(REFEREED RESEARCH)

AN INVESTIGATION ON THE INFLUENCE OF LAUNDERING ON THE DIMENSIONAL STABILITY OF THE DENIM-LIKE KNITTED FABRICS

YIKAMANIN DENİM GÖRÜNÜMLÜ ÖRME KUMAŞLARIN BOYUTSAL STABİLİTESİNE ETKİSİ ÜZERİNE BİR ARAŞTIRMA

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ABSTRACT

Denim-like knitted fabrics have been used to produce softer, cheaper, and more elastic clothes than the clothes produced by woven denim fabrics. Lower dimensional stability and strength properties were the disadvantages of denim -like knitted fabrics. The aim of this study was to reach the more resistant fabric type to successive launderings without losing the attractive denim view. For this purpose eighteen different denim-like knitted fabrics were produced and exposured to successive launderings. The dimensional stabilities of the knitted fabrics were measured after each washing cycles. The total dimensional change of the fabric's dimensions and the structural properties were measured and evaluated after 3rd washing cycles. All of the test results were assessed by using the graphs and the statistical analysis.

Keywords: Denim-like knitted fabrics, Dimensional stability, Fleecy yarn, Successive launderings.

ÖZET

Denim görünümlü örme kumaşlar, dokuma denim kumaşlardan daha yumuşak, daha ucuz ve daha esnek giysiler üretmek amacıyla kullanılmışlardır. Düşük boyutsal dayanım ve düşük mukavemet bu kumaşların dezavantajlarıdır. Bu çalışmanın amacı, denim görünümünü kaybetmeden ardışık yıkamalara en fazla dayanabilen kumaş tipini seçmektir. Bu amaçla çalışmada on sekiz farklı denim görünümlü örme kumaş üretilmiş ve ardışık yıkamalara tabi tutulmuşlardır. Her yıkama sonrasında kumaşların boyutsal dayanımları ölçülmüştür. Kumaşın boyutlarındaki değişimler ve yapısal özellikler ise üçüncü yıkama sonrasında değerlendirilmiştir. Sonuçların analizinde grafiklerden ve istatistiksel yöntemlerden faydalanılmıştır.

Anahtar Sözcükler: Denim görünümlü örme kumaş, Boyutsal stabilite, Astar ipliği, Ardışık yıkama.

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1. INTRODUCTION

Woven denim garments are so popular because they are abrasion resistant, wrinkle resistant, easy cleanable, compatible to other garments. According to some researches; woven denim fabrics have some drawbacks (1). The denim garment wearers thought that woven denim garments were not soft enough, light enough and comfortable enough in summer season. In accordance with the study done by Degirmenci and Çelik (2), especially female students prefer knitted denim fabric to woven one. Since the denim-like knitted fabrics are the type of fleecy fabrics, the properties of fleecy fabrics have to be observed in detail. Dimensional properties of fleecy fabrics are affected from yarn characteristics which are used as face and fleecy, number of tuck stitch, loop length and stitch density of the fabric and also finishing treatments (3).

Producing denim-like knitted fabric has been popular for years but there are limited researches about the properties of them (4-7). In accordance with the available researches denim-like knitted fabrics have similar characteristics to woven denim fabrics but the strength of woven denim fabrics higher than that of knitted denim fabrics. Woven denim fabrics are more resistant to launderings than knitted ones. Shin (6) designed denim-like knitted trousers which were suitable to each season and compared their properties to woven denim fabrics. He reported that this type of trouser was more advantageous than woven type except dimensional stability and strength properties. Gokernasan et al. (7) tried to find the

knitted fabric type which resembled the woven denim fabric with the view and performance properties. Therefore, they produced denim-like knitted fabrics with different patterns and properties. They explained that diagonal two-fleece fabric was the most convenient one.

