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Research Paper

Process Optimization For Bleaching of Banana Fibers

Textiles

KEYWORDS : Banana fiber, Bleach, Hydrogen peroxide.

Amrita Doshi — BSR-SRF, Department of Clothing and Textiles, Faculty and Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara

Prof. Anjali Karolia — Guide & Head, Department of Clothing and Textiles, Faculty and Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara

ABSTRACT

Banana is the second most important food crop grown in India. Every year around a billion tonnes of banana plant stems are thrown on roadside after harvesting of the fruit. Banana fibers are extracted from this roadside thrown biomass using Raspador machine. Being lignocellulosic in nature, banana fibers have excellent strength but are little brittle. Processing can improve certain properties of any textile fiber.

Banana fibers are lustrous fiber, ranging from creamy to off-white in colour. The present study focused on optimization of bleaching recipe for banana fibers. Sodium hypochlorite, Hydrogen peroxide, and a combination of the two bleaches were studied by varying time, temperature, and concentration. Based on the testing results of tensile strength, whiteness index, and weight loss, bleaching parameters were optimized. The best results were obtained by the combination of hypochlorite and peroxide bleach.

Introduction

There is an exhilarating sense of sovereignty in the fiber world. Food and agricultural organisation of United Nations had declared 2009 as the International Year of Natural Fibres. The objective was to raise consumer awareness towards natural fibres, strengthen demand for natural fibre products, improve livelihoods of the farmers who produce them, and revenue generation for the countries that export them. At the same time, promoting the use of natural fibres would enhance the environment. The revolution that had begun long back for natural fibers is now experiences the fruits in holistically approach. This is a constructive shift towards use of natural plant fibers.

The second largest food crop grown in India is Banana. India occupies the largest area under Banana cultivation in the world covering approximately 11% of world area of Banana. After harvesting of the fruit, around a billion tonnes of banana plant stems are wasted each year. These pseudostems are the source of banana fibers. These fibers have excellent tensile strength and good moisture absorption, much higher than cotton. Banana fibers have good crease resistance, which sometimes accounts to its drawback, because the fabric produced cannot attain required drape. However the aesthetics of the fabric is mesmerizing.

Philippines is exporting huge quantity of readymade garments made from banana fiber to Japan, Singapore, Taiwan and all far East Asian countries. However, the use of Banana fiber in commercial production is still to gear up in India, and is currently only limited for consumption by cottage industry. Banana fiber offers excellent potential in terms of its eco-friendly nature and properties as compared to other natural fibers.

Although Banana fibers have excellent strength and lustre, they also have some inherent drawbacks. Lignin content of banana fiber is 6.1%, which contributes to its strength and also to its stiffness. Hence to impart soft hand and spinnibility, focus should be to improve its certain properties.

The present study focuses on bleaching of banana fibers to improve its whiteness.

Material and Methods

Material: For the present study banana fibers were obtained from Navsari Agricultural University, Gujarat. The plant variety used for the extracting banana fibers was *Grand Naine*. The preliminary specifications for the fiber were studied which included its bundle strength, length, fineness. The method for its analysis has been stated further.

Methodology

The present study dealt with bleaching of banana fibers for obtaining sufficiently high and uniform degree of whiteness. Bleaching was carried out with hydrogen peroxide, sodium hypochlorite and peracetic acid.

Optimization of Bleaching with H_2O_2: Experiment was planned to optimize bleaching parameters using hydrogen peroxide. Material liquor ratio was 1:40 and pH was 9-10. These two parameters were kept constant. Bleach concentration, alkali and its concentration, and treatment time were the process conditions examined for hydrogen peroxide.

Set A (variation in bleach concentration) : H_2O_2 bleach, varying 2%, 5%, 10% v/v conc. of 100 volume Hydrogen Peroxide, with 4% NaOH at boil for 20 minutes.

Set B (variation in alkali) : 5% H_2O_2 bleach, varying sodium hydroxide, sodium silicate, sodium carbonate with 4% at boil for 20 minutes.

Set C (variation in alkali concentration) : 5% H_2O_2 bleach, with sodium hydroxide, varying alkali concentration at 4%, 8% and 10% at boil for 20 minutes.

