Volume : 4 | Issue : 4 | April 2015 • ISSN No 2277 - 8179

Research Paper

Bio- softening of Banana Fiber for Nonwoven Application

Textiles

KEYWORDS : Banana fiber, Hemicellulase, Pectinase, Cellulase, Needle punch, Nonwoven

Ms. Ankita Shroff — Department of Clothing and Textiles, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat

Prof. Anjali Karolia — Department of Clothing and Textiles, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat

Dr. Jayendra Shah — Department of Textile Chemistry, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat

ABSTRACT

India is the world's largest producer of banana. The fiber has limited application in textiles due to its high stiffness and less cohesive properties. The aim of the study was to remove noncellulosic gummy materials from banana fiber thus softening it and prepare nonwovens through needle punch method. Grey banana fibers were treated with hemicellulase, pectinase and cellulase enzyme individually by varying its concentration and time. This optimised treatment was treated with different combination of enzymes, and then standardised. The effect of the enzymes on the fibers was measured in weight loss, strength loss and whiteness index of the fiber. Subjective analyses by touch and feel method, SEM analyses were also done. The best softened fibers were then processed for preparation of nonwovens through needle punch method at NIRJAFT Kolkata.

Introduction

Minor Fibres like Flax, Jute, Banana, Sisal, Ramie and fibres of similar plants have been used for more than 8,000 years. Banana is in Musa family. It is the second most important food crops grown in India. It is eco-friendly like jute fibre. It is ligno-cellulosic fiber obtained from the Pseudo-stem of Banana plant. In banana plantations, after the fruits are harvested, the trunks or stems are 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. A stem weighing about 37 kg yields about 1 kg of good quality fibre as a by-product. Banana fiber plays an important role as a textile material owing to its excellent tenacity, increased wet strength, easy drying, lustre, microbial resistivity. The reason for limited use of this fiber is attributed to the difficulties in its production, extraction and processing and also unawareness of the fiber among the people. Another inherent drawback of this minor fiber is its greater stiffness, less cohesiveness and higher irregularity, owing to the multi-cellular nature of the fibres. The individual cells are cemented with hemicellulose and lignin and thus form a complex fibre. Therefore there is no spinnability of the yarn into fine Denier. As they are not able to spun, hence the fibers can be used in fibrous state. Thus nonwoven was the best option to give a new dimension to the minor fibers.

To produce nonwoven through needle punching method, the fibers were softened with enzymes which could prove to be the best alternative as it is regarded as environmentally friendly and the reactions catalysed are very specific with a focussed performance. In contrast, chemical processes are less specific and often result in side effects, mostly undesired. These enzymes help in removing the unwanted components from the fiber and thus making it soft. In this study, the researcher has attempted to remove the noncellulosics with an enzymatic treatment to soften the fiber.

Materials and Methods

Untreated banana fibers were procured from Navsari Agriculture University, Gujarat. Enzyme BGLU with hemicellulase activity and Palcoscour enzyme with pectin activity was supplied by Rossari biotech Pvt Ltd., Bangalore, India and Biofast SBE with cellulase activity was supplied by Maps (India) Ltd, Ahmedabad, Gujarat. Enzyme solution (1%) was prepared by dissolving 1.0 gram of enzyme in 100ml of 1 ml glacial acetic acid solution prepared in distilled water at room temperature. Two grams of banana fibers were treated with enzyme solution of particular concentration at pH 5 at 50-55°C at 1:60 M: L ratio. After the treatment the samples were washed with distilled water and deactivated. Treatment conditions were optimised at different enzyme concentration (10 and 12% owf) and time (8, 12, and 14 hours) with respect to weight loss.

The chemical compositions of the gray fiber were determined using A.J. Turner's scheme. Percentage weight losses were calculated from the different weight of samples (conditioned at 27±1°C and 65% for 24 hours) before and after the treatment and expressed in percent over the original weights of the sample. Strength loss of the fibers was also calculated. Whiteness and yellowness indices of the fibers were measured at standard conditions on Spectrascan 5100A Spectrophotometer (premier colour scan, India). Further the optimised concentration and time were used to treat the fiber with the combinations of the enzyme to form a standardise recipe.

