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A Preliminary Study for Improving the Banana Fibre Fineness using Various Chemical Treatments

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APRELIMINARYSTUDYFORIMPROVINGTHEBANANAFIBREFINENESSUSINGVARIOUSCHEMICALTREATMENTS

A Preliminary Study for Improving the Banana Fibre Fineness using Various Chemical Treatments

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Abstract- This work analyses the effect of various alkali and softness treatments on the physical, chemical and mechanical properties of the banana and banana: cotton fibres blended yarns and fabrics. Fibres were scoured, bleached and mercerized by different concentrations of NaOH, H_2O_2, Na_2 CO_3 and softened with Aloe Vera, castor oil, cotton seed oil and soap. The mechanical characterization indicated that the single yarn strength, tensile strength, tear strength and torsion rigidity became decreased by increasing concentration of the NaOH, H_2O_2, Na_2 CO_3. The adequate (spinnability) fineness (5.8 tex) of the banana fibres have been achieved with Na OH, H_2 O_2 and Na_2 CO_3 combined treatments. The fastness properties of the banana: cotton blended fabrics show equal to the 100 % cotton fabrics in dry and wet conditions.

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I. Introduction

Natural fibres are becoming an attractive alternative over synthetic fibres due to their advantages such as recyclability, biodegradability, renewability, low cost, high specific mechanical properties and low density [1- 4]. Banana is one of the rhizomatous plants and currently cultivating in 129 countries around the world. It is the fourth most important global food crop. In India, about 7.1 lakhs hectares area is under banana crop with the total fruit production of 26.2 million contributing 14.7 percentage of global [1]. In banana plantations, after the fruits are harvested, the trunks or stems will be wasted. Billion tons of stems and leaves are thrown away annually. Such waste provides obtainable sources of fibers, which leads to the reduction of other natural and synthetic fibers' production that requires extra energy, fertilizer and chemical. The banana fibers are good moisture absorbent, highly breathable, quickly dry with high tensile strength.

The semi-cellulose in banana fibre is arranged in the form of a helix at an angle of 11° to 12° with the fibres diameter of 100 to 200 μm contrasts to coir fibre, where the spiral angle was found to vary from 40° to 47° for a diameter 100 to 500 μm [2]. The strand 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, as in hand or machine stripping, fiber strands from the middle sheaths may run as long as 15 feet or more; average length ranges from 3 to 15 ft. The moisture regain percentage of banana fibre is high compared to cotton fibre about 11-15% [5-7]. Compared to other fibers like cotton, jute and flax, banana fibers have higher water absorbency and water release properties owing to a higher content of non-cellulosic material and lower crystallinity (19-24%) in the fiber structure [7].

The mechanical properties of plant fibre mainly depend on factors like the source, age, the species, processing parameters and the internal structure [2]. The mechanical properties of the banana fibres with the various diameters have been studied. There is no appreciable change in the mechanical properties of the fibres with an increase in the diameter of the fibre in the range investigated 50 to 250 μm. A gradual decreases in the initial modulus with an increase in diameter of the fibres in the range of 100 to 450 μm. While ultimate tensile strength and breaking strain increased up to 200 μm diameter after which they remained constant [2 & 4].

In the recent past, banana fiber had a very limited application and was primarily used for making items like ropes, mats, and some other composite materials. With the increasing environmental awareness and growing importance of eco-friendly fabrics, banana fiber has also been recognized for all its good qualities and now its application is increasing in other fields too such as apparel garments and home furnishings. However, in Japan, it is being used for making traditional dresses like kimono, and kamishimo since the Edo period (1600-1868). Due to its being lightweight and comfortable to wear, it is still preferred by people there as summer wear. Banana fiber is also used to make fine cushion covers, Neckties, bags, table cloths, curtains etc. Rugs made from banana silk yarn fibers are also very popular world over.

