Feasibility Study of Integrated Desizing, Scouring and Bleaching of Cotton Woven Fabric with H_2O_2 and Investigation of Various Physical Properties with Traditionally Treated Fabric

Md. Golam Nur, Senior Lecturer
Department of Textile Engineering, Primeasia University, Bangladesh
M. Forhad Hossain, Associate Prof.
Mustafijur Rahman, Lecturer
Department of Wet Process Engineering, Bangladesh University of Textiles

doi: 10.19044/esj.2016.v12n33p26 URL:http://dx.doi.org/10.19044/esj.2016.v12n33p26

Abstract

Pre-treatment plays a significant role for the successful coloration of any kind of natural textile fiber like cotton, wool, flax, silk etc. This research work overview the influence of various types of traditional preparation techniques applied on cotton fiber before coloration such as desizing, scouring and bleaching. The traditional pre-treatment processes consume plenty of environmentally unfriendly chemicals those generate pollution in the effluents. In this research work an endeavour has been made to desize, scour and bleach grey cotton woven fabric simultaneously using caustic soda and hydrogen peroxide. The physical properties like whiteness, percent loss in fabric weight, tensile strength of the treated fabric have been compared with those of the fabric treated to conventional desizing, scouring and bleaching process. It is observed that the whiteness (ready for colouration) obtained by this process is quite satisfactory. Moreover, this process has some other merits such as ecological, economical, energy conserving and time saving aspect.

Keywords: Desizing, Scouring, Bleaching, Pre-treatment, Hydrogen Peroxide

Introduction

Natural fibres like cotton, jute, flax, hemp, kenaf contain some inherent impurities such as oil, fat, wax and pectin within the fiber structure. The impurities present on natural fibre mostly differs based on the variety, maturity of fiber, weathering and agricultural backgrounds, overall treatment

from fibre to fabric etc. (Carr, 1995; Brushwood, 2003). Protoplasm residue of protein and flavones pigments causes yellowness of cotton fiber (Brushwood, 2003). Cotton based woven fabric encompasses desizing of the sizing elements (starch, polyvinyl alcohol etc) are usually applied on warp yarns to avoid breakages during weaving process, alkali scouring to take out the natural impurities such as fats and waxes, pectines and proteins followed by a hypochlorite or hydrogen peroxide bleaching process which imparts whiteness by destroying the natural colouring matters. Basically fabric is made shipshape, hydrophilic, chemical penetrable and comparatively whitened through desizing, scouring and bleaching processes during the pre-treatment (Shore, 1998; Ibrahim et al., 2004; Shamey and Hussein, 2005). These preparatory steps separately responsible for depletion of large quantity of water, steam, electricity, chemicals as well as time consuming and causes rise of chemical oxygen demand (COD) and biological oxygen demand (BOD) loads in the ETP (Shafie et al., 2009; Hardin, 2010). In previous years therefore, different initiatives have been taken for the pre-treatment of grey cotton. One of noteworthy practise was to accomplish all the three processes concurrently that could be named combined process, one-step process, integrated pre-treatment or single bath process.

Zahran (2006) devised an eco-friendly closed-loop process for cotton fabric preparation (desizing, scouring, bleaching) using only a novel bleaching agent, sodium perborate, (SPB) without any additives in the bleaching bath. An aqueous process using a solvent proposed by Gulrajani et al (1984); where sodium hydroxide (scouring agent) has been substituted by a solvent non-ionic surfactant pine oil combination along with hydrogen peroxide. Parikh (1977) suggested a combined desizing, scouring and bleaching of medium and fine varieties of cotton fabrics, in which DTPA (diethylene triamine penta acetic acid) is applied as a stabilizer for hydrogen peroxide. One-step combined desizing, scouring and bleaching method was developed for polyester/cotton blend fabrics by Imran et al., (2015) in which a novel desizer compatible with both sodium hydroxide and hydrogen peroxide had been used. An effort has been made by Prabaharan and Rao (2003) for one step grey cotton fabric preparation with ozone in one or two minute. Eren and Ozturk (2011) in their study, utilized ozone in cotton preparation for greige, desized and scoured 100% cotton fabrics. Hydrogen peroxide bleaching was performed as the control treatment. The degree of whiteness of cotton increased after prolonged ozonation times.

There are other combined processes stated in the literature use tetra potassium perhydroxy phosphate (KPP). sodium dipersulfate (SPS) and various combinations of sequestering agents, wetting agents and peroxide stabilizers. In almost all these works the results were found at the expense of

some quality. Therefore some of them were established by the industry with a lot of reservations.

