Pan et al., J Textile Sci Eng 2013, 3:1
DOI: 10.4172/2165-8064.1000128

Journal of Textile Science & Engineering

Research Article Open Access

Application of Biotechnology in the Colouration of Jute Fabric Using Vinyl Sulphone Type of Reactive Dyes

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Abstract

Two sets of processed jute fabric viz, alkaline scoured-bleached and bioscoured-bleached jute fabrics were dyed separately with two nucleophilic addition type (vinyl sulphone type) of reactive dyes namely, Remazol Yellow FG and Amidazol Brown GR dyes. From the experiment it is revealed 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 vinyl sulphone type of reactive dyes. Biotreatment results in improvement of handle and wash fastness properties of jute fabric. Brightness of the shade was also improved in case of biotreatment-bleached-reactive dyed jute fabric.

Keywords: Bioscouring; Cellulase enzyme; Dyeing properties; Jute fabric; Handle properties; Tensile properties; Vinyl sulphone type of reactive dyes; Xylanase enzyme

Introduction

Jute is a biodegradable and renewable lignocellulosic fibre. It is very strong and used for application in technical textiles. Now a days this fibre finds use in making diversified and value added jute products like upholstery, furnishing textiles and even to some extent as apparel textiles. So, look and feel of the fabric is important now. Colouration of jute fabric improves look and aesthetic appeal whereas feel of the fabric is modified by different finishing treatments. Most of the dyes suitable for cellulosic fibre dyeing can be used for dyeing of jute fibre as well with some modifications of process parameters. Jute has been dyed with direct, sulphur, vat, acid, basic and reactive dyes for different end use requirements. Some work has also been done for imparting different functional properties by application of finishing treatments.

Reactive dyes [1] are very popular for dyeing and printing of lignocellulosic fibres particularly jute as this dye produce jute fabric with excellent fastness characteristics. Bioprocessing [2,3,4] of jute fabric makes the process ecofriendly and improves feel of the fabric by introducing some structural changes in jute fibre. In this work an attempt has been made to combine biotreatment and reactive dyeing process by sequencial treatment to make the process ecofriendly. The study has also been done to evaluate the effect of bioprocessing on colour strength and fastness properties of reactive dyed jute fabric. Reactive dyes are broadly classified into two groups depending on the type of reaction viz i) Nucleophilic substitution type and ii) Nucleophilic addition type of reactive dyes. In nucleophilic addition type of reactive dyes, the dye containing vinyl sulphone group is known as vinyl sulphone type of reactive dye. It is represented as RSO_2-CH_2-CH_2OSO_3Na. It is marketed in soluble form as β-hydroxy ethylene sulphuric acid ester derivative. These dyes can be applied on jute at ambient condition.

Materials and Methods

Materials

Substrate: 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 gm/m^2 (at 65% RH and 27°C)

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

Enzymes: 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.

Dyestuffs: Two neucleophilic addition type (vinyl sulphone) of reactive dyes viz., Remazol Yellow FG (C.I. Reactive Yellow 42) and Amidazol Brown GR (C.I .Reactive Brown 18) were used in the experiment.

For dyeing of jute fabric, different pretreatments were given at sequential manner. The details are as under:

Methods

Chemical scouring: Grey jute fabric was scoured chemically with sodium hydroxide (2%, owf) and non-ionic surface-active agent (2 g/l) at 90°C for 1hour, 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 minutes at room temperature to neutralize the residual alkali present in the fabric. Further cold washing and drying was carried out as usual.

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 a temperature of 50°C for 2 hours, keeping the material-to-liquor ratio at 1:10. The pH 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°C and maintained at that temperature for 15 minutes after which the samples were washed and dried.

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Received July 14, 2012; **Accepted** September 22, 2012; **Published** September 30, 2012

Citation: Pan NC, Chattopadhyay SN, Roy AK, Khan A, Patra K (2013) Application of Biotechnology in the Colouration of Jute Fabric Using Vinyl Sulphone Type of Reactive Dyes. J Textile Sci Eng 3: 128. doi:10.4172/2165-8064.1000128

Bleaching: Bleaching of chemically scoured and bioscoured jute fabrics were done separately in a closed vessel for 90 minutes at 80-85°C, 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 pH 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 minute at room temperature, again washed in cold water and dried.

