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Research Paper

Effects of bleaching on absorbency and strength of jute-cotton union furnishing fabrics

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■ **ABSTRACT :** Bleaching of jute-cotton union fabric has been carried out using different chemicals and methods. It was found that the Sample L bleached with sodium silicate and H_2O_2 sequentially at 85°C for one hour then at room temperature for another hour and the sample M bleached at RT with a sequential combination of chemicals produce acceptable level of whiteness and efficient to carry out the colouration process successfully and these processes are energy saving, economical and also minimize damage in fabric strength. The absorbency property of these samples was very satisfactory, hence, efficient to carry out the colouration process successfully besides, these processes are energy saving, economical and also minimize damage to fabric tearing and bursting strengths. Moreover, the increase in absorbency of these materials, particularly for sample M was at par with conventional kier-boiled and bleached sample N. Conventional bleaching process produces a pure white colour but there was substantial loss in fabric strength and weight.

■ **KEY WORDS:** Union fabrics, Pretreatments, Bleaching, Water absorbency, Strength, Colouring

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Natural fibres such as cotton and jute are always in demand because of their desirable performance qualities, renewability, bio-degradability and eco-friendliness. Though, both jute and cotton are cellulose fibres, jute is a ligno-cellulose, multi-cellular bast fibre; primarily composed of cellulose (58-63%), hemicellulose (20-24%) and lignin (12-15%), and some other small quantities of constituents like fats, pectin, etc. whereas, cotton consists of practically pure cellulose (about 88-96%), the remainder being protein, pectin, and wax and is a unicellular seed hair fibre. Owing to presence of lignin, jute is hard and harsh. Therefore, the inherent drawback of jute, for instance, harshness, brittleness and low extensibility etc pose a hindrance for its use as furnishings and apparels (Mishra, 2005; Gamal *et al.,* 2010; Wei-ming *et al.,* 2008; Bandyopadhyay and Salaskar, 1997; Azad *et al.,* 2006; Rattanaphani *et al.,* 2007 and Karmakar, 1999). To overcome these problem jute fabrics could be produced with blend or union with other natural and manmade fibres. In addition, the cheapness, abundance and versatility of jute fibres in fact, act as an incentive to produce jute union or blend fabrics. As a result, Union fabrics of jute/cotton with cotton yarn in warp and jute in weft form an important item in the area of jute diversified products (Krishnan *et al.,* 2005 and Chhabilendra, 2009).

Furthermore, the colouration of cotton-jute union fabric has become essential for all sorts of fabric whether used for apparel, furnishings or for other value added products (Prathiba Devi, 2013). Before colouration it is necessary to subject the fabric to various pre-treatments like scouring and bleaching to remove impurities, and make the material more absorbent and white so that it can be easily processed further.

Both cotton and jute contains primary and secondary –OH groups of cellulose. In addition to that jute being a ligno-cellulose fibre contains some –CHO and –COOH groups as well as some –C=C– unsaturations and phenolic –OH groups in the lignin component (Mohammad Mostashari *et al.,* 2013 and Samant and Agarwal, 2008). Thus, when the jute-cotton union fabric is subjected to various pretreatments and finishes the receptivity and absorption of any chemical agents and colour will be different for jute and cotton due to their varying chemical composition and divergent structural fineness.

The present of cellulose percentage in the jute is lower than the cotton fibre. On the other hand hemicelluloses is the another component present in the jute. Due to present of hemicelluloses and lignin jute is more stiff and yellowish in colour than cotton (Azad *et al.*, 2006 and Hossain *et al.*, 2012). Since the natural colouring matter present in cotton and jute is different, the condition and extent of bleaching required may be different, even if the method of bleaching is same. Furthermore, a pure white colour for jute is difficult to obtain without significant loss of strength and weight because of the present of lignin. Hence, it is necessary to find right combination of chemicals and bleaching method and condition to minimize damage to jute-cotton union fabric.

The study investigates the effect of different bleaching chemicals and methods on strength and absorbency properties of the jute-cotton union fabric; and their suitability for colouration purpose. The one-way ANOVA and Duncan multiple range test were performed to identify the significance of the difference.