In this research work an attempt has been made to introduce a novel technique which combines the desizing, scouring and bleaching processes in a single-bath by adding little bit more amount of hydrogen peroxide (10-12 gm/L) than the typical amount used in simultaneous scouring and bleaching (2-8 gm/L) process. The principal aim of this study was to devise a one-step preparative method which can be carried out at conserving water, energy in a short duration without the use of harmful chemicals such as hypochlorite.

Materials and Methods

Materials

Commercial 100% cotton 1x1 plain weave fabric (ends/in 60; picks/in 52; and gsm 75) sized with starch was used for the study. The chemicals and auxiliaries used were of lab and commercial grades. Bactosol PHC liq hc (a desizing enzyme), Imerol PCLF (a very low foaming wetting agent and scouring agent), Sirrix 2 UD liquid (sequestering agent), Stabilizer SOF (stabilizing agent for alkaline peroxide bleaching baths) were kindly provided by Archroma (Bangladesh) Ltd. H_2O_2 35 % (HP) and NaOH were obtained from Dysin-Chem Limited.

Apparatus

For the assessment of physical properties of fabric various instruments like tensile strength tester, spectrophotometer, padding mangle, counting glass, gsm meter, electric balance, and dryer etc equipment were used.

Mehods

Several lab trials were conducted to assess the effectiveness and compatibility of one-step desizing-scouring-bleaching process. Some treatments were performed in a laboratory dyeing machine DL-6000 Plus from Starlet in the 500 ml bakers at a liquor ratio of 1: 20. Some are treated in a pad-batch manner while other samples applied to exhaust bath. After each treatment the most the samples were washed in hot water, rinsed in cold water and dried. The sized cotton fabric was treated according to the procedures presented in below.

Process 01 (Sample-1): Grey Fabric→ Padding with Recipe-1→ Hot Air Dried→ Hot wash (80°C for 10 min)→ Rinse→ Hot Air Dried; Recipe-1: NaOH-5gm/L, H_2O_2-8cc/L, Stabilizer SOF-4cc/L, Imerol PCLF-2cc/L, Sirrix 2 UD-2cc/L, M:L-1:20. Padding Temperature- Room Temperature, Pick up Percentage-90%, pH- 10.5

Process 02 (Sample-2): Grey Fabric→ Padding with Recipe-1→ Dried in room Temp* → Hot wash (80°C for 10 min) → Rinse→ Hot Air Dried; As same as Recipe-1. Parameters: As same as Sample-1 fabric was padded for 3hrs*.

Process 03 (Sapmle-3): Grey Fabric→ Padding with Recipe-1→ Dried in Oven (90ºC) for 15min → Hot wash (80°C for 5 min) → Rinse→ Hot Air Dried; As same as Recipe-1. Parameters: As same as Sample-1

Process 04 (Sapmle-4): Grey Fabric→ Padding with Recipe-2 (Desizing) → Dried in Oven (60ºC) for 10min → Hot wash (80°C for 10 min) → Rinse→ Hot Air Dried→ Padding with Recipe-3 (Scouring and Bleaching)→ Dried in Oven (90ºC) for 15min → Hot wash (80°C for 10 min) → Rinse→ Hot Air Dried; Recipe-2 (Desizing): Bactosol Enzyme-4cc/L, Salt- 5 gm/L, Acetic Acid- 1 cc/L, Imerol PCLF-2cc/L, Sirrix 2 UD-2cc/L, M:L-1:20. Recipe-3 (Scouring and Bleaching): NaOH- 4gm/L, H_2O_2-4cc/L, Stabilizer SOF- 2cc/L, Imerol PCLF- 1cc/L, Sirrix 2 UD- 1cc/L, M: L-1:20. Parameters: Recipe-2 (Desizing): Padding Temperature- Room Temp Pick up Percentage-90%, pH:4.5-5.5, Recipe-3 (Scouring and Bleaching): Temperature- Room Temperature, Pick up Percentage-90%, pH: 10.5.

Process 05 (Sapmle-5): Grey Fabric→ Padding with Recipe-2 (Desizing) → Hot Air Dried → Hot wash (80°C for 10 min) → Rinse→ Hot Air Dried→ Padding with Recipe-3 (Scouring and Bleaching)→ Hot Air Dried → Hot wash (80°C for 10 min) → Rinse→ Hot Air Dried; Desizing: As same as Recipe-2, Scouring and Bleaching: As same as Recipe-3. Parameters: As same as Sample-4.

