

## EFFECT OF BLEACH WASH ON THE PHYSICAL AND MECHANICAL PROPERTIES OF DENIM GARMENTS

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### ABSTRACT

Denim garments are most preferred of today's youth. This paper presents the effect of bleach wash using bleaching powder on 100% cotton indigo dyed denim garments (trousers) to develop novel design and cost effective finishing. Garments were processed using three parameters, bleach concentration 5g/l to 15g/l, temperature 40°C to 60°C and time 20 min to 40 min. The effect of each parameter is discussed. Physical and mechanical properties of the treated and untreated garment that were monitored include: tensile strength, stiffness, elongation at break, weight loss, dimensional stability, color fading, water absorption and moisture regain. Scanning electron micrograph (SEM) was also examined. Bleach washing and without washing revealed big differences in tensile strength, stiffness, GSM, color fading and surface roughness. The optimized washing condition for the best value is 10g/l bleach concentration with temperature 40°C and treatment time 20 min.

**Keywords:** Denim Garment, Tensile Strength, Indigo Dye.

### 1. INTRODUCTION

Denim is very strong, stiff and hard wearing woven fabric [1]. Denim is cotton and twill weave fabric that uses colored warp and white weft yarn and used for jeans, work clothes and casual wear [2]. Denim is normally dyed with indigo, vat and sulphur dyes. Among these, indigo share is 67%. Indigo dyes are used for fashion dyeing; in denim, fibers dyed with indigo are not included in fiber-transfer examinations, remains surface dyeing [3]. Denim garment (Jeans) washing is known as one of the widely used finishing treatment that has vast usage in textile sectors because of creating special appearance and making fashionable and wear comfortable garments of the present day world and commonly used. Without finishing treatments, denim garment is uncomfortable to wear, due to its weaving and dyeing effects. For this it essentially needs a finishing treatment to make it softer, more supple, smooth and comfortable to wear performance. Popularity of garments washing specially on denim garments in the World market has been increasing day by day [4]. To meet up the quick change of current demands of customers, technologists are trying to introduce new designs and fashion on denim garments by using different washing methods. The most

commonly denim washing methods are bleach wash, acid wash, enzyme wash, normal wash, stone wash, etc. [2, 4]. Among the washing methods, bleach method is widely used method in industry especially for denim washing to achieve required color shade by hypochlorite bleaching. Although chlorine is a harsh chemical, harmful to human health, causes corrosion to washing machine and destructive to cotton; it may cause damage to cotton due to the decomposition of cellulose in the aqueous solution of hypochlorite bleach and losses its tensile strength; produces many decomposed product in bleach washing and pass into the effluent where it causes environmental pollution [4]. But bleaching treatments have been successful for achieving desirable color shade and soft hand feels of cotton denim garments and are using in textile and washing industry. However, cellulase enzyme treatments have been successful at improving flexibility and soft hand feels of cotton denim garments [5, 6], but it degrades cellulose at the end or in the middle of the cellulose chain [7], yielding shorter chain cellulose polymers, and reduces its mechanical strength [8]. So, denim washing using bleaching powder is chosen for this work.

Many researchers have investigated the washing of denim garments using various methods for the last many years [5, 6] but a few works has been done on washing of denim garments to develop novel design and fashion with high wear performance by bleach method.

Bangladesh is a textile industry based country. Denim garments (trousers) are being produced with other garments to meet its demand in the competitive market of world and Bangladesh earned about 76% foreign currency from ready-made garments sector [4].

In this paper, a novel and cost effective method have explored for denim washing with bleaching powder that developed new design and fashion and is produced a value-added product with high wear performance to satisfy customer's need. In addition, the effects of washing parameters on the physical and mechanical properties of treated denim garments have investigated.

