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Innovative multi-functional treatments of ligno-cellulosic jute fabric

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ABSTRACT

This study is focused on upgrading the functional and dyeing properties of jute, an eco-friendly cellulose-rich ligno-cellulosic fiber, for its further application in diversified and value added products. Grey Jute fabric has been scoured, bleached then post-finished in absence and presence of disperse and basic dyes for imparting easy care, water repellency, a supple handle as well as UV-protecting properties into the finished and finished/dyed Jute fabrics. Factors affecting the functional and dyeing properties such as pretreatment regime, water repellent and finishing agents concentration, finishing in the absence and presence of the nominated dyestuffs as well as durability to wash have been studied. The results demonstrate that increasing the water-repellent agent, Hydrophobol® APK, concentration up to 75 g/L, finishing agent, Fixapret® Eco, concentration up to 50 g/L, using $MgCl_2 \cdot 6H_2O$/citric acid as a mixed catalyst (5 g/2 g)/L, in the absence or presence of the dye (5 g/L) followed by drying at 100 °C/5 min, curing at 150 °C/min, then after washing, is accompanied by a significant enhancement in both the imparted functional and dyeing properties of the treated jute fabrics. The extent of improvement of the aforementioned properties is determined by the pretreatment sequence, i.e. scouring alone or followed by bleaching. The imparted functional properties show some reduction after five home launderings. SEM of untreated, scoured and semi-bleached then finished or finished/dyed fabric samples as well as the fastness properties of the obtained dyeings were also investigated.

1. Introduction

The renewed demand for Jute, cellulose-rich ligno-cellulosic fiber, is mainly attributed to its eco-friendly, biodegradable and hydrophilic nature, renewability, low cost, and diversified outdoor, e.g. outer garments, curtains, tents, etc., and indoor-applications, e.g. upholstery, furnishing, wall hanging, etc., along with its traditional products such as ropes, cords, sacking, carpet backing cloth, etc. (Chattopadhyay, Pan, Roy, & Khan, 2009; Pan, Chattopadhyay, & Day, 2007).

The main chemical components of Jute fiber are cellulose (58–63%), hemicelluloses (20–24%) and lignin (12–15%) along with some other small amounts of constituents like protein (2%), mineral matters (1%), pectin, aqueous extract, etc. (Pan, Day, & Mahalanabis, 1999). Many studies have been done to develop Jute processing as well as to upgrade the quality, coloration and performance properties of Jute-based textiles to be more attractive, cost-effective and eco-friendly (Pan, Chattopadhyay, & Day, 1996; Chattopadhyay et al., 2009; Chattopadhyay, Pan, & Day, 2004; Ghosh & Das, 2000; Ibrahim, El-Gammal, Hassan, & Hussein, 2009; Pan et al., 1999, 2007; Salam, 2006; Samanta, Singhee, Basu, & Mahalanabis, 2007; Shahidullah, Uddin, Sayeed, Shahinur, & Ahmed, 2009; Uddin et al., 2007; Wang, Cai, & Yu, 2008)

In this study, a novel attempt has been done to study the technical feasibility of combined functional finishing and dyeing of Jute fabric for attaining non-traditional and high value added products.

2. Experimental

2.1. Materials

Plain weave 100% Jute fabric (262 g/m^2) was used as a starting grey fabric. Fixapret® ECO (low-formaldehyde crosslinker, BASF), Hydrophobol® APK (cationic, water repellent finish, based on paraffin wax emulsion containing aluminum salt, Ciba), and Hostapal® 3634 (nonionic wetting agent based on alkylaryl polyglycol ether, Clariant) were of commercial grade.

Disperse violet 1, disperse red 60, and basic red 18 were kindly supplied by DyStar whereas basic violet 16 was kindly supplied by Bayer.

All other chemicals used during this study were laboratory grades. Types and amounts are given in the methods section.

2.2. Methods

2.2.1. Scouring

Scouring of the Jute fabric was performed using a solution containing sodium hydroxide (10 g/L) and a nonionic wetting agent

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(2 g/L) at 95 °C for 60 min, with a material-to-liquor (LR) ratio of 1:10, whereafter, the fabric washed thoroughly in hot water and cold water, neutralized with acetic acid (2 mL/L), and followed by washing and air drying.

