STRETCHABLE DENIM PROPERTIES DEPENDENCY ON INDUSTRIAL WASHING TECHNIQUES

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Abstract: *Day by day washing process of denim is turning into the art of new fashion trends as it can create various sorts of style and effect in the denim garment. On account of washing, the properties of denim are additionally built up that expands consumer esteem. The target of the present research work is to disclose the modification of the characteristics of the spandex containing denim fabrics after applying different industrial washing techniques. To perform this work, 3/1 twill weave denim fabric composed of 98% cotton along with 2% spandex has been taken and subjected to different industrial washing techniques viz. bleach, acid, potassium permanganate, enzyme and stone enzyme washing. The surface density of the fabric, weight loss, shrinkage, colour fastness to wash, rubbing, phenolic yellowing, tearing strength and tensile strength have been determined to assess the impact of washing techniques on spandex containing denim fabric. The tested results claim that significant changes have occurred in the denim properties by introducing different washing techniques.*

Keywords: *Denim washing, phenolic yellowing, spandex, tearing strength, tensile strength.*

1 INTRODUCTION

The fashions of today are incomplete without denim. Denim comes in a variety of styles, looks and washes to complement every outfit. Denim is now notably using apparel globally for its consolation and durability. It is leading to the people of every age as it's the symbol of youth, fashion, and attitude and has social and cultural influence. It is an incredibly sturdy, rigid and hard-wearing woven fabric. Denim is generally composed of cotton and twill weave structured cloth used for jeans, work and informal wear, made with coloured warp and white weft yarn [1-4]. Twill fabrics are used to make durable fibrous products that are used in harsh environments. The high longevity of twill fabric is due to the twill structure's few interlacing per inch, which allows for higher fabric counts or more yarn packing. Now-a-days, several developments and innovations are done to customize the denim fabrics employing various kinds of fibres, yarns and finishing treatments. A new trend is introduced to the customer by manufacturing stretch denim fabrics. This breakthrough was made possible by the use of synthetic elastane fibres like Lycra, which can extend up to six times their original length and return to its original state several times. The lack of recovery and sagginess in older jeans after a few wears prompted this concept. Stretch yarn can be unidirectional or bidirectional in both weft and warp [4-7].

Washing is an important finishing process for amendment and introducing new fashion. The denim washing procedure is provided with a rewarding and glassy outlook with the aid of using chemical and mechanical washing processes those consumers so desire. Raw denim fabric is not suitable for clothing because of its weave structure and dyeing effects. So, in order to ensure comfort, the finishing treatments should be carried out. For this, a finishing treatment is basically required to make it softer, more flexible, smooth and comfortable to wear [7-12]. After applying different finishing treatments to the denim fabrics, it offers different shades and interferes with various properties of colour that makes denim attractive as well as influences the clients to purchase them. All applied finishing treatments make some changes of physical, mechanical and colour properties to increase the wear comfort with durability and aesthetical view [13-22].

Over the past few years, several investigators have studied the washing effects of denim garments applying different techniques [11-22]. But, a few works on the washing effects of spandex containing

denim garments have been done to establish novel design and high performance fashion [3, 4]. However, there is still a lack of information in the writing on findings of denim products with incorporated spandex, as well as changes in properties during wear.

Therefore, this article aims to determine the impacts of different industrial washing techniques on the properties of stretchable denim fabrics. The surface density of the fabric, weight loss percentage, shrinkage percentage, colour fastness to washing, rubbing, and phenolic yellowing, tearing strength and tensile strength have been observed conducive to detect the impact of washing techniques on stretchable denim properties.

2 EXPERIMENTAL

2.1 Materials

3/1 twill structure denim fabrics composed of 98% cotton and 2% spandex were used for the experiment. The main characteristics of the spandex containing denim fabric are shown in Table 1. The chemicals used for washing were procured from Redox Chemicals Ltd, Sri Lanka. All chemicals were industrial grade and used without any rectification.

2.2 Methods

Sampling design

Five different washing processes have been used in this current work. The descriptions of denim industrial washing techniques are identified in Table 2.