## 2. MATERIALS AND METHODS

### 2.1 Materials

100% cotton standard denim garments (trousers) were used. These comprised indigo dyed denim fabric, GSM 381, twill weave 3/1, construction 70 x 42 / 9 x 7. Garments were desized using the standard recipe [9]. Then the denim garments were washed using bleaching powder. Washed denim garments were then neutralized with hyposulphite. Denim fabric was collected from Beximco Textile Mills Ltd., Dhaka, Bangladesh.

Bleaching powder (KCI bleach, India); detergent (Hostapur WCTH, Germany), desizing agent (Luzyme FR-HP BASF, Germany) and neutralizing agent sodium hyposulphite (Hypo, China) were purchased.

### 2.2 Methods

#### 2.2.1 Desizing Treatment

Denim trousers were desized using detergent and desizing agent. This pretreatment was conducted in liquor containing Hostapur (1.0 g/l) and Luzyme (0.6 g/l), and material to liquor ratio of 1:10 in a small scale front loading industrial washing machine (Ngai Shing, model-NS 2205, Hong Kong). This treatment was carried out at temperature 60°C for 20 min. After desirable time the liquor was dropped out. The garments were then washed with hot water at 60°C for 3 min then washed with cold water for 2 min.

#### 2.2.2 Bleach Treatment (Bleaching Powder)

Desized denim trousers were treated using bleaching powder. This process was conducted in liquor containing KCI bleach (5g/l to 15g/l), soda ash (5 g/l) at pH 10.5, and material to liquor ratio of 1:10 in the washing machine. The bleach treatment was carried out at different concentrations of KCI bleach (5-15g/l), temperatures (40- 60°C) and treatment time (20 - 40 min). The denim garments were then neutral washed with Hypo (2 g/l) for 5 min at 40°C.

### 2.2.3 Hydro-extracting and Drying Processes

Bleach washed denim trousers were squeezed to a wet pick-up of 70% at 200 rpm for 3-4 min in laboratory scale hydro-extractor machine (Zanussi, Roaches International Limited, England), then dried at 75°C for 35-40 min in a steam drier (Opti-Dry, Roaches International Limited, England). Treated denim garments were then evaluated and characterized of their physical and mechanical properties.

### 2.3 Testing and Analysis

Treated all denim trousers were conditioned in 65% RH and 20°C for 24 h before testing according to BS EN 20139 and ASTM D1776.

- Tensile strength (breaking force) and elongation at break was determined by the US Standard Grab test method according to ASTM D 5034 and ASTM D 1682.
- Dimensional changes / shrinkage (%) was calculated from the difference in fabric length before and after washed garment according to AATCC test methods 135 and 150; ASTM D 2724, BS 4931.
- Weight loss (%) in fabric / GSM was calculated from the difference in fabric weight before and after the treatment according to ASTM D 3776.
- Moisture regains and moisture content (%) was calculated from the difference in total fabric weight and oven dry weight according to BS 4784 and ASTM D 1909.
- Change in the original color shade of the fabric was rated using gray scale for color change according to AATCC test method.
- Stiffness was measured from the bending rigidity in fabric by Shirley stiffness tester according to BS 3356.
- Water absorption was measured in fabric from the differences in rate of uptake according to BS 3449.
- SEM was studied using a scanning electron microscopy (Hitachi, model-S 3400 N, Japan).

## 3. RESULTS AND DISCUSSION

### 3.1 Concentration of bleaching powder

100% cotton denim garments (trousers) were processed through desizing using Hostapur WCTH (detergent), and Luzyme FRHP (desizing agent). Then desized denim garments were processing using KCI bleach (bleaching powder). The physical and mechanical properties of bleach treated denim trousers were examined using testing equipments. Results obtained are summarized in Table 1.

Table 1: Effect of bleaching powder concentration on the physical and mechanical properties of treated denim garments.