Process 06 (Sapmle-6): Grey Fabric→ Exhaust Bath with Recipe-2 (Desizing) → Hot wash (90°C for 5 min) → Rinse → Exhaust Bath with Recipe-3 (Scouring and Bleaching)→ Hot wash (80°C for 10 min) → Rinse→ Dried; Desizing- As same as Recipe-2, Scouring and Bleaching- As same as Recipe-3. Parameters: Desizing (Exhaust Bath): Temperature-60±5ºC, pH:4.5-5.5, Time- 40min, Scouring and Bleaching (Exhaust Bath): Temperature- 90±5ºC, pH:10-11, Time- 45min.

Process 07 (Sapmle-7): Grey Fabric→ Exhaust Bath with Recipe-4 (One-step Desizing, Scouring and Bleaching) → Hot wash (90°C for 5 min) →Rinse→ Dried; Recipe-4 (one step Desizing, Scouring and Bleaching)-NaOH- 10gm/L, H_2O_2- 14cc/L, Stabilizer SOF- 4cc/L, Imerol PCLF- 2cc/L,

Sirrix 2 UD- 2cc/L, M: L-1:20. Parameters: One-step Desizing, Scouring and Bleaching (Exhaust Bath): Temperature- 90±5ºC, pH:10-11, Time- 20min.

Process 08 (Sapmle-8): Grey Fabric→ Exhaust Bath with Recipe-5 (One-step Desizing, Scouring and Bleaching) → Hot wash (90°C for 5 min) →Rinse→ Dried; Recipe-5 (one step Desizing, Scouring and Bleaching): NaOH- 8gm/L, H_2O_2- 12cc/L, Stabilizer SOF- 4cc/L, Imerol PCLF- 2cc/L, Sirrix 2 UD- 2cc/L, M: L-1:20. Parameters: One-step Desizing, Scouring and Bleaching (Exhaust Bath): Temperature- 90±5ºC, pH:10-11, Time- 40min.

Process 09 (Sapmle-9): Grey Fabric→ Exhaust Bath with Recipe-6 (One-step Desizing, Scouring and Bleaching) → Hot wash (90°C for 5 min) →Rinse→ Dried; Recipe-6 (one step Desizing, Scouring and Bleaching): NaOH- 4gm/L, H_2O_2- 8cc/L, Stabilizer SOF- 4cc/L, Imerol PCLF- 2cc/L, Sirrix 2 UD- 2cc/L, M: L-1:20. Parametres: One-step Desizing, Scouring and Bleaching (Exhaust Bath): Temperature- 90±5ºC, pH:10-11, Time- 20min.

Process 10 (Sapmle-10): Grey Fabric→ Exhaust Bath with Recipe-3 (One-step Desizing, Scouring and Bleaching) → Hot wash (90°C for 5 min) →Rinse→ Dried; As same as Recipe-3. Parameters: One-step Desizing, Scouring and Bleaching (Exhaust Bath): Temperature- 90±5ºC, pH:10-11, Time- 40min.

Process 11 (Sapmle-11): Grey Fabric→ Padding with Recipe-2 (Desizing) → Batched for 3hrs → Hot wash (90°C for 10 min) → Rinse→ Padding with Recipe-7 (Scouring) → Hot Air Dried → Hot wash (90°C for 10 min) → Padding with Recipe-8 (Bleaching)→ Hot Air Dried → Hot wash (90°C for 10 min) → Rinse→ Hot Air Dried; Recipe-2 (Desizing):Bactosol Enzyme- 4cc/L, Salt- 5 gm/L, Acetic Acid- 1 cc/L, Imerol PCLF-2cc/L, Sirrix 2 UD-2cc/L, M:L-1:20. Recipe-7 (Scouring): NaOH- 6gm/L, Detergent- 2cc/L, Imerol PCLF- 1.5cc/L, Sirrix 2 UD- 1.5cc/L, M: L-1:20. Recipe-8 (Bleaching): NaOH- 2gm/L, H_2O_2- 8cc/L, Stabilizer SOF- 3cc/L, Imerol PCLF- 1.5cc/L, Sirrix 2 UD- 1.5cc/L, M: L-1:20. Parameters: Recipe-2 (Desizing): Padding Temperature- Room Temp, Pick up Percentage-90%, pH:4.5-5.5, Recipe-7 (Scouring):Padding Temperature- Room Temp, Pick up Percentage-90%, pH:10-11, Recipe-8 (Bleaching): Padding Temperature-Room Temp, Pick up Percentage-90%, pH:10-11.