2.2.2. H_2O_2-bleaching

Bleaching of the scoured-Jute fabric was performed in aqueous solution containing H_2O_2 (5 or 10 g/L, 35%), soda ash (2 g/L), sodium silicate (5 g/L), tri-sodium phosphate (5 g/L), and nonionic wetting agent (2 g/L) for 90 min at 95 °C with a material-to-liquor ration of 1:10. After bleaching, the fabric was washed, neutralized with acetic acid (2 g/L), washed again, and dried.

2.2.3. Multi-functional finish

In a true, single-bath process, Jute fabric samples were padded twice with the reactant resin, Fixapret® ECO (0–100 g/L), water repellent, Hydrophobol® APK (0–100 g/L), $MgCl_2{\cdot}6H_2O$ (1% ow. Fixapret®), citric acid (2 g/L) and nonionic wetting agent (2 g/L) to a 80% wet pick up, followed by drying at 100 °C for 5 min, curing at 150 °C for 3 min, and after washing to remove unreacted/unfixed reactants.

2.2.4. Combined dyeing and functional finishing

Dyeing and finishing was carried out simultaneous according to the following sequence: padding → drying → curing → washing. Padding bath was prepared with Fixapret® ECO (75 g/L), Hydrophobol® APK (75 g/L), $MgCl_2{\cdot}6H_2O$ (7.5 g/L), citric acid (2 g/L), nonionic wetting agent (2 g/L), along with the disperse or basic dye (5 g/L). Jute fabric samples were padded twice through the above mentioned formulations to a 80% wet pick up, followed by drying at 100 °C for 5 min and curing at 150 °C for 3 min, thoroughly washed with cold water, soaped in 2 g/L nonionic detergent at 45 °C for 15 min, to remove the unfixed reactants and/or dyes, again thoroughly washed and dried at 100 °C for 5 min.

2.2.5. Testing

Nitrogen content was determined using micro-Kehjeldal method. Dry wrinkle recovery angle (WRA) was evaluated using the iron recovery apparatus (type FF-07Metrinpex®). Water-repellency rating was evaluated according to AATCC 22-1980 spray test method. Roughness of the treated and untreated samples was measured according to JIS94 standard by using SE 1700α instrument, Japan. Yellowness index was evaluated by using Color-Eye® 3100 Spectrophotometer supplied by SDL Inter, England according to the Standard Test Method ASTM E-313. Color strength, K/S, of the obtained dyeings were measured and evaluated, at the λ_{max} of the dye, using the Color-Eye 3100® Spectrophotometer using the Kubelka–Munk equation: $K/S = (1-R)^2/2R$ (where K: absorption coefficient, S: scattering coefficient, R: reflectance). UV-protection factor, UPF, was determined according to the Australian/New Zealand Standard (AS/NZ 4399-1996). Scanning electron micrographs, SEM's, of untreated and treated Jute fabric samples were taken using a scanning electron microscope JEAOL JXA-840A. Prior to SEM investigation, the samples were coated with gold using a SIS0A sputter coat unit Edward, UK. All the dyed/finished fabric samples were subjected to wash and light fastness tests according to the AATCC Test Methods (61-1972) and (16A-1971), respectively. All the determinations in this study were performed in triplicate and the results represent mean values with less than 0.2% of error. Durability of the imparted functional properties was evaluated, up to 5 launderings according to AATCC test method 124-1975.

3. Results and discussion

3.1. Hydrophobol® APK concentration

In order to obtain the optimum hydrophobic agent concentration for imparting water repellent property, the scoured Jute fabric samples were treated with different Hydrophobol® APK concentration from 0 to 100 g/L along with Fixapret® ECO (50 g/L) as a crosslinking agent and $MgCl_2{\cdot}6H_2O$ (5 g/L)/citric acid (2 g/L), as a mixed catalyst, nonionic wetting agent (2 g/L), to a 80% wet-pick up, followed by drying at 100 °C/5 min and curing at 150 °C/3 min. After the treatment, the nitrogen content (%N), water repellency rating (WRR), roughness and wrinkle recovery angle (WRA), were evaluated. The results are presented in Fig. 1a and b.