Conc. of bleaching powder (g/l)	Tensile strength (Kg f)		Dimensional stability / shrinkage (%)	Weight of fabric (GSM)	Stiffness (cm)	Water absorption (%)	Moisture content (%)	Moisture regain (%)	EPI & PPI (ends/inch)	Elongation at break (%)	Color shade (grey scale)
	Warp	Weft									
0.0 Before wash	246(0)	137(0)	0	381(0)	4.35(0)	128	7.50	7.60	70 x42	L=24 W=16	5
5.0	236 (-4%)	134 (-2%)	L= - 5.0 W= 0	377 (-1.0%)	3.5 (-19%)	136	8.30	8.20	70 x45	L=48 W=22	4/5
7.5	229 (-7%)	133 (-3%)	L= - 5.0 W= 0	372 (-2.37%)	3.4 (-22%)	140	8.34	8.51	70 x45	L=46 W=22	4
10.0	219 (-11%)	129 (-6%)	L= - 6.0 W= +0.5	372 (-2.37%)	3.3 (-24%)	141	8.40	8.54	70 x45	L=44 W=21	3
12.5	212 (-14%)	127 (-7%)	L= -7.0 W= +1.0	371 (-2.62%)	3.3/ (-24%)	141	8.51	8.54	70x46	L= 42 W=21	2/3
15.0	207 (-16%)	127 (-7%)	L= - 7.0 W= +1.0	370 (-2.89%)	3.3/ (-24%)	141	8.51	8.54	70x46	L=41 W=21	1/2

A value at 0.0 concentrations represents the denim garments without bleaching powder treatment. Conditions used for bleach washing treatment: bleaching powder, 5.0-15.0 g/l; soda ash, 5g/l; temperature, 40°C; time, 20 min; pH, 10.5; M: L ratio, 1:10.

The effects of bleaching powder on denim garment washing with different concentrations from 5g/l to 15g/l of KCl bleach for 20 min were investigated. It can be seen from Table 1 that, treatment of denim trousers with bleaching powder at 5g/l concentration cause significant decrease of tensile strength and this decrease was higher at higher bleach concentrations. It is observed that 15g/l concentration exhibited the highest decrease in the loss of tensile strength as compared with the other concentrations. Bleaching powder decomposed cotton under the conditions used. Bleaching powder first attacked on dyed yarn portion, decomposed them slowly and fibers are partly degraded from the yarn chain and step by step penetrated inside fabric. Therefore, the chemical bonds of primary wall (outer layer) are broken by the decomposition of the aqueous solution of hypochlorite bleach. After that it attacked on secondary wall. The result of this reaction is that the primary wall (outer layer) of the cotton fiber is loosened and broken down quicker with the frictional action (mechanical forces) of rotating cylinder of the washing machine. The effect also depends on the conditions of washing. Decomposition of cellulose would certainly affect fabric properties, namely, tensile strength, stiffness, elongation at break, water absorption, moisture regain, moisture content and fabric surface characteristics. Similar results have previously been obtained with undyed cotton cellulose [5].

Denim decomposition by measuring the color fading from denim garments was monitored (Table 1). The same holds true for the color fading also. As already observed, the color shade of denim garments

decreased significantly after they were exposed to hypochlorite bleach treatment particularly at higher concentrations of the bleach. The part of the primary wall of cotton is always in contact with bleach during washing, so at the contact point surface of fibers are decomposed by the aqueous solution of hypochlorite bleach and bleach washed denim garments become duller and color is faded. As a result, the indigo dyed colored warp yarns in denim garments restoring to its original white color, because warp yarns are surface dyed [10]. The results disclose that increasing the bleach concentration from 5 to 15g/l has effect on color shade change, and 10g/l concentration is the optimum result for color fading of denim garments.

Denim decomposition by measuring the stiffness from denim garments was monitored. As evident, the stiffness of the denim garment decreased at 5g/l concentration significantly after treatment with hypochlorite bleach, and the decrease was more pronounced at higher bleach concentration up to 15g/l. By bleach treatment, the cotton fibers are loosened due to fibrils are degraded and partly detached from the main fiber chain, and softness increased. After treatment with hypochlorite bleach, the sizes (starch) of warp yarns were removed. As a result bending length was less and softness was increased. The increase was more pronounced at higher bleach concentration up to 10g/l and softness was 24%. The same holds true for the water absorption also. With 10g/l bleach concentration the water absorption rate of denim garment was 141%, whereas unwashed denim was 128% absorption.

