(REFEREED RESEARCH)

INVESTIGATION OF EFFECT OF SPECIAL WASHING PROCESSES ON DENIM FABRICS' PROPERTIES

ÖZEL YIKAMA UYGULAMALARININ DENİM KUMAŞ ÖZELLİKLERİNE ETKİSİNİN İNCELENMESİ

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ABSTRACT

In this study, the effect of different washing processes on various performance and surface properties of denim fabrics were examined. For this purpose, 3 different types of fabrics (1/1 plain, 2/2 twill and 3/1 twill constructions) were produced from 100% cotton yarn, and 4 different types of washing processes (rinse, enzyme, stone and stone+bleach) were applied. The effect of woven structure and washing processes on denim fabrics performance properties like dimensional stability, breaking strength, tearing strength, bending rigidity, surface views examination and colorimetric evaluation were investigated statistically.

Key Words: Denim, Washing, Enzyme, Stone wash, Rinse.

ÖZET

Bu çalışmada, denim terbiyesinde uygulanan farklı yıkama işlemlerinin denim kumaşların çeşitli performans ve yüzey özelliklerine etkisi incelenmiştir. Bu amaçla, %100 pamuklu iplikten 1/1 bezayağı, 2/2 dimi ve 3/1 dimi konstrüksiyonlarında olmak üzere 3 farklı kumaş üretilmiş, bu kumaşlara rinse, enzim, taş ve taş + hipo olmak üzere 4 farklı yıkama işlemleri uygulanmıştır. Yıkanmış numunelerin boyut değişimi, kopma mukavemeti, yırtılma mukavemeti, eğilme dayanımı, yüzey özellikleri ve renk değerlendirmesi incelenerek istatistiksel olarak örgü yapısının ve yıkama işlemlerinin denim kumaş performans özelliklerine etkisi incelenmiştir.

Anahtar Kelimeler: Denim, Yıkama, Enzim, Taş yıkama, Rinse.

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1. INTRODUCTION

Denim fabric is the most popular fabric type in garment manufacturing. Denim, which is characterized with certain physical properties, is a generally cotton fabric produced for work and sportswear for years thanks to superior abrasion and tear resistance than other fabric types like gabardine and poplin. Denim fabric is used to produce trouser, jacket, shirt, working cloths and bags etc. Its production and the consumption have increased day by day (1).

Nowadays with development of washing processes and chemicals features used, various types of washing processes were applied to denim fabrics. Denim products had submitted without washing, only desizing material out until 1970's. Accordingly, conditions of use of consumers it was taken own color and abrasion effects in time. However, this process takes a long period of time, denim manufacturers were developed different methods for made it in shorter processes (2). These washing methods mentioned in this study were explained below briefly. Also studies about the effect of washing process on denim fabrics can be summarized as follows.

Stone wash

Stone washing is a textiles manufacturing process typically utilized by the fashion industry, in order to give a newly-assembled cloth garments a worn-out appearance. Stone-washing also helps to increase the softness and flexibility of otherwise stiff and rigid fabrics such as canvas and denim. The process does literally use large stones to roughen up the fabric being processed. The garments are placed in a large horizontal industrial clothes washer that is also filled with large rocks. As the wash cylinder rotates, the cloth fibers are repeatedly pounded and beaten as the tumbling stones ride up the paddles inside the drum and fall back down onto the fabric. Stone washing is similar in operation to a ball mill, except that this is a wet process. Stonewashed jeans are jeans that have been treated to produce a faded, worn appearance. This is usually accomplished either by washing the jeans with pumice in a rotating drum, or by using chemicals to create the appearance without the use of a rotating drum. Stonewashed jeans were a popular fashion trend in the 1990s (3).

Denim bleach

Result of this type of bleaching is generally blue tone. It can be possible to reach the light colors with hypochlorite. Because of the excessive loss of resistance of hypochlorite, it must be studied carefully. The optimum temperature range of hypochlorite is 50-60 ˚C. The reason of this, as the harm of hypochlorite to cotton increasing with raise of temperature, the damage to the cotton discoloration comes is very fast. After this bleaching, neutralization should occur immediately. Neutralization is made with peroxide and bisulphate. Peroxide and bisulphate are obtained blue and yellow-red tone respectively (3). Khan et al. (4), investigated the effect of bleach wash using bleaching powder on 100% cotton indigo dyed denim garments. Tensile strength, stiffness, elongation at break, weight loss, dimensional stability, color fading, water absorption and moisture regain properties of the treated and untreated garment were examined. According to the results, bleach washing and without washing revealed big differences in tensile strength, stiffness, GSM, color fading and surface roughness. Eryuruk et al. (5), investigated the effects of three different washing processes (bleach, resin, softener) on transfer wicking properties of different weighted cotton denim fabrics and the results were analyzed statistically.

Enzyme Wash

In recent years, there is an interest in using fully biodegradable enzymes which are environmentally friendly and non-toxic in the modern textile finishing process. A number of mechanical and chemical operations can be replaced by enzymatic treatments, which have been applied to improve fabric quality and comfort.

In the textile industry, enzymes are applied mainly to get a cleaner fabric surface with less fuzz, to reduce tendency to pill formation, to smooth the surface combining with traditional softeners. To improve fabric handle and other valuable properties, softeners are widely used in finishing operations (6).

