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Enzymatic Polishing of Jute/Cotton Blended Fabrics

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Jute is a strong, stiff, natural fiber. When blended with cotton it makes a sturdy but prickly fabric due to protruding surface jute fibers. Samples of jute-cotton blended fabric were treated with commercial cellulases, xylanases and pectinases individually and in combination at various concentrations in order to smooth and soften the fabric. Enzyme treatment was carried out at 50°C in the presence of 0.1 M phosphate buffer (PH 7.0), for 3 h. Enzymatic activities were evaluated by the release of reducing sugars and changes in surface appearance of the fabric. Addition of commercial cellulases alone extensively removed protruding jute and cotton fibers from the fabric, whereas addition of commercial pectinases or xylanases mainly loosened the protruding long jute fiber bundle. Combined treatment of pectinases and xylanases with reduced amounts of cellulases was equally effective as high levels of cellulases in the removal of surface protruding fibers. The amount of reducing sugar released correlated with removal of fibers from the fabric surface. Thus, the fabric surface was smoother in enzyme-treated samples compared to untreated control and treated with mixtures of enzymes were more effective than cellulase alone.

[Key words: jute-cotton fabric, enzymatic polishing, surface protruding fiber]

Jute *(Corchorus capsularis) is* the second most common natural fiber produced in the world. It is grown extensively in Bangladesh, India and China. Raw jute is processed into coarse fibers and used for the production of cords and textiles. With the rise in sales of synthetic fibers, traditional jute markets have been lost, and researchers have sought to develop new products. One application is manufacture of strong, durable fabrics made from 20 to 30% jute and 70 to 80% cotton blends. However, fabrics made from jute and cotton (JC) blends have a distinct prickly sensation when in contact with the skin. This is due to rigid jute fibers protruding from the surface (1-3). Unless the quality of the fabric is improved, garments made with JC are not smooth and soft and will not perform well.

The properties of jute fiber can be improved through biochemical retting. By removing the pectin sheath, the jute fiber is softened. Enzyme treatments can be carried out either before or after weaving. In either case, the jute fiber is smoothed through biopolishing.

The concept of biopolishing was first developed in Japan (1). The objectives were to create a smooth fabric and soften the fibers without the use of traditional, topically applied chemicals. In cotton fabrics, the protruding fibers are removed by biopolishing the fabric surface using cellulases (1, 4-7). Jute fiber consists not only of cellulose but also of hemicellulose, pectin and lignin (8). Microbial pectinases and xylanases allow selective removal of pectin and xylan thereby, making the jute fiber softer (2, 3, 9). Further reactions with cellulase could result in selective removal of protruding fibers.

In the present study, mixtures of microbial enzymes removed protruding jute fibers from the surface of JC fabric. To our knowledge, this is one of the first reports on improved quality of jute blended fabric as a consequence of enzymatic polishing.

MATERIALS AND METHODS

Enzymes Commercial Pectinex USP-a pectinase preparation, and Denimax L-a cellulase preparation were obtained from Novo Nordisk (Denmark). V1–4 xylanase was produced by the cultivation of *Bacillus* sp. under previously described conditions (Yang, V. W. *et al.*, J. Indust. Microbiol., 1995). The protein content of these commercial enzyme preparations was determined by the method of Lowry *et al.* (10). Pectinase, xylanase and carboxymethylcellulase were assayed in all the above enzymes as per Sreenath *et al*, (11). Filter paper degrading activity was also estimated (12). The enzyme activity was expressed as International Units (IU) ml^{-1} enzyme, where 1 IU was the amount of enzyme necessary to produce 1 µmol of reducing sugar (glucose equivalents) in 1 min.

Design of enzymatic treatment of JC fabric Square samples (10 × 10 cm) of 20:80 jute : cotton blended fabric were placed in self sealing plastic bags, and 50 ml of 0.1 M sodium phosphate buffer (PH 7.0) was added along with various amounts of the cellulase, pectinase and xylanase preparations. A modified partial factorial central composite experimental design was used to examine five levels of each of the three enzymes of interest (Fig. 1). This design consisted 15 samples of enzyme combinations at various concentrations (13). The reaction mixtures were mixed and incubated at 50°C for 3 h. Enzymes were then inactivated by boiling in water for 5 min. The clear reaction mixture was saved to estimate reducing sugars using the 3,5 dinitrosalicylic acid (DNS) assay (14). Following enzyme inactivation, the JC fabric was thoroughly washed in tap water then in distilled water and was air dried. Control samples consisted of fabric treated in an identical manner but without enzymes. The reducing sugar levels of controls were subtracted from the experiments. Three determinations for each sample were averaged.

