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Application of biotechnology in the coloration of jute fabric using bis–triazinyl type of reactive dyes

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Two sets of processed jute fabric, viz. alkaline scoured-bleached and bioscoured -bleached jute fabrics, have been dyed separately with two neucleophilic substitution type (bis- triazinyl type) of reactive dyes, namely Procion Blue HERD and Procion Green HE4BD dyes. It is observed that bioscoured - bleached- reactive dyed jute fabric shows higher dye uptake than that produced by alkaline scoured-bleached-reactive dyed jute fabric in case of both the reactive dyes. Bio-treatment results in improvement of handle and wash fastness properties of jute fabric. Brightness of the shade is also improved in case of biotreated-bleached-reactive dyed jute fabric.

Keywords: Bioscouring, Bis -triazinyl reactive dye, Cellulase enzyme, Dyeing, Jute fabric, Xylanase enzyme

1 Introduction

The golden fibre ‘jute’ is lignocellulosic in nature, biodegradable and renewable. This fibre is traditionally used for making packaging material due to its high tenacity and low extensibility. The fibre is stiff and harsh. Jute industry is facing a stiff competition from its synthetic counterparts as the later are light in weight and lower in cost for making packaging material. For the survival of giant jute industry in India, there is a need to diversify the product range so that the jute fibre is properly utilised and farmers are protected. Now-a –days various type of products are produced from jute fibres like upholstery, curtains, furnishing materials, handicraft products, outer garments, etc which are decorative and value-added items. So, the basic raw material of these products (jute fabric) is chemically or biochemically modified[1,2] to overcome the inherent drawbacks of this fibre, like stiffness, harshness, brittleness and to make the fabric soft and lustrous. Apart for the improvement in feel[3], the fabric should also look attractive by means of bleaching and dyeing.

For making diversified and value-added products, several chemical processing methods have been developed, like scouring, bio-scouring and ambient temperature processing during last two decades. Moreover, jute fabrics have also been dyed with several natural and synthetic dyes to make the fabric attractive. In most of the cases, effluents are produced after pretreatment and bleaching and left out dye liquors containing dyes and salts produce pollution. There is a need to reduce the pollution and dye effluent should contain minimum amount of dyes. Therefore, in this work, an attempt has been made to use biotechnical methods to reduce pollution load. Also a special type of reactive dye has been used where minimum dye effluent is produced and deep colour shade is obtained with improved feel.

2 Materials and Methods

2.1 Materials

Grey jute fabric having the following specification was used for the study : warp count 155 tex, weft count 144 tex, ends/dm 67, picks/dm 65, fabric mass 205 g/m^2 (at 65% RH and 27°C)

The following chemicals of analytical grade were used in the experiment: hydrogen peroxide, trisodium phosphate, sodium hydroxide, sodium carbonate, sodium silicate, sodium acetate, acetic acid, non-ionic surface active agent (Ultravon JU) and glaubers’ salt.

A commercial cellulase enzyme ‘EZYSOFT LCP’ (M/s Resil Chemicals Pvt. Ltd.) and xylanase enzyme ‘TEXZYME J’ (M/s Textan Chemicals Pvt Ltd.) were used for the study.

Two bis – triazinyl type of reactive dyes[4], viz. Procion Blue HERD (C.I. Reactive Blue 160) and

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Procion Green HE4BD (C.I. Reactive Green 19) were used in the experiment.

2.2 Methods

2.2.1 Chemical Scouring

Grey jute fabric was scoured chemically with sodium hydroxide (2%, owf) and non-ionic surface-active agent (2 g/L) at 90^0C for 1h, keeping the material -to- liquor ratio at 1:20. Chemically scoured fabric was washed thoroughly in cold water and then treated with acetic acid (2 mL/L) for 20 min at room temperature (30^0C) to neutralize the residual alkali present in the fabric. Further, cold washing and drying were carried out as usual.

2.2.2 Bioscouring

Grey jute fabric was scoured biochemically with cellulase enzyme (Ezysoft LCP, 4% owf), xylanase enzyme (Texzyme J, 4% owf) and non-ionic surface-active agent (3% owf) in the same bath at 50^0C for 2 h, keeping the material-to-liquor ratio at 1:10. The *p*H of the bath was maintained at 4.5 by using acetic acid and sodium acetate buffer. After this treatment, the temperature of the bath was raised to 90^0C and maintained as such for 15 min. Thereafter, the samples were washed and dried.

2.2.3 Bleaching

Bleaching of chemically scoured and bioscoured jute fabrics[5] was done separately in a closed vessel for 90 min at 80–85^0C, keeping the material-to-liquor ratio at 1:20 with hydrogen peroxide (2 Vol), trisodium phosphate (5 g/L), sodium silicate (10 g/L) and non-ionic surface active agent (2 g/L). The *p*H of the bath was maintained at 10. After bleaching, the fabrics were washed thoroughly in cold water, neutralized with acetic acid (2 mL/L) for 15 min at room temperature (30^0C), again washed in cold water and dried.