The fibre portion of the pseudostem left over after extraction of starch was utilized for the preparation of paper pulp by Subrahmanyam et al., (1963). Banana fibres are reported to have been spun on the jute spinning machinery [9 &10] and used in making ropes and sacks. However, Kulkarni et al., (1983) were the first to report on the fibre yield, structure and properties of banana fibres. Subsequently, Bhama Iyer et al., (1995) evaluated yield, structure and properties of banana

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fibres gathered from a few commercially cultivated varieties and observed that variations exist in both structure and properties of fibres from different regions along the length and across the thickness of the pseudostem. They also reported differences in tensile and structural properties among fibres belonging to different varieties and showed that the matrix in which the cells are embedded in the fibre had a role in deciding the tensile strength of the fibre.

Enzyme application increases tensile energy, extensibility and improves the surface characteristics of the cotton-banana union fabric. Detailed study was undertaken to explore the sewability of cotton-banana blended fabrics and it is concluded that they give higher/better seam pucker but higher bending rigidity than 100% cotton [12 & 13].

This study also aims at such an achievement by increasing the fineness of banana stem fibres. However, an alternative solution is found to make effective use of the banana stem in which the banana stem can be extracted of their fibre and converted as a yarn into fabric through simple techniques.

II. Experimental

a) Materials

The banana fibers were collected from representative village (Gobichittipalayam-Erode, India). The collected raw banana fibers were very coarse (140 Denier) and have more lignin content in nature. Subsequently the removal of lignin content from the fibre surface has done by retting process for 2-3 weeks. After retting treatment the banana fibres have been subjected into chemical treatment to reduce the fineness (rigidity) as shown in Table 1.

Table 1 : Fineness of Alkali Treated Banana Fibres

Sl.NO	Concentration of NaOH	Bundle fibre Fineness (Tex)
1	Raw banana fibre	31.2
2	Treated with 2.5%	8.2
3	Treated with 5% NaOH	5.46
4	Treated with 10% NaOH	4.8
5	Treated with 15% NaOH	3.7
6	Treated with 4% H_2O_2 & 2% NaOH	5.5
7	Treated with 4% H_2O_2, 2% Na_2CO_3 and 4% NaOH	5.8

b) Methods

i. *Chemical treatments on raw banana fibres*

Alkalization treatment was done by different chemicals like NaOH and H_2O_2 with different percentages for hemicelluloses analysis. The chemical treatment of fibre was done by two steps. At first the fibre was bleached with H_2O_2 (4% on weight fibres), NaOH (2% on weight fibres), material liquid ratio (MLR) 1:20, few droplets of wetting agent, Temperature of 100°C and Time for 1 hour. After that the fibre was treated with NaOH at different percentages like 1%, 2%, 4% and 8%, with M L R 1:20, Time for 30 min, Temperature of 95°C to reduce the fibre rigidity level (fineness). The softener was prepared by the combination of castor oil (4-6%), Aloe Vera (4-6%), cotton seed oil (4-6%) and emulsifier (2.5%) treated for 1 hour.

III. Calculate Weight Loss for Chemically Treated Banana Fibres

This is a reduction of the total mass of the banana fibres due to a mean loss of fluid, bark, hemicelluloses, lignin etc, by treated the fibers with NaOH (concentration of 2.5%, 5%, 10% & 15%). The fibre weight loss can be calculated by using the given below formula [2].

$$\text{Weight loss } \% = [(IW - AW) / IW] \times 100 \qquad (1)$$

Where, IW- Mass of before chemical treatments (g), AW- Mass of after chemical treatments (g).

When banana fibres were treated with different chemicals like alkali and peroxide, during the removable of bark and other impurities, considerable weight loss was observed. Treatment leads to the irreversible alkalization effect which increases the amount of amorphous cellulose at the expense of crystalline cellulose. Crystalline reduction is achieved by removal of lignin, hemicelluloses and other residues from the surface of the fibers. As the results shown in Table.2 the weight of the banana fiber was decreased with increases concentration of the alkali.

IV. Evaluation of Banana Fiber Fineness

The fineness of representative raw banana fibers was determined by using a microscope (single fiber fineness tester) and torsion balance. Microscope works on the theory of vibrating strings to measure the fineness of individual fibers. The result showed that the average fineness of chemically treated banana fiber is 5.57 Tex (As in table.1, Sl.No. 2-7). The fineness has been improved by treated the banana fibers with alkali, so as to manufacture fine yarn. The fineness of the fiber is related to the hardness and rigidity of the fibers.