According to the study of Shahbaz et al (8), when the fleecy yarn become thinner, the shrinkage of the fabric both widthwise and lengthwise increase. Candan and Önal (9) reported that pattern and fiber types of the knitted fabrics were the main factors which affect the dimensional stability property. In two-fleeced knitted fabrics, the change of dimensions depended on the fleecy yarns of the fabrics. In another study done by Önal and Candan (10), successive launderings caused dimensional change in the two-fleeced knitted fabrics. They found out that the lengthwise dimensional change of these fabrics related with the type of the yarn and the fiber more than the widthwise dimensional change of these fabrics. Although there were miss stitches in this type of the knitted fabrics, widthwise shrinkage was lower. The reason of this phenomenon was the fleecy yarns were thicker and the tendency to the shrinkage of them was higher. However, pattern type and the tightness of the fabrics were more effective than the count and the raw material of the fleecy yarns. In accordance with the results of the study done by Demirhan and Meriç (11), the dimensional change of the two and three-fleeced fabrics decreased when the polyester yarn ratio increased. The dimensional stability of the two-fleeced fabrics produced by cotton and modal resembled that of cotton fabrics. Özbağcı (12), reported that the knitted fabric which was produced by tencel had most similar dimensional stability property to the knitted fabric produced by cotton.

After analyzing the observations about woven denim fabrics and knitted fabrics, combining the view of the woven denim fabric and the advantages of knitted fabric, producing denim-like knitted fabric is considerably interesting. The view of the fabric resembles woven denim fabric as seen from Table 1. However if the view and dimensions of the fabric change intolerably with successive launderings, the garment will not be used as the alternative for woven denim fabric. Therefore, the primary aim of present study was examining the dimensional stability of denim-like knitted fabrics after successive launderings which were produced with different fleecy yarns. Selecting most suitable fleecy yarn type according to dimensional stability results of the knitted fabrics was the other purpose of the research. Graphics and statistical analyses were used to reach these aims.

2. MATERIAL AND METHOD

Knitted fabrics are produced by double fleece circular knitting machine by the loop, tuck and miss stitches combinations. The knitted fabrics used in this study had three different yarns inside. To reach the woven denim view the yarn used on the face side of the fabric should be dyed by indigo color (by rope dyeing method) while the fleecy yarn used in the inner side of the fabric should be gray. Owing to the fact rope dyeing method has been very popular for woven denim fabrics, the face yarns were dyed by indigo color with rope dyeing method. Also, in the literature there has not available research about denim-like knitted fabrics produced by rope indigo dyed yarn. The face yarn of all the samples was 30/1 Ne and 100 % cotton and ring spun. The elastomeric yarn used inside fabrics was 40/1 denier. The counts of the fleecy yarns varied as 20/1 Ne and 30/1 Ne. Dimensional property of the knitted fabrics depended on the hydrophilic or hydrophobic structure of the fibers which formed the yarns. Then the raw material of the fabrics were different each other. The raw materials of the fleecy yarns varied as cotton, modal, viscose, polyester, tencel, bamboo, polyester-cotton blend (65-35 %), polyester-viscose blend (65-35 %) and cotton-modal blend (65-35 %). They were vortex spun. The view of the knitted fabric and the needle diagram were presented in Table1.

In present study samples and their abbreviations were given in Table 2. In this table, in the abbreviation like “DB30”; “D” refers to denim fabric, “B” refers to the fleecy yarn of fabric was bamboo and “30” refers to the count of the fleecy yarn was 30/1 Ne. The explanation of the abbreviation of “30-30 Fabrics” was the face yarn count and fleecy yarn counts are 30/1 Ne and the explanation of the abbreviation of “30-20 Fabrics” was the face yarn’s count is 30/1 Ne while fleecy yarn’s count is 20/1 Ne.

All the samples were produced with the circular knitting machine with 22 gauge 30" diameter by 2,20 tightness factor. After knitting process, pre-fixation, cold washing, and sanforizing processes were applied to the gray knitted fabrics. Then the produced fabrics were conditioned and the structural properties of the fabrics were measured and presented in Table 3. Then the fabrics were washed three times with home type laundering machine. After laundering the structural properties of the knitted fabrics were measured again to compare the results.

Table 1. Production properties of knitted fabrics

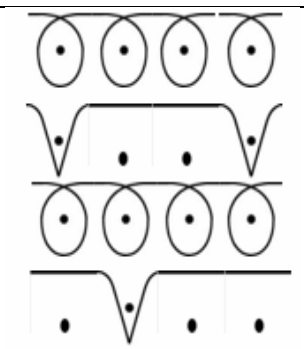
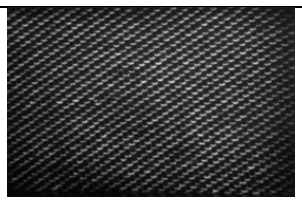
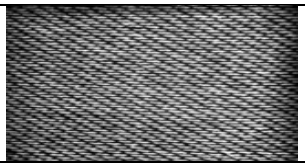
Row	Needle Diagram	Yarn Type	Yarn Combinations	Denim-like knitted fabric
1		face	30/1 Ne Cotton and 40 Denier Elastomeric yarn	Face side 
2		fleecy	30/1 Ne or 20/1 Ne Raw material	
3		face	30/1 Ne Cotton and 40 Denier Elastomeric yarn	Reverse side 
4		fleecy	30/1 Ne or 20/1 Ne Raw material	