As is evident, Fig. 1a, increasing the water repellent agent concentration up to 75 g/L results in a significant increase in the water-repellency rating from 0 up to 80 along with a gradual slight decrease in the nitrogen content of the treated fabric samples. Further increase in the Hydrophobol® APK concentration has no effect on water repellency rating with a marginal decrease in the nitrogen content. On the other hand, Fig. 1b shows that increasing

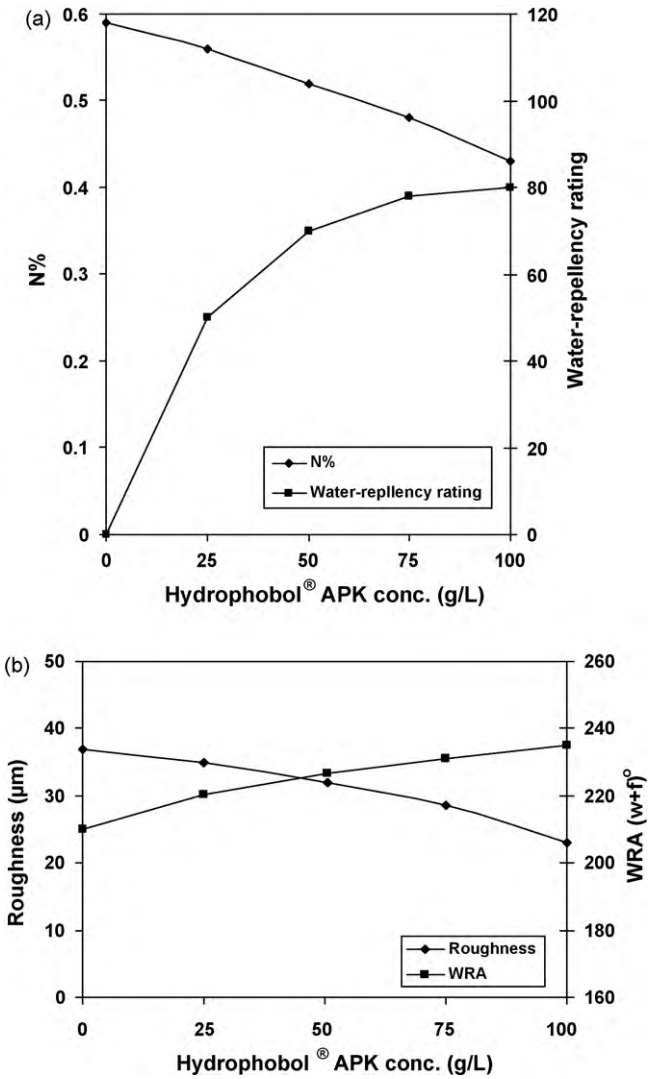


Fig. 1. Effect of Hydrophobol® APK concentration on nitrogen content and water repellency rating (a), and on roughness and wrinkle recovery angle (b) of treated jute fabric samples. Substrate: scoured jute, Fixapret® ECO (50 g/L), $MgCl_2{\cdot}6H_2O$ (5 g/L), citric acid (2 g/L), nonionic wetting agent (2 g/L), wet-pickup (80%), drying at 100 °C, curing at 150 °C/5 min, followed by afterwashing.

