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Research Article

Development of Eco-friendly Garments Washing for Localized Fading Effect on Garments: A Future Sustainable Process for Single Step Dyeing Fading Effect

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Abstract

This article deals with some unconventional but eco-friendly processes for creating fading effect on denim garment dyed with natural indigo dye. Three different methods namelya) fading by UV radiation of sunlight [Method I] b) fading by calcium hydroxide [Method II] and c) fading by stitched with extra fabric [Method III] were followed for during experiment. To measure and compare the different physico-mechanical properties for instance color strength, rubbing fastness, drape- ability, fabric stiffness and fabric strength of the developed samples, in depth characterization was conducted. Appreciable results were observed for the faded sample developed by method III, exhibiting higher fading percentage i.e. 84.58% with higher drape ability, lower stiffness and higher strength.

Keywords: Denim; Fading; Natural indigo dye; Physio-mechanical properties

Introduction

Outlook of the garments is one of the most powerful aspects of its quality [1] and various chemical and mechanical treatments on ready-made garments offer the creation of very interesting and original visual effects on their surfaces. One of the current fashion trends is vintage look or aged look or faded look for casual wear which have become very popular amongst young customers [2]. In most cases, this worn look is applied to the garments made of denim fabric [3-5]. This fashionable effect may be obtained using laser, scraping, rubbing, sandblasting or through various wet treatments with enzymes, oxidizing agent, bleaching agents and pumice stones etc. The degree of fading may be adjusted to suit the physical properties of the fabrics as well as garments [6-8]. However, fading processes, which change the aesthetic appearances of denim products, also cause deterioration in their structural and mechanical properties, especially their strength and durability [8,9]. Also manual scraping and rubbing process have discrete work flow problem causes much time consumption, inability to create standard designs, inability to produce identical fading effect on both sides of the products [10]. Besides enzyme wash, which is eco-friendly, breaks the cellulose fibers from the fabric's surface. The broken fibres and certain amount of dye are removed during the washing process. This process must be strictly controlled enzyme's sensitivity to temperature, time and pH. These three parameters have significant effect on the results and particularly large variations can cause damage to fabric. Jevsnik et al. [10] showed that an increase in enzyme dosage causes cotton fabric to become smoother, but also thinner. Therefore, although enzymatic treatment causes "polishing" of the surface of fibers, it reduces not only fabric's flexural rigidity but also breaking strength due to destruction of the fiber structure. Fading conditions also affect the color change intensity. An increase in enzyme's (cellulose) concentration increases fabric brightness. During enzyme wash, cotton fabrics may lose 10% of their weight and about 5%-15% of its strength [10-11]. Mechanical action, such as abrasion, may also change fabric appearance and color [12]. The degree of change depend on the fabric characteristics and the conditions of rubbing. Though abrasion may cause a more worn appearance and give an aged look to the garment, it can damage the fabric and greatly reduce its mechanical properties. In addition, the production of faded looks in fabric using conventional technologies involves large amount of water and most of which being highly contaminated by chemical products used in the process. Especially sand blasting fading process is posses seriously health hazards and banned by many countries. Also the time consuming and old-fashioned processes are not suitable for mass production as they increase production cost [13-15]. Therefore, researchers have been trying in recent years to develop various techniques to improve the visual aspect of fabrics especially the faded looks [16-18]. Fading with CO_2 laser treatment, ozone treatment, bio-stoning technology, natural reducing agents are some mentionable contemporary researches in fading technology [18-22].

In this study three new techniques have been developed and applied to denim fading processes using natural indigo dye and analyzed their performance regarding to ecological impact with process sustainability.

Materials and Methods

Materials

Natural indigo dye (Brand-living blue), natural reducing agent (Date), calcium hydroxide were used for reduction and dyeing. Commercially unbleached grey denim fabric (3/1 twill) was collected from local market and scoured & bleached by using sodium hydroxide, hydrogen peroxide, wetting agent, sequestering agent, stabilizer, acetic acid etc. The fabric specification was EPI = 75, PPI = 42, warp count = 10 Ne, weft count = 10 Ne and GSM = 340.