Test analysis

In accordance with ASTM D 3776, the fabric surface density (GSM) was determined [23] and weight loss percentage was calculated from the difference of weight (GSM) before and after the treatment of fabric. As stated in AATCC test method 96, the shrinkage percentage was determined from the difference in fabric length before and after treatment [24]. The colour fastness to washing, rubbing and phenolic yellowing were measured followed by ISO 105-C06:2010 [25], ISO 105-X12:2016 [26] and ISO 105-X18:2007 [27], respectively. Tearing strength and tensile strength of the samples were evaluated according to ASTM D1424:09 [28] and ASTM D5034 [29] correspondingly. Before testing, treated fabrics were conditioned in 65% RH at 20°C temperature for 24 hrs as maintained by ASTM D1776 [30].

Table 1 Characteristics of the unwashed sample

Fabric code	Weave	Composition	Warp and weft density [cm^{-1}]		Surface density W [g/m^2]	Linear density [tex]	
			warp	weft		warp	weft
F0	Twill 3/1	98% cotton 2% spandex	180	102	370	83	74

Table 2 Sample identification and descriptions of denim industrial washing techniques

Fabric code	Washing techniques	Description		
		Main process	Softening	Hydro-extracting and drying
F1	Bleach washing	A standard recipe of bleaching powder (10 g/L), soda ash (5 g/L), sequestering agent (2 ml/L) at pH 10, and 1:5 material-liquor ratio was applied for bleach wash and this process was carried out for 20 min at temperature of 40°C. After washing, the cold wash was carried out for 5 min.	GN Soft 150 softener was used for softening keeping the concentration of 1 g/L at liquor ratio of 1:4 for 5 min.	The processed stretchable denim fabric was squeezed in a hydro-extractor at 200 rpm for 4 min and then dried in a tumble drier for 30 min.
F2	Acid washing	Acid wash was done by acetic acid with potassium permanganate (1 g/L) and 1:5 materials to liquor ratio at room temperature for 20 min. The thermocol balls are placed in the washing machine and the solvent is diffused through the machine. Washing was accomplished at temperature of 40°C for 20 min. The cold wash was executed for 5 min after washing.		
F3	PP washing	A standard recipe of potassium permanganate (5 g/L), sodium metabisulfite (1.5 g/L), sequestering agent (2 ml/L) at 1:5 material-liquor ratio was applied for potassium permanganate washing. Washing was carried out at 40°C for 20 min. After PP wash, the cold wash was follow-out for 5 min and lastly invalidated in sodium metabisulfite solution for 20 min.		
F4	Enzyme washing	The enzyme wash was done with acetic acid (1 ml/L), anti-back staining agent (0.5 g/L), wetting agent (1 g/L), sequestering agent (2 ml /L) at pH 5.5 and material to liquor ratio of 1:4 with Cellulase enzyme (1.5 g/L) for 40 min at 50°C. And then, the cold wash was carried out.		
F5	Stone-enzyme washing	Same as Enzyme washing but only 10 kg of pumice stone was employed in the bath during enzyme wash.		

3 RESULTS AND DISCUSSION

The certain physical, mechanical and colour properties were determined to judge the impact of different industrial washing on spandex containing denim fabrics qualities. Here, the numbers of specimens are six and the result of changes in surface density, weight loss percentage, shrinkage percentage, colour fastness to washing, rubbing and phenolic yellowing, tensile strength and tearing strength are discussed.

3.1 Washing effect on surface density

The surface density was measured for all samples to analyse the impact of washing. The results are presented in Figure 1.

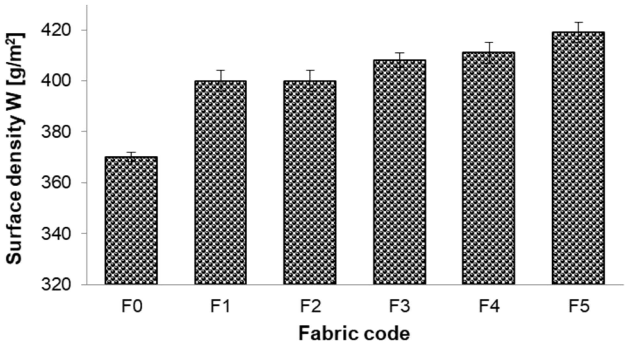

Figure 1 Surface density changes of stretchable denim fabrics at different washing techniques

As a consequence of the washing process, all the washed denim fabrics show an increase in surface density (weight per square meter). The increment of fabric weight shows the following order: F5>F4>F3>F2=F1>F0. The reason behind the increasing weight of fabrics can be explained by the changes in fabric structural parameters, like increasing the density of the yarn because of fabric shrinkage. From Figure 1, the higher increase of fabric GSM has been observed for the fabrics F5 and it is 13.24% higher than F0. Correspondingly, it was found that the surface density was shown by 8.11%, 8.11%, 10.27%, and 11.08% higher for F1, F2, F3 and F4 respectively compared to the sample F0.