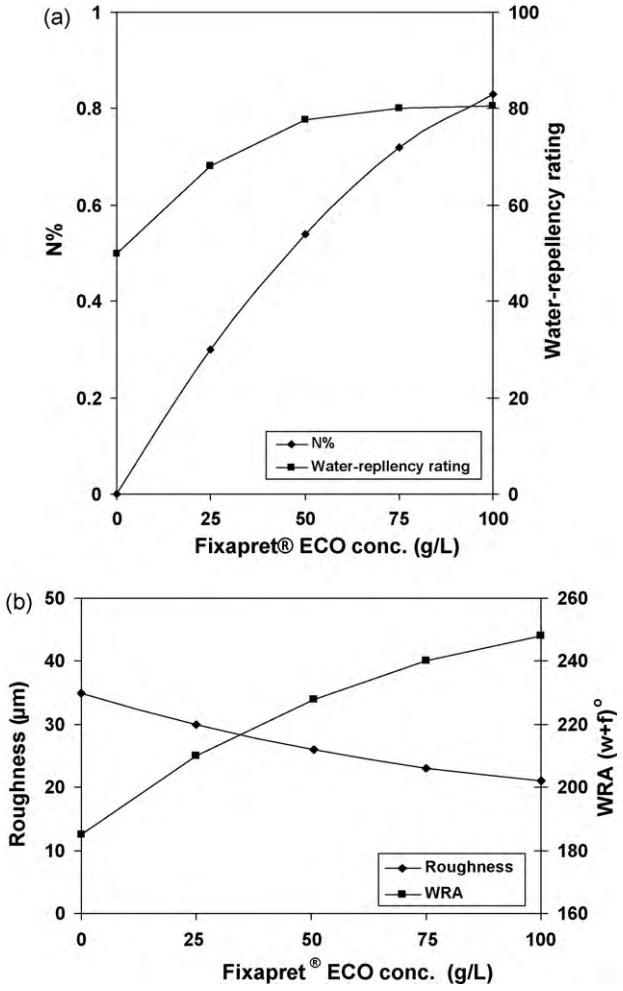


Fig. 2. Effect of Fixapret® ECO concentration on nitrogen content and water repellency rating (a), and on roughness and wrinkle recovery angle (b) of treated jute fabric samples. Substrate: scoured jute, Fixapret® ECO (0–100 g/L), $MgCl_2{\cdot}6H_2O$ (1% ow Fixapret®), citric acid (2 g/L), Hydrophobol® APK (75 g/L), nonionic wetting agent (2 g/L), wet-pickup (80%), drying at 100 °C, curing at 150 °C/5 min, followed by afterwashing.

the water-repellent agent concentration, within the range examined, is accompanied by an improvement in surface smoothness, or a decrement in fabric roughness from 37.5 to 23, along with an enhancement in fabric resiliency, expressed as WRA, from 205° up to 235°.

The enhancement in WRR, WRA as well as the surface smoothness of the treated fabric samples is certainly attributed to the deposition and formation of a repellent film on the fiber surface thereby reducing the energy at fiber surfaces, and reducing surface inter-fibers and inter-yarn frictions (Abo-Shosha, El-Sayed, Fahmy, & Ibrahim, 2005; Amr, 2008; Ibrahim et al., 2009). On the other hand the decrease in the nitrogen content by increasing the water-repellent agent concentration is unequivocally due to the decrease in the extent and penetration of the used crosslinking agent within the fabric structure thereby minimizing the extent of crosslinking. Based on the above discussion, it was concluded that the optimum concentration should be controlled at 75 g/L.

3.2. Crosslinking agent concentration

For a given set of finishing conditions, it is seen (Fig. 2a) that increasing Fixapret® ECO concentration up to 50 g/L is accompanied by a significant improve in water-repellent rating (from 50 to 80) along with a sharp increase in the nitrogen content of the treated fabric samples. But further increase in the concentration to 100 g/L has no positive impact on the imparted water-repellency along with an increase in the nitrogen content.

On the other hand, Fig. 2b shows that increasing the crosslinking agent concentration up to 75 g/L brings about a significant improvement in fabric resiliency as well as softness. But further increase in the concentration was unnecessary.

The enhancement in the above mentioned functional and performance properties reflects the positive role of crosslinking agent, at optimum concentration, on enhancing: (i) the extent of crosslinking of adjacent cellulose chains as well as (ii) the extent of fixation of the water-repellent agent onto and/or within the fabric structure.

Thus it can be seen that using 50 g/L Fixapret® ECO was sufficient to obtain a jute fabric with favorable functional and performance properties taking in consideration both the economical and ecological concerns.

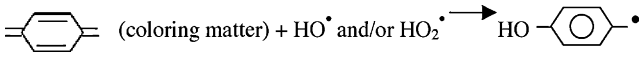
3.3. Pretreatments vs. performance and functional properties

Table 1 shows effect of pretreatment steps on performance and functional properties of the treated jute fabric samples. For a given set of pretreatment and finishing conditions, the results of Table 1 reveal that: (i) the extent of crosslinking, expressed as %N and WRA values, depends on the pretreatment steps and follows the decreasing order: Scouring → bleaching → finishing > scouring → semi-bleaching → finishing > scouring → finishing > untreated → finishing > untreated, (ii) the yellowness index, YI, of the pretreated → finished fabric samples is governed by the pretreatment regime, i.e. scouring > untreated > scouring → semi-bleaching > scouring → bleaching, (iii) the above mentioned results reflect the positive impact of scouring → bleaching sequence on enhancing the wettability of the pretreated substrates via removal of non-cellulosic hydrophobic impurities, e.g. fats, waxes, nitrogenous compounds, pectin, etc., as well as generation of hydrophilic groups, i.e. –COOH groups, due to oxidative treatment of jute along with removal and/or destruction of natural coloring matters according to the following equations (Hashem, El-Bisi, Sharaf, & Refai, 2010; Ibrahim et al., 2009; Salam, 2006; Shukla & Pai, 2005; Steinmiller & Cates, 1976):