Evaluation Methods

Prior to the measurements, samples were conditioned for 24 hours at 20 °C and 65 % relative humidity. The pH was measured using a pH meter. The degree of whiteness and reflectance percentage were measured with

Dual-beam Datacolor Spectraflash SF 600 plus spectrophotometer (Datacolor International, Switzerland. The water absorbency was measured according to Column Test or Wicking Height Test. The measurements of Tensile Strength (Strip Test) at maximum load were performed on digiSTRENGTH I Nx (Digital Tensile Strength Tester for Textiles, Paramount Instruments Private Limited, India). The Weight loss of fabric was measured taking weight before and after pre-treatment in digital electric balance.

Results and Discussion

Weight loss evaluation

At the end of each method, the fabrics were removed from the liquor, washed thoroughly and dried, after that conditioned in standard testing atmosphere (Temperature- 20º±2ºC, RH-65±2%). Table-1 shows the percent loss in fabric weight when the cotton fabric was treated with various concentrations of H_2O_2 and NaOH under different conditions. The results of the weight loss from different samples are obvious on Figure-1. Samples 4, 5, 6, 7, 10 and 11 exhibit a relatively higher percent of weight loss because of higher concentration of H_2O_2 and NaOH. The highest amount of weight loss (12.8%) is observed for Sample 10 which is one of the proposed integrated desizing, scouring and bleaching process. The reason behind this considerable amount of weight loss perhaps the application of higher alkaline condition (pH 10-11), temperature 95^0-100^0C and longer process time (40 mins). On the contrary, the lowest amount of weight loss (8.2%) is found in sample 1 which is the traditional pad-batch method. Perhaps the cause behind this less amount of weight loss is the fabric padded in room temperature. Although integrated pre-treated samples exhibit little bit higher weight loss in comparison with conventionally pre-treated samples, but whiteness indices and reflectance percentage values are higher for these samples which has been discussed later on this article.

Table 1. Comparison of weight loss

Sample Identification	Weight Loss Percentage
Sample 1	8.2
Sample 2	9.7
Sample 3	10.2
Sample 4	11.5
Sample 5	11.1
Sample 6	12.4
Sample 7	11.6
Sample 8	9.7
Sample 9	9.9
Sample 10	12.8
Sample 11	12.5

Whiteness index

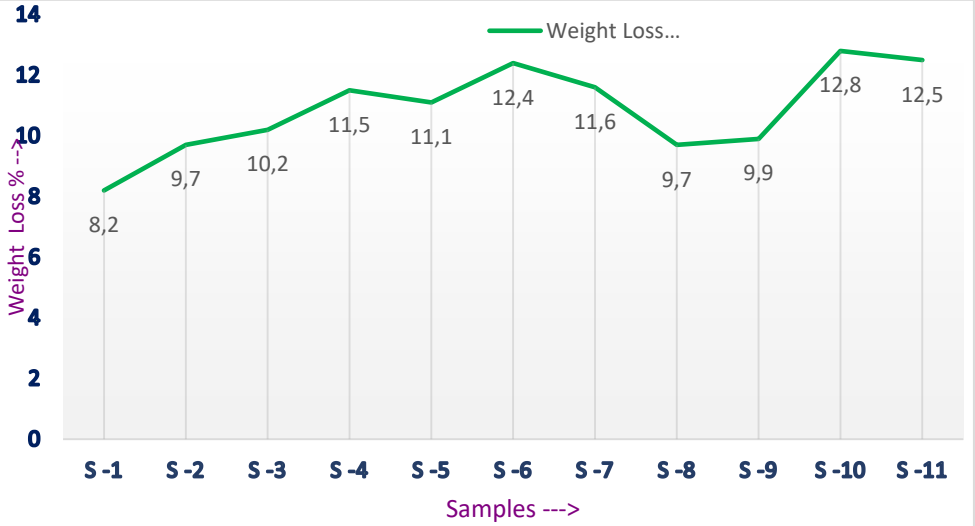

Figure 1. Weight loss percentage for various samples

Table-2 represents The CIE Whiteness Index (WI) values for each sample were determined using Dual-beam Datacolor Spectraflash SF 600 plus spectrophotometer (Datacolor International, Switzerland) with the following settings: illuminant D65 and F_{11}, large area view, specular excluded, UV included and CIE 1964 Supplementary Standard Observer (10º observer). According to AATCC Test Method 110-2005, WI is given by the following equation:

$WI = Y + 800\ (0.3138 - x) + 1700\ (0.3310 - y)$

Where, WI is the whiteness value or index; Y, *x*, *y* are chromaticity coordinates of the treated specimen. The instrument was operated with Spyder3Pro Version 4.0.2 computer software.