■ RESEARCH METHODS

Materials:

Jute/cotton union fabric with cotton yarn (3 Ne) in the warp and Jute yarns of the same count in the weft direction was produced in a handloom with the specification mentioned in Table A.

Laboratory grade reagents such as hydrogen peroxide [H_2O_2 (50%)], sodium thiosulphate ($Na_2S_2O_4$), sodium hydrosulphite ($Na_2S_2O_4$), sodium silicate ($Na_2(SiO_2)_nO$), sodium hypochlorite (NaOCl), sodium sulphite ($NaSO_3$), sodium nitrate ($NaNO_3$), soda ash(Na_2CO_3), sodium hydroxide (NaOH), acetic acid (CH_3COOH), reactive dye (Blue-81), sodium chloride and distill water were used for the experimental purpose.

The fabric details measured were: warp and weft sett, fabric weight per unit area and fabric thickness. Warp and weft thread densities were measured using the counting glass according to ASTM D3775-03 standard. Fabric weight per unit area was determined according to ASTM D1059 standard using Eureka Cloth Quadrant Balance. The thickness of the fabrics was measured according to ASTM D1777-96 standard with the Hungarian thickness gauge. Standard atmospheric conditions have been maintained for all experiments. The fabric parameters have also been mentioned in Table A.

Scouring and bleaching :

Table B presents the fabric coding and process parameters for pre-treatments. While scouring is beneficial for wettability, when carried out in severe condition, it induces fibre deterioration. Traditionally, cotton fibre is scoured with caustic soda as a key ingredient but Jute fibre is sensitive to alkali. Hence, no separate scouring treatment was given to the jute-cotton union samples I, J, K, L and M with the exception of conventional kier-boiled sample N.

Grey Jute/cotton union fabrics were subjected to separate or combined pretreatments. (i) Samples I, J, K, and L were bleached at 85°C for 1hr and at room temperature (RT) for another 1hr ; (ii) samples M was subjected to combined pretreatment with a sequential combination of chemicals by cold method (RT); (iii) and sample N was subjected to separate scouring and bleaching treatment following conventional kier-boiling and steam method (Table A). Conventional bleaching agents such as hydrogen Peroxide and hypochlorite were used along with other chemicals. Hydrogen Peroxide being a universal bleacher was used along with other auxiliaries for all samples except sample M. Sample N was bleached at Bhavani Textile Mill, Bhavani, Tamil Nadu following conventional method used for bleaching cotton.

Sodium hypochlorite is the strongest oxidative bleach used in textile processing but, it is necessary to remove fats, waxes and pectin impurities prior to bleaching with hypochlorite otherwise these impurities deplete the available hypochlorite, reducing its effectiveness for whitening fabric (Cardamone and Marmer, 1995 and Roy Choudhury, 2011). Hence, in case of sample M the fabric is first treated with sodium silicate, soda ash, caustic soda, sodium hydrosulphite and sodium nitrate for 4hr and then for another 2hr (at RT) with sodium hypochlorite.

Visual inspection :

The level of whiteness of all the samples bleached using different chemicals and methods were evaluated visually by individuals specialized in the fields of textiles.

Tearing and bursting strengths :

Elmendorf tearing tester was used for determining the tear strength of the samples by following the procedure mentioned in IS 1966-75. Bursting strengths of the materials were determined as per IS 1966 (Part 2): 1999 method using Eureka bursting strength tester.

Absorbency testing of bleached samples :

The following tests were done to measure the absorbency of the jute-cotton union fabric samples.

Sinking time :

Absorbency may be assessed in various ways, the most popular being the sinking time test (Roy Choudhury, 2006). Absorbency based on sinking time was measured as per IS: 2369-1967 for treated fibres and fabrics (Indian Standard, 2003). Test specimens of 5cmx5cm were cut at random and placed on the surface of water. Slowly the fabric samples were wetted and the entrapped air was removed. The time taken by the fabric samples to go inside water from floating state and sank in completely was noted down. The shorter the time taken by the specimen to sink in water completely, the greater is its absorbency.