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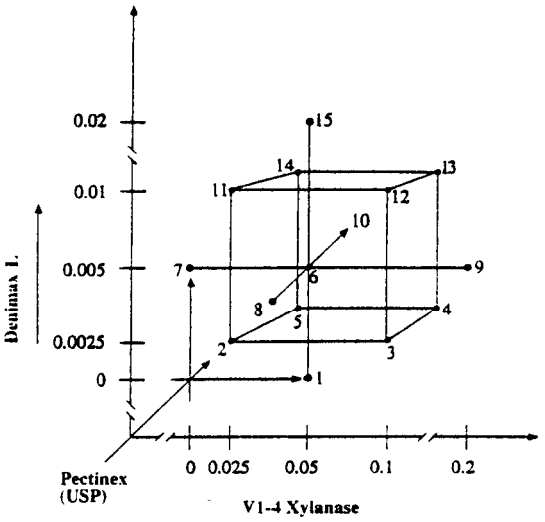

FIG. 1. Partial factorial design for enzymatic treatment of a 20 : 80 jute : cotton blended fabric with Denimax L, V1–4 xylanase, and Pectinex preparations.

High performance liquid chromatography (HPLC) Sugars obtained during enzyme treatment were separated by HPLC (Hewlett Packard series 1050, USA) with an RI detector using an Aminex Carbohydrate HPX 87C, column (300 × 7.8 cm) maintained at 85°C (15). The mobile phase was degased distilled water at a flow rate of 0.5 ml · min $^{-1}$ and pressure of 50 to 55 bar. The filtered clear sample (980 µl) was mixed with 20 µl of sucrose (500 g · l^{-1}, as internal standard before injection.

Microscopy The control and enzyme treated fabric were observed by light microscopy (M 400, Photomikroskop, Wild Heerbrugg, Switzerland). For scanning electron microscopy (SEM), the enzyme treated fabric was placed on silver conductive tape mounted on specimen stubs and coated with a thin layers of gold *in vacuo*. Enzyme-treated samples were compared to controls using a JSM-840, JEOL Scanning Microscope (USA).

RESULTS AND DISCUSSION

Polysaccharide degrading activities of commercial enzyme preparations Each enzyme level was determined prior to use. The Pectinex (USP) and Denimax L enzyme preparations contained considerable xylanolytic activity in addition to pectinase and cellulase whereas the V1-4 preparation was essentially xylanase (Table 1). The activity of the Denimax L preparation was lower than originally supplied. These enzymes were used individually as well as mixed in various permutations and combinations with varying enzyme concentrations to treat JC blended fabric in order to remove surface protrusion of jute and cotton fibers of the JC blended fabric.

TABLE 1. Activities of commercial enzymes on some polysaccharides

Enzyme	Enzyme activity (IU ml^{-1})			
	Xylan	Pectin	CMC	Filterpaper
V1–4 xylanase	37.04	0.09	0.25	0.17
Denimax L	64.8	62.5	62.5	21.48
Pectinex (USP)	95.67	53.7	11.85	2.04

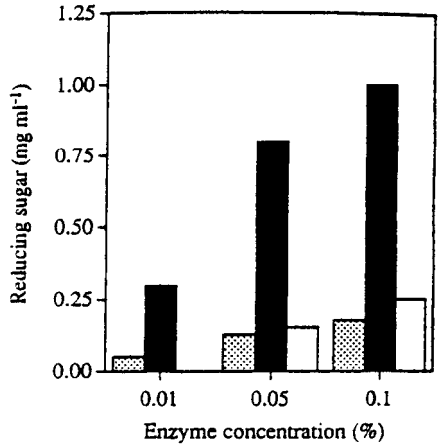

FIG. 2. Release of reducing sugar during enzymatic treatment of a 20 : 80 jute : cotton blended fabric. Symbols: ▨, V1–4 xylanase; ■, Denimax L; □, Pectinex (USP).

Enzymatic polishing of JC fabric The effect of the Denimax L in removing the protruding fibers was visually obvious. Treated fabric was noticibly smoother than untreated samples. Neither Pectinex nor V1-4 xylanases were as effective as cellulases when they were used alone. The release of reducing sugar increased much more with Denimax L than with other enzymes during fabric treatment (Fig. 2). Three concentration of individual enzymes (0.01, 0.05 and 0.1 %) were studied. Under both 0.05 and 0.1 % Denimax treatment, we found that enzyme treated JC fabrics were softer than untreated control fabric. Microscopic observations showed that Denimax L removed all protruding surface fibers compared to untreated control fabric (Fig. 3).

Similar removal of surface fibers during the first few hours of hydrolysis with cellulase on cotton fabrics have been reported (1, 5, 16). The pectinex or V1-4 xylanases alone did not show much alteration in ultrastructure of fiber morphology unlike that of Denimax treatment (data not shown). Probably the low filter paper activity of pectinex or V1-4 xylanase accounted for its inability to remove protruding fibers. Because prolonged cellulolysis leads to fabric damage, weight loss, and a considerable decrease in strength (16), fabric treatment with cellulase alone, is not fully beneficial.