Ganz-Griesser Whiteness Index is also evaluated by using The X-Rite Ci7800 benchtop sphere spectrophotometer with $D_{65}/10^o$ and reference wavelength 470nm, the formula the index is calculated with is as follows:

$$W_{Ganz} = Y + P.\ x + Q.\ \mathbf{y} + C$$

Where the (nominal) coefficients are given for $D_{65}/10^o$ as:

P = -1868.322

Q = -3695.690

C = 1809.441

Table 2. CIE and Ganz-Griesser Whiteness Index

Sample Identification	CIE Whiteness Index		Ganz-Griesser Whiteness Index
	$D_{65}/10^o$	$F_{11}/10^o$	
Sample Grey	1.73	12.57	37.24
Sample 1	30.21	36.51	52.64
Sample 2	32.04	38.01	52.52
Sample 3	31.11	36.92	52.83
Sample 4	25.77	32.67	44.37
Sample 5	24.09	30.12	42.81
Sample 6	52.22	55.68	77.72
Sample 7	58.60	61.30	76.93
Sample 8	53.02	56.35	79.17
Sample 9	50.48	54.08	71.53
Sample 10	53.14	56.42	74.22
Sample 11	19.70	27.65	38.31

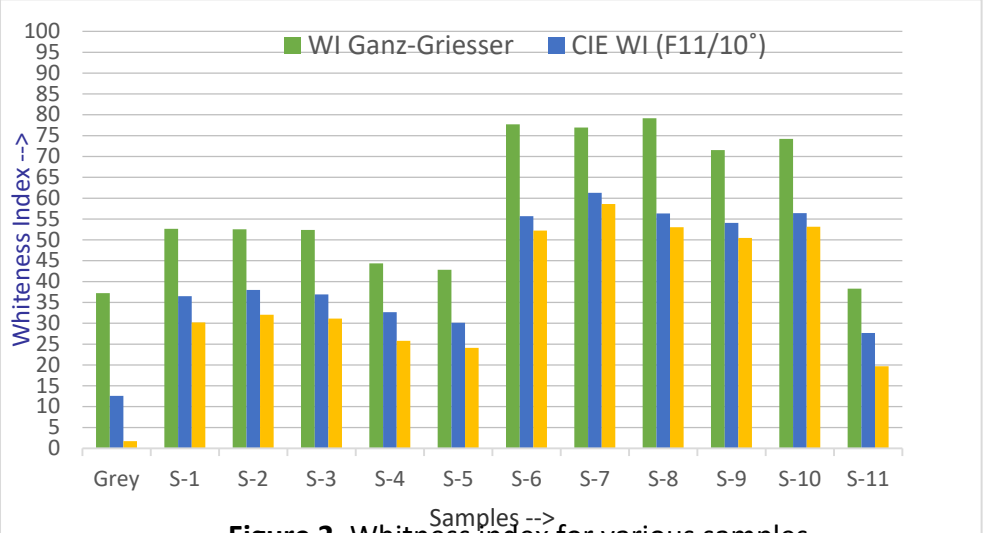

Figure 2. Whitness index for various samples

A significant degree of fabric whiteness is prerequisite of fabric pre-treatment for finishing the fabric as white or before its dyeing, particularly in light and bright shades. As it can be seen from Table 2 and Figure-2, the achieved degree of whiteness is comparatively much higher for one step integrated pre-treated samples like 7, 8, 9, 10 than the traditionally pre-treated samples. According to CIE Whiteness Index, the maximum value is observed in Sample 7 for both $D_{65}/10^o$ (Whiteness Index, 58.6) and $F_{11}/10^o$ (Whiteness Index, 61.3). This may be the enactment of higher concentration of Hydrogen Peroxide (14 cc/L) and Sodium Hydroxide (10 g/L). On the other hand, the lowest value of whiteness index is found in Sample 11 for

both observers $D_{65}/10^{o}$ (Whiteness Index, 19.7) and $F_{11}/10^{o}$ (Whiteness Index, 27.65). The reason behind this less whiteness index is perhaps the application of semi-continuous pad-batch method for individual pre-treatment process. According to Ganz-Griesser Whiteness Index, the highest value of whiteness is found in Sample 8. It is obvious that a higher degree of whiteness could be obtained at the cost of increment of weight loss percentage as well as strength loss.

Reflectance value

When a fabric is bleached, its light reflecting capacity increases which can be assessed by reflectance percentage and reflectance curve. Figure-3 represents reflectance percentages of various samples at 400nm – 700nm wavelength at 10nm intervals.