Set D (variation in bleaching time) : 5%

H_2O_2 bleach, with 4% sodium hydroxide at boil for 15, 20, and 30 minutes.

Bleaching with H_2O_2 in combination with NaOCl : Sodium hypochlorite improved the whiteness and the hand (feel) of banana fibers but adversely affected the strength. A fact associated with sodium hypochlorite bleach is that due to the presence of Cl, NaOCl aids in softening of bast fibers. Chlorine bleaches helps in lignin removal to certain extent. Considering this fact, sodium hypochlorite was combined with hydrogen peroxide in a small proportion. Two combinations that were studied are mentioned below. Besides concentration, other parameters were kept similar that were optimized for bleaching banana fibers with H_2O_2.

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Set E (variation in combination of H_2O_2

and NaOCl)

Combination 1: H_2O_2 (0.50%) + NaOCl (0.25%)

Combination 2: H_2O_2 (0.40%) + NaOCl (0.35%)

Fabrication of FFT apparatus: While treating the fibers in bulk for spinning of yarn, lot of entanglements was a major issue. Thus to overcome this problem, an equipment was fabricated in the Department of Clothing and Textiles. This fabricated instrument was termed as FFT (Filament Fiber Treatment) apparatus. It worked on simple principle of rotation. From Fig 1 and 2, the apparatus was made from aluminium vessel. The capacity of the vessel was 12 litres. A disc was attached in the centre of the vessel. The disc was 8-10 cms above the base and was attached to a motor. The capacity of the motor was 15 rpm.

This disc was an important part of FFT apparatus that actually performs the operation. During the treatment the disc rotates continuously and produces strong rotating currents within the water due to which the fibers also rotate inside the vessel. The rotation of the fibers within water containing the bleach enables the bleaching action evenly. Thus the disc produced most important function of rubbing the fibers with each other as well as with water without any entanglements.



Figure 1: FFT apparatus for Treatment of Filament fibers



Figure 2: Banana fiber in FFT apparatus

Testing of fibers for analyzing results:
Bundle fiber Strength: For testing the bundle fibre strength Pressley Fibre – Strength Tester was used

Weight loss: Weight loss % was calculated by the given formula.

[(IW – AW) /IW] x 100

Whiteness index: Spectrophotometer was use for testing the whiteness index with CIE standard and Yellowness with ASTM D1925.

Results and Discussions:
The purpose of the study was to explore the possibility of bleaching banana fibers.

The preliminary specifications for the raw fiber are given in Table 1.

Table 1: Fiber Specifications

Properties	Values of Raw Banana Fiber
Length	80 – 110cms
Fineness	14.4 tex
Bundle Strength	40gms/tex

Different bleaches were studied. Peracetic acid did not show any results on banana fibers and hence it was discarded. Hydrogen peroxide was effective on banana fibers and is discussed below in detail. Sodium hypochlorite was used in small portion in combination with hydrogen peroxide for the reasons mentioned earlier. Hence, two bleaching methods were optimized. One with hydrogen peroxide and another with hydrogen peroxide in combination with sodium hypochlorite, other parameters were kept constant as for hydrogen peroxide. The results are discussed under the following heads :

- Effect of hydrogen peroxide (H_2O_2) on banana fibers
1. Effect of process time and temperature of bleaching with H_2O_2
2. Effect of H_2O_2 bleach concentration.
3. Effect of alkali and its concentration for bleaching with H_2O_2
- Effect of H_2O_2 in combination with NaOCl bleach.
- Effect of utilization of FFT apparatus for treatment.

1. (a) Effect of process time and temperature of bleaching with H_2O_2
In general, the time of bleaching is inversely proportional to the temperature of the bleaching bath. The bleaching bath was at boil and dwell time of the process was 15, 20 and 30 minutes. It was observed that best results of whiteness were obtained in 20 minutes, and further increase in time affected the strength. Hence 20 minutes of treatment time at boil was optimized for bleaching banana fibers.

1. (b) Effect of H_2O_2 bleach concentration
Three different bleach concentrations were studied. As shown in Figure 3, 10% concentration of H_2O_2 affected the strength sternly, with maximum whiteness obtained (Table 3).