3.2 Weight loss percentage

A main aspect of washing is the weight loss percentage of the denim washed specimens, as it is linked to cost benefit, excellence of washed fabrics, durability, comfort capacity and other features. The weight loss percentage of the stretchable denim fabrics has been evaluated and the results of the weight loss percentage are reported in Figure 2. The weight loss percentage of dyed denim fabric was observed not too significant. This is because of the structure of the fabric and there is less potential to allow the agencies to destroy fibres. However, the weight loss percentage of bleach wash, acid wash and PP washed samples showed moderately high among all types of washing techniques, since oxidative treatment caused some damage to cellulose. In comparison, the cellulase enzyme hydrolyses the cotton during enzyme wash which is very prominent in knit fabrics due to this floppy structure. Whatever, firstly cellulose enzyme impairs projecting fibres on the surface, then attacks on the yarn portion; here the hydrolyse action is very slow due to the compact structure of denim. That is why in case of enzyme and enzyme-stone washing, cellulose degradation or weight loss percentage is insignificant for denim wash. However, the highest weight loss was observed for bleach washed sample and lowest for enzyme washed sample. The sample order was found as F1>F3>F2>F5>F4.

The weight loss was observed 177.8%, 144.4%, 155.6% and 44.4% higher for bleach, acid, PP and stone-enzyme washed specimen compared to enzyme washed specimen.

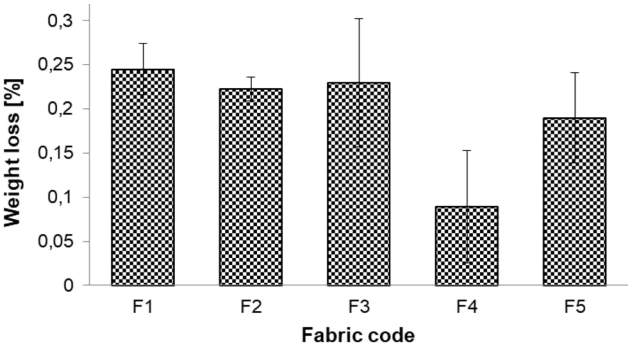

Figure 2 Weight loss percentage of stretchable denim fabrics at different washing techniques

3.3 Shrinkage percentage

It is important to measure fabric shrinkage in the phase of clothing design; otherwise, measurements of a readymade article would mismatch the planned ones. Results of the denim shrinking capacity after industrial washing are presented in Figure 3.

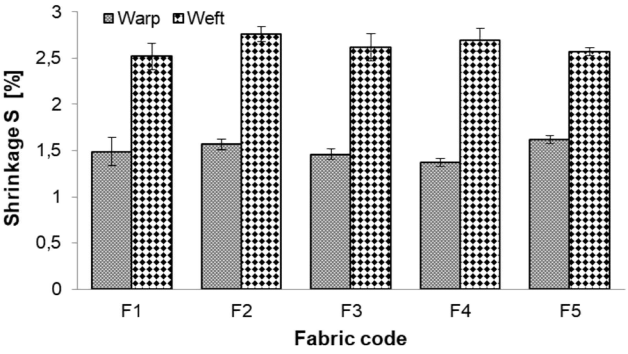

Figure 3 Shrinkage behaviour of denim of stretchable denim fabrics at different washing techniques

Table 3 Colour fastness to wash

Fabric code	Colour change	Staining					
		Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
F0	4	4/5	4	5	4/5	4	4/5
F1	4	4/5	4	5	4/5	4	3/4
F2	3/4	4	3/4	4	4/5	3/4	4
F3	4	4	3/4	4	4/5	4	4
F4	4	4/5	4/5	4/5	4/5	4/5	3/4
F5	4	4	3/4	4/5	5	4/5	4

Analysis of the findings reveals that different shrinkage value has found against various washing techniques. The shrinkage of stretchable denim is intimately linked to the alternation in its structural features after washing. Shrinkage in the weft showed higher than that of warp direction. In the case of warp direction shrinkage, the sample order was found as F5>F2>F1>F3>F4. Regarding weft direction shrinkage, the sample order was found as F4>F2>F3>F5>F1.