In denim clothes, laccase enzyme, which is affected to molecules of blue indigo dye, is generally used as well as amylase and cellulose. It is reported that, 80-90% of bleaching of denim products was completed in first 15-20 minutes, in the case of using 0,25-1,5 % of laccase use (7). The effect of the washing parameters, such as the temperature, time and pH on the result of the cotton and cotton spandex denim after treatment were studied by Yi (8). The study concluded that cellulase treated in cotton and cotton denim got a larger various change than the original denim. The cellulase treatment decreases the strength of the properties of the tensile strength and elongation to break. Juciene et al. (9), determined the influence of different methods of industrial washing (silicone softening, washing with chlorine solution, enzyme and double enzyme washing) on denim properties. According to the results that the silicone softening made the greatest influence on the change of denim properties, whereas the simple softening the least one.

Rinse wash

In the classical denim washing process, rinse wash is the last step before the drying. Touch effect requested on the product is provided with softening. Various chemical materials are used to provide this. Softener used provides specific drape and softness of the fabric. They may be effect inflator and lubricant improver (2). Denim fabrics, made of 100 % cotton yarn and dyeing with indigo dyestuff, were subjected to different washing process (rinse, stone, hypo, etc.) and investigated changes in tearing strength and tensile strength by Cetinaslan et al.(10). The strength values of denim fabrics with three selected weights were compared. The strength values of denim fabrics were decreased after washing process.

In this study, the effect of different washing processes on various performance and surface properties of denim fabrics were examined. For this purpose, 3 different types of fabrics (1/1 plain, 2/2 twill and 3/1 twill constructions) were produced from 100 % cotton yarn, and 4 different types of washing processes (rinse, enzyme, stone and stone+bleach) were applied. Different performance and color properties of washed samples were examined as statistically.

2. MATERIAL AND METHOD

2.1. Materials

In the study, 3 different weave pattern structure of denim fabrics as 100 % cotton, warp yarn Ne 10 carded shantung, weft yarn Ne 12.5 carded, 1/1 plain, 2/2 twill and 3/1 twill were produced. During fabrics' production, the same weaving machine was used and weaving parameters were kept stable. Picanol Rapier weaving machine was used in fabrics weaving, parameters were determined as comb number: 72, number of warp ends per tooth of a comb: 4, comb width: 180, number of warp ends: 5184. Also, all of the warp yarns were dyed with indigo dyestuff in rope form. Table 1 presents the specifications of the denim fabrics.

Table 1. Specifications of the denim fabrics

Fabric type	Yarn count (Ne)		Density (ends/cm)		Weave type	Weight (g/m^2)	Dyestuff type/dying method
	Weft	Warp	Weft	Warp			
PD 1	12,5	9,85	16	31	1/1 plain	327,00	İndigo/rope dying
PD 2	12,5	9,85	19	34	2/2 twill	349,10	
PD 3	12,5	9,85	19	32	3/1 twill	351,10	

2.2. Methods

Production and washing processes of the fabrics used in the study were achieved in Bossa T.A.Ş, Adana plant. In order to eliminate the effect of machine differences on the fabrics, all washing processes were achieved in the same machine. Denim fabrics were washed in the cut fabric form .Washing and drying of the samples are performed by using Tolon brand washing and drying machine (10 kg capacity and 1000 rpm). During stone washing, pumice stone having a weight of double of the sample weight was used. Also weight of each batch was 3 kg of sample fabric.

Simple process flow of washing process applied can be seen in Table 2.

By considering the applications and fabric types in Table 2, at the end of washing processes of 12 different fabrics were obtained and these fabrics are coded as listed in Table 3.

Tests Applied

Washed samples were conditioned at the standard atmospheric conditions during 24 hours then the tests shown in Table 4 were applied.

Table 2. Descriptions of denim industrial washing techniques

Process	Step name	Step details			
		Time (min.)	Temperature (ºC)	Chemical name	Quantity
Rinse washing	Softening	10	40	Belfasin EG	4 ml/lt
				Adasil SM	4 ml/lt
	Drying	45	80		
Enzyme washing	Enzyme washing	60	50	Enpilase	% 0,8
	Drying	30	40		
Stone washing	Stone washing	30	45	ATB 96L	3 ml/lt
				Levasperse KKC	2 ml/lt
	Softening	10	40	Belfasin EG	4 ml/lt
				Adasil SM	4 ml/lt
	Drying	45	80		
Bleaching	Bleaching	15	30	Hypo	20 ml/lt
	Neutralization	10	40	Product PER	2 ml/lt
	Softening	10	40	Belfasin EG	4 ml/lt
				Adasil SM	4 ml/lt
	Drying	45	80		