Table 2. Samples and their abbreviations

Fabric	Abbreviation	Face (ground) yarn	Fleecy (inlay) yarn
30-20 Fabrics	**DB20**	30/1 Ne Indigo cotton	20/1 Ne Bamboo
	DT20	30/1 Ne Indigo cotton	20/1 Ne Tencel
	DM20	30/1 Ne Indigo cotton	20/1 Ne Modal
	DV20	30/1 Ne Indigo cotton	20/1 Ne Viscose
	DC20	30/1 Ne Indigo cotton	20/1 Ne Cotton
	DP20	30/1 Ne Indigo cotton	20/1 Ne Polyester
	DP-C20	30/1 Ne Indigo cotton	20/1 Ne Polyester-Cotton (65-35 %)
	DM-C20	30/1 Ne Indigo cotton	20/1 Ne Modal-Cotton (65-35 %)
	DP-V20	30/1 Ne Indigo cotton	20/1 Ne Polyester-Viscose (65-35 %))
30-30 Fabrics	**DB30**	30/1 Ne Indigo cotton	30/1 Ne Bamboo
	DT30	30/1 Ne Indigo cotton	30/1 Ne Tencel
	DM30	30/1 Ne Indigo cotton	30/1 Ne Modal
	DV30	30/1 Ne Indigo cotton	30/1 Ne Viscose
	DC30	30/1 Ne Indigo cotton	30/1 Ne Cotton
	DP30	30/1 Ne Indigo cotton	30/1 Ne Polyester
	DP-C30	30/1 Ne Indigo cotton	30/1 Ne Polyester-Cotton (65-35 %)
	DM-C30	30/1 Ne Indigo cotton	30/1 Ne Modal-Cotton (65-35 %)
	DP-V30	30/1 Ne Indigo cotton	30/1 Ne Polyester-Viscose (65-35 %)

Table 3. Structural properties of the knitted fabrics

	Samples	cpc	wpc	Thickness (mm)	Weight (g/m^2)	Stitch Length, mm	
30-30 Fabrics	**DB20**	21	12	0.69	201	Face yarn	3.2
	DT20	21	13	0.72	200		
	DM20	20	13	0.67	194		
	DV20	22	12	0.69	197	Elastomeric yarn	1.4
	DC20	21	12	0.74	196		
	DP20	20	12	0.69	210		
	DP-C20	21	12	0.70	200	Fleecy yarn	1.6
	DM-C20	20	13	0.71	199		
	DP-V20	21	13	0.71	204		
30-20 Fabrics	**DB30**	21	13	0.66	169	Face yarn	3.2
	DT30	21	12	0.70	179		
	DM30	20	13	0.64	170		
	DV30	22	12	0.66	165	Elastomeric yarn	1.4
	DC30	21	12	0.69	167		
	DP30	20	12	0.66	171		
	DP-C30	21	12	0.65	171	Fleecy yarn	1.6
	DM-C30	20	13	0.67	167		
	DP-V30	21	12	0,67	184		

The dimensional changes of the fabrics were measured after each washing cycle according to AATCC 135, (2002) standard by home type washing machine up to three times. During laundering the temperature was 30 ºC, the detergent was ECE non-phosphate (66 gr) and the duration was 50 minutes. These parameters were selected conveniently to the laundering conditions of denim clothes at home. The lengths of the loop and tuck stitches before and after washing were measured with SEM. The results of all tests were evaluated by graphics and statistical analysis.

3. RESULTS AND DISCUSSIONS

3.1. Structural parameters

In the knitted fabrics stitch length, stitch density (cpc X wpc), tightness and loop shape factor (cpc/wpc) are the distinctive characteristics on many properties of them like the dimensional stability property. Among these characteristics, stitch length remains more or less constant after laundering (13) and therefore tightness of the fabrics remains approximately constant. However, both stitch density and loop shape factor of the knitted fabrics change after laundering. When these characteristics change, the dimensional stability of the knitted fabrics changes too. The changes in knitted fabrics' dimensions were largely affected by the changes in loop shape rather than stitch length (13). Stitch densities and loop shape factors of the knitted fabrics were calculated before and after laundering and were illustrated in Table 4.