Effect of various enzyme combinations on JC fabric The combination of cellulase, pectinase and xylanase effectively attacked surface jute fibers. Using these enzyme(s) in combinations at their optimum levels helped the effectiveness of lower cellulase levels and therefore prevented extensive hydrolysis of the fabric. The protruding fibers were not removed in the absence of Denimax L, but addition of low levels of Pectinex and V1-4 xylanase enhanced the specificity of jute fiber treatment over that of cotton. The partial factorial design helped to estimate the optimum concentrations of enzyme(s) required for biopolishing. As shown in Table 2, the amounts of reducing sugar released during fabric treatment correlated with surface fiber removal and they indicated synergistic activities of these enzymes when used in combination(s). Low amounts of glucose, xylose and other unidentified oligosaccharides were found in the hydrolyzates obtained during fabric treatment with enzyme combinations. The removal of protruding JC fibers was prominent with enzyme combinations as compared

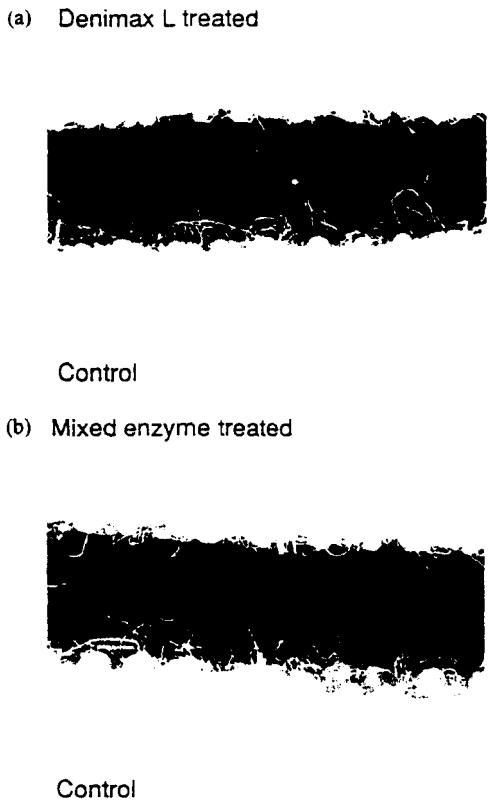

FIG. 3. (a) Photomicrograph of control and Denimax L treated JC fabric. (b) Photomicrograph of control and mixed enzyme treated JC fabric.

with untreated fabric (Fig. 3). The best combination of enzyme to use in this fabric polishing was no. 6 (Table 2). After enzyme treatment, the JC fabric was softer because of removal of protruding jute-cotton fibers.

The contaminating activities of technical preparations of Pectinex and Denimax L make it difficult to assess and interpret the roles of individual enzymes in degrading plant cell walls (17). However, the main advantages of using commercial enzyme preparations are their readily availability and low cost. Our results showed that the mixture of enzyme was effective in biopolishing application to improve the quality of jute blended fabrics. Further work is needed in measuring of physical parameters of JC fabric such as degree of softness, strength, fuzz and pilling as a consequence of biopolishing.

TABLE 2. Release of reducing sugars during fabric treatment by various combination of enzymes using partial factorial design

Partial factorial[b] #	Enzyme[a] (%, v/v)			Total enzymes (%)	Reducing sugar ($mg \cdot ml^{-1}$)
	Xylanase	Cellulase	Pectinase		
1	0.05	—	0.05	0.1	0.22
7	—	0.005	0.05	0.055	0.425
8	0.05	0.005	—	0.055	0.525
2	0.025	0.0025	0.025	0.0525	0.25
11	0.025	0.01	0.025	0.06	0.475
6	0.05	0.005	0.05	0.105	0.55
15	0.05	0.02	0.05	0.12	0.575
3	0.1	0.0025	0.025	0.1275	0.32
5	0.025	0.0025	0.1	0.1275	0.4
12	0.1	0.01	0.025	0.135	0.6
14	0.025	0.01	0.1	0.135	0.5
4	0.1	0.0025	0.1	0.2025	0.5
13	0.1	0.1	0.01	0.21	0.775
9	0.2	0.005	0.05	0.255	0.775
10	0.05	0.005	0.2	0.255	1.1

[a] Xylanase V1–4 was obtained from *Bacillus* sp. Cellulase (Denimax L) and pectinase [Pectinex (USP)] were obtained from Novo Nordisk.

[b] See Fig. 1 for design of fabric treatment with combination(s) of enzymes.

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