Uludağ University Journal of The Faculty of Engineering, Vol. 24, No.1, 2019 RESEARCH

DOI: 10.17482/uumfd.481041

COMPARISON OF THE SELECTED PHYSICAL PROPERTIES OF ELASTANE WEFT KNITTED FABRICS BEFORE AND AFTER REPEATED LAUNDERINGS

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Received: 09.11.2018; revised: 03.01.2019; accepted: 24.01.2019

Abstract: It was aimed to investigate the influence of washing cycle and fabric type on stretching (%), unrecovered elongation (%) and elastic recovery properties of plain knitted fabrics made of different ground yarn types having the same elastane ratio (%). For the plain knitted fabrics; Elastane ratio was kept constant as 5% for all fabric types whereas the ground yarns were selected as 70% polyester 30% cotton vortex yarn, 70% polyester 30%viscon ring yarn, 70% polyester 30%cotton ring yarn, 100%viscon vortex and 100% cotton ring spun yarns respectively. Knitted samples were objected to repeated laundering and flat dried after each washing cycle. Fabric weight (g/m^2) after the washing cycles of 1, 5 and 10 were premeasured. Fryma fabric extensometer device was used for determining the stretching ratios (%), unrecovered elongation (%) and elastic recovery (%) of the samples both in wale and course way. Two-Way ANOVA was performed in order to investigate the influence of washing cycle and fabric type on stretching (%) and unrecovered elongation (%) properties of the elastane knitted fabrics.

Keywords: Plain knitted fabric, elastane, washing cycle, stretching ratios (%), unrecovered elongation (%), elastic recovery (%)

Elastan İçerikli Atkılı Örme Kumaşların Bazı Fiziksel Özelliklerinin Yıkama Öncesi ve Tekrarlı Yıkamalar Sonrasında Karşılaştırılması

Öz: Bu çalışmada aynı elastan oranına sahip ancak farklı zemin ipliklerden üretilen düz örme kumaşların esneme (%), geri toparlanamama (%) ve elastik toparlanma özelliklerine yıkama tekrar sayısı ve kumaş tipinin etkisi incelenmeye çalışılmıştır. Düz örme kumaşlar için elastan oranları tüm kumaşlar için sabit tutulurken (%5) zemin iplikleri sırasıyla; %70 poliester %30 pamuk vorteks iplik, %70 poliester %30 viskon ring iplik, %70 poliester %30 pamuk ring iplik, %100 viskon vorteks iplik, %100 pamuk ring iplik olarak seçilmiştir. Numuneler tekrarlı yıkama işlemine tabi tutulmuş olup her yıkama devri sonrasında sererek kurutma yapılmıştır. 1, 5 ve 10 devir yıkama sonrası kumaş gramajları belirlenmiştir. Numunelerin çubuk ve sıra yönlü esneme yüzdesi (%), geri toparlanamama yüzdesi (%) ve elastik toparlanma yüzdesi (%) ölçümleri için Fyrma kumaş ekstensiyometresi kullanılmıştır. Kumaş tipi ve yıkama devir sayısı faktörlerinin elastan örme kumaşların esneme ve geri toparlanamama özelliklerine etkisini incelemek amacıyla iki faktörlü ANOVA testi uygulanmıştır.

Anahtar Kelimeler: Düz örme kumaş, elastan, yıkama devir sayısı, uzama yüzdesi (%), geri toparlanamama yüzdesi (%), elastik toparlanma (%)

1. INTRODUCTION

Beside the aesthetic appearance, clothing comfort during the usage is one of the important factors for the consumers. Since the skin can easily stretch with the body movements, the same property is also expected from the fabrics and garments as well. Comfortable stretching and recovery properties are one of the most desired characteristics for the fabrics in recent years

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(Özdil, 2008). Knitted fabrics offer the stretchability and elasticity property. In order to provide more stretchability and elasticity incorporation of elastane yarn into knitted fabrics have been very popular in the textile market recently (Fatkić et al., 2011). For a whole understanding of recovery properties of elastane knitted fabrics, some terms related to rheological phenomena in fibers and yarns are briefly introduced below.

The behaviour of engineering materials varies between each other in terms of their extension levels with the applied stresses. Although stress and extension are proportional at the beginning of stretching, more stretching results with faster increase in the extension than the stress. Yield point acts as a border area where relation between stress and extension is linear and where they are not linear. The plastic deformation takes place above the yielding point. When the textile fabrics are considered; As the fabrics are exposed to constant loads, the overall deformation increases with time. Deformation is recoverable until the yield point however the increase in the yield point causes fiber movement in the yarn core hence recovery requires some time. As the load is removed from the textile material, a part of deformation disappears after some time while some of it stays as a permanent deformation which cannot be recovered. (Fatkić et al., 2011; Gorjanc and Bukosek, 2008).