As seen from the Table 4, by the effect of successive launderings while the stitch densities of the fabrics decreased; the loop shape factors of the fabrics increased. It means by the impact of the water and the temperature during laundering the fibers swelled and the yarn inside the fabrics become thick. Owing to the fact that the fleecy yarns of the samples were different each other the characteristics of the samples were different. For detecting this difference statistically, the test results were evaluated by SPSS 17 package programme. The statistical results were given in Table 5. In this table structural parameters of the fabrics were selected as fixed factors while the fleecy yarn properties were selected as dependent variables.

Table 4. Structural parameters of sample fabrics

	Samples	Stitch density		Loop shape factor	
	Laundering (3 times)	Before	After	Before	After
30-30 Fabrics	DB20	252	220	1.75	1.82
	DT20	273	180	1.62	1.80
	DM20	260	190	1.54	1.90
	DV20	264	190	1.83	1.90
	DC20	252	220	1.75	1.82
	DP20	240	209	1.67	1.73
	DP-C20	252	210	1.75	1.82
	DM-C20	260	220	1.54	1.82
	DP-V20	273	190	1.62	1.90
30-20 Fabrics	DB30	273	190	1.62	1.90
	DT30	252	220	1.75	1.82
	DM30	260	209	1.54	1.73
	DV30	264	190	1.83	1.90
	DC30	252	220	1.75	1.82
	DP30	240	209	1.67	1.73
	DP-C30	252	210	1.75	1.82
	DM-C30	260	190	1.54	1.90
	DP-V30	252	180	1.75	1.80

Table 5. Two way ANOVA test results of structural properties of knitted fabrics before and after laundering

		Univariate analysis of variance						
Laundering. (3 times)	Fixed factor	Dependent variable	Sum of squares	df	Mean square	F	p	Part. Eta Squ.
Before	Loop shape factor. (cpc/wpc)	Fleecy yarn's raw material	.430	8	.054	537.00	.000	.992
		Fleecy yarn's count	.003	1	.003	32.667	.000	.476
		Interaction of factors	.085	8	.011	106.16	.000	.959
	Stitch density. (wpc*cpc)	Fleecy yarn's raw material	4041.8	8	449.09	13.53	.000	.628
		Fleecy yarn's count	102.3	1	102.37	3.084	**.083**	**.041**
		Interaction of factors	2836.4	8	405.21	12.20	.000	.543
After	Loop shape factor. (cpc/wpc)	Fleecy yarn's raw material	.108	8	.013	134.41	.000	.968
		Fleecy yarn's count	.001	1	.001	13.500	.001	.273
		Interaction of factors	.077	8	.010	96.000	.000	.955
	Stitch density. (wpc*cpc)	Fleecy yarn's raw material	5369.33	8	671.167	671.17	.000	.993
		Fleecy yarn's count	20.16	1	20.167	20.167	.000	.359
		Interaction of factors	5771.33	8	721.417	721.4	.000	.994

According to the Table 5, structural properties of knitted fabrics were quite different each other. This table suggested that changing fleecy yarn's count affected the loop shape factor significantly before and after laundering. Also changing the count of fleecy yarn did not significantly affect the stitch density before laundering but after laundering by the effect of water and temperature the stitches swelled and the density was affected by this swelling. It means water changed the loop distortion by swelling and eliminating the torsion inside fabric.

3.2.Dimensional Stability

Dimensional stability refers to a fabric's ability to resist a change in its dimensions. A fabric or garment may exhibit shrinkage in some dimensions or growth in other dimensions under conditions of washing, drying, steaming and pressing. Relaxation shrinkage, progressive shrinkage and thermal shrinkage are three major types of shrinkage that may occur when fabric is subjected to heat and/or moisture (14). This study interested in progressive shrinkage which is dimensional change that continues through successive washings. Due to the fact that denim clothes are frequently washed so denim-like knitted fabrics have to be resistant to the successive washings. The dimensional changes of the knitted fabrics after three washing cycles were given in Table 5.