The stone-enzyme washed sample shrank the most in the warp direction, while the enzyme washed sample shrank the least. As compared to enzyme washed specimens, shrinkages were 8.76%, 14.59%, 6.57%, and 19.71% higher for bleach, acid, PP and stone-enzyme washed specimens in the warp direction.

In the weft direction, the highest shrinkage was observed for the acid washed samples and the lowest for bleach washed samples. The shrinkages were observed 9.52%, 3.97%, 7.14% and 1.98% higher for acid, PP, enzyme and stone-enzyme washed specimen compared to bleach washed specimen in the weft direction.

3.4 Colour fastness to wash

Table 3 presented the colour fastness to wash. The overall results of colour fastness to washing of samples were very good to excellent.

F1, F3, F4 and F5 samples were shown very good and F2 showed good to very good results in colour change. From the Table 3 it is depicted that only washing does not affect the colour fastness property of denim fabric too much. Before washing, colour change grading was 4. Slightly colour staining has occurred on cotton and wool for all samples.

3.5 Colour fastness to rubbing

Observing the changes in colour properties of the denim after rubbing is an important factor. The rubbing fastness of the washed denim specimens is presented in Table 4.

From the Table 4, it is observed that better results showed for dry rubbing than wet rubbing in all cases. The very good to excellent fastness properties have been found for the denim fabrics F1 and F2. Very good fastness result has been shown by the sample F3 and moderate results showed for F4 and F5 in dry conditions. A very poor result has been found for the fabric F4 caused by enzyme washing in wet conditions. So, it is cleared that bleach and acid washed specimens showed very good to excellent rubbing fastness in dry conditions. Conversely, bleach, acid and PP washed samples showed comparatively good rubbing results in wet conditions.

Table 4 Colour fastness to rubbing for dry and wet

Fabric code	Rubbing	
	Dry	Wet
F0	4	2
F1	4/5	3
F2	4/5	2/3
F3	4	2/3
F4	3	1
F5	3	1/2

3.6 Colour fastness to phenolic yellowing

Table 5 indicates the effect of washing on colour fastness to phenolic yellowing of denim fabric.

Table 5 Colour fastness to phenolic yellowing

Fabric code	Change in colour
F0	4/5
F1	4/5
F2	4/5
F3	4/5
F4	4
F5	4

According to the Table 5, it is depicted that colour fastness properties to phenolic yellowing were shown grading of 4-5 for the fabric sample of F0, F1, F2 and F3. That means, the specimens of before wash and after bleach, acid and PP wash were shown very good to excellent colour fastness to phenolic yellowing. For the fabrics of F4 and F5, the fastness to phenolic yellowing grading decreases and it is 4. It means, by doing enzyme and stone enzyme wash, it shows a very good washing effect to the denim fabrics.

3.7 Washing effects on tearing strength

The data of differently washed denim fabric is shown in Figure 4 describes tearing strength changes of the fabric both in warp and weft direction.

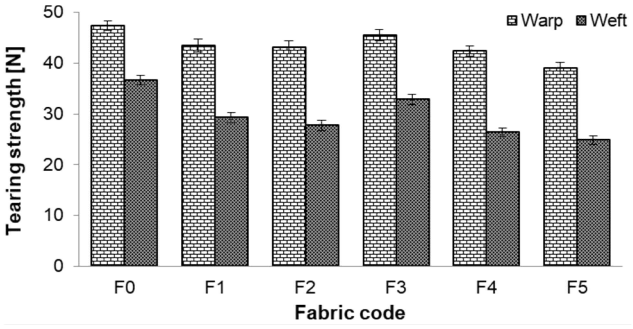

Figure 4 Changes in tearing strength of stretchable denim fabrics at different washing techniques

From the Figure 4, it was found that tearing strength alters due to washing and it decreases. Enzyme washed sample was excessively affected in both its warp and weft direction because the enzyme hydrolysed the cotton. In the case of tearing strength in the warp direction, it was observed that the change was not very prominent. The higher tearing strength was detected in warp direction caused by PP wash and less by stone enzyme wash compared in all washing processes (Figure 4). It was observed that the tearing strength in warp direction was 8.32%, 8.98%, 3.93%, 10.52%, and 17.80% lower for F1, F2, F3, F4, and F5 respectively compared to the sample F0.

