Effect of different washing processes, twill direction and yarn types on the performance properties of denim fabrics

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ABSTRACT – REZUMAT

Effect of different washing processes, twill direction and yarn types on the performance properties of denim fabrics

This study aims to investigate the effects of different washing processes, twill directions, and yarn types on the performance properties of denim fabrics. For this purpose, 100% cotton elastane, 85% cotton/15% Modal elastane, and 85% cotton/15% Tencel elastane including denim fabrics were produced with two different weaves (3/1 Z and 3/1 S), and four different industrial washing operations were applied to these denim fabrics. In addition, untreated fabrics (not industrially washed) were used to compare the performance of the fabrics before and after industrial washing. The highest warp-breaking strength values were observed in the rinse-washed fabrics, whereas the highest shrinkage, elasticity, and rubbing fastness values were observed in the bleach-washed fabrics. In addition, it can be said that industrial washing processes reduce the growth values of untreated fabrics and reduce the bagging during use. Although the crystallisation degree of Tencel fibre is higher than that of Modal fibre, it was concluded that the use of Modal fibre with cotton increased the strength values. In contrast, the use of Tencel fibre with cotton increased the elasticity and rubbing fastness values of the denim fabrics.

Keywords: *denim, Tencel, Modal, bleach washing, enzyme washing, rinse washing, stone washing*

Influența diferitelor procese de spălare, direcția legăturii diagonal și tipurile de fire asupra proprietăților de performanță ale țesăturilor denim

Acest studiu își propune să investigheze influența diferitelor procese de spălare, direcțiile legăturii diagonal și tipurile de fire asupra proprietăților de performanță ale țesăturilor denim. În acest scop, ţesături din 100% bumbac elastan, 85% bumbac/15% Modal elastan și 85% bumbac/15% Tencel elastan, inclusiv țesături din denim, au fost produse cu două legături diferite (3/1 Z și 3/1 S) și patru operaţii de spălare industriale diferite au fost aplicate acestor ţesături denim. În plus, țesăturile netratate (care nu au fost spălate industrial) au fost folosite pentru a compara performanța țesăturilor înainte și după spălarea industrială. Cele mai mari valori ale rezistenței la rupere a urzelii au fost observate la țesăturile spălate şi clătite, în timp ce cele mai mari valori de contracție, elasticitate și rezistență la frecare au fost observate la țesăturile spălate cu înălbitor. În plus, se poate spune că procesele de spălare industrială reduc valorile de creștere ale țesăturilor netratate și reduc deformarea în timpul utilizării. Deși gradul de cristalizare al fibrei Tencel este mai mare decât cel al fibrei Modal, s-a ajuns la concluzia că utilizarea fibrei Modal cu bumbac a crescut valorile rezistenței, în timp ce utilizarea fibrei Tencel cu bumbac a crescut elasticitatea și valorile de rezistență la frecare ale țesăturilor denim.

Cuvinte-cheie*: denim, Tencel, Modal, spălare cu înălbitor, spălare cu enzime, spălare cu clătire, spălare chimică*

INTRODUCTION

Denim fabrics are typically produced as 100% cotton or polyester in the weft direction. Today, expectations from denim have increased, and consumers demand aesthetic, comfort, and performance features. Different fibre structures are used in denim production to satisfy comfort features. Owing to the increasing consumption rates of natural textile fibres, cellulosic regenerated fibres (viscose, Modal, and Tencel) have emerged. Tencel fibre, which can be given as an example of these fibres, provides production opportunities without harming the environment. Modal fibres are preferred especially in textile products where comfort, aesthetics, brightness, and naturalness are sought. Currently, yarns such as core-spun and dual-core are used in denim structures to improve elasticity and recovery properties. In addition, different industrial washing processes (bleach, enzyme, rinse and stone) have been applied to denim fabrics to improve their aesthetic properties. Sülar and Kaplan investigated the impact of different finishing operations on the performance of denim fabric. It was found that stone washing and its combination with bleaching produced pleasant hand assessment results, despite poor mechanical properties [1]. Khan and Mondal (2012), investigated the amount of enzyme, washing temperature, and time on indigo-dyed cotton denim fabrics. The results indicated that enzyme washing decreased the tensile strength, stiffness, and colour shade of denim fabrics [2]. Juciene et al. explored the impact of laser treatment and industrial washing on denim fabrics. It was observed that the thickness of fabrics increased after laser operation and industrial washing; however, mechanical features were damaged because the fabric became thinner [3]. Another study investigated the impact of washing operations on the physical properties of twill and dobby woven denim fabrics. The results showed that the colourfastness values of the washed and unwashed fabrics were the same, and the highest shrinkage was measured in the weft direction for the light-washed fabrics [4]. While some studies on denim fabrics have focused on the impact of the washing process, others have focused on the elasticity features of denim fabrics and the elastane yarn used in the weft. Eryürük investigated the effects of elastane on the performance of denim fabrics. It was found that elastane increased the drape and handling features of denim fabrics by decreasing bending and shear stiffness [5]. In another study, the impact of the elastane composition on the stretch and bagging features of denim fabrics was investigated. It was found that the bagging and permanent bagging results for denim fabrics declined with an increase in the elastane ratio [6]. Üte investigated the impact of core-spun and double-core yarns in the weft direction on the mechanical and dimensional features of denim fabrics. It was found that the elongation and elasticity of double-core woven fabrics were higher than those of core-spun woven fabrics [7]. In another study, the impact of the elastane properties on the dimensional and mechanical features of stretchable denim fabrics was investigated. It was found that the linear density and draft ratio of elastane equally affect the stretchability, stiffness, skewness, and bow of denim fabrics [8]. Shaw and Mukhopadhyay (2021) investigated the impact of wear on body movement and shape retention, so the effect of the fabrics on the first break, recovery and flexibility properties, and the effect of the elastane ratio were examined. It was found that fabrics with higher elastane content suffered more loss of shape retention owing to abrasion [9].