According to the Table 5, denim-like knitted fabrics exhibited shrinking behavior both two dimensions and successive washing process increased the amount of this shrinkage. The knitted fabrics were laundered up to 5 times and the shrinkages were not significantly different from the shrinkages measured after 3rd washing. Therefore, it was decided that after 3rd washing, the samples were full relaxed and the evaluations were done according to the values of 3rd washing. Figure 1 shows the dimensional stability of the samples after 3rd washing.

Table 5. Dimensional change of knitted fabrics after each laundering

FABRICS	1st washing		2nd washing		3rd washing	
Dimensional Change	Lengthwise %	Widthwise %	Lengthwise %	Widthwise %	Lengthwise %	Widthwise %
DT30	-2.4	-5.3	-2.1	-7.6	-2.4	-7.6
DB30	-2.3	-9.0	-2.6	-9.5	-2.6	-10.1
DV30	-1.2	-9.0	-2.1	-9.7	-2.6	-10.1
DP30	-0.9	-3.2	-1.2	-3.8	-1.3	-4.2
DM30	-2.2	-7.3	-3.0	-8.6	-3.3	-8.9
DC30	-2.2	-8.1	-2.0	-8.6	-2.6	-8.9
DP-C30	-0.9	-4.6	-1.6	-4.8	-1.8	-5.1
DM-C30	-0.9	-8.2	-1.3	-8.9	-1.8	-9.2
DP-V30	-2.3	-4.8	-2.6	-5.4	-2.4	-5.3
DT20	-1.4	-7.1	-1.0	-7.9	-1.8	8.1
DB20	-2.2	-9.7	-2.3	-10.1	-2.1	-10.6
DV20	-2.5	-7.7	-2.3	-8.7	-3.4	-9.7
DP20	-0.8	-2.8	-1.1	-3.6	-1.1	-3.6
DM20	-1.3	-7.6	-1.7	-8.7	-2.4	-9.4
DC20	-3.3	-6.1	-3.0	-7.0	-3.8	-7.3
DP-C20	-2.7	-4.1	-3.3	-4.8	-3.7	-5.2
DM-C20	-2.8	-6.4	-2.2	-7.4	-3.2	-7.5
DP-V20	-1.1	-5.0	-2.2	-5.6	-2.1	-5.7

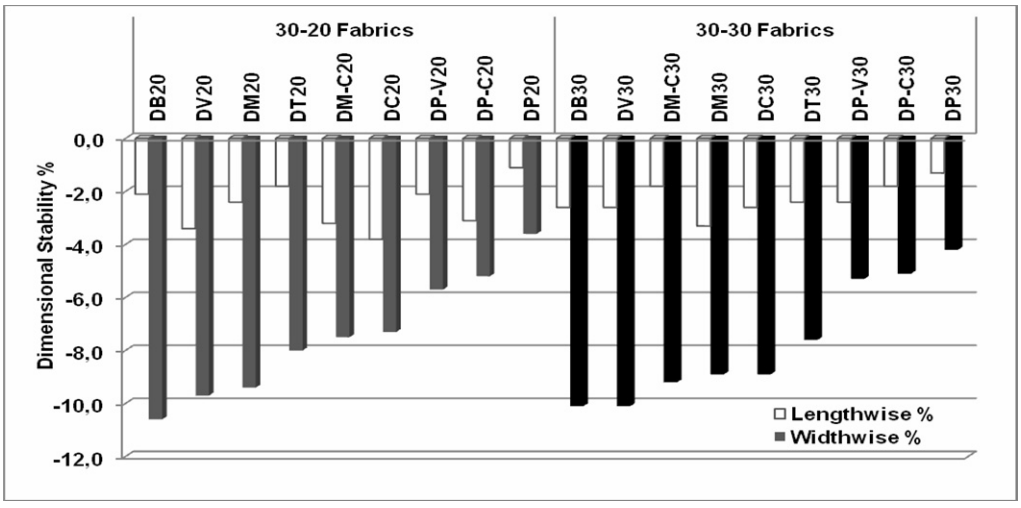


Figure. 1. Dimensional stability of knitted fabrics after 3rd washing

The widthwise shrinkage values were changed between 3,6 and 10,6 %. The lowest shrinkage value belonged to the fabric of which fleecy yarn was polyester and the count was 20/1 Ne. The reason of this was related to the hydrophobic structure of the polyester. Because of polyester did not take water, the structure did not change significantly by the effect of water. The highest shrinkage value belonged to the fabric whose fleecy yarn was bamboo and the count was 20/1 Ne. The reason of this was related to the hollowed structure of bamboo (15). Since the outer layer of bamboo fiber formed with hollowed structure, water penetrated inside the fabric easily and then fabric shrank.