Moisture content is a measure of the level of water in the denim samples. It can be seen from Table 1 that the moisture contents of the bleach treated samples with various concentrations from 5g/l – 15g/l are similar and are the range of 8.3-8.51%, whereas untreated sample was 7.5%. Same holds true for the elongation at break also. Elongation at break of the treated denim garments with various concentrations is similar and the range of elongation 41-48% lengthwise and 21-22% widthwise, whereas untreated sample was 24% and 16% respectively.

It can also be observed seen from Table 1 that, treatment of the denim garments with hypochlorite bleach at 5g/l concentration cause significant decreased the GSM (fabric weight) of the garments, whereas weight loss (GSM decreased) results have previously been obtained with direct and reactive dyed cotton fabric substrate. During weaving cotton fabrics were subjected to considerable tensions, particularly in the warp direction. In subsequent finishing processes such as calendaring this stretch was increased and temporarily set in the fabric. The fabric is then in a state of dimensional instability [11]. Subsequently when the denim garment was thoroughly wetted in bleach washing, it tended to revert its more stable dimensions which results in the contraction of the yarns. This effect is usually greater in the warp direction than in the weft direction. This is known as relaxation shrinkage [11]. Due to relaxation shrinkage, PPI (picks per inch) was increased than untreated denim garments, as a result fabric weight loss is slightly minimized and 10g/l concentration is optimum result for bleach washing. Although decomposition occurred in hypochlorite bleach washing, at the same time relaxation shrinkage happened, and the GSM

/fabric weight loss of denim garments were minimized slightly. This was observed that 10g/l concentration exhibits the minimum decrease in the fabric weight as compared with the other concentrations.

Thus, 10g/l bleach wash is optimal and this concentration of bleach exhibited the maximum decrease in fabric stiffness; and maximum increase in water absorption, elongation at break and GSM as compared with the other concentrations.

### 3.2 Temperature of Hypochlorite Bleach Treatment

The effects of bleach in denim garment washing under the influence of 40, 45, 50, 55 and 60°C for 20 min were investigated. The effect of temperature on loss in tensile strength, stiffness, color fading, fabric weight, elongation at break, water absorption, moisture regain, moisture content and shrinkage is shown in Table 2. By and large the results disclose that raising the bleach washing treatment from 40 to 60°C has an adverse effect on tensile strength, stiffness and color fading. With decreased tensile strength, the elongation at break decreased by elevating the washing temperature within the range studied. Temperatures of washing treatment specifically 55 and 60°C decrease the color shade remarkable. The effect of temperature on stiffness and water absorption is clear particularly when washing was performed at 40 and 45°C, because the looseness of surface fibers by washing temperature. The loss of GSM exhibit values which were at 40 and 45°C. The effect of temperature on surface roughness is clear particularly when bleach wash was performed at 40°C. So, it can be selected that 40°C washing temperature is optimum result for bleach washing.

Table 2: Effect of temperature on the physical and mechanical properties of treated denim garments.

Temp. (°C)	Tensile strength (Kg f)		Dimen- sional stability/ shrinkage (%)	Weight of fabric (GSM)	Stiffness  (cm)	Water absorp- -tion (%)	Moisture content (%)	Moisture regain (%)	EPI & PPI (ends/in & picks/in)	Elong- ation at break (%)	Color shade (grey scale)
	Warp	Weft									
0.0 Before wash	246(0)	137(0)	0	381(0)	4.35(0)	128	7.50	7.60	70 x42	L=24 W=16	5
40	219 (-11%)	129 (-6%)	L= - 6.0 W= +0.5	372 (-2.37%)	3.3 (-24%)	141	8.40	8.54	70 x45	L=44 W=21	3
45	209 (-15%)	129 (-6%)	L= - 6.0 W= +0.5	370 (-2.89%)	3.3 (-24%)	144	8.44	8.56	70 x45	L=42 W=21	2/3
50	197 (-20%)	125 (-9%)	L= - 6.5 W= +0.5	368 (-3.5%)	3.2 (-26%)	145	8.53	8.57	70 x45	L=40 W=21	2
55	180 (-27%)	119 (-13%)	L= - 7.0 W= +0.5	362 (-5%)	3.2 (-26%)	143	8.52	8.55	70 x46	L=37 W=20	1/2
60	162 (-34%)	115 (-16%)	L= - 7.0 W= +0.5	358 (-6%)	3.4 (-22%)	142	8.46	8.52	70 x46	L=33 W=20	1/2