Table 3. Samples obtained after washing and their codes

Sample no	Sample code	Warp yarn	Weft yarn	Weft density	Woven type	Washing type
1	**PD-11**	9.85 Ne Carded Shantung	12,5 Ne Carded	16	1/1 Plain	Rinse
2	**PD-12**	9.85 Ne Carded Shantung	12,5 Ne Carded	16	1/1 Plain	Enzyme
3	**PD-13**	9.85 Ne Carded Shantung	12,5 Ne Carded	16	1/1 Plain	Stone
4	**PD-14**	9.85 Ne Carded Shantung	12,5 Ne Carded	16	1/1 Plain	Stone+Bleach
5	**PD-21**	9.85 Ne Carded Shantung	12,5 Ne Carded	19	2/2 Z Twill	Rinse
6	**PD-22**	9.85 Ne Carded Shantung	12,5 Ne Carded	19	2/2 Z Twill	Enzyme
7	**PD-23**	9.85 Ne Carded Shantung	12,5 Ne Carded	19	2/2 Z Twill	Stone
8	**PD-24**	9.85 Ne Carded Shantung	12,5 Ne Carded	19	2/2 Z Twill	Stone+Bleach
9	**PD-31**	9.85 Ne Carded Shantung	12,5 Ne Carded	19	3/1 Z Twill	Rinse
10	**PD-32**	9.85 Ne Carded Shantung	12,5 Ne Carded	19	3/1 Z Twill	Enzyme
11	**PD-33**	9.85 Ne Carded Shantung	12,5 Ne Carded	19	3/1 Z Twill	Stone
12	**PD-34**	9.85 Ne Carded Shantung	12,5 Ne Carded	19	3/1 Z Twill	Stone+Bleach

Table 4. Applied tests and standard in the experimental study (11-14)

Test Name	Test Standard
Dimensional stability	TS EN ISO 5077
Breaking strength	TS EN ISO 13934-1
Tearing strength	TS EN ISO 13937-1
Bending rigidity	TS 1409
Color difference	-
Examine surface views	-

3. RESULTS AND DISCUSSION

Tests and assessments are given below.

3.1. Assessment results of dimensional stability

It is firstly thought that dimension stability in textile is dimensional change by washing material. According to related standard average dimension change values were examined by taking three measurements in the both directions of width and length (Figure 1).

As seen in the Figure 1, in fabrics, including the more size in warp direction, both weft and warp directions were occurred the dimensional change (shrinkage). However, shrinkage values are in permissible limits. Variance analysis was carried out according to α=0,05 significance to determine the effect of weave type and washing process on dimensional change, also difference between weave types and difference between washing processes were examined with multiple comparison test (LSD test) (Table 5-6).

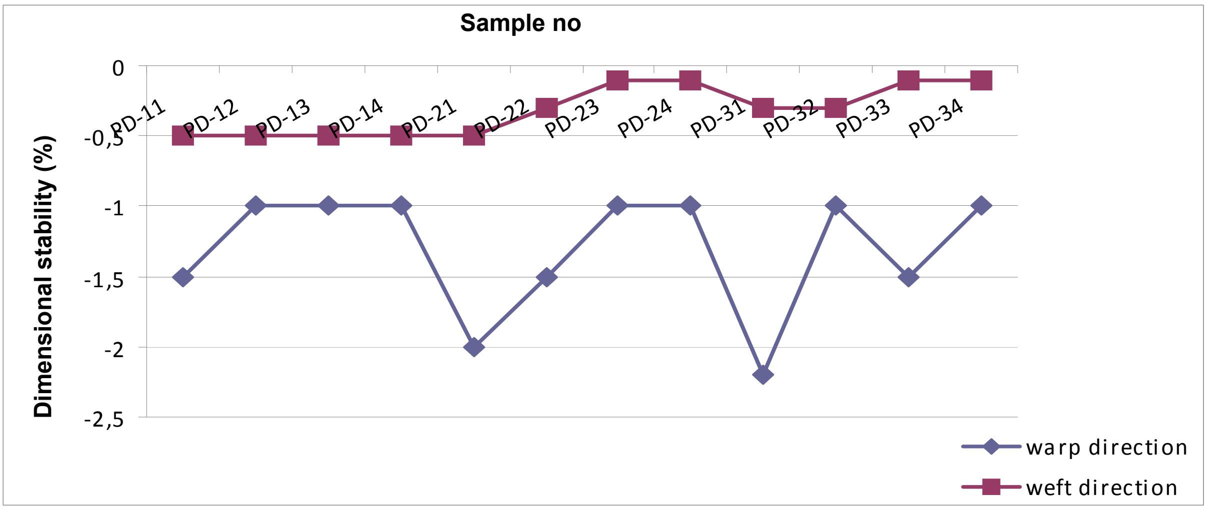

Figure 1. Dimensional stability of fabrics

Table 5. The effect of weave and washing type on dimensional stability

Factor	Dependent variable	F	Sig.
Weave type	Dimensional change for weft direction	39,267	,000
	Dimensional change for warp direction	2,959	,002
Washing type	Dimensional change for weft direction	6,300	,001
	Dimensional change for warp direction	36,658	,000