Subjective analysis by touch and feel method was done for the softness of the fiber. The best softened fiber was further SEM tested. The best softened fiber selected was further treated on 10kg fiber for preparing nonwovens through needle punch method. The fabrics were prepared at NIRJAFT, Kolkata. The machine and the fabric parameters to prepare nonwovens were selected by the NIRJAFT depending upon the softness and properties of the fibers.

Results and Discussions

Banana fiber under microscope reveals that it is approximately cylindrical in shape. Bundles of polygonal shape having large oval to circular lumen was also observed. The cell walls were thin and uniform. Being cellulosic in nature, it dissolves only in 72% concentrated sulphuric acid when subjected to heat. It burns quickly when subjected to heat and gives paper burn smell. The physical properties of the fiber were tested at standard conditions which are presented in Table 1.

Table 1: Physical properties of the Banana fiber under study

Sr. No	Property	Value
1	Length of the fiber (cm)	89
2	Fineness of the fiber (Denier)	130
3	Moisture regain (%)	8.63
4	Tensile strength (gm/tex)	40.05

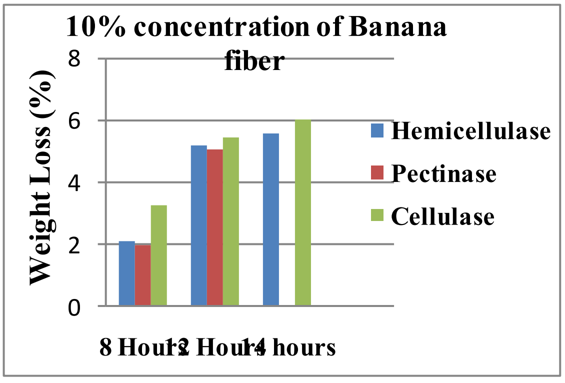
The chemical composition of the gray banana fiber was analysed by A.J. Turner's scheme (Table 2)

Table 2: Chemical composition of gray banana fiber

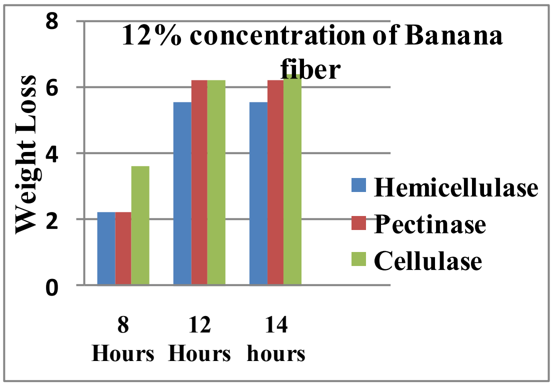
Sr. No	Content	Banana fiber (%)
1	Cellulose	69.5
2	Hemicellulose	15
3	Lignin	5.45
4	Pectin	0.5
5	Fats and waxes	1.5

Banana fiber behaves differently (as expressed by weight loss) at different reaction conditions with enzymes. Therefore it was treated with different enzyme concentrations for various time periods. The percent weight losses of the fiber are given in Graph1 and 2.

Graph 1: Weight loss of banana fiber at 10% concentration of enzyme



Graph 2: Weight loss of banana fiber at 12% concentration of enzyme



From Graph 2 it was observed that the maximum weight loss for the banana fiber was observed 6.4% when treated with cellulase enzyme at 12% concentration for 14 hours.