Fabrics with elastane yarn have high breaking extension with low breaking force at the yield point. Those fabrics also have wider viscoelastic regions (Morton and Hearle, 1993). Knitted fabrics are inherently stretchable owing to having loop forms. Using elastane in knitted fabrics provide the wearer easier movement with high comfort. The elastane incorporated knitting can retain their original shape without any deformation (Song, 2011; Ertekin vd., 2018). Bare elastane can be used in circular knitting or plated with a ground yarn such as polyester, cotton, viscose (Marmaralı, 2003). The investigations about elastane yarn focus on the effect of production parameters such as elastane draw ratio, elastane feeding ratio (%), elastane linear density on the final yarn properties. Su et al. (2004) investigated the elastane draw ratio, fineness, migration of elastane inside the core yarn on the structure and elastic recovery of core-spun cotton yarns. Dhouib et al. (2006) investigated the influence of elastane ratio on mechanical properties of cotton covered elastane core-spun yarns. There are also some investigations focusing on some properties of elastane fabrics; Meriç and Gürarda (2002) investigated the mechanical properties of elastane fabrics. They concluded that high elastane ratio provides more flexible yarn and added that elastane ratio (%) has a significant effect on the fabrics' tensile and tearing strength. Marmaralı (2003) investigated the characteristics of single jersey fabrics made of cotton/spandex yarns. It was concluded in the study that physical and dimensional properties except the loop length were significantly influenced from the tightness and elastane amount. It was also declared that the air permeability, pilling degree and spirality values decreased as the elastane ratio in the structure increased. Tezel and Kavuşturan (2008) analysed the effects of elastane brands, tightness factor of the ground and elastane yarns on dimensional and physical properties of cotton-elastane single jersey fabrics. The authors concluded that all factors influenced weight, loop length, wale-course densities and thickness of cotton-elastane single jersey fabrics. Özdil (2008) evaluated the stretch and bagging properties of denim fabrics containing different rates of elastane. After evaluating the mechanical properties such as tensile and tearing strength, bending rigidity, stretching (elongation, maximum elongation, permanent elongation, elastic recovery) and bagging characteristics, the authors concluded that increasing amount of elastane usage in denim fabric provided comfort properties. Abdessalem et al. (2009) investigated the relation between elastane consumption and fabric dimensional and elastic behavior. The authors concluded that elastane proportion inside fabric has an effect on fabric width, weight and elasticity. Sacevičienė et al. (2011) investigated the influence of elastane fiber on structural mobility of woven fabrics. The authors declared that using elastane fibers in picks and ends provide the structural mobility of woven fabrics. Sadek et al. (2012) studied the effect of elastane extension on fabric properties such as air permeability, bursting strength, breaking load in single jersey structures. Half and full plating fabrics were compared to find the optimal elastane extension for the best fabric properties. Laundering on dimensional characteristics of core spun cotton-elastane rib knitted fabrics were also investigated. It was emphasized in Herath and Choon Kang's study that cotton-elastane rib structures had higher stability comparing to cotton fabrics after the 10^{th} washing cycle (Herath and Choon Kang, 2007).

Usage of knitted fabrics has been gradually increasing in casual wear, sports, daily activity recently owing to their high elastic property. However, recovery properties of plain knitted fabrics after stretching should be improved with elastane in order to provide a higher level of stretch and dimensional recovery property than can be provided with cotton, polyester, viscon..etc alone. The aim of this study was built on the investigation of the effect of ground yarn with a constant elastane feeding ratio as well as the washing cycles on the knitted fabrics' elastic behaviour such as stretching ratio (%) and recovery properties. To the best of our knowledge there are not many researches concerning the evaluation of fabric type and laundering cycles on stretching and recovery properties. Apart from the previous studies, our research summarizes a whole evaluation of effect of ground yarn type and washing cycle on stretching ratio (%), unrecovered elongation (%) and elastic recovery properties of plain knitted fabrics which have the same elastane ratio (%).

2. Material Method

Five different plain knitted fabrics were produced by using Mayer&Cie branded industrial circular knitting machine (gauge 28 and diameter 30''). Ground yarns were selected as 70% polyester 30% cotton vortex yarn, 70% polyester 30% viscon yarn, 70% polyester 30 % cotton ring spun yarn, 100 % viscon vortex yarn, 100% cotton ring spun yarn (Ne 30/1) and plating yarn was selected as 20 denier elastane monofilament. The fabrics were knitted with elastane in every alternating courses (half plating). The feeded 20 denier elastane ratio (%) was constant as 5% for all samples. The structural properties of plain knitted fabric samples were indicated in Table 1. After the relaxation process of supreme knitted fabrics, the samples were exposed to laundering cycles of 1, 5 and 10 by Using Wascator**.** 8A program was selected for laundering at 20° by using the ECE reference detergent with the ratio of 10g/kg according to EN ISO 6330 (ISO 6330, 2012). Plain knitted fabrics were laid on a smooth surface and flat dried for 40 minutes after each washing cycle. Before the measurements, all fabric samples were conditioned for 24 hours in standard atmospheric conditions (at a temperature of 20 ± 2 °C and relative humidity of 65 ± 2%). Fabric weights of plain knitted samples were premeasured according to standard of ASTM D3776 after the repeated washing cycles (ASTM D3776, 2017).

Table 1. Structural properties of supreme fabric samples

Fabric code	ground yarn composition	ground yarn type	ground yarn linear density	elastan type	elastan linear density	elastan ratio (%)	Fabric weight (g/m^2)
a	70% pes 30% cotton	vortex spun	Ne 30/1	Monofilament	20 denier	5	155
b	70 % pes 30% viscon	ring spun	Ne 30/1	Monofilament	20 denier	5	170
c	70% pes 30% cotton	ring spun	Ne 30/1	Monofilament	20 denier	5	145
d	100% viscon	vortex spun	Ne 30/1	Monofilament	20 denier	5	203
e	100% cotton	ring spun	Ne 30/1	Monofilament	20 denier	5	176

Stretching tests were conducted in context of performance tests. The extensibility of supreme knitted fabrics was tested in both wale and course direction, using a Fryma Fabric Extensometer under a 6 kg tensile force which is considered to be in the range of the regular strain (Figure 1). Fyrma fabric extensometer is a stretch testing instrument for determining the stretching ratio (%), unrecovered elongation (%) and elastic recovery according to test standard of BS 4952:1992 (BS 4952, 1992). The specimens were prepared so that they would be (85±1.0) mm in longitudinal and (75±1.0) mm wide wise. Stretching tests were evaluated for the non-washed samples and fabrics applied to 1, 5 and 10 washing cycles respectively

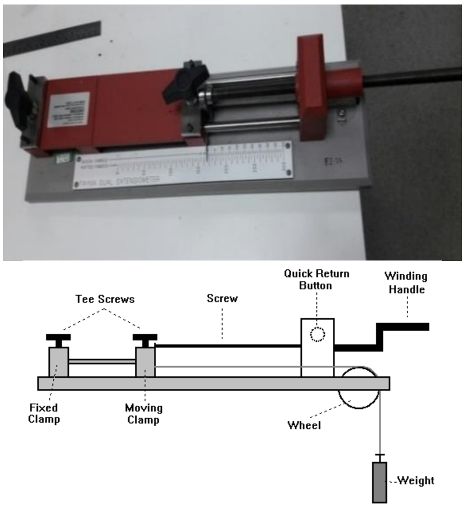

Figure 1:
FRYMA Fabric Extensometer Device (SDL Atlas)