A value at 0.0 concentrations represents the denim garments without bleaching powder treatment.

Conditions used for bleach washing treatment: bleaching powder, 10.0 g/l; soda ash, 5g/l; temperature, 40-60°C; time, 20 min; pH, 10.5; M: L ratio, 1:10.

### 3.3 Time of Bleaching Powder Treatment

The effects of hypochlorite bleach in denim garment washing under the influence of 20, 25, 30, 35 and 40 min at 40°C were investigated. The effect of time on tensile strength, stiffness, color fading, fabric weight, elongation at break, water absorption, moisture regain and content and shrinkage is shown in Table 3.

Table 3 shows results of denim fabric properties after being applied various times. The comparison indicates that there are marginal differences in moisture content, moisture regain, shrinkage, GSM, EPI and PPI. But it affects on fabric strength loss, color fading, softness and elongation at break with the increases of time up to 40 min. So it can be selected that 20 min time is optimum for denim washing with hypochlorite bleach.

Table 3: Effect of time on the physical and mechanical properties of treated denim garments by bleach washing.

Time (min)	Tensile strength (Kg f)		Dimensional stability/ Shrinkage (%)	Weight of fabric (GSM)	Stiffness (cm)	Water absorption (%)	Moisture content (%)	Moisture regain (%)	EPI & PPI (ends/in & Picks/in)	Elongation at break (%)	Color shade (grey scale)
	Warp	Weft									
0.0 Before wash	246(0)	137(0)	0	381(0)	4.35(0)	128	7.50	7.60	70 x42	L=24 W=16	5
20	219 (-11%)	129 (-6%)	L= - 6.0 W= + 0.5	372 (-2.37%)	3.3 (-24%)	141	8.40	8.54	70x45	L=44 W=21	3
25	207 (-16%)	127 (-7%)	L= - 6.0 W= +0.5	372 (-2.37%)	3.3 (-24%)	142	8.42	8.55	70 x45	L=43 W=21	2/3
30	197 (-20%)	127 (-7%)	L= - 6.0 W= + 0.5	368 (-3.4%)	3.45 (-21%)	141	8.40	8.54	70x45	L=40 W=21	2
35	185 (-25%)	123 (-10%)	L= -6.3 W=+1.0	365 (-4.1%)	3.48 (-20%)	140	8.39	8.54	69 x46	L=38 W=20	2
40	180 (-27%)	123 (-10%)	L= - 6.3 W= +1.0	364 (-4.4%)	3.52 (-19%)	140	8.39	8.55	69 x46	L=37 W=20	1/2

A value at 0.0 concentrations represents the denim garments without bleaching powder treatment.

Conditions used for bleach washing treatment: bleaching powder, 10g/l; soda ash, 5g/l; temperature, 40°C; time, 20-40 min; pH, 10.5; M: L ratio, 1:10.

### 3.4 Scanning Electron Micrograph

Scanning electron microscopy was done on the untreated sample and after bleach washed sample. Fig. 1 shows SEM images of untreated cotton denim garment. The figure shows smoothed surfaces and no ruptures were visible in the images, because yarns are coated with sizing materials.