Table 6. Multiple comparison test results between weave type and washing type

Dependent variable	I (Weave type)	J (Weave type)	Mean difference (I-J)	Sig.
Dimensional change for weft direction	1/1 plain	2/2 z twill	-,2500	,000
		3/1 z twill	-,3000*	,000
	2/2 z twill	1/1 plain	,2500*	,000
		3/1 z twill	-,0500	,173
	3/1 z twill	1/1 plain	,3000*	,000
		2/2 z twill	,0500	,173
Dimensional change for warp direction	1/1 plain	2/2 z twill	,2500	,064
		3/1 z twill	,3000*	,027
	2/2 z twill	1/1 plain	-,2500	,064
		3/1 z twill	,0500	,707
	3/1 z twill	1/1 plain	-,3000*	,027
		2/2 z twill	-,0500	,707
	I(Washing type)	**J(Washing type)**	**Mean difference (I-J)**	**Sig.**
Dimensional change for weft direction	Rinse	Enzyme	-,0667	,242
		Stone	-,2000*	,001
		Stone+bleach	-,2000*	,001
	Enzyme	Rinse	,0667	,242
		Stone	-,1333*	,021
		Stone+bleach	-,1333*	,021
	Stone	Rinse	,2000*	,001
		Enzyme	,1333*	,021
		Stone+bleach	,0000	1,000
	Stone+bleach	Rinse	,2000*	,001
		Enzyme	,1333*	,021
		Stone	,0000	1,000
Dimensional change for warp direction	Rinse	Enzyme	-,7333*	,000
		Stone	-,7333*	,000
		Stone+bleach	-,9000*	,000
	Enzyme	Rinse	,7333*	,000
		Stone	,0000	1,000
		Stone+bleach	-,1667	,081
	Stone	Rinse	,7333*	,000
		Enzyme	,0000	1,000
		Stone+bleach	-,1667	,081
	Stone+bleach	Rinse	,9000*	,000
		Enzyme	,1667	,081
		Stone	,1667	,081

*: The mean difference is significant at the ,05 level

According to Table 5, it was determined statistically that both weave type and washing process are effective on dimensional stability. When the multiple comparison test results in Table 6 were examined, it was determined that especially 1/1 plain weave structure differs on the both weft and warp direction values. Its reason can be explained with the 1/1 plain fabric's structure having more yarn interlacing number. During the washing, as a result of expansion of cross-section of yarn, fabric tended to shorten.

When the washing processes effects on dimensional changes were examined, especially difference between rinse washing and the other washings were determined as meaningful. Softener used in rinse washing was thought as inflated fiber structure increase dimensional change.

3.2. Assessment results of breaking strength

Breaking strength is especially used in one of weave fabric's properties that are determined the using performance. Breaking strength of a fabric is related with fiber, yarn, fabric properties and finishing process that treated the fabric. Breaking strength is one of the most important properties of denim fabrics (15).

In the study, breaking strength test is applied to the samples by using Titan Universal device with take notice of TS EN ISO 13934-1 standard. Each of the fabric samples was taken average of 5 measurements in the weft and warp directions and results with unwashed samples are given in Figure 2.

According to Figure 2, when the breaking strength values were examined, it can be seen that 1/1 plain weaving type had the least strength value. When it compared with unwashed sample's value, stone + bleach washing was determined as the most decreased washing type for each fabric type.

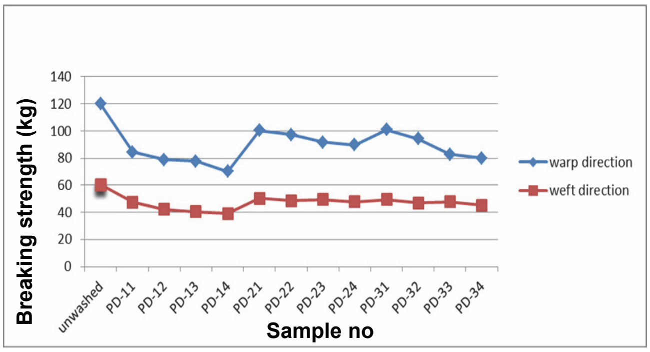

Figure 2. Values of breaking strength

In order to determine the effect of weaving type and washing process on the breaking strength, analysis of variance was done according to α=0,05 significance level, also the difference between weaving types and difference between washing types were examined with multiple comparison test (LSD) (Table 7-8).

Table 7. Effect of the weaving type and washing type on the breaking strength

Factor	Dependent variable	F	Sig.
Weave type	Breaking strength for weft direction	7,646	,001
	Breaking strength for warp direction	32,470	,000
Washing type	Breaking strength for weft direction	1,659	,186
	Breaking strength for warp direction	10,395	,000