Stretching ratio (%) may be described as the ratio of extension of the test specimen to its initial length expressed as a percentage (%). In the Fryma fabric extensometer device, the test specimens (85*75 mm) were subjected to 5 cycling created between gauge length and the required force of 6 kg by using cross-head in motion. The stretching ratios (%) were recorded after 10 seconds and after 30 minutes according to equation 1 where ;

S: indicates the elongation (%)

E: is the extension (mm) at the maximum force on the 5th cycle

L: is the initial length (mm)

$$S=\frac{E-L}{L} \text{ x100} \qquad (1)$$

For the unrecovered elongation (%); the specimens were marked 5 mm inside the short edge of the fabric and a 6 kg of load was applied for 30 minutes. At the end of 30 minutes, the fabrics exposed to stretching test were released for 1, 5 and 30 minutes and the shortening distance of marked points were calculated.

$$C=\frac{Q-P}{P} x100 \qquad (2)$$

where “C” is unrecovered elongation (%), “Q” is the distance between applied reference marks (mm) after a specified recovery period, “P” is the initial distance between applied reference marks (mm). If recovered elongation (%) is required, it can be calculated with the equation below ;

$$D= S-C \qquad (3)$$

The recovery percentage of the material after deformation is calculated by the ratio of elastic stretching to total stretching. Elastic recovery “R” may be expressed as a percentage (%) as indicated in equation (4) ; Where “D” is the recovered elongation (%) and “S” is the stretching ratio (%).

$$R=\frac{D}{S}x100 \quad (4)$$

In order to understand the statistical importance of fabric type and washing cycle on supreme knitted fabrics’ stretching properties, two way ANOVA was performed. Student-Newman-Keuls (SNK) tests were conducted for comparing the means of stretching ratios (%) at different washing cycles (non-washed, 1, 5 and 10 washing cycle) also for comparing the means of different fabric types. For this aim, the statistical software package SPSS 21.0 was used to interpret the experimental data. All test results were assessed at 95% confidence interval.

3. RESULTS&DISCUSSION

3.1. Fabric Weight

Fabric weights were measured before and after the repeated laundering cycles. According to Figure 2, elastane knitted fabrics’ mass per unit area (g/m^2) increased gradually as the washing cycle increased. “d” coded elastane knitted fabrics made of 100 % viscon ground yarn had the highest fabric weight whereas the lowest values were belong to “c” coded elastane fabrics made of polyester-cotton ground yarn.

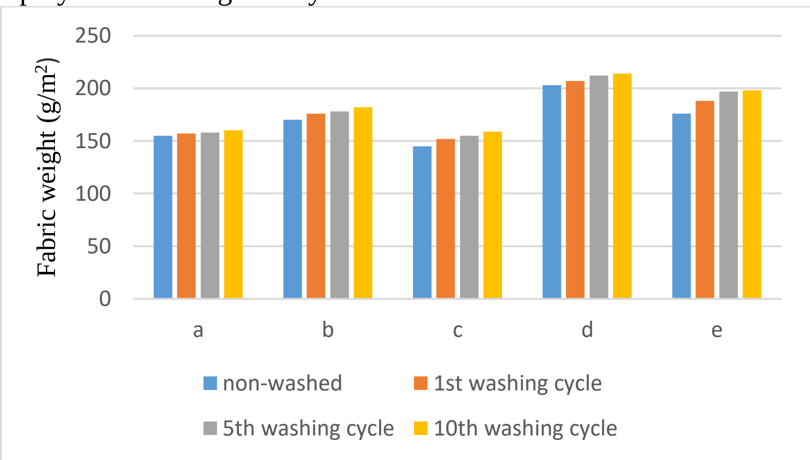

Figure 2:
Fabric weight (g/m^2)

3.2. Stretching Ratio (%) Results

The stretching ratios (%) of supreme fabrics in wale and course direction regarding to washing cycles are revealed between Figure 3 and Figure 6 respectively. Considering the wale way; Stretching ratio (%) after 10 seconds (Figure 3) and stretching ratio (%) after 30 minutes (Figure 4) indicates that the highest stretching ratio (%) was obtained from “d” coded elastane knitted fabrics which are made of 100% viscon vortex ground yarns whereas “a” and “c” coded elastane knitted fabrics made of polyester-cotton ground yarns revealed lower stretching ratios (%) comparing to others. Regarding to both figures of 3 and 4; There is a decreasing trend of stretching ratios (%) in “a” coded polyester-cotton and “b” coded polyester-viscon elastane knitted fabrics as the washing cycle increases whereas the other samples exhibited a fluctuated trend regarding to washing cycle.