2.2.4 Dyeing

Chemically scoured-bleached and bioscoured-bleached jute fabrics were dyed separately with bis-triazinyl type of both reactive dyes. Dye bath was made with dye (4%, owf) , Glauber's salt (80 g/L) and keeping the material-to-liquor ratio at 1:20. The bleached fabric samples were dipped into the dye bath and kept as such for 45 min with stirring at 85^0C. After this treatment, alkali (sodium carbonate 50 g/L) was added in the same bath and kept at 85^0C for 1h for fixation of dye. Thereafter, the dyed fabric samples were washed with cold water, soaped with non-ionic surface-active agent (2 g/L) for 15 min at boil followed by usual cold washing and drying

2.2.5 Evaluation of Fabric Properties

Grey chemically scoured, bioscoured, chemically scoured-bleached, bioscoured-bleached, chemically scoured-bleached-dyed and bioscoutred-bleached-dyed jute fabrics were evaluated by using different standards, such as whiteness index (Hunter), yellowness index (ASTM D1925), brightness index (TAPPI 452), *K*/*S* value (Kubelka-Munk equation), L, a,b values (computer colour matching system), wash fastness (IS: 3361-1979), light fastness (IS: 2454-1967), handle properties (IS: 6490-1971), tensile properties (ASTM D1682-1975), UV-protection factor (UPF) (AATCC 183-2004).

3 Results and Discussion

Cellulose, hemicellulose and lignin are the main constituent of jute fibre. Optical properties of grey, chemically scoured, bioscoured, chemically scoured – bleached and bioscoured – bleached jute fabrics were determined as per standard procedure mentioned above . The results are given in Table 1.

Whiteness and brightness of chemically scoured-bleached and bioscoured-bleached jute fabric improve significantly in comparison to only chemically scoured and bioscoured jute fabric. Improvement in whiteness and brightness is more in case of bioscoured-bleached jute fabric.

Between the two enzymes used in this study, cellulase enzyme[6] acts on the cellulose part of the fibre and xylanase enzyme acts on the hemicellulosic part of the fibre. Jute fibre is having a composite structure consisting of cellulose, hemicelluloses and lignin as major constituents and pectin, mineral matter and little amount of fats and waxes as minor constituents. During the fibre processing it acquires dirt and dust particles as well as batching oil. So, the scouing of jute means removal of added and inherent impurities. Treatment with cellulase and xylanase enzyme leads to enzymolysis and a small part of

Table 1 — Optical properties of jute fabrics

Jute	Whiteness index	Yellowness index	Brightness index
Grey	48.32	43.75	18.99
Chemically scoured	42.78	39.70	15.43
Bioscoured	47.63	43.51	18.67
Chemically scoured-bleached	81.98	20.63	62.03
Bioscoured- bleached	83.11	20.21	63.16

Table 2 — Dyeing properties of jute fabrics

[Light fastness 4]

Jute	Dye	λ_{max}, nm	*K*/*S* value	L	a	b	Wash fastness
Chemically scoured-bleached-dyed	Procion Blue HERD	610	11.80	28.09	0.92	–19.65	4
Bioscoured-bleached-dyed	Procion Blue HERD	610	12.07	27.83	1.32	–19.21	4-5
Chemically scoured-bleached-dyed	Procion Green HE4BD	580	10.77	26.09	0.60	– 4.65	4-5
Bioscoured-bleached-dyed	Procion Green HE4BD	580	11.61	26.09	0.90	–5.12	5

Table 3 — Handle and tensile properties of jute fabrics

Jute	Dye	Bending length cm		Flexural rigidity mg.cm		Bending modulus kg/cm^2		Tenacity, cN/tex		Extension, %	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
Grey	-	4.68	4.80	2101	2267	44.09	44.57	4.67	5.18	5.38	5.32
Chemically scoured-bleached	-	3.07	3.16	660	719	9.84	10.72	4.11	4.39	8.54	8.83
Bioscoured-bleached	-	2.81	2.95	537	621	8.01	9.26	4.21	4.35	9.41	9.74
Chemically scoured-bleached-dyed	Procion Blue HERD	3.10	3.15	679	712	10.12	10.62	3.91	4.00	9.56	9.82
Bioscoured-bleached-dyed	Procion Blue HERD	3.05	3.12	646	692	9.63	10.32	4.00	4.11	9.42	9.65
Chemically scoured-bleached-dyed	Procion Green HE4BD	3.05	3.10	652	685	9.12	9.58	3.94	4.11	9.38	9.32
Bioscoured-bleached-dyed	Procion Green HE4BD	3.08	3.13	672	705	9.40	9.86	4.05	4.31	9.46	95

cellulose and hemicelluloses is removed along with a small part of soluble lignin[7,8]. The treatment is carried out in such a way that no major strength loss occurs and by inhibition method enzymolysis is stopped. By this process, porosity of jute fibre increases and the non-ionic surface active agent present in the bioscouring liquor helps to remove the added as well as inherent impurities present in the fibre. Hence, the bioscouring process becomes effective and produces absorbent fabric. Alkali treated and enzyme treated fabrics, i.e. chemically scoured-bleached and bioscoured – bleached jute fabrics have been dyed separately with two bis-triazinyl type of reactive dyes. The dyed fabrics were evaluated for the properties like λ_{max} , *K*/*S* value, L , a, b values, wash fastness [9] and light fastness (Table 2).