Drop test :

The test was done according to the AATCC Test Method 79 that measure a fabric's propensity to take up water, in which water drops are allowed to fall by gravity from a burette placed at a certain height from the fabric surface (Roy Choudhury, 2006). A burette filled with distilled water was clamped to a stand, and so adjusted that it delivered a drop of water approximately in every 5sec. The sample was mounted in an embroidery hoop with all creases out of it. The height between the test sample and burette nozzle was kept constant (1cm). The nozzle of the burette was opened to allow one drop of water to fall on to the sample and a stopwatch was started just as the drop falls on the fabric. Time is recorded until the water drop absorbs completely.

Capillary rise :

Absorbability is the ability of a fabric to take up a liquid and the capillary travel method measures the rapidity of absorption. Specimens were cut into 15cm length and 2.5cm width both warp- and weft-wise. One end of the sample strip was pasted with a glass rod and at the other end; 10gms weight was attached to keep the sample strip straight. Both the ends of the glass-rod were placed on heavy wooden blocks. At the weighted end, 2cm of strip was allowed to immerse in a tray containing distilled water to which 1 per cent reactive dye (Prussian blue) was added for tracking the movement of water and simultaneously a stop watch was started. The height to which the water was transported along the strip is measured after 15minutes, and reported in centimeters (cm). Higher wicking values show greater capability for transporting liquid water.

Statistical analysis :

The results obtained were analyzed statistically using the following tests.

ANOVA (one-way analysis and duncan multiple range test) :

The extent of variation among the samples was found out using Analysis of variance test. Duncan Multiple Range Test was used to determine where significant differences between the means occurred using the following formula (Snadecor and Cochran, 1964) :

$$D = Q \times S_{\bar{x}}; \; S_{\bar{x}} = \sqrt{E/C}$$

where, D = difference in the means which is significant at 5 per cent level.

Q = Table value with the number of treatments and degree of freedom

Table A : Yarn and fabric specification

Fabric	Fibre composition and count		Loom	Weave	Thickness (mm)	Thread density		Weight/unit length
	Warp yarn	Weft yarn				EPI	PPI	
Jute-cotton union	Cotton (3Ne)	Jute (3Ne)	Handloom	Plain	0.87	28	24	10.55 oz/ sq. yard

Table B : Fabric coding and process parameters for bleaching

Fabric code	Liquor-bath composition and methods
O (Control)	No treatment given
I	Bleaching at 85°c for 1hr and at room temperature (RT) for another 1hr with Hydrogen Peroxide (4%) + Sodium Thiosulphate (4%); Neutralization and thorough washing; M:L Ratio- 1:30
J	Bleaching at 85°c for 1hr and at RT for another 1hr with Hydrogen Peroxide (4%) + Sodium Nitrate (3%); Neutralization and thorough washing; M:L Ratio- 1:30
K	Bleaching at 85°c for 1hr and at RT for another 1hr with Hydrogen Peroxide (4%) + Sodium Sulphite (3%); Neutralization and thorough washing; M:L Ratio- 1:30
L	Bleaching at 85°c for 1hr and at RT for another 1hr with Hydrogen Peroxide (4%) + Sodium Silicate (3%); Neutralization with acid and thorough washing; M:L Ratio- 1:30
M	Combined bleaching at RT for 4hr with Sodium Silicate(3%) + Soda Ash(2%) + Caustic Soda (1%)+Sodium Hydrosulphite (0.25%)+ Sodium Nitrate(0.5%) and for another 2hr (at RT) with Sodium Hypochlorite (8gpl); antichlor with Sodium Hydrosulphite and thorough washing; M:L Ratio- 1:30
N	Conventional Method: Kier-boiling process. Scouring at boiling temperature for 1hr with Caustic soda (4%)+Soda Ash (1%)+Sarotex (0.2%)+Chemiking (2gpl avl cl) for 10 min. Bleaching at steam for 1hr with Kiersol (0.3%) + Hydrogen Peroxide (1%) + Soda (0.5%) + Organo metal based stabilizer (1%) + Ranipal (0.5%); M:L Ratio- 1:50

E = Mean square within samples and
C = Number of columns

Dyeing :

Basing on the whiteness parameters samples L, M and N were dyed with Reactive Blue M2R (Blue-81) and their colour fastness properties were evaluated.