Table 8. Multiple comparison results between weaving types and washing process

Dependent variable	I (Weave type)	J (Weave type)	Mean difference (I-J)	Sig.
Breaking strength for weft direction	1/1 plain	2/2 z twill	-5,4500*	,000
		3/1 z twill	-3,7250*	,011
	2/2 z twill	1/1 plain	5,4500*	,000
		3/1 z twill	1,7250	,231
	3/1 z twill	1/1 plain	3,7250*	,011
		2/2 z twill	-1,7250	,231
Breaking strength for warp direction	1/1 plain	2/2 z twill	-17,0250*	,000
		3/1 z twill	-11,6500*	,000
	2/2 z twill	1/1 plain	17,0250*	,000
		3/1 z twill	5,3750*	,016
	3/1 z twill	1/1 plain	11,6500*	,000
		2/2 z twill	-5,3750*	,016
	I (Washing type)	**J (Washing type)**	**Mean difference (I-J)**	**Sig.**
Breaking strength for weft direction	Rinse	Enzyme	3,1333	,086
		Stone	3,2333	,076
		Stone+bleach	3,4000	,063
	Enzyme	Rinse	-3,1333	,086
		Stone	,1000	,956
		Stone+bleach	,2667	,882
	Stone	Rinse	-3,2333	,076
		Enzyme	-,1000	,956
		Stone+bleach	,1667	,926
	Stone+bleach	Rinse	-3,4000	,063
		Enzyme	-,2667	,882
		Stone	-,1667	,926
Breaking strength for warp direction	Rinse	Enzyme	5,2333	,081
		Stone	11,2000*	,000
		Stone+bleach	15,3333*	,000
	Enzyme	Rinse	-5,2333	,081
		Stone	5,9667*	,048
		Stone+bleach	10,1000*	,001
	Stone	Rinse	-11,2000*	,000
		Enzyme	-5,9667*	,048
		Stone+bleach	4,1333	,167
	Stone+bleach	Rinse	-15,3333*	,000
		Enzyme	-10,1000*	,001
		Stone	-4,1333	,167

*: The mean difference is significant at the, 05 level

According to Table 7, it can be seen that fabric construction has an effect on both weft and warp directions, especially washing process has an important effect on the breaking strength with warp direction.

According to multiple comparison test results based on LSD method (Table 8), the difference between the weaving types became meaningful on the breaking strength values. It was determined that 1/1 plain weaving type, which had maximum yarn interlacing number, had minimum breaking strength and difference between the other two types of weaving breaking resistance became meaningful. Difference between the effects of washing process on the breaking strength in the warp direction became meaningful. It was seen that rinse washing in the both weft and warp directions caused the minimum breaking strength lost, stone+bleach combination washing application caused maximum breaking strength lost. When enzyme applications removed the surface smoothness, also it caused damaged to fiber structure were known. While bleach washing especially was removing the pigment on the fabric, it can be damaged the fiber. Because of the samples was exposed to mechanical waste away during the stone washing, resistance of them can be decrease. So, harm of the samples has increased in the application of stone bleach combination.

3.3. Assessment results of tearing strength

Tearing strength is a necessary performance property especially on the denim fabrics that used commonly. Properties like especially resistance of the single yarns, construction of fabric, finishing process are affected on tearing resistance values.

In the study, tearing strength test is applied to the samples by using Titan Universal device with take notice of TS EN ISO 13937-1 standard. Each of the fabric samples was taken average of 5 measurements in the weft and warp directions and results with unwashed samples are given in Figure 3.

When the tearing strength values were examined, a curve that is similar to breaking strength values were observed. Fabrics in the warp direction were determined stronger than in the weft direction, since there is more yarn in there (warp direction) (Figure 3).

In order to determine the effect of weaving type and washing process on the tearing strength, analysis of variance was done according to α=0,05 significance level, also difference between weave types and difference between washing processes were examined with multiple comparison test (LSD test) (Table 9-10).

According to Table 9, weaving types have an effect on both weft and warp directions of tearing strength. It is concluded that there is no meaningful effect of washing type on tearing resistance. Can and Kırtay (2007) indicated in their study that it hard to control by the reason of weaving fabrics tearing resistance depends on fiber, yarn, fabric and finishing features (16). Tearing resistance is related to the yarn's ability to move that it is in the fabric. So that; while washing processes especially effected on fabrics surface properties, it was estimated that it was not effected of tearing resistance effected on yarn motions. According to multiple comparison test results with LSD method (Table 10), the difference between the weaving types became meaningful on the tearing strength values. It was seen that twill weaves which its yarns tendency of making group and slipping on each other had higher tearing strength than plain weave, which yarns located closely. When they evaluated according to washing types, enzyme washing that the maximum providing tearing strength can be seen. Washing type value could not be meaningful between average of statistical difference for all weaving types, while the fibers that formed the fabric with enzyme washing process were removing yarns were soften so they slipping on each other simplified. This situation provides not to decrease too much in tearing resistance value. As a result of tearing resistance, stone+bleach was the application that decreases the tearing resistance at most. Mechanical harm to the fiber with stone application with chemical harm was decreased the tearing strength values of samples.