This is observed from Figure 3 traditionally pre-treated samples have higher reflectance percentage than that of grey fabric but integrated desized, scoured and bleached fabric like samples 7, 8, 9 ,10 shows much more reflectance than those of grey fabric and traditionally pre-treated samples. It can be seen from recipes, gm/L of H_2O_2 used for the samples 7, 8, 9, 10 are 14 cc/L, 12cc/L, 8cc/L and 4cc/L respectively which depicts that higher amount of H_2O_2 has miniscule influence on reflectance percentage and whiteness index. So Figure-2 and Figure-3 interpret integrated desizing, scouring and bleaching of cotton woven fabric is possible with 6-10 cc/L H_2O_2.

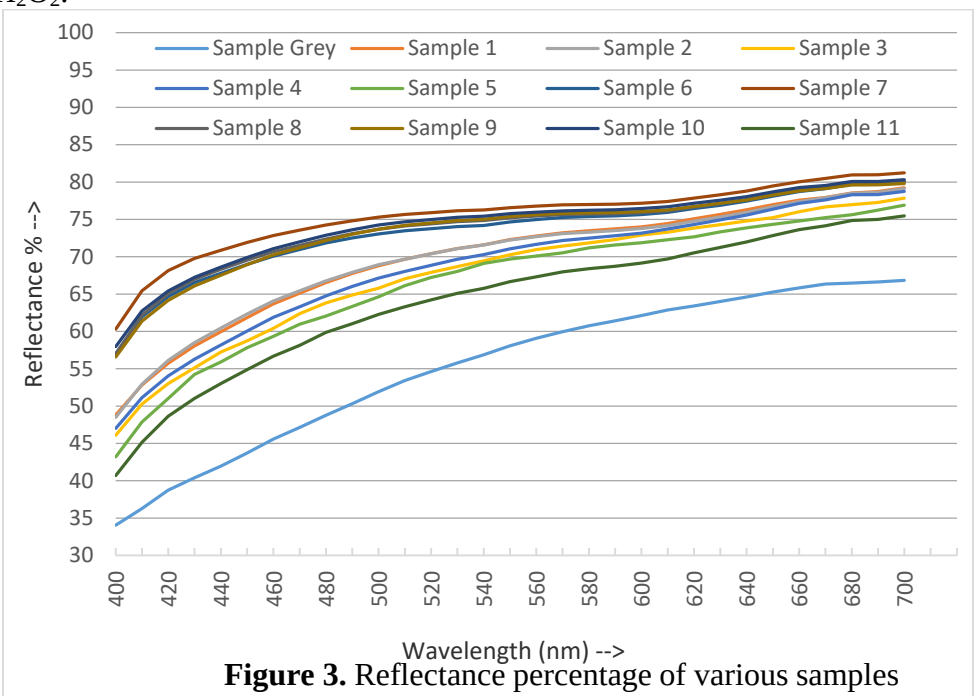

Figure 3. Reflectance percentage of various samples

Fabric Strength

During desizing, scouring and bleaching one of the significant concerns is to preserve the fabric mechanical properties as much as possible. Tensile strength is one of the most key indicators of degradation of mechanical properties of the fabric during pre-treatment. For the assessment of tensile strength 8inch x 2inch strip of fabrics were taken and tested in digiSTRENGTH I Nx (Digital Tensile Strength Tester for Textiles, Paramount Instruments Private Limited, India). The warp and weft tensile strength (Strip Test) of the treated samples are compared with tensile strength of grey fabric. Results related to this set of examinations are given in Table-4. It is clear from Figure-4 that one step pre-treatments do not cause any appreciable loss in fabric strength of sample-7, 8, 9 and 10 comparing with the traditionally pre-treated samples. Though, increase in hydrogen peroxide concentration results in decrease in fabric strength in the presence of higher amount of sodium hydroxide (Badaras et al., 1993; Vigo, 1994).

Table 4. Tensile Strength (Strip test) and Strength Loss Percentage of Treated Samples

Sample Identification	Warp Strength (Kg)	Weft Strength (Kg)	Warp Strength loss %	Weft Strength loss %
Sample Grey	12.2	9.3	-	-
Sample-1	9	9.3	26.23	0
Sample-2	8.6	9.2	29.5	1.07
Sample-3	9.6	9.2	21.31	1.07
Sample-4	7.9	8	35.25	13.98
Sample-5	9.8	8.2	19.67	11.82
Sample-6	9.4	8.9	22.95	4.3
Sample-7	9.7	8.3	20.5	10.75
Sample-8	10.2	9.2	16.4	1.07
Sample-9	8.7	8.3	28.68	10.75
Sample-10	9.3	9	23.77	3.23
Sample-11	9.7	8	20.5	13.98