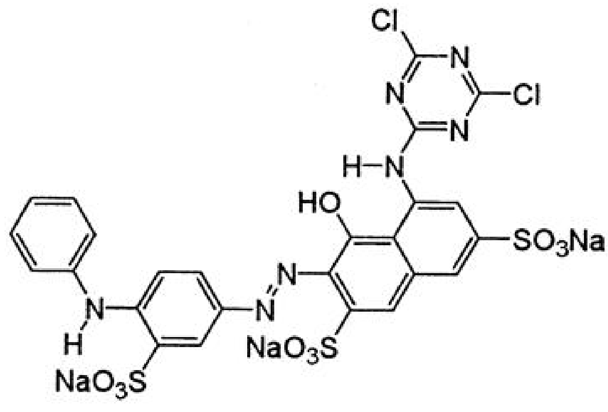

Fig. A : **C.I. Reactive Blue 81, (Source [*http://www.worlddy-evaricty.com*])**

Molecular formula:
$C_{25}H_{14}Cl_2N_7Na_3O_{10}S_3$;

Molecular structure:
Single azo class

Dyeing condition :
Dye – 4 per cet
NaCl – 30 g/lt.
Soda ash – 10 g/lt.
MLR – 1:20
Temperature – 30 to 50^{0}C

Samples were soaked in water for 15 minutes to increase the dye penetration. The samples were dipped in the dye bath for 10 minutes. The required amount of salt was added in 3 steps over period of 30 minutes. The samples were frequently turned up and down and required amount of soda ash was added to it. The materials were worked further for about an hour. Then removed, squeezed evenly, washed well and soaped at boil for 15 minutes, washed and dried.

Tests for fastness properties :

The fastness properties of the dyed samples towards washing, rubbing and light were assessed using standard methods. Evaluation of colour fastness to washing was determined as per IS: 764 – 1984 method using a Sasmira launder-O-meter and following IS-3 wash fastness method. The wash fastness rating was assessed using grey scale as per ISO-05-A02 (loss of shade depth) and ISO-105-AO3 (extent of staining). Colour fastness to rubbing (dry and wet) was assessed as per IS: 766-1984 method using a manually operated Paramount crock meter. Colour fastness to light was determined as per IS: 2454-1984 method. The sample was exposed to xenon light in a Paramount digiLIGHT fade-O-meter along with the eight blue wool standards (BS 1006: BOI: 1978).

■ RESEARCH FINDINGS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Effect of processing chemicals and methods on whitening parameter of fabric :

Bleaching is essential in the case of fabrics intended for white end uses or needs to be dyed or printed. If bleaching is meant for colouration, apart from the removal of colour impurities its purpose is to facilitate ready absorption and uniform distribution of the dye. Therefore, the actual purpose of bleaching varies with the end use of the fabrics and this variation is partly responsible for the variety of bleaching conditions and methods used. Sample N scoured and bleached at processing unit by conventional hot bleaching process produces a pure white colour whereas, sample M, sequential combined chemical bleaching at room temperature (RT) and sample L, sequentially bleached at 85°C temperature and at RT, produced creamy white colour; sample M being whiter than sample L. This may be attributed to the following reason, firstly the source of natural colouring matter being organic compounds with conjugated double bonds, the combined effect of various oxidizing/reducing bleaching chemicals broke the chromophore, most likely by destroying the one or more double bonds within this conjugated system and secondly, lignin present in jute is soluble in sodium hypochlorite/chlorite bleach than any other oxidative bleaches, thus yielding a whiter fabric. Further, it was also established that for bleaching jute-cotton union fabric, sodium silicate is a very effective alkali that not only stabilizes the bleach bath but also break down lignin component giving a whiter look to the sample L.

In case of sample I, J, and K there was no improvement in whiteness of jute fibre rather the jute became dull brown in colour. This might be due to the presence of non-cellulosic constituents, especially lignin in the jute, which was sensitive to chemicals namely Sodium Thiosulphate, Sodium sulphite and Sodium nitrate. It was observed that in case of the samples I (treated with H_2O_2 + Sodium Thiosulphate), J (treated with H_2O_2 + Sodium nitrate), and K (treated with H_2O_2 + Sodium sulphite), the jute components of the materials turned reddish in colour on storing over a period of time whereas the cotton component was unaffected by the chemical treatments given, indicating that the chemical compositions of fibre is the primary determining factor in its behaviour toward any chemical treatment. Accordingly, the action of different reducing/ oxidizing bleaches such as Sodium Thiosulphate, Sodium sulphite, Sodium nitrate, Hydrogen peroxide along with alkalis like Caustic soda and Sodium silicate etc. are somewhat different on jute as compared to their action on cotton.