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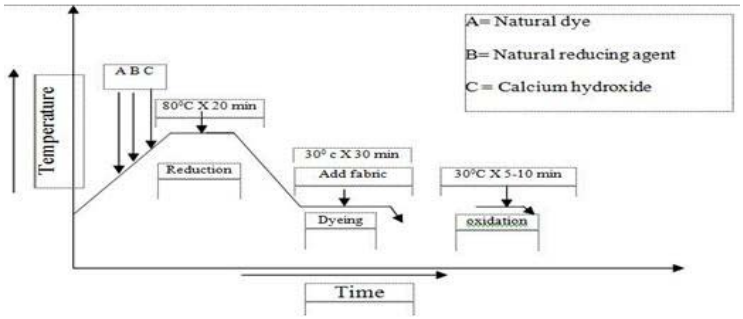

Figure 1: Dyeing curve of cotton fabric with Natural Indigo Dye.

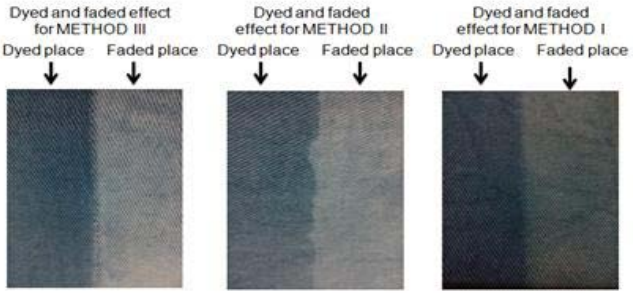

Figure 2: Faded effect of different developed sample.

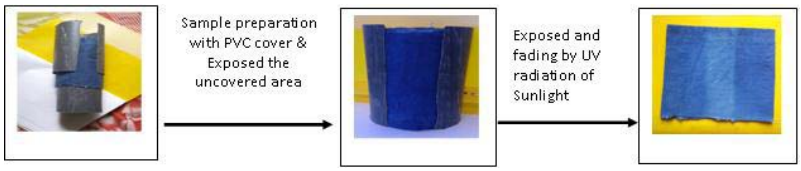

Figure 3: Fading process by UV radiation by sunlight.

Figure 4: Fading process by coating with calcium hydroxide $Ca(OH)_2$.

Equipments

The garments dyeing and testing procedure was performed by using the following equipments: Electronic balance (Model: PGW-253i, Origin-UK), spectrophotometer (Model-650, Brand-Data Color, Origin-USA), Tumble dryer (Model-VT DOOP, Brand-Hot Point, Origin-UK), Drying oven (Model-HX30, Brand-James H. Heal, Origin-UK), P^H meter (Brand-Eutech, Origin-Singapore), Fabric drape tester (Model-M213, Brand-SDLATLAS, origin-UK), Testrometric machine (Model:M250-3CT, Origin-India), Fabric stiffness tester (Model-M003B, Brand-Mesdan, Origin-UK), Rubbing fastness tester(Crock meter, Model- 670, Brand- James H Heals, Origin - UK).

Pre-treatment of the samples

The collected fabric was scoured and bleached with- H_2O_2 @ 5cc/l, NaOH @ 4g/l, Na_2CO_3 @ 2g/l, wetting agent@ 1cc/l, sequestering agent @1cc/l keeping temperature 90°C for 55 minutes. After that neutralization was done with acetic acid @ 1 cc/l at room temperature for 10 minutes. The M: L ratio for both stages maintained was 1:20.

Dyeing of the samples

Pre-treated samples were dyed with above mentioned natural dye for all method. The recipe was- Natural dye@10 gm/l, reducing agent@200 ml/l and $Ca(OH)_2$ @ 10-15 gm/l. During dyeing temperature was at 30°C and alkaline pH was maintained keeping M: L ratio1:20. The procedure of dyeing is shown in (Figure 1).