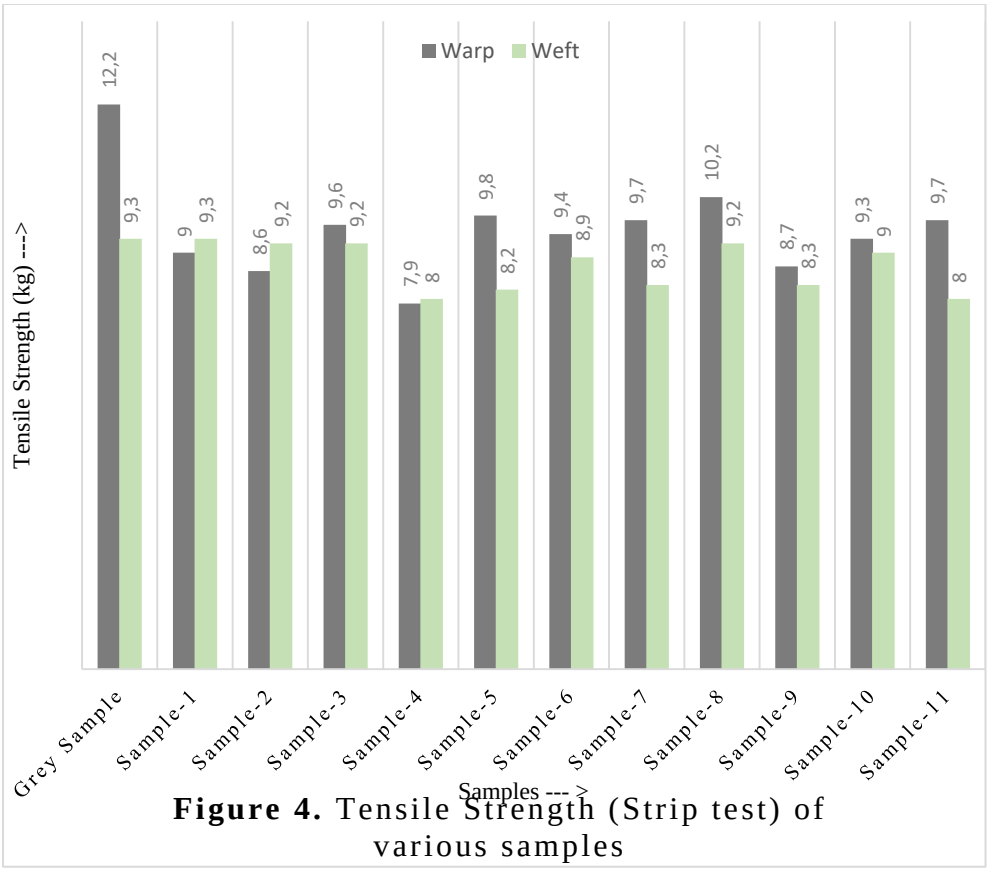

Figure 4. Tensile Strength (Strip test) of various samples

Fabric Absorbability

Absorption of water or that containing dyes or finishes on cotton is mired due to different impurities including oily, fatty and waxy components on it. Application of starch during sizing further deteriorates the fabric absorbency. For measuring absorbency of various samples column (wicking) test was applied where 18cm x 5cm specimens were taken then absorbed length is measured along the specimen length in mm after immersing 1cm portion in 0.1% direct red solution for 5 minutes. It can be observed from Table 5 sample-6 reveals maximum absorbency (wicking rise) i.e. the best possible fabric absorbency is attained in conventional two step pre-treatment process. When NaOH and H_2O_2 were applied in several concentrations for sample-7, 8, 9 and 10 (one step pre-treatment) absorbability of the fabrics also increases, which is probably due to better removal of starch through its hydrolysis by hydrogen peroxide and on the other hand sodium hydroxide results in better removal of the saponifiable oils, fats and waxes present in cotton. Figure 5 specifies that the fabric absorbency is optimal when the gm/L of hydrogen peroxide is also higher in combination with the

concentration of sodium hydroxide. The removal of motes and other non-cellulosic contents, with the help of both sodium hydroxide and hydrogen peroxide also contribute towards the improvement in fabric absorbency.