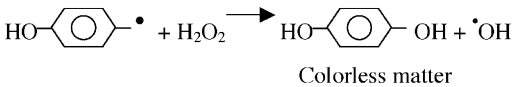
$$H_2O_2 + {}^{-}OH(\text{alkali}) \rightarrow HO_2{}^{-}(\text{perhydroxylion} - \text{responsibleforbleachingaction}) + H_2O \quad (1)$$

$$H_2O_2 + HO_2{}^{-} \rightarrow {}^{\bullet}OH + HO_2{}^{\bullet} + {}^{-}OH \quad (2)$$

$$HO^{\bullet} + H_2O_2 \rightarrow HO_2{}^{\bullet} + H_2O \quad (3)$$



(4)



(5)

(6)

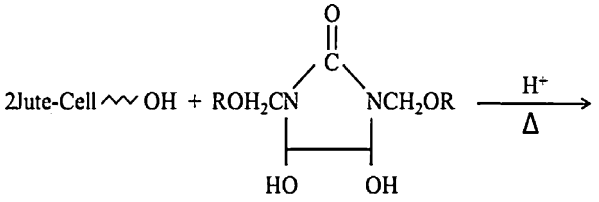
thereby enhancing the extent of penetration and fixation of the used finishing agents onto and/or within the jute cellulose struc-

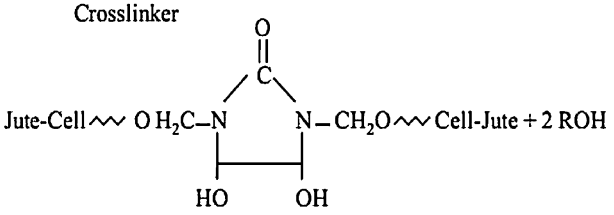
Table 1
Effect of pretreatment on the performance and functional properties of the finished jute fabric samples.

Pretreatment	N%	YI	WRA ($w+f$) (°)	Roughness (μm)	WRR	UPF
None (grey) (wettability: 35 s)	0.230	54.4	199	36.2	50	37
Scouring (wettability: 5 s)	0.551	65.5	230	27.5	80	65
Scouring → semi-bleaching (H_2O_2: 5 mL/L) (wettability: 2 s)	0.585	35.9	245	24.3	80	48
Scouring → bleaching (H_2O_2: 10 mL/L) (wettability: 1 s)	0.603	29.7	255	21.8	80	48
Untreated	–	56.3	170	39.5	0	22

Finishing bath: Fixapret® ECO (50 g/L); $MgCl_2{\cdot}6H_2O$ (5 g/L); citric acid (2 g/L); Hydrophobol® APK (75 g/L); nonionic wetting agent (2 g/L); wet pick-up (80%); drying at 100 °C/5 min; curing at 150 °C/3 min; followed by after washing. %N: nitrogen content; YI: yellowness index; WRA: wrinkle recovery angle; WRR: water repellency rating; UPF: UV-protection factor.

ture, i.e. better resiliency along with higher %N, according to the following equation (Ibrahim, El-Zairy, Allam, & Hassan, 1996; Schindler & Hauser, 2004):





(7)

Crosslinked Jute Structure

(iv) the enhancement in the WRR values of the pretreated → finished fabric samples (from 50 to 80) reflects the positive impact of pretreatment on enhancing the extent of deposition, entrapment as well as fixation of the used water-repellent agents onto and/or to certain extent, into the finish/fabric matrix thereby improving the surface softness properties of the treated fabric samples (decreasing the fabric roughness from 36.2 to 21.8 μm), (v) the enhancement in the UPF values of the retreated → finished fabric samples is a direct consequence of minimizing and/or blocking the UV-B transmittance through: reduction in the total void area as well as in the number of voids, increase in cover factor, and/or better UV-B absorbance due to the presence of remnant natural pigments as well as Al-containing water-repellent moieties onto the finished fabric surfaces (Gorensek, Urbas, Strnad, & Osterman, 2007; Ibrahim, Refai, Ahmed, & Youssef, 2005), and (vi) the greige jute fabric becomes darker and more yellowish after scouring (Chattopadhyay et al., 2004).