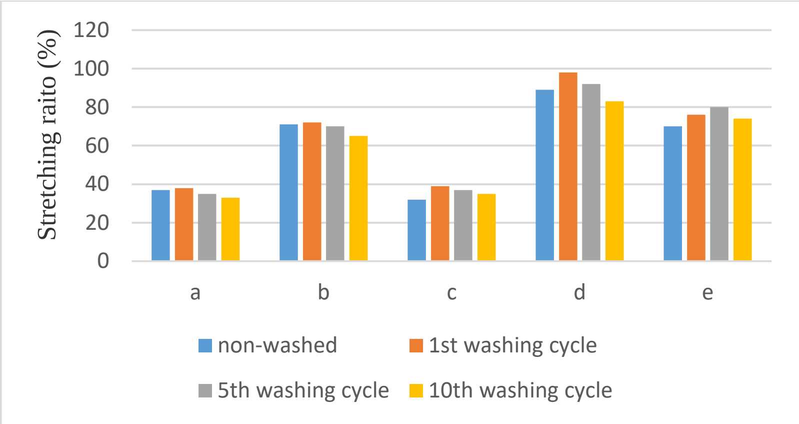

Figure 3:
Stretching ratio (%) after 10 seconds in wale way

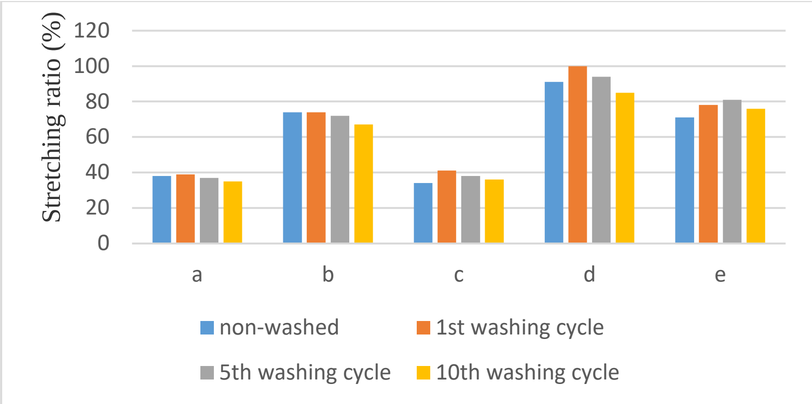

Figure 4:
Stretching ratio (%) after 30 minutes in wale way

When considering the course way; Figure 5 and Figure 6 indicate the stretching ratio (%) after 10 seconds and after 30 minutes respectively. According to Figure 5 and Figure 6; "d" and "e" coded knitted fabrics which are made of "100% viscon" and "100% cotton" ground yarns respectively revealed higher stretching ratios (%) comparing to "a", "b" and "c" coded plain knitted fabrics. There is not a prominent trend for the samples 'stretching ratios (%) after 10 seconds and after 30 minutes in course way regarding to washing cycles.

Additionally, Two-way ANOVA test was performed in order to analyse the influence of fabric type and washing cycles on stretching ratios (%) of the samples. According to Table 2, fabric type and washing cycle (0,1,5,10) have statistically significant effect on stretching ratios (%) after 10 seconds and after 30 minutes respectively both in wale and course way ($p = 0.00 < 0.05$). Moreover, the interaction between fabric type and washing cycle were also found to be statistically significant ($p = 0.00 < 0.05$) which means the effect of fabric type on stretching ratios (%) in wale as well as in the course way differentiates for each washing cycle.

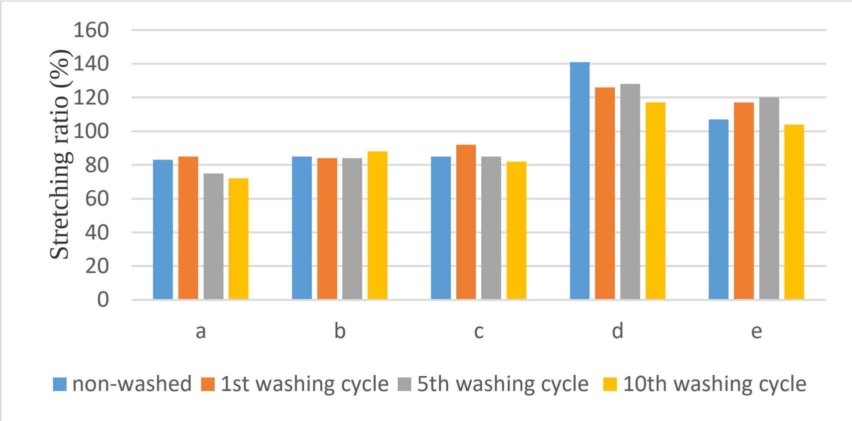

Figure 5:
Stretching ratio (%) after 10 seconds in course way

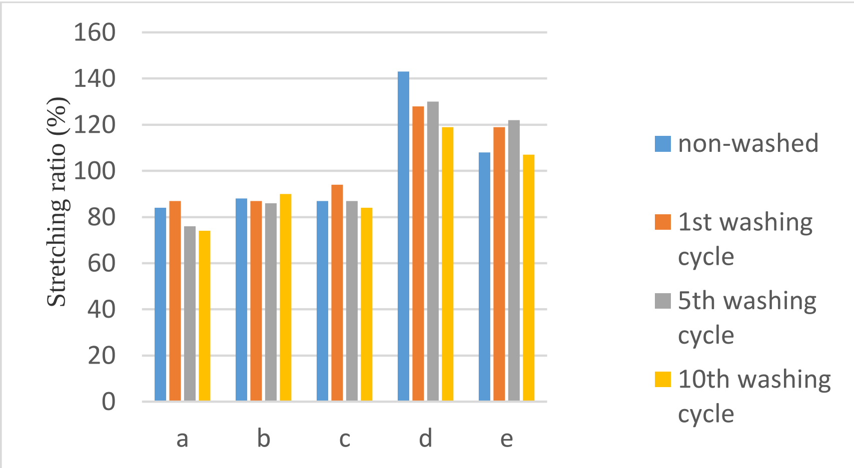

Figure 6:
Stretching ratio (%) after 30 minutes in course way

Table 2. Two-Way ANOVA for stretching ratios (%)

		stretching ratio (%) after 10 seconds in wale way				stretching ratio (%) after 30 minutes in wale way			
Source		**ss**	**ms**	**F**	**Sig.(p)**	**ss**	**ms**	**F**	**Sig.(p)**
Main Effect	fabric type (T)	2.87	0.72	5265.97	0.00*	2.918	0.72	5914.4	0.00*
	washing cycle (W)	0.03	0.01	92.272	0.00*	0.03	0.01	101.49	0.00*
Interaction	T*C	0.03	0.00	19.691	0.00*	0.03	0.03	23.17	0.00*
		stretching ratio (%) after 10 seconds in course way				**stretching ratio (%) after 30 minutes in course way**			
Source		**ss**	**ms**	**F**	**Sig.(p)**	**ss**	**ms**	**F**	**Sig.(p)**
Main Effect	fabric type (T)	2.10	0.52	2354.79	0.00*	2.13	0.53	2354.79	0.00*
	washing cycle (W)	0.06	0.02	99.79	0.00*	0.06	0.02	89.84	0.00*
Interaction	T*C	0.13	0.01	49.93	0.00*	0.13	0.01	49.10	0.00*

*statically significant at 0.05 level (“ss” indicates sum of square “ms” mean square)