Table 3: Whiteness and Yellowness index of Bleached Banana fibers at different concentrations

S. No.	Sample	Whiteness	Yellowness
1	Untreated	-84.577	47.982
2	2% Hydrogen Peroxide	-62.849	39.488
3	5% Hydrogen Peroxide	-59.084	37.748
4	10% Hydrogen Peroxide	-33.875	29.316

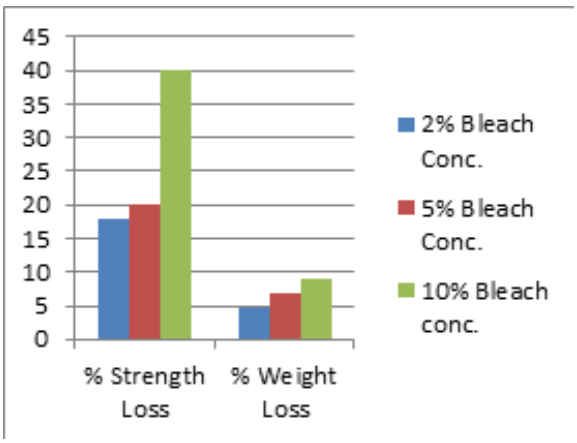


Figure 3: Percent strength loss and Percent weight loss of Banana fibers at different bleaching concentration

It was observed that as the concentration of the bleach increased, the strength of banana fiber decreased and simultaneously percent weight loss also increased. Weight loss was due to removal of unwanted impurities. Hence it was a positive sign that the treatment was effective. From Figure 3 and Table 3, it can be concluded that 5% hydrogen peroxide bleach concentration is suitable for banana fibers, which also maintains the strength and improves whiteness as well.

1. (c) Effect of alkali and its concentration for bleaching with H_2O_2:

For the present study, three different alkalis with same concentrations were studied. From Table 4 and Figure 4 it can be concluded that sodium hydroxide is the best suitable alkali for bleaching banana fibers with hydrogen peroxide.

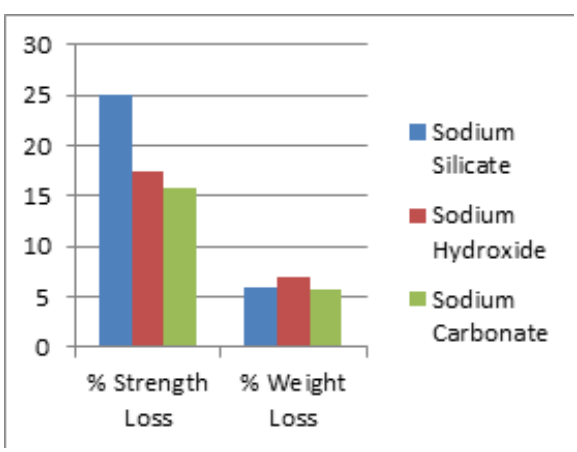


Figure 4: Percent strength loss and Percent weight loss of Banana fibers bleached using different alkalis

Table 4: Whiteness and Yellowness index of Bleached Banana fibers at different alkalis

S. No.	Sample	Whiteness	Yellowness
1	Untreated	-84.577	47.982
2	Sodium Silicate	-61.307	37.517
3	Sodium Hydroxide	-58.493	37.132
4	Sodium Carbonate	-65.876	38.950

Maximum whiteness, minimum strength loss and maximum weight loss was observed by using Sodium hydroxide as alkali. Besides this another reason for optimizing sodium hydroxide is the fact that treatment with sodium hydroxide reduces thickness of bast fibers. There was not much difference observed in banana fiber by varying alkali concentration. Hence, minimum percent concentration was optimized.

2. Effect of H_2O_2 in combination with NaOCl:

Owing to the fact that chlorine bleaches aids in lignin removal, sodium hypochlorite was used in combination with Hydrogen peroxide. Sodium hypochlorite bleach improved the handle (feel) of banana fiber, although severely affected the strength. It is not safe bleach for banana fiber when used exclusively. Therefore an experiment was planned to combine sodium hypochlorite with hydrogen peroxide. This combination was of dual benefit. 5% concentration of hydrogen peroxide was optimized when used without any combination, whereas in combination it was reduced up to 0.50%. As stated earlier chlorine bleaches helps in lignin removal, but cannot be used completely for banana fiber, but when used in combination, it serves the purpose. This combination proved to be successful as best results in terms of whiteness, softness and weight loss were obtained.