3.4. Functional finishing/disperse dyeing

Results in Table 2 show the effect of pretreatment steps on combined functional finishing and disperse dyeing of treated jute fabric samples. For a given set of finishing and dyeing conditions, it is evident that; (i) %N and WRA values follow the decreasing order; scouring → bleaching → combined process > semi-bleaching → combined process > scouring → combined process, (ii) pretreatment regime has no effect on the imparted water-repellency properties of the treated fabric samples, regardless of the used disperse dyestuff, (iii) UV-protection property, expressed as UPF value, and K/S value are governed by the pretreatment sequence, i.e. scouring > scouring → semi-bleaching > scouring → bleaching, followed by combined finishing and dyeing, as well as the type of disperse dye, disperse red 60 > disperse violet 1, (v) the differences in K/S of the obtained dyeing arises from the initial yellowness values of the pretreated fabric samples before finishing and dyeing, type of disperse dye as well as possibilities for adsorption, fixation and accommodation of the sublimable disperse dye molecules during the thermofixation step (Ibrahim, El-Zairy, & Eid, 2010), (vi) type of disperse dye has practically no significant effect on %N and WRA and WRR values, and (v) the variation in UPF values of the obtained dyeings reflects the difference between the two dyes in ability to adsorb the harmful UV-B radiation.

On other hand, the impact of pretreatment regime on the extent of functional finishing and basic dyeing of jute fabric samples is shown in Table 3. For a given finishing and dyeing conditions, it is seen that; (i) bleaching of the scoured jute fabric samples followed by combined finishing and basic dyeing results in an increase in the %N and fabric resiliency, expressed as WRA, along with a decrease in both UPF and K/S values, regardless of the used basic dye, (ii) the extent of improvement in the %N, UPF and K/S values is determined by the nature of the used basic dye, i.e. chemical composition, functionality, molecular size, compatibility with other ingredients, mode of interaction and extent of fixation as well as UV-B absorption capacity, and iii) type of basic dye has practically no effect on the extent of inter-crosslinking of the jute-cellulose chains, expressed as WRA, in the amorphous regions, as well as the on the WRR rating.

3.5. Dyeing properties

Dyeing properties, expressed as K/S, washing fastness and light fastness, of the simultaneously finished and dyed jute fabric samples are shown in Table 4. For a given set of finishing/dyeing conditions, it is clear that; (i) the depth of the obtained dyeings is determined by the pretreatment sequence as well as the type of the used dye, e.g. chemical structure, molecular size, their penetrating or diffusing power, mode of interaction and extent of

Table 2
Effect of pretreatment on the extent of combined functional finishing and disperse dyeing of jute fabric samples.

Pretreatment	Wet (s)	YI	Disperse violet 1					Disperse red 60				
			%N	WRA ($w+f$) (°)	WRR	UPF	K/S	%N	WRA ($w+f$) (°)	WRR	UPF	K/S
Scouring	5	65.50	0.573	215	80	93	10.75	0.565	219	80	106	12.25
Scouring → semi-bleaching	2	35.15	0.617	228	80	72	4.24	0.608	230	80	93	4.67
Scouring → bleaching	1	27.28	0.630	236	80	65	3.50	0.626	239	80	85	3.86

Combined bath: Fixapret® ECO (50 g/L); $MgCl_2{\cdot}6H_2O$ (5 g/L); citric acid (2 g/L); Hydrophobol® APK (75 g/L); nonionic wetting agent (2 g/L); disperse dye (5 g/L); wet pick-up (80%); drying at 100 °C/5 min; curing at 150 °C/3 min; followed by after washing; wet: wettability (s);%N: nitrogen content; YI: yellowness index; WRA: wrinkle recovery angle; WRR: water repellency rating; UPF: UV-protection factor; K/S: color strength.

Table 3
Effect of pretreatment on the extent of combined functional finishing and basic dyeing of jute fabric samples.

Pretreatment	Wet (s)	YI	Basic red 18					Basic violet 16				
			%N	WRA ($w+f$) (°)	WRR	UPF	K/S	%N	WRA ($w+f$) (°)	WRR	UPF	K/S
Scouring	5	65.50	0.395	202	80	123	23.88	0.439	197	80	83	33.80
Scouring → semi-bleaching	2	35.15	0.429	212	80	119	19.25	0.482	206	80	76	31.25
Scouring → bleaching	1	27.28	0.562	220	80	97	18.45	0.510	215	80	64	30.78

Combined bath: Fixapret® ECO (50 g/L); $MgCl_2{\cdot}6H_2O$ (5 g/L); citric acid (2 g/L); Hydrophobol® APK (75 g/L); nonionic wetting agent (2 g/L); basic dye (5 g/L); wet pick-up (80%); drying at 100 °C/5 min; curing at 150 °C/3 min; followed by after washing. Wet: wettability (s); %N: nitrogen content; YI: yellowness index; WRA: wrinkle recovery angle; WRR: water repellency rating; UPF: UV-protection factor. K/S: color strength.