The results indicate that the percent weight loss increases with increased severity of the treatment conditions of enzymolysis. This weight loss occurs due to the removal of impurities from the banana fiber. During the enzyme treatment, hydrolysis of hemicellulose occurs along with the removal of other impurities. The BGLU has a hemicellulose degrading activity, which consists of several xylan- hydrolysing components with exo and endo activity as well as side chains cleaving glucoronides and acetyl xylan esterase's detaching o-acetyl groups. Endo types attack hemicellulose chain, decreasing the degree of polymerisation of the substrate. Cellulases hydrolyse the ß-1,4-glycosidic linkages of cellulose. Traditionally, they are divided into two classes referred to as endoglucanases and cellobiohydrolases. Endoglucanases (endo-1,4-b-glucanases, EGs) hydrolyses the internal bonds (preferably in cellulose amorphous regions) releasing new terminal ends. Cellobiohydrolases (exo-1,4-b-glucanases, CBHs) acts on the existing or endoglucanase-generated chain ends. Both enzymes degrade the amorphous cellulose but, Cellobiohydrolases are the only enzymes that efficiently degrade crystalline cellulose. (12)

While pectinase enzyme (E2) is a mixed enzyme which effectively removed pectin, fats and waxes. From Graph 1 it is seen that maximum weight loss in banana fiber was observed by cellulase enzyme followed by pectinase and then by hemicellulase enzyme. The difference between the weight loss of banana fiber when treated with cellulase enzyme at 12% for 12 hours and 14 hours was 0.2% which was minimal. Also 15% enzyme concentration (owf) treatment was given on the banana fibers which showed similar weight loss of that of 12%.

Table 3 shows the percent weight loss of the banana fiber when treated with enzymes individually.

Table 3: Percent strength loss of banana fiber

Sr. No	% of enzymes	Enzyme	Percent Strength loss		
			8 Hours	12 Hours	14 Hours
1	10	E1	6.5	7.2	10.78
2	10	E2	8.1	17.07	19.59
3	10	E3	7.09	7.44	13.9
4	12	E1	6.9	7.4	16.4
5	12	E2	8.4	9.1	21.7
6	12	E3	8.2	9.5	21.8

Enzyme Code: E1- Hemicellulase, E-2 Pectinase, E3- Cellulase

From the Table 3 the results indicate that the percentage tensile strength of the fiber decrease with the increase in the weight loss. Noncellulosic materials impart strength to the fibers which are removed with the progress of the enzymatic treatment. This lowers the tensile strength of the fibers. Strength loss of banana fiber was observed maximum by cellulase enzyme and then followed by pectinase and hemicellulase enzyme. Strength loss of banana fiber was observed maximum by cellulase enzyme (E3) at 12% concentration for 8, 12 and 14 hours. This was because banana fiber contains equal amount of impurities and hence cellulase reacts first on the surface of the fiber, hemicellulase weakens the chain of hemicellulose and then pectinase removes the pectins.

Enzymes help the fiber to remove the pectin, fats and waxes. This helps in reducing the yellowness colour of the fibers and thereby increases the whiteness of the fibers.

Table 4: Whiteness index of Banana Fiber

Sr. No	Name	Whiteness	Yellowness	Brightness
1	Untreated	55.09	47.643	24.444
2	E1 12% 8 HOURS	57.671	47.184	27.032
3	E2 12% 8 HOURS	53.384	49.08	22.986
4	E3 12% 8 HOURS	54.384	46.755	24.083
5	E1 12% 12 HOURS	57.865	47.873	27.077
6	E2 12% 12 HOURS	54.119	48.7	23.672
7	E3 12% 12 HOURS	58.825	47.6	28.312
8	E1 12% 14 HOURS	53.754	47.342	23.515
9	E2 12% 14 HOURS	59.016	41.859	29.092
10	E3 12% 14 HOURS	58.352	45.01	27.944

Enzyme Code: E1- Hemicellulase, E-2 Pectinase, E3- Cellulase

From the above results, it was concluded that 12% concentration for 12 hours gave the best results on the fibers. Hence the enzymatic treatment was optimized at 12% concentration for 12 hours. The noncellulosic impurities present in the grey fibers are hemicellulose, pectin, lignin, fats and waxes. These have specific activity towards various constituents of the fibers. Therefore, an individual enzyme cannot impart adequate level of performance even though it gives weight loss in the required range. This is because a single enzyme cannot remove all noncellulosic constituents uniformly from the gray fibers. Therefore in order to achieve satisfactory enzymatic performance, three enzymes were mixed together.