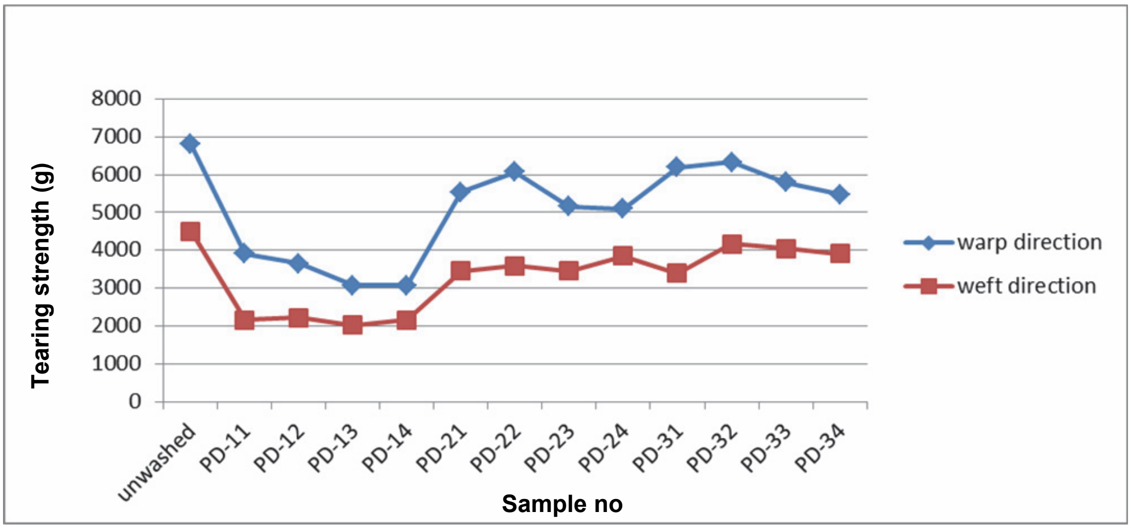

Figure 3. Values of tearing strength

Table 9. Effect of the weaving type and washing type on the tearing strength

Factor	Dependent variable	F	Sig.
Weaving type	Tearing strength for weft direction	165,007	,000
	Tearing strength for warp direction	190,086	,000
Washing type	Tearing strength for weft direction	,474	,701
	Tearing strength for warp direction	1,281	,290

Table 10. Multiple comparison results between weaving types and washing process

Dependent variable	I (Weave type)	J (Weave type)	Mean difference (I-J)	Sig.
Tearing strength for weft direction	1/1 plain	2/2 z twill 3/1 z twill	-1451,7500* -1745,2500*	,000 ,000
	2/2 z twill	1/1 plain 3/1 z twill	1451,7500* -293,5000*	,000 ,006
	3/1 z twill	1/1 plain 2/2 z twill	1745,2500* 293,5000*	,000 ,006
Tearing strength for warp direction	1/1 plain	2/2 z twill 3/1 z twill	-2152,7500* -2528,0000*	,000 ,000
	2/2 z twill	1/1 plain 3/1 z twill	2152,7500* -375,2500*	,000 ,010
	3/1 z twill	1/1 plain 2/2 z twill	2528,0000* 375,2500*	,000 ,010
	I (Washing type)	**J (Washing type)**	**Mean difference (I-J)**	**Sig.**
Tearing strength for weft direction	Rinse	Enzyme Stone Stone+bleach	-326,6667 -174,0000 -304,6667	,294 ,575 ,327
	Enzyme	Rinse Stone Stone+bleach	326,6667 152,6667 22,0000	,294 ,623 ,943
	Stone	Rinse Enzyme Stone+bleach	174,0000 -152,6667 -130,6667	,575 ,623 ,673
	Stone+bleach	Rinse Enzyme Stone	304,6667 -22,0000 130,6667	,327 ,943 ,673
Tearing strength for warp direction	Rinse	Enzyme Stone Stone+bleach	-130,6667 543,6667 521,6667	,766 ,218 ,237
	Enzyme	Rinse Stone Stone+bleach	130,6667 674,3333 652,3333	,766 ,128 ,141
	Stone	Rinse Enzyme Stone+bleach	-543,6667 -674,3333 -22,0000	,218 ,128 ,960
	Stone+bleach	Rinse Enzyme Stone	-521,6667 -652,3333 22,0000	,237 ,141 ,960

*: The mean difference is significant at the,05 level

3.4. Assessment results of bending rigidity

The test to determine the “Stiffness of fabric” was carried out according to TS 1409 with using a stiffness tester. Equation (1), (2) and (3) was used to calculate the strip.

$$c = O / 2 \quad (1)$$

c = Bending length

O= The length of overhang, cm

$$G = W (O / 2)^3 = W \times c^3 \quad (2)$$

G = Flexural rigidity, mgcm

W = Weight per unit area, mg/ cm^2

$$G_o = (G_w . G_f)^{1/2} \quad (3)$$

G_o = Overall flexural rigidity

G_w = Warp flexural rigidity

G_f = Weft flexural rigidity

Overall flexural rigidity was used in assessments. Each of the fabric samples was taken average of 8 measurements and results with unwashed samples are given in Figure 4. Also, in order to determine the effect of weaving type and washing process on the bending rigidity, analysis of variance was done according to α=0,05 significance level, also difference between weave types and difference between washing processes were examined with multiple comparison test (LSD test) (Table 11-12).