The mixture of NaOCl and H_2O_2 in water results in a redox reaction which gives the following equations:

$$NaOCl \circledcirc Na^+ + ClO^- \quad (1)$$

$$Na^+ + ClO^- + H_2O_2 \circledcirc Na^+ + ClO_2^- + H_2O \quad (2)$$

Equation 2 shows that when sodium hypochlorite disassociates in presence of hydrogen peroxide, it liberated chlorine dioxide anion (ClO_2^-). This ClO_2^- de-lignifies and bleaches simultaneously. It oxidizes lignin, but does not add chlorine atoms onto lignin fragments. It also acts on carbon carbon double bonds in the lignin side chains. Hence ClO_2^- acts as a dual agent of removing lignin and bleaching the fibers.

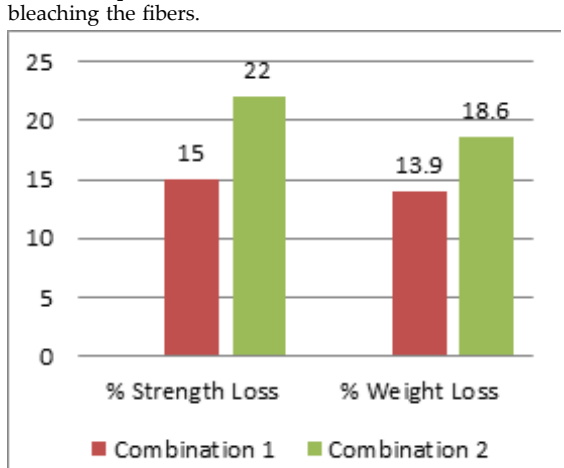


Figure 5: Percent strength loss and Percent weight loss of Banana fibers bleached with combination of bleaches

Table 5: Whiteness and Yellowness index of Banana fibers bleached with combination of bleaches

Sr. No.	Sample	Whiteness	Yellowness
1	Untreated	-84.577	47.982
2	Combination 1	-58.711	38.722
3	Combination 2	-50.350	37.300

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Hydrogen Peroxide is universal bleach, and is also suitable for Banana fibers. 5% concentration of H_2O_2 was the best suited for banana fibers when used as exclusive bleach. Adding a small portion of sodium hypochlorite in the bleaching bath of hydrogen peroxide, the bleaching efficiency increases. At the same time concentration of H_2O_2 is also reduced. Two combinations were studied, combination 1 was $NaClO_2$ (0.25%) + H_2O_2 (0.50%) and combination 2 was $NaClO_2$ (0.35%) + H_2O_2 (0.40%). The other parameters were constant as optimized for bleaching with hydrogen peroxide. From Figure 5 and Table 5, it can be observed that sodium hypochlorite affects the strength of banana fiber, as the concentration of the sodium hypochlorite in combination increase, the strength decreases. Thus Combination 1 was the best suited bleaching recipe for banana fibers.

3. Effect of utilization of FFT apparatus for treatment:
After bleaching the fibers, they were combed and weighted. Combing removed the pithy material from the fiber. Along with the pithy material, filament fibers are also removed due to entanglements. From Table 6 it can be observed that less wastage was generated after treating banana fibers in FFT apparatus. The apparatus let the fibers rotate without entangling with each other. This observation was measured by weighing the combed waste.

Table 6: Weight loss of banana fibers after combing

Weight of fibers before bleaching	Weight of fibers after bleaching and combing	Weight of fiber after bleaching in FFT apparatus and combing
200 grams	60 grams	80 grams

Conclusion
Hydrogen peroxide is universal bleach, and can be safely used for banana fibers. However, efficiency of hydrogen peroxide can be increased by adding sodium hypochlorite in the bleaching bath. The most effective bleaching treatment for banana fibers was the combination 1 of the two bleaches, which is H_2O_2 (0.50%) + NaOCl (0.25%). Also FFT apparatus is a potential instrument for treating banana or any filament length fibers.

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Nomenclature

Hydrogen peroxide	H_2O_2
Sodium hypochlorite	NaOCl
Filament Fiber Treatment apparatus	FFT apparatus
chlorine dioxide anion	ClO_2^-

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