SNK tests were conducted (Table 3) in order to compare the means of stretching ratios (%) of different fabric types. It was observed that knitted samples of different fabric type possessed statistically different stretching ratios (%) in wale and course way. Considering the wale way; The highest stretching ratio (%) after 10 seconds and after 30 minutes was obtained from “d” coded elastane fabrics with 100 % viscon ground yarn. Stretching ratios (%) of “a” and “c” coded fabrics made of polyester-cotton yarns were in the same subset at significance level of 0.05. When it comes to course way; the lowest stretching ratio (%) after 10 seconds and after 30 minutes were both found in the “a” coded fabrics whereas the highest stretching ratios (%) were obtained from “d” coded fabrics. Additionally, “b” coded fabrics of polyester-viscon and “c” coded fabrics of polyester-cotton revealed the same stretching ratio (%) at significance level of 0.05. SNK tests were also performed for comparing the means of stretching ratios (%) of the fabrics subjected to different washing cycles (0,1,5,10). The SNK results revealed that the knitted samples exposed to different washing cycles possessed statistically different stretching ratios (%) in wale and course way. Considering the wale way; the lowest stretching ratio (%) after 10 seconds and after 30 minutes were both obtained from the samples exposed to 10 washing cycles whereas the highest values were provided from the samples exposed to 1 washing cycle. Considering the course way; the highest stretching ratios (%) were obtained from non-washed samples and the samples exposed to 1 washing cycle which indicated the same value at significance level of 0.05. The lowest stretching ratios (%) after 10 seconds and after 30 minutes were both obtained from the samples exposed to 10 washing cycles

Table 3. SNK tests for stretching ratios (%)

Parameter: **Fabric type**	**stretching ratio (%) after 10 seconds in wale way**	**stretching ratio (%) after 30 minutes in wale way**	**stretching ratio (%) after 10 seconds in course way**	**stretching ratio (%) after 30 minutes in course way**
a	35i	37i	78i	80i
b	69ii	71ii	85ii	87ii
c	35i	37i	86ii	87ii
d	90iv	92iv	127iv	129iv
e	74iii	76iii	112iii	114iii

Parameter: **washing cycle**	**stretching ratio (%) after 10 seconds in wale way**	**stretching ratio (%) after 30 minutes in wale way**	**stretching ratio (%) after 10 seconds in course way**	**stretching ratio (%) after 30 minutes in course way**
non-washed	59i	61ii	101iii	101iii
1 washing cycle	64iv	66iv	102iii	102iii
5 washing cycles	62iii	64iii	98ii	100ii
10 washing cycles	58i	59i	92i	94i

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %

3.3. Unrecovered Elongation (%)

The unrecovered elongations (%) in wale and course way of 5 different fabric types are revealed between Figure 7 and Figure 12. Considering the wale way; “d” and “e” coded fabrics generally revealed the higher unrecovered elongation (%) for all washing cycles comparing to “a”, “b” and “c” coded samples. There is a prominent decrement for unrecovered elongation (%)

value after 1, 5 and 30 minutes of “b” and “c” coded fabrics made of polyester-viscon and polyester-cotton yarns respectively as the washing cycle increases. Considering the course way, unrecovered elongation (%) after 1 minute, 5 minutes and 30 minutes of “c” coded fabrics indicated a decreasing the trend as the washing cycle increased However, the other knitted samples did not indicate a prominent trend regarding to laundering. Additionally, unrecovered elongation (%) of “a” coded fabrics were generally slightly lower than the unrecovered elongation (%) of “c” coded fabrics although they are made of the same fiber blend ratio. This result may be attributed to their yarn spinning system difference.