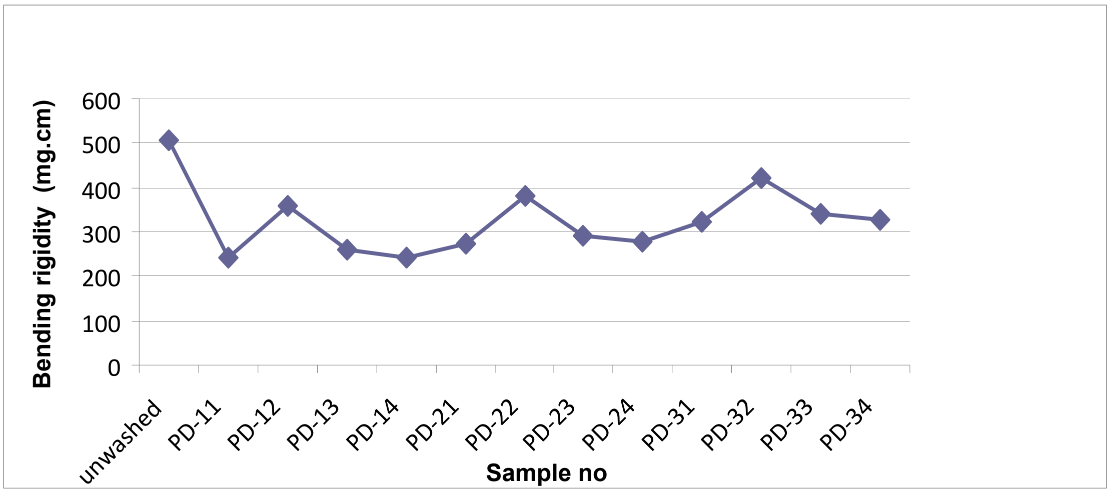

Figure 4. Values of bending rigidity

Table 11. The effect of weave and washing type on bending rigidity

Factor	Dependent variable	F	Sig.
Weave type	Bending rigidity (Overall flexural rigidity)	8,601	,001
Washing type		19,954	,000

Table 12. Multiple comparison test results between weave type and washing type

Dependent variable	I (Weave type)	J (Weave type)	Mean difference (I-J)	Sig.
Bending rigidity	1/1 plain	2/2 z twill	-77,4975*	,000
		3/1 z twill	-30,6075	,113
	2/2 z twill	1/1 plain	77,4975*	,000
		3/1 z twill	46,8900*	,018
	3/1 z twill	1/1 plain	30,6075	,113
		2/2 z twill	-46,8900*	,018
Bending rigidity	**I(Washing type)**	**J(Washing type)**	**Mean difference (I-J)**	**Sig.**
	Rinse	Enzyme	-106,7633*	,000
		Stone	-17,5433	,283
		Stone+bleach	-1,9167	,906
	Enzyme	Rinse	106,7633*	,000
		Stone	89,2200*	,000
		Stone+bleach	104,8467*	,000
	Stone	Rinse	17,5433	,283
		Enzyme	-89,2200*	,000
		Stone+bleach	15,6267	,338
	Stone+bleach	Rinse	1,9167	,906
		Enzyme	-104,8467*	,000
		Stone	-15,6267	,338

*: The mean difference is significant at the ,05 level

As the Figure 4 examined, a decrease in bending rigidity values of the samples was observed at the end of industrial washing processes. So samples have a softer handle.

According to Table 11 and 12, it can be seen that fabric construction has an effect on bending rigidity; especially washing process has an important effect on the bending rigidity. From all the treatment methods applied to denim, the greatest influence on the bending rigidity was made by rinse washing. Also, Juciene et al. (2006) reported in their study that at the end of the applications especially softener washing, the bending rigidity values drastically drop down. It is seen that 2/2 twill fabric samples show a harder handle with respect to the other types.

3.5. Surface views examination and color differences

In order to examine the effects of different washing processes on surface views and color differences of the samples, unwashed and washed with 4 different types of washing processes fabrics of 3/1 twill were examined in detail (Figure 5).

When analyzing the surface appearance at the end of the washing process, especially stone and stone+bleach application was found to discolor the fabric by removing the pigment molecules. Especially these results show that mechanic application made more significant changes on denim color values.

Color measurements of the selected samples were performed by employing CIELab system, with 10° standard observer and under D65 daylight. And L*, a*, b*, C*, h values were recorded. In the study a Minolta brand CM 3600 D model spectrophotometer was employed. RealColor1.3® and CHROMA CMY® software were used to calculate the color difference values (17).

In the study L*, a*, b*, C*, h values of unwashed and washed samples were measured. Then by referencing the color values of unwashed (original) samples, color values of the washed samples were determined. In order to see the effect of washing process on color, total color difference values were examined. There is no international standard for total color difference. This value is determined with respect to quality standards of the manufacturer and customer demands. In this experimental study, total color difference tolerance was assumed as 1,0.

Color values of all samples are presented in Table 13. Δ values of washed samples, determined by referencing unwashed (original) samples can be seen in Table 14.

If Table 13 and 14 were examined, it is seen that the maximum color change occurs in stone+bleach application, as supported by the views shown in Figure 5.