According to the international standards, the shrinkage or growth values which are up to 3 % are in the acceptable intervals (ASTM-D 4235 – 01). Again, as seen from the Figure 1, the lengthwise shrinkage of the knitted fabrics were below 3 % and so it was decided that all the fabrics were convenient to the standard according to these values. The reason of this difference was related to the knitted structure of two-fleeced fabrics. These fabrics were produced according to weft knitting principle. Therefore, the loops which form the same wale were fed from the same bobbin. The width of the fabric forms with the adjacent loops while the length of the fabric forms with over on end loops. In this case, each loop joins to adjacent loop with foot and to upper loops with head. When the cpc and the wpc values of the fabrics were examined, it was seen that the cpc values of the knitted fabrics were double the amounts of wpc values of them. This mean the number of loops in the lengthwise was more than that of in the widthwise. If the stitch density of the fabrics decreases, loops can move easily and the dimensional stability of the fabrics decreases too. At the same time, the tuck loops in the fleecy fabrics caused the lower dimensional change in the lengthwise of the fabric. The fibers inside knitted fabric penetrated water during laundering and then they shrunk. The length of shrunk yarn became short and since the width of fabric was related to the yarn, the width of the fabric became narrow at the same time. Due to the change in the lengthwise of the fabric was related to the change which formed over the joining point of the loops, lower change in the lengthwise of the fabric was an expected situation. This situation confirmed the phenomenon that the dimensional change of the knitted fabric is more on the looser direction of it (7).

As known to measure the dimensional change of the fabrics, the fabrics are marked by template and the amount of change after laundering is measured by rulers. For supporting the measurements and to confirm the effect of laundering on the dimensions of the loops inside the fabric, SEM photographs of sample DPV20 which was selected randomly were given in Figures 2, 3 and 4.

According to the values given in Figures 2, 3 and 4 the yarn length of tuck stitches in DP-V20 decreased approximately 6 % while the distance between two loops in DP-V20 decreased approximately 2 % by the effect of three successive launderings. When these results were compared to the measured values given in Table 6, it was seen that the lengthwise change of DP-V20 was -2,1 while the widthwise change of DP-V20 was -5,7. As seen from the values, the lengthwise change of the fabric was closer to the distance between two loops while the widthwise change of the fabric was closer to the yarn length of tuck stitches in DP-V20. Statistical analysis test results of dimensional stability were presented in Table 6.