Table 4
Dyeing properties of the simultaneously finished and dyed jute fabric samples.

Pretreatment	Disperse violet 1				Disperse red 60				Basic red 18				Basic violet 16			
	K/S	WF		LF	K/S	WF		LF	K/S	WF		LF	K/S	WF		LF
		St.	Alt.			St.	Alt.			St.	Alt.			St.	Alt.	
Scouring	10.75	3	3	3–4	12.25	3	3	3–4	23.88	3	2–3	4	33.80	3	2–3	3–4
Scouring → semi-bleaching	4.24	3–4	3	4	4.67	3	3	4	19.25	3	3	4	31.25	3	3	4
Scouring → bleaching	3.50	3–4	3	4	3.86	3	3	4	18.45	3	3	4	30.78	3	3	4
None	13.6	3	2–3	3	14.05	3	2–3	3	25.20	2	2	3	35.10	2–3	2	3

Combined bath: Fixapret® ECO (50 g/L); $MgCl_2{\cdot}6H_2O$ (5 g/L); citric acid (2 g/L); Hydrophobol® APK (75 g/L); nonionic wetting agent (2 g/L); dye (5 g/L); wet pick-up (80%); drying at 100 °C/5 min; curing at 150 °C/3 min; followed by after washing. K/S: color strength; WF: wash fastness; ST: staining of white cotton; Alt: alteration of color; LF: light fastness.

fixation onto and/or within the modified cellulosic matrix of jute along with the remnant lignin component, after pretreatment, via hydrogen bonding, Van der Waal's forces and dipole interactions as in case of disperse dyeing, or via an ion exchange mechanism between the dye cations and the accessible anionic dye sites in the modified jute fibers, e.g. –COOH, phenolic–OH groups of lignin, etc. as in case of basic dyeing (Choudhury, 2006; Kundu, Ghosh, & Chakrabarti, 1993), (ii) pretreatment of grey jute fabric has a positive impact on the evaluated washing and light fastness of the finished/dyed fabric samples, and (iii) the variation in the evaluated fastness properties reflects the differences among the used dyestuffs in type as well as extent of fixation as mentioned before.

3.6. Durability to wash

The durability of the imparted properties, i.e. wrinkle-recovery angle (WRA), water-repellency rating (WRR), as well as UV-protecting (UPF) properties, of finished and simultaneously finished/dyed jute fabric samples was evaluated in term of retention of the above mentioned properties on washing (Table 5). For a given set of pretreatment and finishing conditions, it is clear that; (i) the WRA of the finished fabric samples is better in the absence than in presence of dye, regardless of the used dye, (ii) type of included dye in the finishing formulation has practically a slight effect on fabric resiliency, i.e. disperse dyeings > basic dyeings, (iii) incorporation of the used dyestuffs separately in the finishing formulations

Table 5
Durability of the imparted functional properties to wash.

Functional property	Wash cycle	Treatment of scoured → semi-bleached substrate				
		Finishing	Finishing + dyeing			
			Disperse violet 1	Disperse red 60	Basic red 18	Basic violet 16
WRA ($w+f$) (°)	0	245	228	230	218	215
	1	236	217	220	210	208
	5	210	200	194	195	190
WRR	0	80	80	80	80	80
	1	70	70	70	70	70
	5	50	50	50	50	50
UPF	0	48 (excell.)	65 (excell.)	85 (excell.)	97 (excell.)	64 (excell.)
	1	40 (excell.)	58 (excell.)	72 (excell.)	88 (excell.)	54 (excell.)
	5	32 (very good)	48 (excell.)	56 (excell.)	70 (excell.)	42 (excell.)