Effect of processing chemicals and methods on weight of the fabrics :

From Fig. 1, it was observed that the highest loss in fabric weight was for sample N (loses 29.6% over the original weight) followed by Sample I treated with H_2O_2 + Sodium Thiosulphate; (11% of the original weight) and Sample K treated with H_2O_2 + Sodium sulphite; (10% of the original weight). The loss in fabric weight for other samples such as J, L and M were negligible (within 2.2%). Conventional scouring and bleaching method and process parameters use for cotton is not directly suitable for bleaching jute-cotton union fabrics.

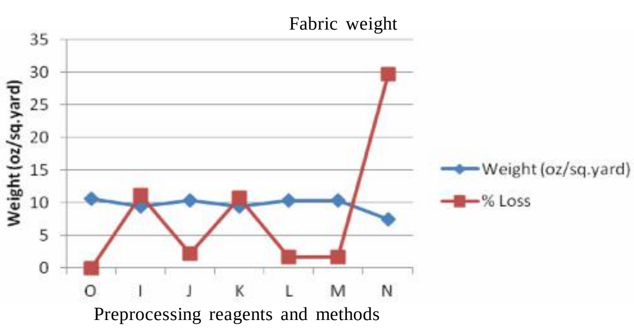

Fig. 1 : Fabric weight of grey and pretreated fabrics

Effect of processing chemicals and methods on tearing and bursting strengths :

While introducing a bleaching chemical and method, it is necessary to achieve acceptable level of whiteness and absorbency with minimize fibre damage.

From Tables 1, it was observed that the pure white colour of sample N was achieved through a significant loss of tearing and bursting strength. This is because of the fact that at high temperature, the presence of hydrogen atoms in the polymer molecule greatly decreases the energy of the C-C bond. When the fabric is heated, the energy of thermal motion causes fluctuation of the chemical bond, which causes the weakening of bond in the cellulose chain which in turn, decreases the strength of the fibre (Salam, 2006). There was no significant loss in tearing and bursting strength with regards to samples I, J, K and L. The loss in tearing and bursting strength was less adversely affected in case of sample M compares to sample N.

The one-way ANOVA and Duncan multiple range analysis (Tables 2-4) were used to test the consistency of mean observation among samples. One-way ANOVA test result showed that there are significant differences between the tearing and bursting strengths of all the samples. Duncan test analysis further revealed that the sample I showed the lowest variation in the mean tearing strength and the Samples M and N showed the highest variation in the result, which is attributed to the facts that different bleaching chemicals and methods affect the strength of the samples. Regarding bursting strength, only sample N showed significant difference in the result and there was no significant variation among the mean bursting strengths of all other samples *i.e.* I, J, K, L and M which

Table 1 : Effects of chemical reagents and methods on properties of Jute/cotton union fabric

Fabric code	Visual inspection	Fabric thickness (mm)	Fabric weight in oz/sq. yard	Tearing strength in kg		Bursting strength in kg	Sinking time in sec	Drop test in sec	Capillary rise in cm (15min)
				Warp	Weft				
O (Control)	Golden brown	0.87	10.55	3.51	>6kg (exceed capacity of M/c)	16.0	1140	180	2.0
I	Dull brown	0.83	9.37	3.36	-do-	15.96	540	30	4.3
J	Dull brown	0.84	10.32	3.50	-do-	15.50	600	60	4.6
K	Dull brown	0.80	9.42	3.48	-do-	16.0	360	30	4.2
L	Cream white	0.80	10.37	3.16	-do-	15.4	60	5.0	6.1
M	Creamy white (Whiter than L)	0.80	10.36	2.81	5.0	14.8	2.0	0.5	10.0
N	Pure white	0.67	7.42	2.56	4.0	10.1	0.5	0.5	10.0

Table 2 : One-way ANOVA (Tearing Strength)

Source of variation	SS	df	MS	F
Between groups (before and after processing)	3.69	5	0.73	25.13*
Within groups (Error)	0.70	24	0.02	
Total	4.39	29		

* indicate significance of value at P=0.01

indicated that scouring and bleaching at conventional kier-boil method significantly lower the bursting strength of the material.