Dyeing: Chemically scoured-bleached and bioscoured-bleached jute fabrics were dyed separately with vinyl sulphone type of reactive dyes viz Remazol Yellow FG and Amidazol Brown GR. Dye bath was made with dye (4% owf) and 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 for 40 minutes with stirring at 30°C. After this treatment, alkali (Sodium hydroxide, 4 g/l) was added in the same bath and kept for one hour for fixation of dye under same condition. 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.

Evaluation: Grey chemically scoured, bioscoured, chemically scoured-bleached, bioscoutred-bleached, chemically scoured-bleached-dyed and bioscoutred-bleached-dyed jute fabrics were evaluated by using different standards as under:

a) Whiteness index: As per HUNTER scale

b) Yellowness index: As per ASTM D1925 scale

c) Brightness index: As per TAPPI 452 scale

d) K/S value: As per Kubelka-Munk equation

e) L, a, b values: As per computer colour matching system

f) Wash fastness: As per IS:3361-1979

g) Light fastness: As per IS:2454-1967

h) Handle properties: As per IS:6490-1971

i) Tensile properties: As per ASTM D1682-1975

Results and Discussion

Cellulose, hemicellulose and lignin are the main constituent of jute fibre. Bright coloured jute fabrics were produced by different routes namely I) chemically scoured-bleached-reactive dyeing and ii) bioscoured-bleached-reactive dyeing. Optical properties of chemically scoured, bioscoured, chemically scoured-bleached and bioscoured-bleached jute fabrics were studied thoroughly (Table 1).

It is clear from table 1 that whiteness and brightness of chemically scoured-bleached and bioscoured-bleached jute fabric improves significantly in comparison to only chemically scoured and bioscoured jute fabric. Improvement of whiteness and brightness is more in case of bioscoured-bleached jute fabric.

Jute fabric	Whiteness index (HUNTER)	Yellowness index (ASTM D 1925)	Brightness index (TAPPI 452)
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	20.21	62.03
Bioscoured- bleached	83.11	20.63	63.16

Table 1: Optical properties of grey, chemically scoured, bioscoured, chemically scoured-bleached and bioscoured-bleached jute fabric.

Jute Fabric	λ_{max} (nm)	K/S value	L	a	b	Wash fastness	Light fastness
Chemically scoured-bleached-dyed with Remazol Yellow FG dye	460	3.45	74.76	11.69	55.43	4	4
Bioscoured-bleached-dyed with Remazol Yellow FG dye	460	3.66	77.78	12.01	61.11	4-5	4
Chemically scoured-bleached-dyed with Amidazol Brown GR dye	500	7.19	39.87	29.70	12.27	4	4
Bioscoured-bleached-dyed with Amidazol Brown GR dye	500	7.79	39.59	29.73	12.78	4-5	4

Table 2: Dyeing properties of chemically scoured-bleached-dyed and bioscoured-bleached-dyed jute fabrics (Dyed with Remazol Yellow FG and Amidazol Brown GR dyes).

The enzymes used in this study consist of cellulase enzyme and xylanase enzyme. Cellulase enzyme [5] 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 cellulose and hemicelluloses is removed along with a small part of soluble lignin [6,7]. 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. So the bioscouring process becomes effective and produces absorbent fabric. Thus these enzymes acts as a supporting agent for effective scouring of jute fabric hence the process is termed as bioscouring and this process is widely accepted in the field of textile wet chemical processing. Alkali treated and enzyme treated fabrics i.e. chemically scoured-bleached and bioscoured-bleached jute fabrics were dyed separately with two neucleophilic addition type of reactive dyes (vinyl sulphone type of reactive dye). The dyed fabrics were evaluated for the properties like λ_{max}, K/S value, L, a, b values, wash fastness [8] and light fastness (Table 2).

Table 2 indicates that the dye uptake, in terms of K/S value, of bioscoured-bleached-dyed jute fabric is higher than the chemically scoured-bleached-dyed jute fabrics in case of both the dyes i.e. Remazol Yellow FG and Amidazol Brown GR dye. This may be due to more creation of pores inside the fibre structure during enzyme treatment resulting easy access of the dye molecules in the fabric. Wash fastness in case of bioscoured-bleached-dyed jute fabrics are slightly better in comparison to chemically scouted-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.