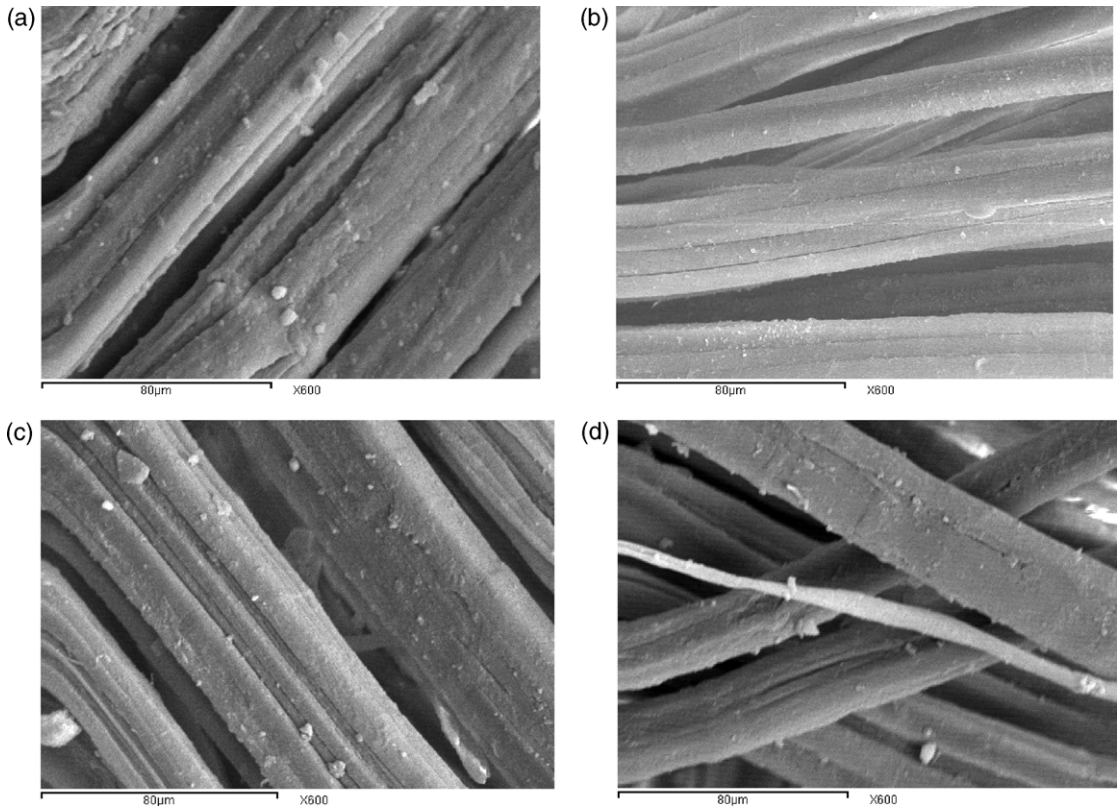


Fig. 3. SEM images of (a) untreated, (b) scoured → semi-bleached, (c) scoured → semi-bleached → finished and (d) scoured → semi-bleached → simultaneously finished/dyed Basic red 18.

has practically no effect on the imparted water-repellency, (iv) incorporation of the nominated dyestuffs in the finishing formulations results in a significant improvement in the UPF values of the obtained dyeings and the extent of improvement is governed by the ability of the used dye to absorb the harmful UVB-radiation, and (v) increasing the home laundering cycles ups to 5 results in; a reasonable decrease in retained fabric resiliency (≈10–15%), and a reduction in the imparted water-repellency (37.5%), without adversely affecting UV-protection category (very good-excellent), regardless of the used finishing formulation.

3.7. Surface characterization

The SEM images of (a) untreated, (b) scoured → semi-bleached, (c) scoured → semi-bleached → finished and (d) scoured → semi-bleached → simultaneously finished/dyed fabric samples were presented in Fig. 3. Micrograph (a) shows that unit cells run longitudinally with parallel orientations and the intercellular space is filled up by binder lignin and fatty substances that hold the unit cells firmly in the fiber, while micrographs (b) reveals a clean smooth surface, the parallel unit cells looks partially split due to removal of waxes and other surface impurities as a result the surface area becomes available for contact with the finishing formulation. Micrographs (c and d) show the spread and deposition of the finishing formulation film onto the surface of the fiber and it can be observed that the intercellular gaps are reduced in micrographs (c) and almost disappeared in micrographs (d) showing an excellent film forming character as well as basic dye fixation onto and/or within the jute structure.

4. Conclusions

The results reported in this research and development work demonstrate the technical feasibility of enhancing the functional and dyeing properties of the jute fabrics to make jute fabrics attractive and cost effective. Fixation of the water-repelling agent onto and/or within the jute structure, in the absence or presence of disperse and basic dyestuffs, via crosslinking has ultimately led to impart water-repellency, UV-protection, soft feel, easy care properties into the crosslinked/dyed substrates. The extent of improvement in the gained properties as well as the loaded dyes is governed by the pretreatment sequence, finishing formulation components as well as type of included dyestuff.

Both the finished and finished/dyed jute fabrics can be utilized in versatile indoor applications such as colored products with specific fastness, decorative fabrics, upholstery, curtains, outer carpets, etc. taking in consideration both the economical and environmental requirements.

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