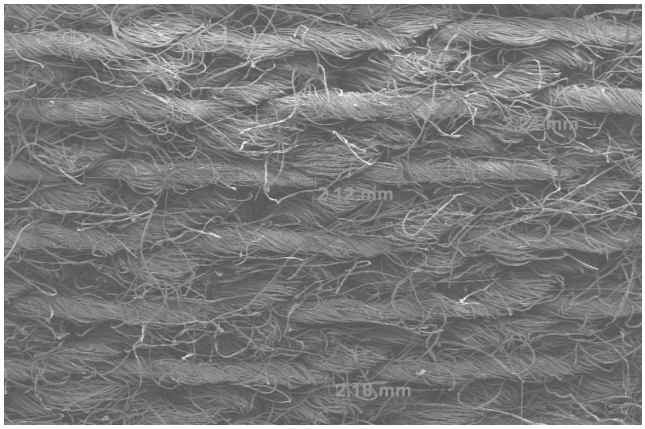


Figure.2. The course spacing of sample before laundering

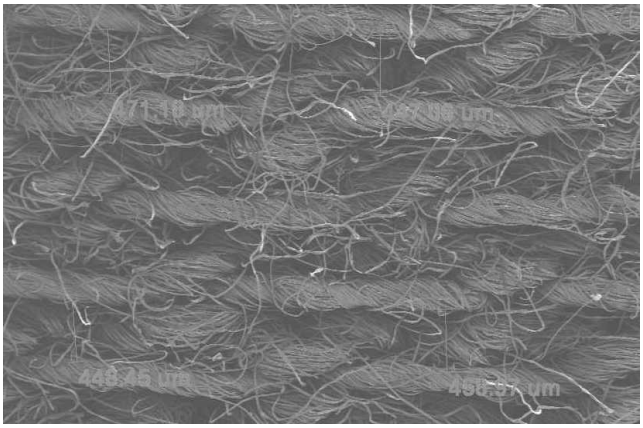


Figure. 3. The yarn length of tuck stitches of the sample before laundering

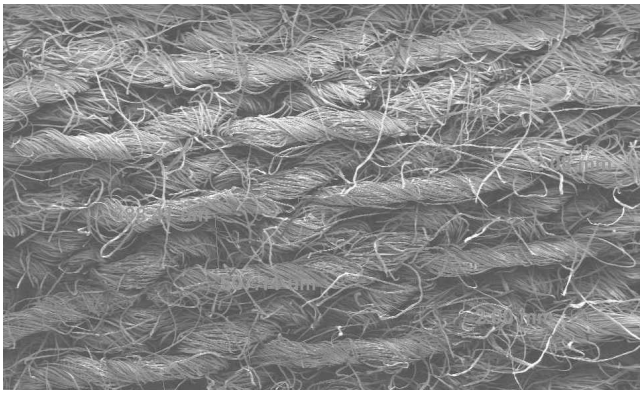


Figure. 4. The yarn length of tuck stitches and course spacing of the sample after laundering

According to the Table 6, fleecy yarn count variances had not significant effect on the dimensional changes of the fabrics both the widthwise and the lengthwise directions. While the raw material variances of the fleecy yarns had significant effect on the dimensional changes of the fabrics both two directions, it was apparent that the widthwise direction of the fabric was affected considerably more than the lengthwise direction of the fabric.

Table 6. Two way ANOVA test results of dimensional changes of knitted fabrics before and after laundering

	Univariate analysis of variance						
Fixed factor	**Dependent variable**	**Sum of squares**	**df**	**Mean square**	**F**	**p**	**Part. Eta Squ.**
Widthwise change. %	Fleecy yarn's raw material	699.389	8	87.424	144.33	.000	.889
	Fleecy yarn's count	1.784	1	1.784	2.945	.088	.020
	Interaction of factors	26.105	8	3.263	5.387	.000	.230
Lengthwise change. %	Fleecy yarn's raw material	48.429	8	6.054	5.346	.000	.229
	Fleecy yarn's count	1.483	1	1.483	1.310	**.254**	.009
	Interaction of factors	31.836	8	3.980	3.514	.001	.163

4. CONCLUSIONS

The aim of this study was investigating the influence of laundering on the dimensional stability of the denim-like knitted fabrics. Since there was no available research about denim-like knitted fabric whose yarn was dyed by rope dyeing method, this study was important to find out the dimensional properties of these products. For this aim the knitted fabrics were laundered three times and the structural properties, the dimensional stabilities of the fabrics and course spaces and the yarn length of tuck stitches viewed by SEM were measured both before and after launderings. The effect of launderings on the structural property and the dimensional stability of fabrics were evaluated and the relation between dimensional stability and microscopic views was tried to find out.

With each washing cycle the dimensions of the knitted fabrics changed. The knitted fabrics shrank from both sides but the lengthwise shrinking values of all the samples were acceptable according to the international standards but according to the results of the study, using polyester yarn as fleecy yarn was quite suitable to design dimensionally stable denim-like knitted fabric. The reason of it was related to the hygroscopic structure of the polyester fiber as fleecy yarn. If the water cannot penetrate inside the fiber the structure of the yarn does not change and therefore the dimensions of the fabric does not change too.

The denim-like knitted fabric was produced as the diagonal two-fleece knitted fabric so the dimensional stability of the fabric was related to the characteristics of both the face and the fleecy yarn inside the knitted fabric. If the fleecy yarn of the sample knitted fabric likes water the widthwise dimension of the fabric changes. There was no significant relation between fleecy yarn count and dimensional stability of the sample knitted fabric. Exactly the twist ratio is a primary parameter in dimensional change property of knitted fabrics but fleecy yarns were vortex spun and there was no real twist on the fleecy yarns. Therefore the only important parameter was seen as raw material. In accordance with the measurements done with SEM views, the lengthwise change of the fabric was related to the distance between two loops while the widthwise change of the fabric was related to the yarn length of tuck stitches inside denim-like knitted fabric.

Finally it was decided that according to the dimensional change behavior of the knitted fabrics using polyester and blended yarns as fleecy is suitable for producing denim-like knitted fabric because these type of fabrics are resistant to laundering more.

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