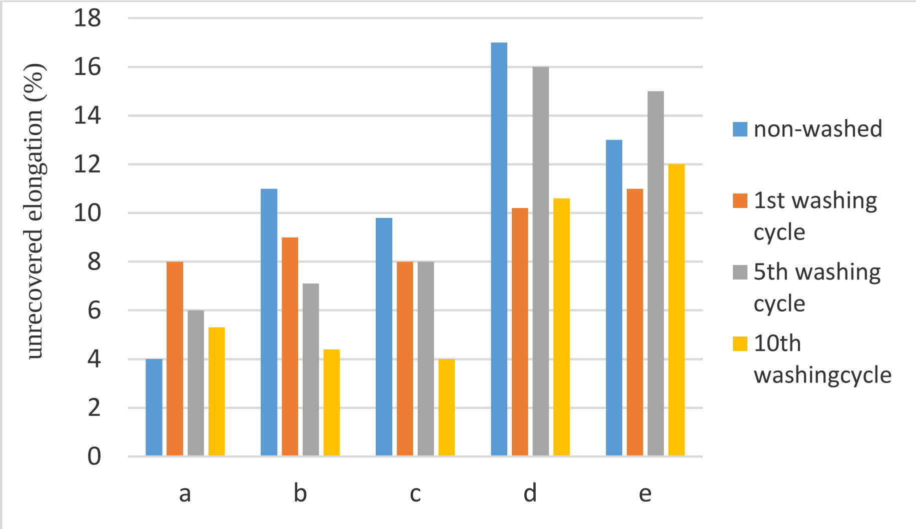

Figure 7:
Unrecovered elongation (%) after 1 minute in wale way

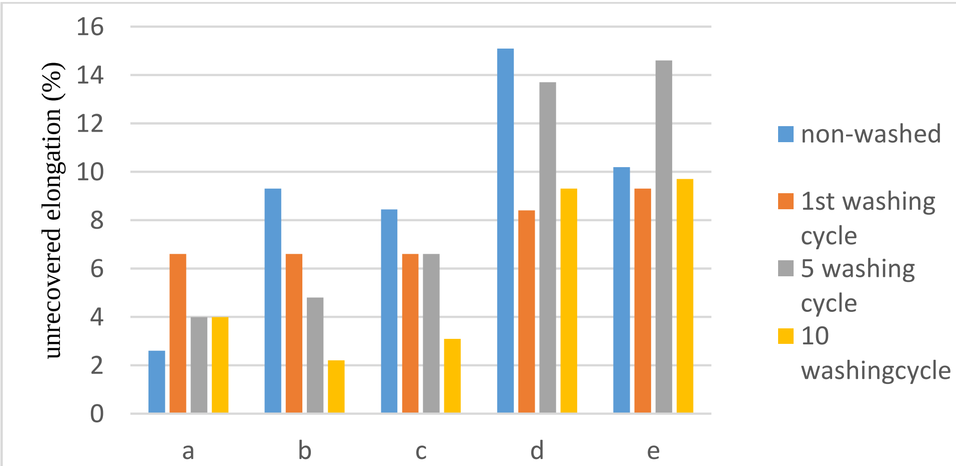

Figure 8:
Unrecovered elongation (%) after 5 minutes in wale way

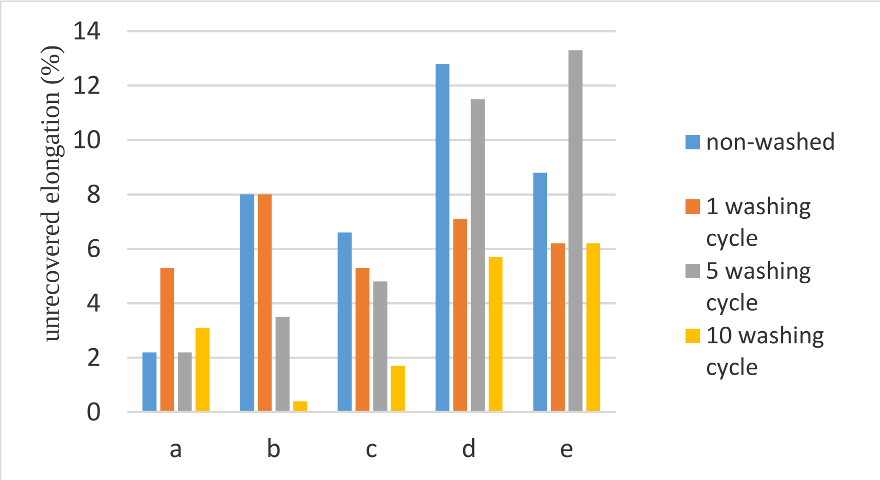

Figure 9:
Unrecovered elongation (%) after 30 minutes in wale way

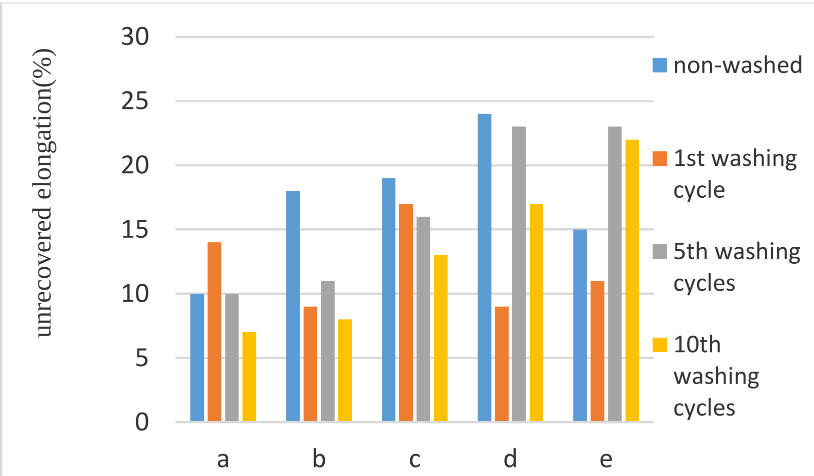

Figure 10:
Unrecovered elongation (%) after 1 minute in course way

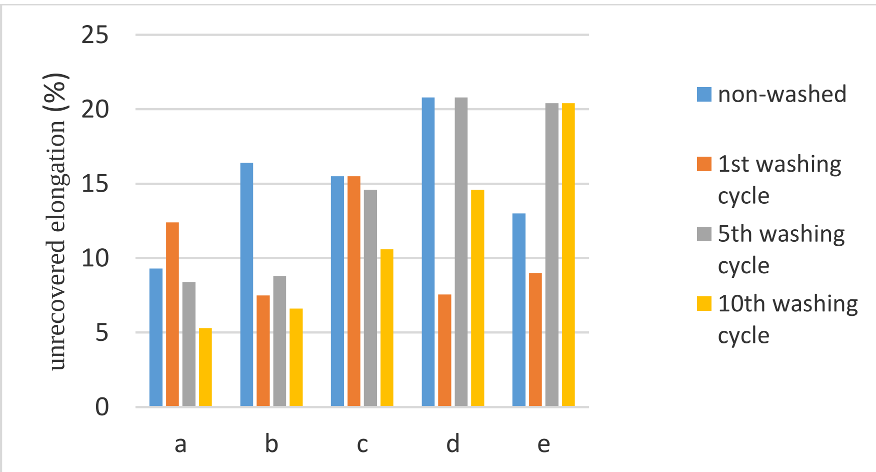

Figure 11:
Unrecovered elongation (%) after 5 minutes in course way

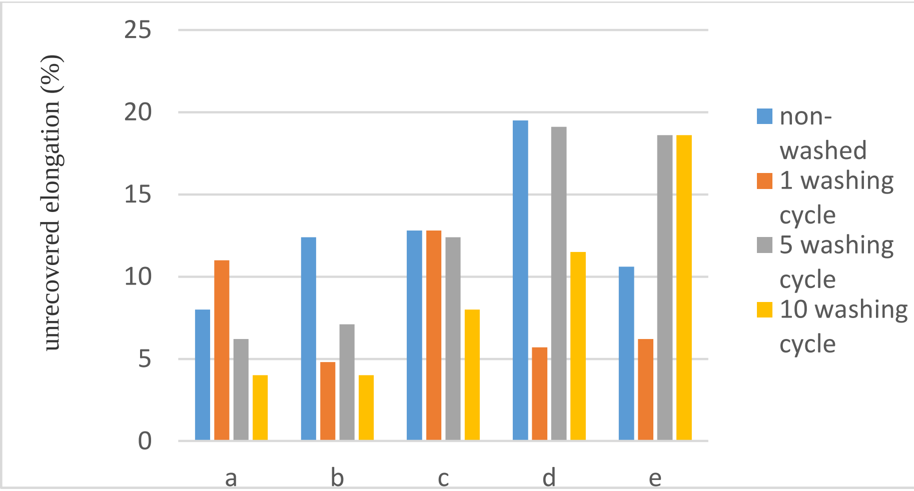

Figure 12:
Unrecovered elongation (%) after 30 minutes in course way

Additionally, Two-way ANOVA test (Table 4) was conducted in order to analyse the influence of fabric type and washing cycles on unrecovered elongation (%) of the knitted fabrics. Fabric type and washing cycle (0,1,5,10) have statistically significant effect on unrecovered elongation (%) after 1, 5 and 30 minutes in wale and course way (p = .000 < 0.05). Moreover, the interaction between fabric type and washing cycle were found statistically significant which indicates that effect of washing cycle on unrecovered elongation (%) in wale and also in course way differentiates for each fabric type. SNK tests were conducted (Table 5) in order to compare the means of unrecovered elongation (%) of different fabric types in wale and course way. It was observed that knitted samples of different fabric type and the knitted samples exposed to different washing cycles possessed statistically different unrecovered elongation (%) after 1, 5 and 30 minutes in wale and course way. According to Table 5, considering the wale way; the lowest unrecovered elongation (%) after 1 minute, 5 minute and 30 minutes were both obtained from "a" coded fabrics whereas the highest unrecovered elongation (%) values were obtained from "d" coded fabrics. The sample groups of "b" and "c" coded fabrics made of polyester-viscon and polyester-cotton yarns "d" and "e" coded fabrics made of 95% viscon and 95% cotton indicated the same unrecovered elongation (%) after 1, 5 and 30 minutes at significance level of 0.05. Considering the course way; "a" coded fabrics of vortex polyester-cotton yarns indicated the minimum value of unrecovered elongation (%) after 1,5 and 30 minutes whereas the highest values were found in "d" coded fabrics made of viscon-elastane yarns. Regarding to washing cycles; considering the wale way; the samples exposed to 10 washing cycles indicated the lowest unrecovered elongation (%) after 1, 5 and 30 minutes whereas non-washed samples revealed the highest unrecovered elongation (%) values. When it comes to unrecovered elongation (%) after 1,5 and 30 minutes in course way, the samples exposed to 1 washing cycle indicated the lowest value whereas the non-washed samples and the samples treated to 5 washing cycles which were in the same subset at significance level of 0.05 revealed the highest unrecovered elongation (%) after 1, 5 and 30 minutes.

Table 4. Two-Way ANOVA for unrecovered elongation (%)

		unrecovered elongation (%) after 1 minute in wale way				**unrecovered elongation (%) after 5 minutes in wale way**				**unrecovered elongation (%) after 30 minutes in wale way**			