Effect of processing chemicals and methods on absorbency :

Absorbency characteristics of a fabric can influence the uniformity and completeness of textile processing by the ability to take in water into the fibre, yarn or fabric structure. Scouring imparts consistent and sufficient absorbency apart from enhancing the cleanliness of the material; bleaching further enhances the absorbability and imparts whiteness to the materials. In case, no separate scouring and bleaching treatment is given, it is important that the absorbency and whiteness imparted by combined pretreatment processes are sufficient for colouration and other application finishes.

Fig. 2 revealed the average time taken by the samples to sink under their own weight. It was evident that absorbency time decreases according to the methods and bleaching chemicals chosen. There was a significant improvement in the absorbability of samples L (treated sequentially at 85^{0}C and at RT with H_2O_2 + Sodium Silicate), M (combined pre-treatment at RT) and N (conventional scoured and bleached) with sinking time 60 sec, 2.0sec, and 0.5sec, respectively over the control sample O (grey fabric), which had a sinking time of 1140sec. Rest of the samples showed less improvement in the absorbability of the fabric in comparison to sample L, M and N. Low sinking time indicates rapid wettability resulted because of good pre-treatment.

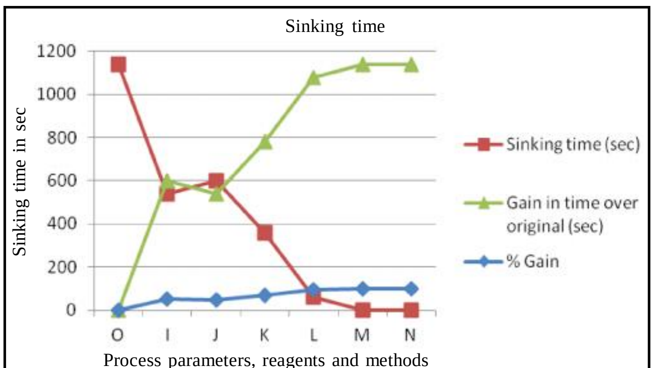

Fig. 2 : Sinking time of gray and pretreated fabrics

The fullness of bleaching as well as the suitability of a fabric for a particular use is dependent upon its ability and propensity to take up water. The absorbency of the samples assessed through drop test (Fig. 3) showed, there was tremendous improvement in the wettability of jute-cotton union fabric for sample L, M, and N with absorbing time of 5.0 sec, 0.5sec and 0.5sec, respectively, whereas, the test result of control sample was 180sec. A time of about 10sec is considered satisfactory [15-**7**]. The absorbency of other samples namely I, J, and K though increased was not satisfactory.

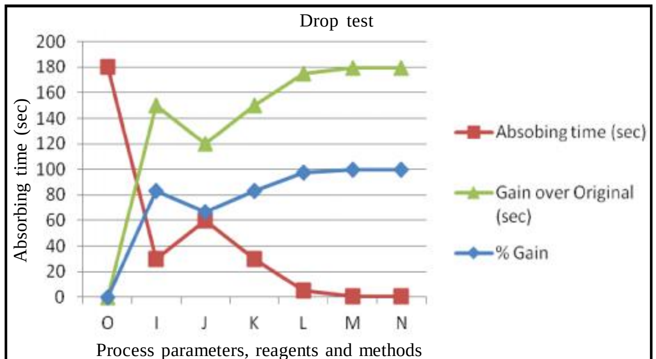

Fig. 3 : Drop test of gray and pretreated fabrics

The capillary rise of the sample M bleached at RT was at par with the mill-bleached sample N (Fig. 4), which proved

Table 3 : One-way ANOVA (Bursting strength)

Source of variation	SS	df	MS	F
Between Groups (before and after processing)	126.95	5	25.39	12.26*
Within Groups (Error)	49.9	24	2.07	
Total	176.85	29		