Fig. 2 shows SEM images of bleach treated cotton denim garment. The figure shows loosened, degraded and ruptured surfaces that are produced with the aqueous solution of hypochlorite bleach and abrasions were due to mechanical friction by washing machine in processing. As observed from the figure 2, there are more cracks on the surface of fibers. This is formed on cotton denim garments to bleaching attack.

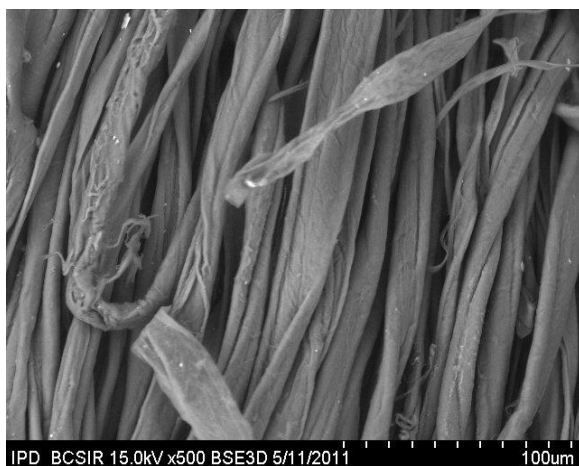


Fig 1(a). Scanning electron micrograph of untreated denim garment.

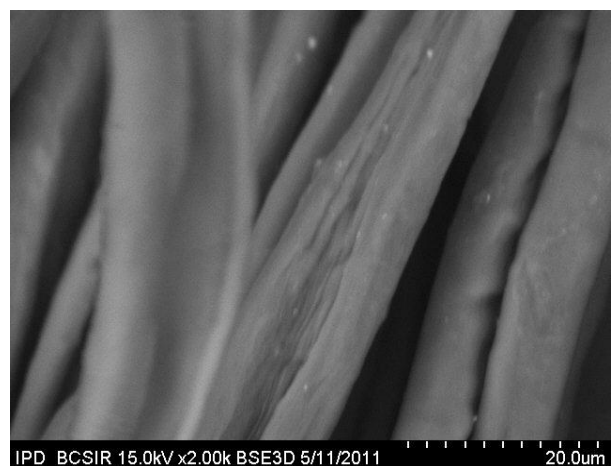


Fig. 1(b). Scanning electron micrograph of untreated denim garment (magnified).



Fig 2(a). Scanning electron micrograph of denim garment after bleach treatment.

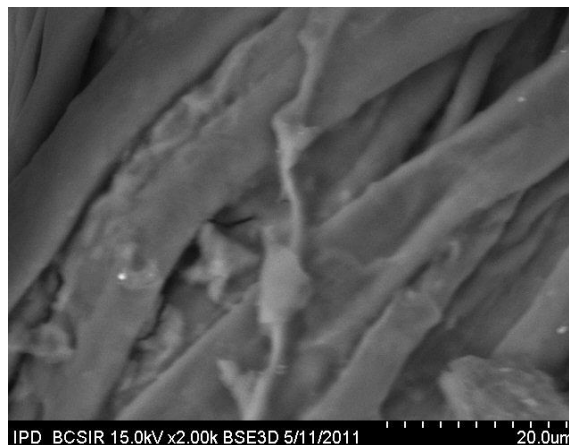


Fig 2(b). Scanning electron micrograph of denim garment after bleach treatment. (magnified)

#### 4. CONCLUSIONS

The effect of bleach washing of the denim garments under investigation could be realized by comparing the physical and mechanical properties, namely, tensile strength, stiffness, color fading, water absorption, moisture regain, elongation at break, weight loss and shrinkage before and after bleach washing. The tensile strength, stiffness, fabric weight and color shade decrease after hypochlorite bleach washing treatment. Examination of the bleach treated fabrics by SEM shows more crack and decomposition on the surface, as a result fibers are loosened, weaker and rough surface on denim fabrics. It is further noted that unwashed denim samples are almost more smooth, stiffer, and harder and less water absorbent than the bleach treated cotton denim garments.

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