment or green treatment facilitates better fiber durability and improved mechanical properties. The natural ash removes the oil, wax, gum and other attaching impurities efficiently without damaging the fiber's surface and interior cellulosic structure. On the other hand, the inner and outer surface of the fiber becomes weak due to high chemical action in chemical treatment. Consequently, the tensile strength is higher in natural treatment in compare to chemical treatment. So according to the above tensile strength analysis, it can be assumed that the banana fiber treated with natural ash that is a part of eco-friendly treatment may introduce in the textile industry.

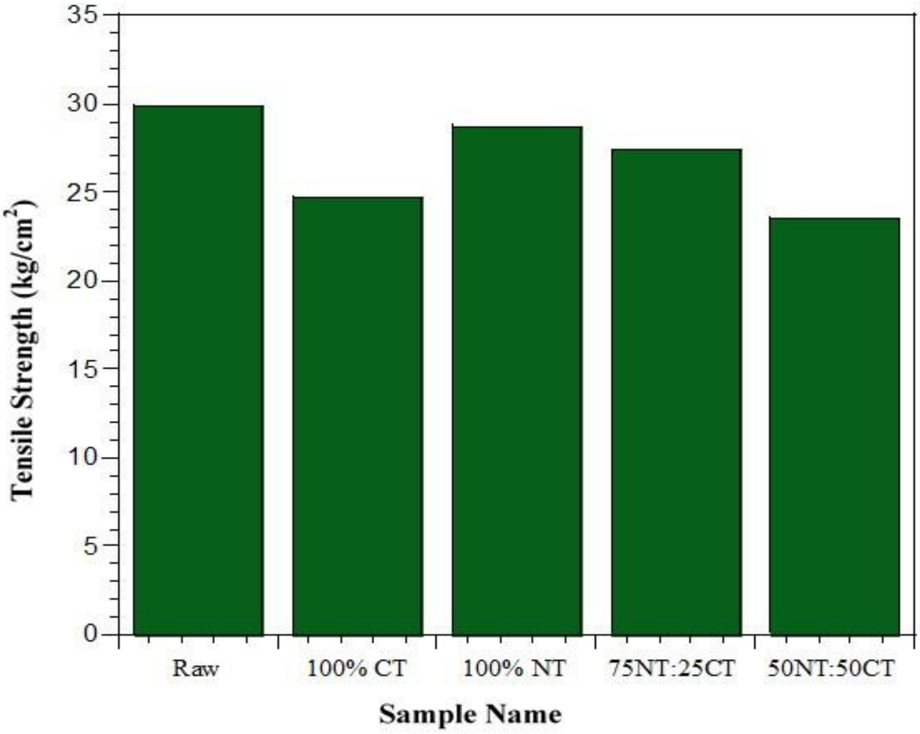

Figure 7 Tensile behavior of Raw, 100% CT, 100% NT, 75NT:25CT and 50NT:50CT banana fibers.

3.6 Elongation Behaviour Analysis

In the column graph as shown in Fig. 8 shows the elongation behavior of Raw, 100%CT, 100%NT, 75NT:25CT and 50NT:50CT banana fibers. It is found that the 100%NT sample gives better elongation at break of 34.44%, than 100%CT sample of 32.22%.

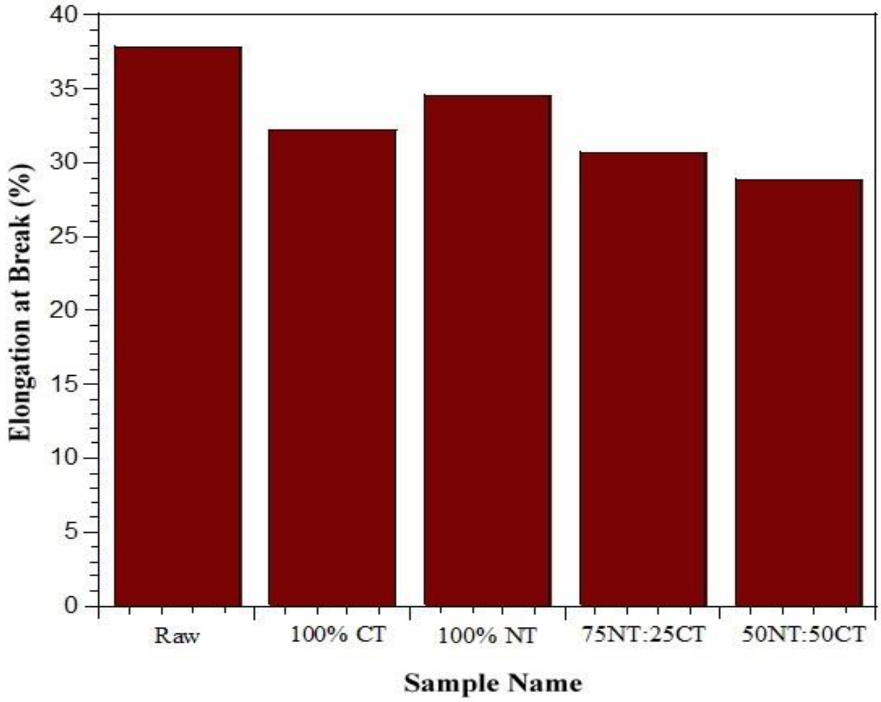

Figure 8 Elongation behavior of Raw, 100% CT, 100% NT, 75NT:25CT 50NT:50CT banana fibers.

So this type banana fiber possess maximum strain before breaking in compare with the chemically treated sample. The 75NT:25CT and 50NT:50CT sample show elongation at break of 30.66% and 28.88, respectively. It is already mentioned in the tensile analysis section that in chemical treatment, the inner and outer surface of the fiber becomes weak due to high chemical action and in parallel this degradation can reduce the elasticity of the fiber and that is why shorted the strain rate of the fiber. So according to the above analysis, it can be declared that the banana fiber treated with natural ash, which is a part of eco-friendly treatment, may compete in the textile industry as textile fiber.

4. Conclusions

The entire investigation on various banana fiber samples based on chemical and natural treatment and their physico-chemical, physico-mechanical behavior were studied. The results obtained in this work shown that the naturally treated banana fiber regained higher mechanical strength than that of the chemically treated fibers. In case of chemical behavior, the samples treated with banana tree trunk ash and others chemical natural mixed treated samples has provided results which are nearly close to conventional chemically treated samples. Therefore, with the aid of eco-friendly treatment of textile wet processing technology that is carried out by preparing banana tree trunk ash would be a fundamental section of reducing the chemical dependency in the scouring process of textile industries. Moreover, the use of banana fiber that is a natural plant fiber can make a significant role in supplying the demand of natural textile fiber.

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