Table 2 : Weight Losses of Alkali Treated Banana Fibres

Sl. No	NaOH concentration	Weight before alkalization(g)	Weight after alkalization(g)	Weight loss (%)	Conditions
1	2.5%	338.16	324.22	4.122	MLR=1:20 Temp=95°c Time=30min
2	5%	338.16	306.42	9.386	
3	10%	126.08	111.99	11.172	
4	15%	126.08	106.13	15.823	

V. Raw Material Preparation for Open End (OE) Spinning

The filament form of chemically treated and softened banana fibre was taken up to 40-50 mm length to avoid the fibre loss and rupturing during carding process. Then the banana fibre was blended with cotton in two different blend proportions like 50:50 and 70: 30 (Banana: Cotton).

a) Open end spinning

The well blend two different fibres were made into web by the help of miniature carding in TIFAC CORE Coimbatore, India. After that the banana and cotton fibres yarn was spun using OE spinning technique. The given below spinning particulars have been followed during the yarn manufacturing process.

b) Spinning Particulars

Sliver Hank - 0.165, Twist per Inch TPI – 36, Opening Roller Speed – 8000 rpm, Rotor speed 30000 rpm, Twist Direction – Z and Yarn count- 10Ne. After spinning the spun the banana yarn, it has been subjected into single yarn strength testing.

VI. Scoured and Dyed of Banana Fibre based Fabrics

The grey banana fabrics have been scoured using following recipe, NaOH 2%, wetting agent 0.5%, temperature 90°C, MLR of 1:30 and time for 1 hour. The scoured banana fabric is dyed using following recipe, Reactive dye 2%, NaCl-20 gpl, Na_2 CO_3-10 gpl, temperature- 60°C, Material Liquid Ratio (MLR)-1:30 and time for 1 hour. After dyed the banana fibre based fabrics were subjected into various rubbing and wash fastness evaluation.

VII. Development of Innovative Banana Fibre Based Fabrics

The two different spun yarns (50:50 and 70:30 banana: cotton) were used as weft yarn to produce the fabrics using conventional shuttle loom with production rate of 160 PPM. After manufacturing the fabrics were subjected into various tests' to analyze the physical and mechanical properties of the fabrics. The fabrics constructional parameters are shown Table 3.

VIII. Results and Discussions

a) Chemical Treatments Influencing on the Banana Fibre Fineness

The retting and alkalization treatments improve the fiber surface adhesive characteristics by removing natural and artificial impurities, there by producing a rough surface topography. After chemical treatment the size of crystallites, longitudinal shape and their orientation have been modified from cylindrical in to convoluted shape. The fineness of banana fibre is also reduced from 140 Denier to 90 Denier as shown in Table 4. The vegetable oils softening process reduces the fibre roughness and enhances the spinability of the fibers because of that; the fibers can easily pass through different rollers without slippage.

Table 3 : Different Fabric Constructions and Parameters

Fabric	Warp count, 100% cotton (Ne)	Weft count (Ne)	EPI	PPI	Fabric width (inches)	Cloth Cover Factor	GSM	Thickness (mm)
100% cotton	40	10	80	32	41	18.2	135	0.59
70:30, Banana: Cotton	40	10	78	30	41	17.9	196	0.82
50:50, Banana: Cotton	40	10	79	31	41	17.7	125	0.63

Table 4 : Banana Fibres Treated With Different Concentration of NaOH

Chemical Treatment (NaOH)	Single Banana fibre fineness in (Denier)	Single fibre Strength in (g)
Raw banana fibres	140	314.8
0.5%	120	242.7
1%	120	182.5
4%	100	101.6
8%	90	95.6

b) *Chemical treatments influencing on the mechanical properties*

The cotton and banana fibre blend proportion made greater influences in yarns' and fabrics' mechanical properties. The single yarn strength of the banana fibre blended yarns have decreased compared to 100% cotton yarn (as shown in Table 5) because of poor cohesion between cotton and banana fibres.