Source		**ss**	**ms**	**F**	**Sig.(p)**	**ss**	**ms**	**F**	**Sig.(p)**	**ss**	**ms**	**F**	**Sig.(p)**
Main Effect	fabric type (T)	0.05	0.01	93.03	0.00*	0.05	0.01	93.09	0.00*	0.03	0.00	12.42	0.00*
	washing cycle (W)	0.01	0.00	29.19	0.00*	0.01	0.00	29.19	0.00*	0.01	0.00	8.632	0.00*
Interaction	T*C	0.01	0.00	10.52	0.00*	0.08	0.00	39.19	0.00*	0.02	0.00	2.815	0.00*

		unrecovered elongation (%) after 1 minute in course way				unrecovered elongation (%) after 5 minutes in course way				unrecovered elongation (%) after 30 minutes in course way			
Source		**ss**	**ms**	**F**	**Sig.(p)**	**ss**	**ms**	**F**	**Sig.(p)**	**ss**	**ms**	**F**	**Sig.(p)**
Main Effect	fabric type (T)	0.06	0.01	84.35	0.00*	0.03	0.00	42.81	0.00*	0.05	0.01	82.80	0.00*
	washing cycle (W)	0.01	0.00	29.19	0.00*	0.02	0.00	45.39	0.00*	0.02	0.00	53.40	0.00*
Interaction	T*C	0.01	0.00	10.52	0.00*	0.08	0.00	39.19	0.00*	0.07	0.00	39.19	0.00*

*statically significant at 0.05 level ("ss" indicates sum of square "ms" mean square)

Table 5. SNK tests for unrecovered elongation (%)

parameter: Fabric type	**unrecovered elongation (%) after 1 minute in wale way**	**unrecovered elongation (%) after 5 minutes in wale way**	**unrecovered elongation (%) after 30 minutes in wale way**	**unrecovered elongation (%) after 1 minute in course way**	**unrecovered elongation (%) after 5 minute in course way**	**unrecovered elongation (%) after 30 minutes in course way**
a	5.7i	4i	3i	10i	8i	7i
b	8.0ii	5ii	5i	11ii	9i	7i
c	7.5ii	6ii	4i	16iii	14ii	11ii
d	13.4iii	11iii	9ii	18iv	14ii	14iii
e	12.8iii	11iii	8ii	17iv	13ii	13iii

parameter: washing cycle	**unrecovered elongation (%) after 1 minute in wale way**	**unrecovered elongation (%) after 5 minutes in wale way**	**unrecovered elongation (%) after 30 minutes in wale way**	**unrecovered elongation (%) after 1 minute in course way**	**unrecovered elongation (%) after 5 minute in course way**	**unrecovered elongation (%) after 30 minutes in course way**
non-washed	10.9iii	9.2iii	7.8ii	17iii	14iii	12iii
1 washing cycle	9.2ii	7.5ii	6.4ii	12i	9i	8i
5 washing cycles	10.6iii	8.8iii	7.0ii	16iii	13iii	12iii
10 washing cycles	7.2i	5.7i	3.4 i	13ii	10ii	9ii

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %

3.4. Elastic Recovery

Figure 13 and Figure 14 indicates the elastic recovery of the samples in wale and course way respectively. The stretching ratios (%) after 10 seconds and the recovered elongation (%) of the samples after 1 minute were utilized in equation (4) in order to calculate the elastic recovery (%) of the samples in wale and course way. According to Figure 13, elastic recovery (%) of the "b" coded elastane fabrics made of polyester-viscon yarns revealed an increasing trend as the washing cycle increases whereas the other samples indicated a fluctuation between 65% and 95% elastic recovery ratio (%) regarding to washing cycles. Considering the course way; There is a prominent increment of elastic recovery with the 1st washing cycle of "d" and "e" coded fabrics which are made of 100% viscon vortex yarn and 100%cotton ring yarns respectively. A sharp decrement of elastic recovery was observed for the "e" coded elastane fabrics made of 100% cotton ground yarns after the 1st washing cycle.