Table 5. Absorbency Test of various samples using Column (Wicking) Test Method

Sample Identification	Wicking height (mm)	
	Warp	Weft
Sample Grey	17	19.5
Sample-1	37	34
Sample-2	43.5	45
Sample-3	49	47.5
Sample-4	33	31.5
Sample-5	25	28
Sample-6	59.5	56
Sample-7	53	54
Sample-8	48	48
Sample-9	50	52
Sample-10	52	54
Sample-11	45	46

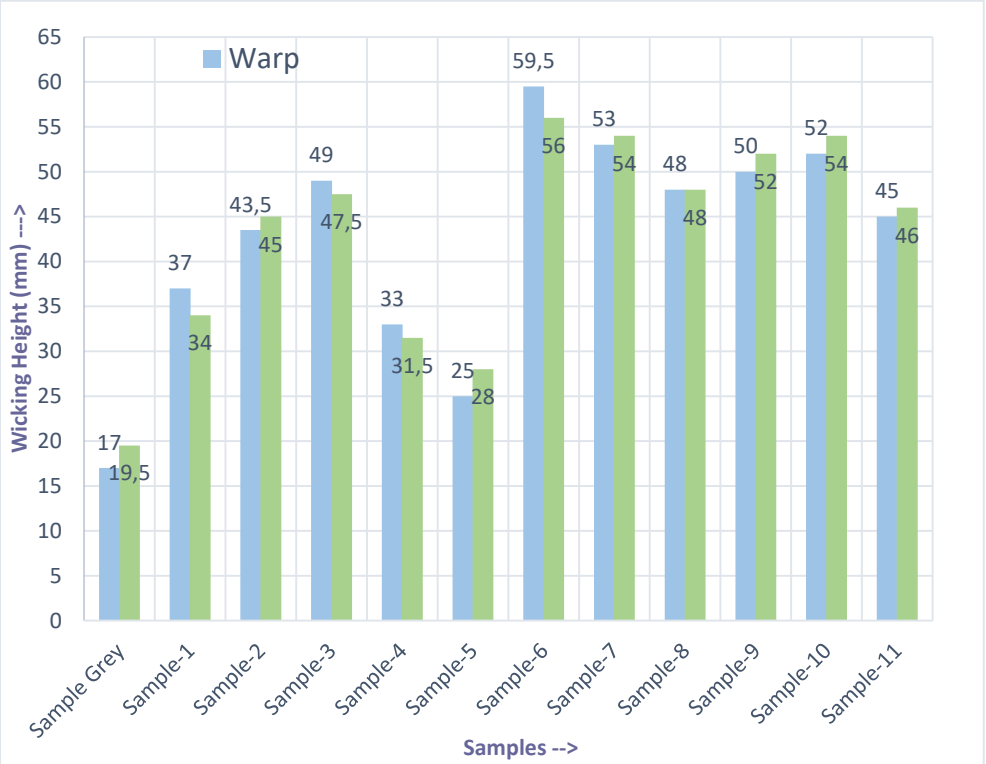

Figure 5. Column (Wicking) Height for various samples

Acknowledgements

The authors acknowledge South China Bleaching & Dyeing Factory, Archroma (Bangladesh) Ltd, Dysin-Chem Limited, Mashriquee Textiles Limited, Textile Testing Services Ltd (DBL Group), Primeasia University as well as Bangladesh University of Textiles (BUTex) for their generous and amiable support all the way through the study. We also want to take the opportunity to show gratitude to those academic and industrial professionals for all their great help because without your support and encouragement, our attainment wouldn't have been possible.

Conclusion

In our study we tried to develop the one-step combined desizing, scouring and bleaching process which is done only using various concentrations of Sodium Hydroxide (NaOH) and Hydrogen Peroxide (H_2O_2) with commercial grade of some auxiliaries. Under some circumstances, the fabrics treated by this method achieved properties superior to those treated by traditional methods, with the exception of strength and weight loss. As this work requires further study for industrial application on large scale production but it could be assumed Hydrogen Peroxide (H_2O_2) played a key part as a desizing and bleaching agent here. Some fruitful trials were made following this integrated pre-treatment method at industry for short quantity fabric (sample section). This technique is very feasible for medium to dark shade coloration of fabric whereas satisfactory aftermath was not found for white finish or light coloured cloth. This implies that the process entails advance exploration for positive adaptation and effective application by the textile industry, in which the bulk production could be made possible with minimum weight and strength loss with higher degree of desizing, absorbency and whiteness. A rough analysis divulges that the one-bath pre-treatment process could bring remarkable conservations in water (35%), steam (30%), chemical cost (25%), electricity (25%) and the process time (40%) in woven fabric pre-treatment process. If the suggested one-step process could be established in textile industries of Bangladesh it will not only be cost-effective but also be more proficient and green because of much reduced influence on the environment.

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