The single yarn strength reduction can be affected both physical and mechanical properties of the banana fibre based fabrics. As shown in Table 5, tensile strength of the 50:50 banana: cotton fabric shows higher than the 70:30 banana: cotton fabrics due to lack of single yarn strength of the higher banana fibre content in the yarn. In the fabric tear testing, 70:30 banana: cotton fabric shows more strength because of higher banana fibre content in the yarn (Table 5). The fastness property of the banana fibre based fabric is equal to the 100% cotton fabrics expect rubbing fastness of 50:50 banana: cotton blended fabric in wet condition (Table 6).

Table 5 : Mechanical Properties for the Cotton and Banana/Cotton Blended Yarns and Fabrics

Materials	Yarn Count, Ne	Single yarn strength (Kgf)	Fabric tensile strength (Kgf)	Fabric tear strength (Kgf)
100% Cotton	10	11.50	36.97	3.64
50:50, Banana/Cotton fibres	10	8.10	20.34	2.26
70:30, Banana/Cotton fibres	10	6.35	18.14	2.95

c) *The flexural rigidity of chemically treated banana fibres*

The flexural rigidity is a characteristic for estimating the degree of softness of the banana fibres. The experimental results show the changes in the basic mechanical properties of the banana fibers after peroxide, alkalization and softening processes. The flexural rigidity and percentage improvements in softness obtained with banana fibres after the above said chemical treatments. Fibers treated with different softeners are shown in the Table 7.

Table 6 : Fastness Properties of the Various Fabrics

FABRIC	Wash Fastness Rating*	RUBBING FASTNESS Rating*	
		DRY	WET
100% Cotton	3	4	3
70:30, Banana/Cotton fibres	3	4	3
50:50, Banana/Cotton fibres	3	4	2

* *Fastness Rating: 5-Excellent, 4-Very good, 3-Good, Average-2 and 1-poor*

Table 7 : Percentage Improvement in Softness after Various Chemical Treatments

SI.NO	SAMPLES	FLEXURAL RIGIDITY(Ncm^2)	IMPROVED SOFTENING (%)
1	Raw banana fibres	1.2438	Taken as reference
2	Treated with silicon (4%) and NaOH (2%)	0.7768	37.54
3	Treated with silicon (4%) and NaOH (2%) then softened with castor oil (4%), cotton seed oil (4%) and emulsifier (2.5%)	0.6900	44.52
4	Treated with H_2O_2 (4%) and softened with Aloe Vera (4%), castor oil (4%), cotton seed oil (4%) and emulsifier (2.5%)	0.3326	74.06

After the chemical treatments (NaOH and Silicone), the flexural rigidity of banana fiber reduced approximately by 37.54%. In addition, the banana fibers were treated with NaOH and silicone, softened with castor oil, cotton seed oil and soap, the flexural rigidity of banana fibers have been reduced approximately by 44.52%. Finally the raw banana fibers were treated with hydrogen peroxide softened with castor oil, cotton seed oil, soap. Now, the banana fibres have been improved their flexibility by approximately 74.06 %.

IX. Analysis of Variance (ANOVA) for Mechanical Properties of the Banana Based Yarns and Fabrics

The results of analysis of variance (ANOVA) for cotton and banana: cotton blended yarns and fabrics are listed in Table 8. It shows that the effects of cotton: banana fibres blended ratios have significant effects on various mechanical properties. The critical value is the number that the test statistic must exceed to reject the test. In this $F_{critical\ values}$ (3, 8) = 4.07 at $\alpha = 0.05$. Since F= 21.282 > 4.07, the results are significant at the 5% significance level. The p-value for this test is P =<0.001.

Table 8 : The ANOVA Table for Mechanical Properties of the Cotton and Banana: Cotton Fibres Blended Yarns and Fabrics

Source of Variation	DF	SS	MS	F	P
Between Groups	3	124.656	41.552	21.282	<0.001
Residual	8	15.619	1.952		
Total	11	140.275			

X. Conclusions

From the experimental results the banana fibre fineness influences the greater in yarn and fabric mechanical properties. The 50:50 banana: cotton fibres blended single yarn strength is more than that the 70:30 banana: cotton fibres blended. The tensile strength, tear strength, torsion rigidity and fastness properties of the banana fibre based fabrics depend on the banana fibre based single yarn strength and banana fibre content in the yarns. Once the banana fibre gets better fineness it meets required strength and the applications of banana fibre based fabrics will become high in the future.

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