The fibers were further treated with different combinations of enzymes. The weight loss of the fibers represents the removal of the noncellulosic components in the fibers. Therefore, weight loss of the each combination was measured.

Table 5: Effect of optimum enzymatic treatment conditions on weight loss and strength loss of the Banana fiber

Sr. No	Concentration of Enzyme (%owf)			Weight loss (% owf)	Strength loss (%)
	E1	E2	E3		
1	4	4	4	8.65	12.4
2	3	2	7	7.2	7.01
3	5	2	5	8.55	9.6

Enzyme Code: E1- Hemicellulase, E-2 Pectinase, E3- Cellulase

Maximum weight loss of 8.64% is seen at the enzyme ratio of 4:4:4 in the banana fiber. Banana fiber contains equal amount of impurities in it. Hence when treated with equal amount of enzymes the weight loss was maximum. The hemicellulase enzyme would attack the hemicellulose of the fiber and weaken its chain first as the degree of polymerization of hemicellulose is less than cellulose, while cellulase enzyme would attack the surface of the fibers and then pectin's would enter in the inner surface of the fiber and removed pectin's efficiently.

In order to prepare nonwoven fabric, it was necessary to maintain the strength of the fibers. Therefore, bundle strength test of the fibers was tested. The maximum strength loss of the banana fiber was when treated with 4% hemicellulase, 4% pectinase and 4% cellulase enzyme while it was less when treated with 3% hemicellulase, 2% pectinase and 7% cellulase. The fibers when treated with single enzymes showed very minimal effect on the whitening of the fibers.

Therefore the effect of the combination of the enzyme on the whitening of the fibers was determined.

Table 7: Whiteness index of the combinations of enzyme on the banana fiber

Sr. No	Name	Whiteness	Yellowness	Brightness
1	Untreated	55.09	47.643	24.444
2	12% 4:4:4 12 HOURS	58.396	39.363	28.771
3	12% 3:2:7 12 HOURS	55.698	44.599	25.592
4	12% 5:2:5 12 HOURS	55.645	33.298	26.361

Hemicellulase: Pectinase: Cellulase

Table 7 indicated that the yellowness of the banana fiber decreased much when treated with 5% hemicellulase, 2% pectinase and 5% cellulase enzyme combination. And also the whiteness of the fiber increased when treated with the same combination.

Subjective analysis-
The fibers treated with the combinations of the three enzymes where given to panel of five judges along with the untreated fiber. The majority chosen combination by touch and feel method for the fiber was selected as the best softened fiber. The best combination of the enzymes selected for the fiber was 4% hemicellulase, 4% pectinase and 4% cellulase.

From the above analysis done by the weight loss, strength loss, whiteness index, and softness test, it was concluded that the best softened result obtained for banana fiber was when treated with 4% hemicellulase, 4% pectinase and 4% cellulase enzyme followed by the combination of 5% hemicellulase 2%, pectinase, and 5% cellulase%. But the 4:4:4 percent combination of enzyme showed maximum tensile strength loss which would be not suitable for preparing nonwoven enzyme. Therefore enzyme concentration 5% hemicellulase 2%, pectinase, and 5% cellulase was selected best for the preparation of the nonwovens.

SEM Analysis-
SEM tests of the untreated and best selected fiber were done at the magnification of 100X and 550X.