Development of fading effect

Three different fading processes were followed to develop fading effects following the same dyeing process. The comparison of fading effect created by all processes is shown in (Figure 2).

Figure 5: Fading process by stitching with extra fabric.

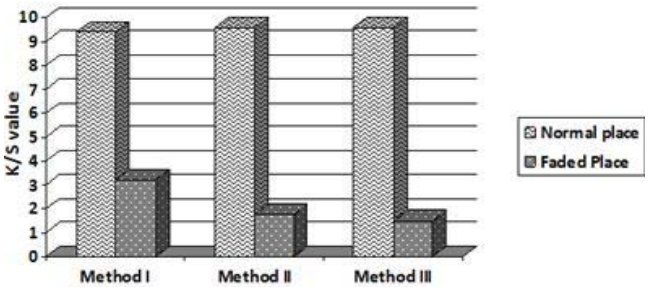

Figure 6: K/S value of different methods.

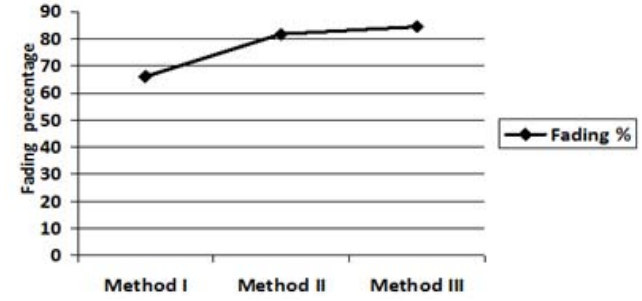

Figure 7: Fading percentage of different methods.

Method I: Fading by UV radiation of sun light: This a post fading technique where after dyeing samples panels are covered with PVC and left the desire fad area uncovered and exposed on direct sunlight with different time interval which are 1hrs, 3hrs, 5hrs, 1day, 2day, 3day and 6day. The procedure is given in (Figure 3).

Method II: Fading by calcium hydroxide: This is a pre-process for achieving fading next to dyeing process. This consist of coating on the pre-treated samples with 10gm/l solution of $Ca(OH)_2$ and then dried at room temperature and finally dying with natural indigo dye. After washing and drying the fading effect developed simultaneously with dyeing effect. The procedure is given in (Figure 4).

Method III: Fading process by stitching extra fabric: This consist of a dyeing the samples with given recipe, followed by stitching the extra fabric in particular area where fading effect is necessary to create. After washing and drying removal of extra stitched fabric gives a desire fading effect on the dyed garments. After washing and drying the fading effect developed simultaneously with dyeing effect. The procedure is given in (Figure 5).

Testing and analysis

Tensile strength and elongation at break was determined by using fabric strength tester according to ASTM-D-5034 test method. Fabric stiffness measured according to ASTM D1388 method using cantilever stiffness process also fabric drapebility was tested according to Cusick Drape test (BS 5058) method. Color fastness to rubbing was measured using ISO 105 X 12: 1993 method.

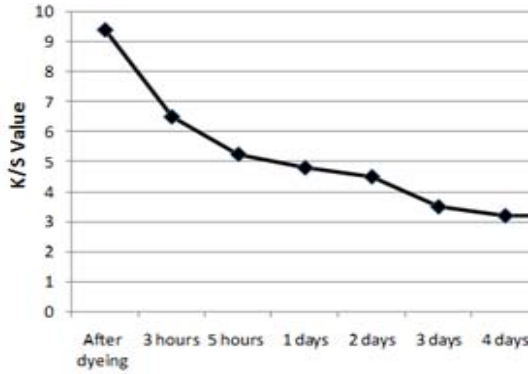

Figure 8: K/S value of UV radiation fading by sunlight.