The dye uptake, in terms of *K*/*S* value, of bioscoured-bleached-dyed jute fabric is higher than that of chemically scoured-bleached-dyed jute fabrics in case of both the dyes. This may be due to more creation of pores inside the fibre structure during enzyme treatment, resulting in easy access of the dye molecules in the fabric. Wash fastness in case of bioscoured-bleached-dyed jute fabrics is found slightly better in comparison to chemically scoured-bleached-dyed jute fabrics. Light fastness ratings of both the dyed fabrics are similar. L,a,b values of both the dyed fabrics are as expected .

Table 4 — UPF ratings and protection categories

UPF rating	Protection category	% UV radiation transmitted
15-24	Good	6.7-4.2
25-39	Very good	4.1-2.6
40-50+	Excellent	≤ 2.5

Handle properties[9] in terms of bending length, flexural rigidity and bending modulus, of raw, chemically scoured-bleached, bioscoured-bleached and their respective dyed fabrics were evaluated (Table 3).

There is sufficient reduction in bending length, flexural rigidity and bending modulus of chemically scoured-bleached jute fabric compared to raw jute fabric. But these values are further reduced in case of bioscoured-bleached jute fabric. Removal of impurities, removal of a portion of cellulose & hemicellulose constituent of the fibre , cleavage of ester linkage and shortening of cellulose chain during

Table 5 — Ultraviolet protection properties of jute fabrics

Sample	Dye	UPF		UPF rating	UVA % Transmittance	UVB % Transmittance
		Mean	SD			
Grey	-	8.50	0.88	5.00	12.86	11.74
Chemically scoured	-	11.44	3.32	5.00	11.12	9.32
Bioscoured	-	13.21	3.67	5.00	11.01	8.72
Chemically scoured-bleached	-	16.25	2.51	10.00	10.70	7.12
Bioscoured- bleached		16.10	4.28	10.00	7.85	6.34
Chemically scoured-bleached-dyed	Procion Blue HERD	18.54	4.94	15.00	6.21	5.59
Bioscoured-bleached-dyed	Procion Blue HERD	26.86	9.05	15.00	4.80	4.02
Chemically scoured-bleached-dyed	Procion Green HE4BD	18.70	3.79	15.00	5.64	5.51
Bioscoured-bleached-dyed	Procion Green HE4BD	25.90	6.32	15.00	4.58	4.00

bioscouring make the fabric softer. Bending length, flexural rigidity and bending modulus values are not changing significantly after dyeing of both the fabric both with Procion Blue HERD and Procion Green HE4BD dyes.

Tensile properties like tenacity and extension values of grey, chemically scoured-bleached, bioscoured-bleached and their respective dyed fabrics were measured on a tensile testing machine and the results are given in Table 3.

Chemically scoured-bleached jute fabric leads to loss in strength compared to grey jute fabric. This may be due to more drastic chemical reaction during conventional alkaline scouring process. Bioscoured–bleached jute fabric also shows loss in strength. This may be due to the enzyme action on the fibre. Dyeing operation shows very minimum loss in strength compared to chemically scoured-bleached and bioscoured-bleached jute fabric.

UV transmission analysis[10] of grey, chemically scoured, bioscoured, chemically scoured-bleached, bioscoured-bleached, chemically scoured-bleached-dyed and bioscoutred-bleached-dyed jute fabrics were done by using Labsphere UV transmittance analyser. Grading of fabrics and their corresponding %UV radiation transmitted is given in Table 4. Mean UPF reported is an average of nine readings.

UV protection properties of undyed jute fabrics (Table 5) can be explained in terms of fibre composition and fabric construction. Plain weave grey, chemically scoured, bioscoured, chemically scoured-bleached and bioscoured-bleached jute fabric shows poor UV protection property and transmission of solar radiation both UV-A and UV-B are very high.

There is an improvement of UPF (ultraviolet protection factor) rating of jute fabric after dyeing with bis-triazinyl type of reactive dyes which is evident from Table 5 and the UV transmission value is less. So, the dyed fabric shows good UV protection properties.

4 Conclusion

Sequential treatment like bioscouring-bleaching-reactive dyeing of jute fabric shows higher dye uptake than that produced by alkaline scouring - bleaching-reactive dyeing of jute fabric in case of both the dyes. Removal of impurities as well as removal of small amount of jute constituent during bio-treatment result in easy access of the dye molecules. Brightness of the shade is also improved in case of biotreated jute fabric. Wash fastness properties is found slightly better in case of biotreated – bleached-dyed jute fabrics. The dyed fabric also shows good UV protection properties. Bio-treatment results in improvement of handle properties of jute fabric. There is small drop of tensile strength after biotreatment.

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