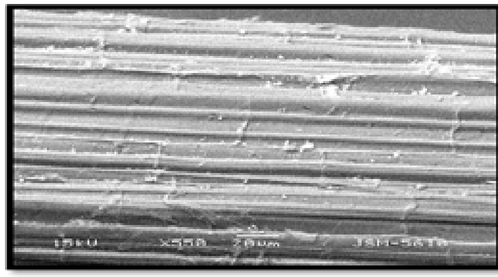


Plate 1: SEM test of untreated banana fiber at 550X

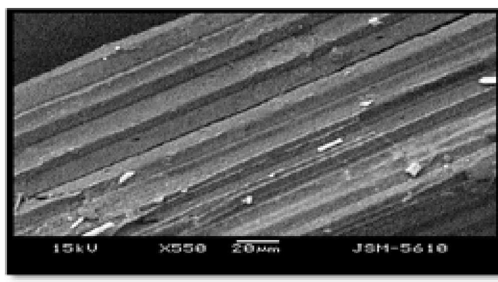


Plate 2: SEM test of treated banana fiber at 550X

The primary function of fiber softening is to make the fibers surface smooth. Plate 1 showed that the untreated banana fiber had rough and irregular surface. While from the Plate 2 it was observed that the surface of the banana fiber after treatment was smoothen to some extent.

The best softened fibers selected were further treated on 10kg of fiber for preparing nonwovens through needle punch method. The fabrics were prepared at NIRJAFT, Kolkata. The machine and the fabric parameters to prepare nonwovens were selected by the NIRJAFT depending upon the softness and properties of the fibers. The nonwoven fabrics prepared were 100% banana. Combinations of the fabric were also prepared by blending 50:50% banana and sisal fibers and 60:40% ramie and banana fibers.

For preparing 100% banana nonwoven fabric, the fibers were passed through the softener machine where the fibers where passed through the rollers to remove the dust particles. Then the fibers were sprayed with 2% oil- water emulsion and kept in the chamber for 24 hours to gain 30% moisture in them. The fibers were then processed through the first carding machine where slivers were prepared. These slivers were then proceed for preparing nonwoven in the DILO machine. Here the slivers were first hand opened and then passed through the carder and then forwarded to the camel- back cross lapper where the cross laying of fiber is done. The fibers here were not able to form a thin layer of sheet after carding process. This was due to the lack of cohesiveness in the banana fiber. Also the inherent strength of the banana fiber was not appropriate to prepare nonwovens in DILO nonwoven machine. Therefore the 100% banana nonwoven was prepared manually on manual needle punch machine.

In the manual needle punch machine the fibers were cut into staple lengths of 3 inches. These fibers were laid first in the parallel direction and then passed through the needle board consisting of 1332 number of needles. The fibers was then again laid in the opposite side of the fabric in the horizontal direction and then passed through the needle board. In this manner fibers were laid in the cross direction and punching was done from the both side of the fabric.

Table 8: Constructional details of experimental fabrics

Sr. No	Blended composition	Fiber laying technique	Needle penetration	Punch density Punches /cm^2	Stroke f requency Stroke/min	GSM
1	100% Banana	Cross-laid	9mm	150	240	466 and 690

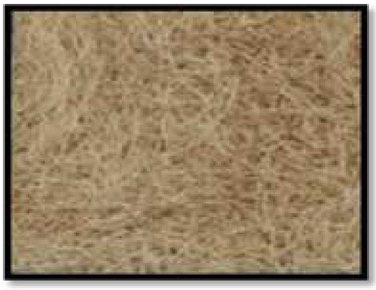


Plate 5: 100% Banana nonwoven fabric of 466 GSM (Cross laid)

Plate 6: 100% Banana nonwoven fabric of 690 GSM (Cross laid)

Conclusion

The three eco-friendly enzymes used in this study were hemicellulase, pectinase and cellulase enzyme. These were used to soften the fiber by removal of pectins, waxes, lignin and hemicellulose.