* indicate significance of values at P=0.01

Table 4 : Duncan test for analyzing mean variation for tearing and bursting strength*

Fabric code	Tearing strength						Bursting strength					
	I	J	K	L	M	N	I	J	K	L	M	N
I	□	–	–	–	+	+	□	–	–	–	–	+
J	–	□	–	+	+	+	–	□	–	–	–	+
K	–	–	□	+	+	+	–	–	□	–	–	+
L	–	+	+	□	+	+	–	–	–	□	–	+
M	+	+	+	+	□	+	–	–	–	–	□	+
N	+	+	+	+	+	□	+	+	+	+	+	□

*At 5% confidence limit, "+" denotes statistically significant and "–" denotes statistically insignificant bleach process at RT with right combination of chemicals and conditions are equally effective in increasing the absorbability of jute-cotton union fabrics besides, saving energy. Though the absorbability of samples I, J and K increased, it was not up to the standard.

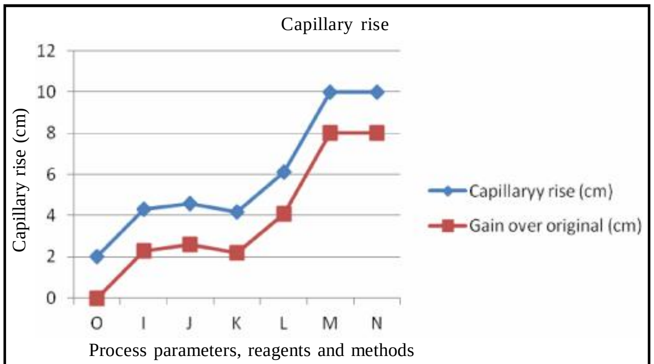

Fig. 4 : Capillary rise of gray and pretreated fabrics

Cost comparison :

The expenditure incurred in different methods of bleaching are calculated for kilograms of fabrics. It is found that fabric L bleached with sodium silicate and hydrogen peroxide involves lowest expenditure followed by cold bleached fabric M. The highest expenditure incurred is for fabric N that involved boiling and steaming process.

Fastness properties :

The investigation showed that the whiteness obtained in samples M and L is acceptable for colouring purpose. Table 5 revealed the fastness properties of the dyed samples L, M and N. The washing and rubbing fastness properties were very good to excellent for Sample M and N samples and that of L was good to excellent. The Light fastness rating of the sample N was in between good to very good, and that of sample M was good and, for sample L the rating was Fairly Good which showed the light fastness properties of the samples affected slightly particularly for sample L. But the overall fastness properties of coloured fabrics L, M, and N were not significantly affected by the bleaching chemicals and methods and the absorbency of the materials were sufficient to carry out the colouration process successfully.

Table 5 : Fastness properties of the printed Jute/cotton union fabrics towards washing and rubbing

Sample code	Washing fastness			Rubbing fastness		Light fastness
	CC	CS		Dry	Wet	
		C	W			
L	4	4/5	4/5	5	4/5	5
M	4/5	4/5	5	5	5	5/6
N	4/5	4/5	5	5	5	6

CC – Colour Change, CS – Colour Staining, C- Cotton, W– Wool

Conclusion :

It was found that no single chemical and process gives satisfactory results in bleaching of jute/cotton materials. Conventional boiling process produces a pure white colour material but the process is costlier and there is substantial loss in fabric strength.

The Sample L and M produce acceptable level of whiteness and efficient to carry out the colouration process successfully. The creamy white colour can be ignored owing to the fact that the end use is intended for furnishing purpose and these processes are energy saving, economical and also minimize damage to fabric strength. Moreover, the increase in absorbency of these materials over original is at par with sample N.

It can be concluded that the judicious selection of chemicals and processes in bleaching of jute/cotton materials results in improvement of fabric's properties and saves energy and money.

The overall colour fastness properties of the Reactive cold dye (Blue M2R) towards washing, and rubbing and light for samples L, M and N was satisfactory, (rating lies between good to excellent).

It can be concluded that the judicious selection of chemicals, methods for pretreatments of jute/cotton materials results in minimizing fabric's strength and increases absorbency apart from being cost-effective.

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