Accordingly, in the warp direction tearing strength, it was observed that the change was noticeable in the weft direction. The higher tearing strength was detected in the weft direction caused by PP wash and less by stone enzyme wash also compared in all washing processes (Figure 4). It was observed that the tearing strength was 20.24%, 24.20%, 10.43%, 27.94%, and 32.34% lower for F1, F2, F3, F4, and F5 respectively compared to the sample F0 in the weft direction. So, it is found that the best washing effect on tearing strength was gained by PP wash. On the contrary, stone enzyme wash shows less tearing strength both for warp and weft direction.

3.8 Washing effects on tensile strength

The tensile strength of denim is a dominant variable and basically, testing is carried out onto warp and weft direction separately. Here, Figure 5 presents the results of the effects of washing on tensile strength in the direction of warp and weft for the denim fabric.

For tensile strength in the warp direction, it was observed from Figure 5 that the sample F3 showed the highest strength, and F4 showed the lowest strength. It was found that the tensile strength was 9.80%, 8.26%, 6.24%, 14.90%, and 11.76% lower for F1, F2, F3, F4, and F5 respectively compared to the sample F0.

For weft direction, the same scenario was observed for tensile strength. The specimen of F3 showed the highest tensile strength and F2 and F4 showed the lowest tensile strength (Figure 5). It was observed that the tensile strength was 16.96%, 22.32%, 11.61, 22.32% and 16.96% lower for F1, F2, F3, F4, and F5 respectively compared to the sample F0. So, it is depicted that enzymes give the higher washing effect of tensile strength in both warp, and weft direction and less effect were obtained for PP wash.

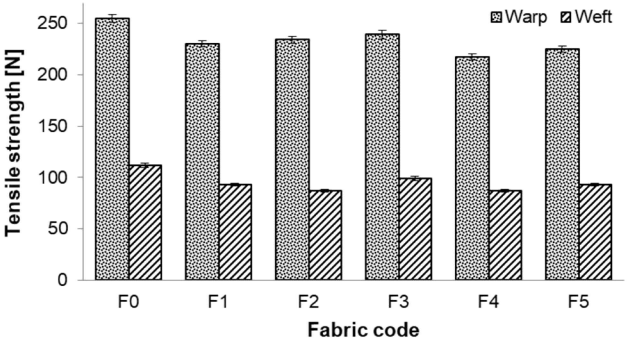

Figure 5 Changes in tensile strength of stretchable denim fabrics at different washing techniques

4 CONCLUSIONS

Denim washing is the core of the denim finishing and final process of denim production. After washing it becomes preferable to wear. This experiment deals with the changes of different properties of denim fabric after implementing different industrial wash. In this study, different characterizations such as surface density changes, shrinkage and weight loss percentage, colour fastness to wash, rubbing and phenolic yellowing, tearing strength and tensile strength were evaluated. Based on the related test outcomes it was obtained that the surface density of the fabrics increases especially stone enzyme washed specimen shows higher value. The colour fastness of the denim fabrics due to washing is very good to excellent for all washes. Excellent colour fastness is gained to phenolic yellowing for bleach, PP and acid washes and good colour fastness is found for enzyme and stone enzyme wash. For dry conditions, bleach and acid wash show excellent rubbing fastness than PP, enzyme and stone enzyme wash. For wet conditions, bleach wash shows good rubbing fastness. Tearing strength in the warp direction of PP wash is higher and less for stone enzyme wash while in the weft direction enzyme wash shows higher tearing strength and stone enzyme wash shows less. Determining tensile strength in the warp direction, the highest value is found for stone enzyme wash,

while acid and enzyme wash shows less tensile strength. All these test results will help to make sure of new possibilities for further changes in denim production to grab consumer attraction.

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