- From the single enzyme treatment it was also concluded that-

- The cellulase and pectinase enzyme removed more impurities from the banana fiber thus making them softer.
- Good results were not seen for improvement of whiteness index.
- The single enzyme treatment on the fiber gave best result at 12% concentration (owf) at 12 hours. And hence the enzymatic treatment was optimized at 12% concentration (owf) for 12 hours.
- But the fiber when treated with enzymes individually they removed particular impurity only. The impurities were not evenly removed as the enzymes are specific in their action i.e. Hemicellulase enzyme removes hemicellulose from the fiber, pectinase enzyme removes pectins and cellulase enzyme affects the cellulose and makes the surface soften.
- Therefore, the fiber was treated with combination of enzymes. It was concluded that the fiber when treated with the combination of the enzymes gave better results than the fiber treated with single enzymes. The impurities i.e. the non-cellulosic particles from the fiber were removed more evenly when treated with combination of enzymes as it acts synergetically.
- It was also concluded that the weight loss in the fiber increased with increase in concentration and time. And more the weight loss in the fiber more was the strength loss as the removal of more amount of impurities and fats would loosen the binding force and thus reduce its resistance to breaking on application of load.
- Analysis of the treatment of combination of the enzymes on the fibers gave a standard combination recipe for each fiber. The best combination selected for the fiber was 5% hemicellulase, 2% pectinase and 5% cellulase.
- 100% banana nonwoven fabric was prepared on DILO nonwoven mechanical machine of 466 and 690 GSM.

REFERENCE

1. Anandjiwala R., and Boguslavsky L. (2008). Development of Needle-punched Nonwoven Fabrics from Flax Fibers for Air Filtration Application. Textiles Research Journal, 78(7), 614-624. | 2. Banik S. and Ghosh S N. (2008). Pectinolytic activity of microorganisms in piling of jute. Indian Journal of Fibre and Research, 33, 151-156. | 3. Bhattacharya S., and Shah J.N. (2004). Enzymatic Treatments of Flax Fabric. Textile Research Journal, 74(07), 622-628. | 4. Chakraborty J N,S Tharakeswari S. (2013). Enzymatic colouration of textiles. Asian Textiles Journal, 22(10), 49-54. | 5. Chattopadhyay D. , Sharma J. and Chavan R . (2000). Improvment in jute fabric handle through biofinishing. Indian Journal of Fabric and Textiles Research, 25, 121-129. | 6. Chattopadhyay R., Pradhan A., Das D. (2013). Composite Nonwoven Air Filter: A Review. Textile Review, 71-76. | 7. Debabandya M., Sutar N. (2010). Banana and its by-product utilisation: an overview. Journal of scientific and inudstrial research, 69, 323-329. | 8. Gomes I., Sarkar P., Rahman S., Rahim A. and Gomes J. (2007). Production of cellulase from Talaromyces emersonii and Evaluation of its application in Eco-Friendly Functional Finishing of Jute-Based Fabrics. Bangladesh J Microbiol, 24(2), 109-114. | 9. Jabasingh A., Nachiyar V. (2012). Bio-Softening of Jute Fibers using Aspergillus nidulans SU04 Cellulase. Advanced Biotech, 11(07), 38-42. | 10. Karthick A., Gobi N. (2012). A Review on Methods, Application and Properties of Immobilized Enzyme. Chemical Science Review and Letters. | 11. Sabale A, Rane V. (2012). Enzymes: for today and tomorrow. Colourage, 33-39. | 12. Samanta A K, Singhee Deepali, Basu Gautam and Mahalanabis K K. (2005). Effect of selective pretreatments and subsequent mixed enzyme treatment on properties of jute-cotton union fabric. Indian Journal of Fabric, 30, 451-467. | 13. Sengupta Surajit, Chattopadhyay Sambu N, Samajpati Soma and Day Abhindra. (2008). Use of jute needle-punched nonwoven fabric as reinforcement in composite. Indian Journal of Fabric and Textile Research, 33, 37-44. | 14. Senthil R, Sundaresan S, Gowri K. (2012). Needle punching process: A technological review. The Indian Textile journal, 121, 81-86. |