Handle properties [8] in terms of bending length, flexural rigidity and bending modulus of raw, chemically scoured-bleached, bioscoured-bleached and their respective dyed fabrics were evaluated and tabulated in table 3.

Jute fabric	Bending length (cm)		Flexural rigidity (mg.cm)		Bending modulus (kg/cm²)	
	Warp	Weft	Warp	Weft	Warp	Weft
Grey	4.68	4.80	2101	2267	44.09	44.57
Chemically scoured-bleached	3.07	3.16	660	719	9.84	10.72
Bioscoured-bleached	2.81	2.95	537	621	8.01	9.26
Chemically scoured-bleached-dyed with Remazol Yellow FG dye	3.05	3.12	655	701	11.93	12.77
Bioscoured-bleached-dyed with Remazol Yellow FG dye	2.95	3.00	603	634	10.98	11.55
Chemically scoured-bleached-dyed with Amidazol Brown GR dye	3.12	3.18	729	771	13.75	14.54
Bioscoured-bleached-dyed with Amidazol Brown GR dye	3.05	3.00	675	642	12.73	12.11

Table 3: Handle properties of grey, chemically scoured-bleached, bioscoured-bleached, chemically scoured-bleached-dyed and bioscoured-bleached-dyed jute fabrics (Dyed with Remazol Yellow FG and Amidazol Brown GR dyes).

Jute fabric	Tenacity (cN/tex)		Extension (%)	
	Warp	Weft	Warp	Weft
Grey	4.67	5.18	5.38	5.32
Chemically scoured-bleached	4.11	4.39	8.54	8.83
Bioscoured-bleached	4.21	4.35	9.41	9.74
Chemically scoured-bleached-dyed with Remazol Yellow FG dye	3.96	4.02	9.66	9.85
Bioscoured-bleached-dyed with Remazol Yellow FG dye	4.00	4.11	9.42	9.65
Chemically scoured-bleached-dyed with Amidazol Brown GR dye	3.94	4.21	9.52	9.32
Bioscoured-bleached-dyed with Amidazol Brown GR dye	4.05	4.31	9.46	9.95

Table 4: Tensile properties of grey, chemically scoured-bleached, bioscoured-bleached , chemically scoured-bleached-dyed and bioscoured-bleached-dyed jute fabrics (Dyed with Remazol Yellow FG and Amidazol Brown GR dyes).

There is sufficient reduction of 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 biotreated-bleached jute fabric. Removal of impurities, removal of a portion of cellulose and hemicellulose constituent of the fibre, cleavage of ester linkage and shortening of cellulose chain during bioscouring makes the fabric softer. Bending length, flexural rigidity and bending modulus values are not changing significantly after dyeing of both the fabric with vinyl sulphone type of reactive dyes.

Tensile properties [9] like tenacity and extension values of grey, chemically scoured-bleached, bioscoured-bleached and their respective dyed fabrics were measured in a tensile testing machine and the results are tabulated in table 4.

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. Total loss is about 14-15% after completion of all the processes.

Conclusions

1. Sequential treatment like biotreatment-bleaching-reactive dyeing of jute fabric shows higher dye uptake compared to alkali treatment-bleaching-reactive dyed jute fabric in case of vinyl sulphone type of reactive dyes.

2. Removal of impurities as well as removal of small quantity of jute constituent during biotreatment results in easy access of the dye molecules inside the fibre structure.

3. Brightness of the shade was improved in case of biotreatment-bleaching-reactive dyed jute fabric.

4. Wash fastness properties are slightly better in case of biotreated–bleached-reactive dyed jute fabrics.

5. Biotreatment results in improvement of handle properties of jute fabric.

6. There is a small drop of tensile strength of after biotreatment

Acknowledgement

The authors are thankful to Dr K K Satapathy, Director, National Institute of Research on Jute & Allied Fibre Technology (ICAR), Kolkata, India for his continuous encouragement and support in this work. Authors are also thankful to M/s Resil Chemicals Pvt Ltd, Bangalore, India and M/s Textan Chemical Pvt Ltd., Chennai, India for supplying enzymes for this work.

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