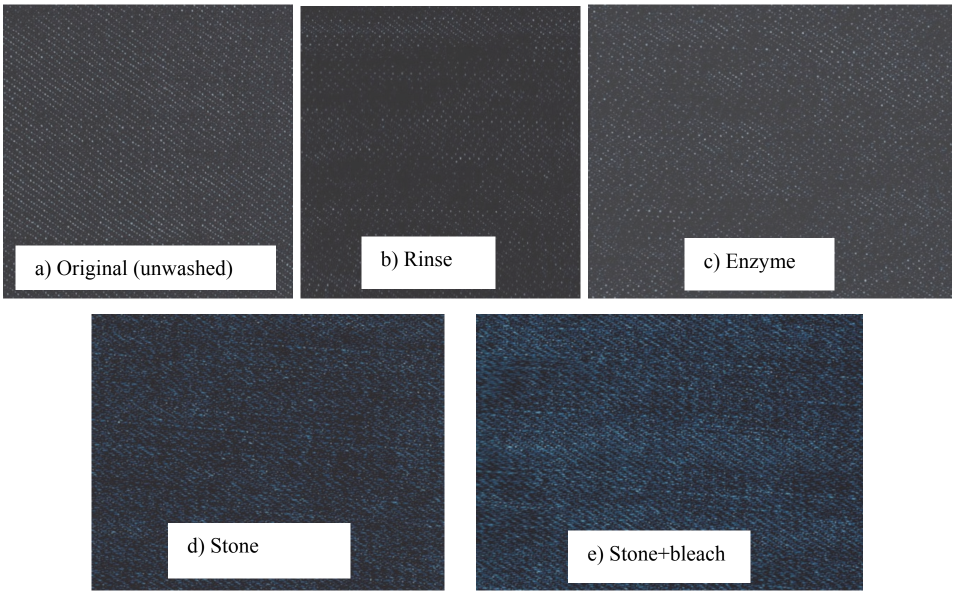

Figure 5. Views of samples after washing

Table 13. Measured CIELab values of samples

Sample	Color values				
	L^*	C	a^*	b^*	h
Original (unwashed)	19,94	2,95	1,0	-2,78	289,81
Rinse	15,91	4,87	0,49	-4,84	275,74
Enzyme	17,67	6,38	0,96	-6,31	278,65
Stone	21,80	11,98	-0,29	-11,98	268,61
Stone+bleach	26,72	13,5	-1,21	-13,45	264,88

Table 14. Color differences on washed samples

Reference: Original (unwashed) fabric	Color differences						Assessment
	Δ L	Δ C	Δ a	Δ b	Δ h	ΔE	
Rinse	-4,026	1,912	-0,514	-2,062	0,929	4,55	FAIL (darker, greener, bluer, brighter)
Enzyme	-2,264	3,43	-0,041	-3,532	0,845	4,2	FAIL (darker, greener, bluer, brighter)
Stone	1,862	9,031	-1,291	-9,202	2,188	9,48	FAIL (lighter, greener, bluer, brighter)
Stone+bleach	6,789	10,548	-2,207	-10,669	2,726	12,84	FAIL (lighter, greener, bluer, brighter)

Δ L^* = Difference in lightness/darkness value, Δ C = Difference in chroma, Δ a^* =Difference on red/green axis, Δ b^*= Difference on yellow/blue axis, Δ h = Difference in hue, ΔE =Total color difference value

4. CONCLUSIONS

The main factors affecting consumers when selecting garments are aesthetic, appearance and fashion. Denim garments are subjected industrial washing to obtain specific appearance and hand. The washing and finishing processes are fashion oriented and different recipes are applied for different effects which are quite significant for marketing. This study aims to analyze the effect of washing processes on the performance properties of denim fabrics.

The results of the experimental studies carried out are summarized as follows.

✓ It was determined statistically that both weave type and washing type are effective on dimensional stability.

Analyzing the test results of multiple comparisons, especially 1/1 weave pattern structure by having more yarn interlacing number has more dimensional changes. When analyzing the effect of the washing type on dimensional stability of fabrics, rinse washing were found to be significant. It is thought that softener used in rinse washing is increasing the dimensional changing by inflated fiber structure. Since the sizing material subtracted from the fabric, interacting between fabric and water molecules get simpler and dimensional change will occur.

- ✓ 1/1 plain weave type that the maximum number of yarn interlacing number has the lowest breaking strength and the most significant value is difference between other two weave types of strength values were determined. It was seen that rinse washing have minimum resistance lost both in the weft and warp direction, stone+bleach combination washing is caused of the maximum resistance lost. When the bleach washing especially pull out pigment on the fabric, it can damage fiber. During the stone washing, sample that treated with rottenstone's resistance can decrease because of the mechanical wear down. So that, damage of the samples which application of stone+bleach combination increase.
- ✓ When the denim fabric's tearing strength was examined, in the warp direction is more strong than in the weft direction because of the more yarn. It was observed that weave types in the both weft and warp directions is effective on the tearing strength. It was seen during the tearing groups tend to form yarns and twill weave have slipping tendency more higher than tearing resistance. Enzyme washing operation on the fabric forming yarns of filaments is move away the yarns are soft, because of slipping tendency is facilitated. So that tearing strength of fabrics not too much decrease treated with the enzyme. Stone+bleach application is more reducing tearing resistance values of denim fabrics.
- ✓ The obtained results demonstrate that different methods of industrial washing make different influence on the bending rigidity of denim fabrics and at the same time on the properties of a ready-made garment. From all the treatment methods applied to denim, the greatest influence on the bending rigidity was made by rinse washing.
- ✓ At the end of the washing process, when the surface appearance and color values of samples analyzed, especially combined with the mechanical effect chemical applications (stone+bleach) of denim fabric made important changes on denim fabric color values.
- ✓ At the end of the washing process, fabric strength loss is not desired; it may be prefer to rinse washing. If decolorization is necessary, stone washing may be preferred.

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