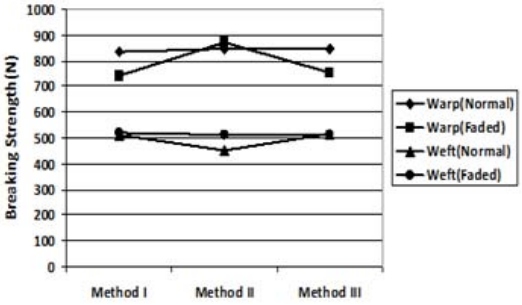

Figure 9: Comparison of breaking strength for different fading methods.

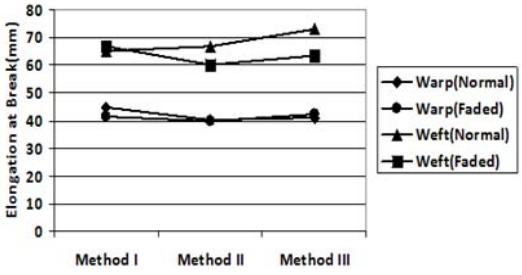

Figure 10: Elongation of normal place and faded place in warp and weft direction.

K/S value determination

The K/S value at 650 nm was determined by Data Color spectrophotometer. The color yield of dyed samples was evaluated by light reflectance measurement using Data Color machine. The color strength (K/S value) was evaluated utilizing the following Kubelka-

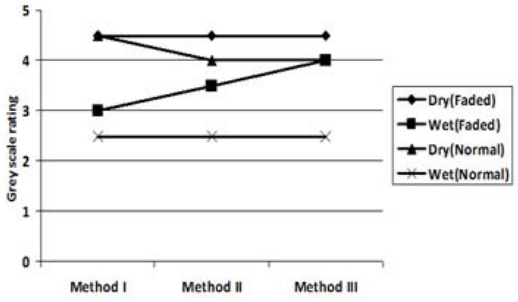

Figure 11: Color change value in rubbing test on faded place.

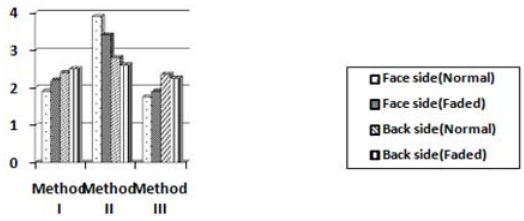

Figure 12: Sample bending length of three processes.

Munk equation:

$K/S = (1-R)^2/2R$ (Figure 6)

Results & Discussion

Analysis of color change

Color changes have been observed for different developed process of fading. Among all of these results, desired faded effect on the denim goods could be obtained by stitching with extra fabric. The experimental results show the differences among the samples of Method I, Method II and Method III with respect to their K/S values (Figure 7). The decreased value of K/S indicates fading efficiency of different methods and higher fading percentage was obtained for Method-III having value of 84.58 and Method I shows less fading percentage of 62.76%. However in case of Method I, fading percentage and intensity depends on duration of time. Figure 8 gives a clear idea about the increment of fading effect depending upon time and up to 5 days the fading effect gives a proportionate relation and after that it reaches to its optimal condition.

Effect of different fading technique on fabric strength and elongation

Changes in strength in warp and weft direction were determined as results of fading effects were realized after Method I, Method II and Method III were being applied. Higher strength loss resulted after method I and low strength loss was analyzed for method III (Figure 9, 10).

Effect of different fading technique on color fastness to rubbing

The color fastness of the samples by using different fading methods was determined (Figure 11). shows the collar fastness to rubbing results from faded place is comparatively higher than the dyed place. In case of rubbing fastness method III shows higher results with grade 4-5 for dry and grade 4 for wet condition. As it is expected the results are better than wet condition. This implies that the faded area contain less dyes in the surface of the samples after treat them with different method. In addition it is also confirmed that the method III is more effective as the rubbing fastness is higher and prove for less dye presence at the faded surface.

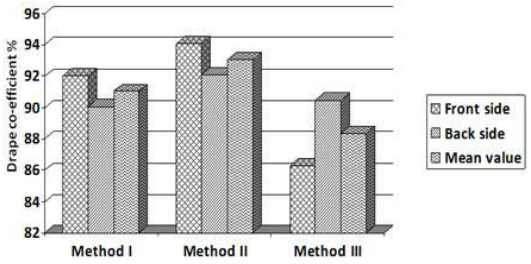

Figure 13: Drape co-efficient of samples developed in different methods.