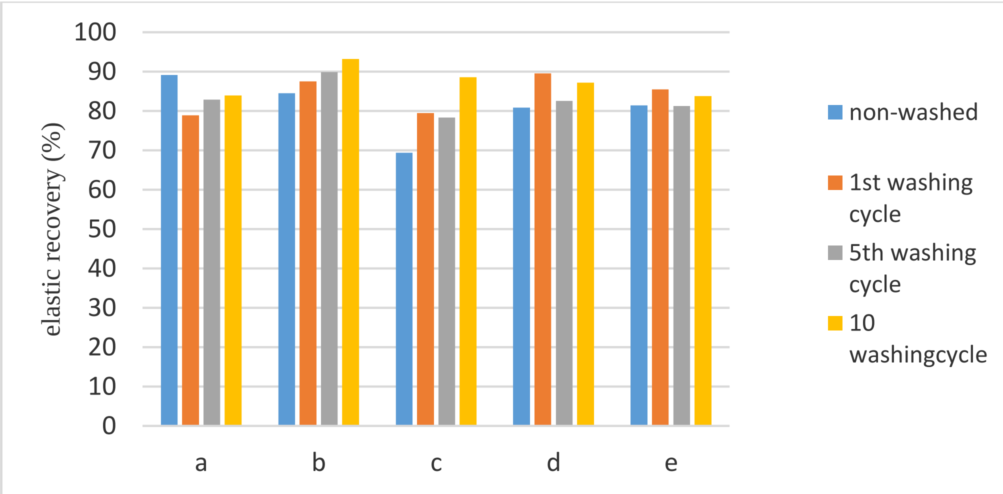

Figure 13:
Elastic recovery in wale way

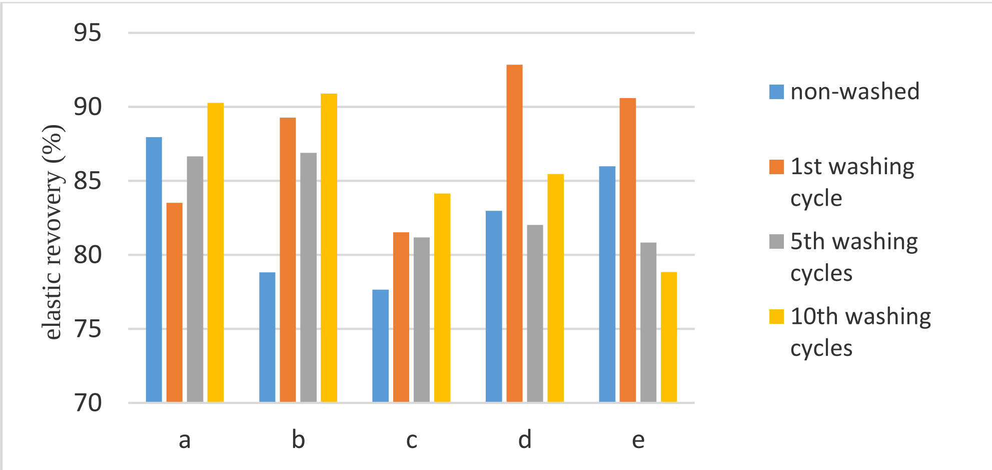

Figure 14:
Elastic recovery in course way

4. CONCLUSIONS

This study has been focused on the influence of fabric type and washing cycles on stretching ratios (%), unrecovered elongation (%) and elastic recovery values of elastane knitted fabrics having the same elastane ratio (%). ANOVA tests revealed that knitted fabric type with different ground yarns, washing cycle (0,1,5,10) and as well as their interaction influenced the stretching ratios (%) and unrecovered elongation (%) values both for wale and course way at the significance level of 0.05. Stretching ratios (%) of the elastane knitted fabrics generally exhibited an increasing trend first and then a decreasing trend until the 10^{th} washing cycle. 100% cotton elastane fabrics and 100% viscon elastane fabrics indicated higher stretching ratios (%) both in wale and course way comparing to other samples. SNK tests also revealed that knitted samples of different fabric type possessed statistically different stretching ratios (%) in wale and course way moreover the samples exposed to different washing cycle possessed statistically different stretching ratios. When considering unrecovered elongation (%) in wale and course way, “a” and “c” coded fabrics which have the same fiber composition but different yarn spinning system revealed different unrecovered elongation (%) values where the elastane fabrics of polyester-cotton vortex yarn had generally lower unrecovered elongation (%) value comparing to ring spun ground yarn. Gradual decreasing of unrecovered elongation (%) in wale way was observed on “b” coded elastane fabrics made of polyester-viscon and on “c” coded elastane fabrics made of polyester-cotton yarns regarding to washing cycles. Considering the course way, unrecovered elongation of “c” coded fabrics decreased as washing cycle increased. For the wale and course way; Elastic recovery of the “a” and “c” knitted fabrics indicated different values regarding to washing cycle which showed that knitted samples made of the same fiber blend but with different spinning system may differ between each other in terms of elastic recovery values (%) .Since stretching characteristics of elastane knitted fabrics provide a comfortable clothing which makes it preferable, further detailed studies related to thermal comfort characteristics of knitted structures having different elastane ratio (%) are also suggested.

ACKNOWLEDGEMENT

The authors wish to express their thanks to Ersoy YILMAZ who is senior fabric technologist in Aster Textile and to Hakan KIRER for their contributions to the study.

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