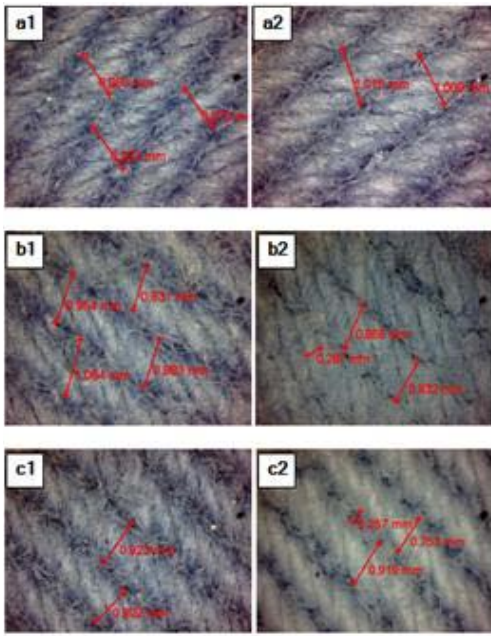

Figure 14: Morphology of experimental samples; a1) dyed sample of Method I a1) faded sample of Method I b1) dyed sample of Method II b2) faded sample of Method II c1) dyed sample of Method III c2) faded sample of Method III.

Effect of different fading technique on fabric stiffness

Analysis of fabric stiffness results show that, method III has less bending length, thus it can be said the fabric contain more comfortably to ware (Figure 12). Moreover, bending length is higher in Method I. In addition to, the bending length of method II is slightly higher than method III. This is due to the treatment of $Ca(OH)_2$ solution the fabric surface getting rough and stiffer than method II. In addition due to expose by UV radiation from sunlight, the fabric presents an uneven surface due to degradation.

Effect of different fading technique on fabric drapes co-efficient

Figure 13 shows the drape co-efficient after different fading methods. It is known that drape co-efficient indicates the handle properties of fabric. Higher the drape co-efficient results softer the

fabric. In this research faded samples were examined separately from Method I, Method II and Method III. As a result of drape co-efficient %, it was observed that drape co-efficient % value is higher for Method III than Method II. Results variation can expressed in terms of fabric softness which can be more for Method III samples. Sample of Method III is softer than Method I as no chemical treatment is required here. On the other hand, due to exposure of sunlight, sample surfaces become rough and irregular for Method I whereas because of chemical exposure, samples get more hard and grumpy effect for Method II.

Morphology analysis of different samples

Figure 14 illustrates the microscopic images of Method I, Method II and Method III at 50X magnification with the help of digital camera by Coolingtech. Result reveals that the degree of fading is higher in c2 and the surface is clear and compact than b2 and a2 respectively. The existence of $Ca(OH)_2$ is clear in b2 sample as expected and the sample a2 is fluffier, irregular having more diameter than b2 and c2.

Conclusion

Based on the results obtained, it can be concluded that the intensity of fading or fading percentage depends on the types of methods being used. The highest degree of fading occurred in Method III as the stitched fabric acts as a barrier and restricts the penetration of dye molecules on fabric surface. Additionally, this extra stitched fabric can be reused for making pockets and waist belt loops. All though Method I show less degree of fading but yet it is an ecological process where no harmful chemicals were used but occupied more time than other methods. In case of Method II, the use of $Ca(OH)_2$ makes the sample stiffer with moderate fading effect. Among the three methods, Method-III is not only easy to perform, eco-friendly & economical but also effective as showed in the result of fading percentage, drape co-efficient, fabric stiffness, fabric strength and elongation and fabric fastness properties. The results are found to be comparable to those samples which are obtained from conventionally faded samples, even better at many instances of other experimental methods hence the processes can be easily adopted in the industry.

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