As a result of the literature research, it was observed that there are not many studies on the effect of weft yarns with different fibre compositions on the performance properties of denim fabric, and the studies are mostly focused on cotton denim fabrics. This study aims to investigate the effects of using cotton/elastane, cotton/Tencel elastane, cotton/Modal elastane weft yarns, two twill directions (S and Z), and industrial washing differences on the performance properties of denim fabric. In addition, untreated fabric samples were used to compare the effects of industrial washings on the performance properties of denim fabrics.

MATERIALS AND METHODS

In this study, three different types of weft yarn and two different weave types (S and Z-twill directions) were used to produce 3/1 twill-weaved denim fabrics. All the fabrics were woven with the same warp yarns by exchanging the weft yarns. The yarns used in all fabrics were produced by twisting in the Z direction. The properties of the tested samples and the washing operations applied are listed in table 1. Denim fabrics composed of 100% cotton elastane, 85% cotton 15% Modal elastane, and 85% cotton 15% Tencel elastane were treated with different industrial washing methods such as bleach, enzyme, rinse, and stone washings, to improve fabric quality and comfort. In addition, fabrics subjected to industrial washing processes were compared to untreated fabrics (not industrially washed). The flow of the industrial washing processes is presented in table 2. During the bleach-washing process, the bleaching effect was applied to the denim fabric with sodium hypochlorite. A soft touch effect has been given to the fabrics with the rinse-washing process. In the enzyme-washing process, the denim fabric is given a soft and shiny touch with the help of the cellulase enzyme. In the stone washing process, with the help of pumice stones, the denim fabric is given a soft and full attitude as well as ageing effects. The thickness of the fabrics was measured according to the TS 7128 EN ISO 5084 standard using a James Heal thickness tester (ASTM D1777). The shrinkage values of the denim fabrics in the weft and warp directions after washing were measured using the ISO 6330 3XHL test standard (%). The Crockmaster device and the AATCC 8 standard were used to measure the rubbing fastness values of the fabrics under dry and wet conditions. The breaking strength values of fabrics were measured with Titan 5 device according to ASTM D-5034 and the elasticity value of fabrics was measured with this device according to EN 14704-1 9.1 Method A. The tear strength of the denim fabrics in the warp and weft directions was measured according to the ASTM D-1424 test standard using an Elmatear device. The growth values of the fabrics were measured using a Prowhite test device, according to ASTM3107. All washing operations were performed using the same machine to eliminate machine differences. The effect of the factors was investigated by performing a multivariate test in the SPSS 28 statistical package program, and the Student-Newman-Keuls (SNK) test was performed to analyse the difference between the groups at a level of $p < 0.05$.

RESULTS AND DISCUSSIONS

Results of shrinkage in warp and weft direction

The shrinkage values of the fabric in the weft and warp directions were determined after washing to ensure that the designed garment was produced by predetermined dimensions during the usage phase. More shrinkage values were observed in the weft direction because elastane yarn was used in the denim structure, as in a previous study. Double-core and core-spun weft yarns were used in the denim structure, and the highest shrinkage value in the weft direction was measured at 23% in the denim [7]. For

Table 1

PROPERTIES OF DENIM FABRICS					
Fabric type	**Warp yarn count (Ne)**	**Weft yarn count (Ne)**	**Composition**	**Washing type**	**Weight (g/m^2)**
CZ	9.97	16	100% Cotton + 78 Dtex Elastane	Untreated	322
CZ1	9.97	16	100% Cotton + 78 Dtex Elastane	Bleach	405
CZ2	9.97	16	100% Cotton + 78 Dtex Elastane	Enzyme	396
CZ3	9.97	16	100% Cotton + 78 Dtex Elastane	Rinse	396
CZ4	9.97	16	100% Cotton + 78 Dtex Elastane	Stone	408
CS	9.97	16	100% Cotton + 78 Dtex Elastane	Untreated	330
CS1	9.97	16	100% Cotton + 78 Dtex Elastane	Bleach	393
CS2	9.97	16	100% Cotton + 78 Dtex Elastane	Enzyme	388
CS3	9.97	16	100% Cotton + 78 Dtex Elastane	Rinse	387
CS4	9.97	16	100% Cotton + 78 Dtex Elastane	Stone	396
MZ	9.97	16	85%Cotton + 15% Modal + 78 Dtex Elastane	Untreated	337
MZ1	9.97	16	85%Cotton + 15% Modal + 78 Dtex Elastane	Bleach	415
MZ2	9.97	16	85% Cotton + 15% Modal + 78 Dtex Elastane	Enzyme	412
MZ3	9.97	16	85% Cotton + 15% Modal + 78 Dtex Elastane	Rinse	411
MZ4	9.97	16	85% Cotton + 15% Modal + 78 Dtex Elastane	Stone	419
MS	9.97	16	85% Cotton + 15% Modal + 78 Dtex Elastane	Untreated	327
MS1	9.97	16	85% Cotton + 15% Modal + 78 Dtex Elastane	Bleach	401
MS2	9.97	16	85% Cotton + 15% Modal + 78 Dtex Elastane	Enzyme	407
MS3	9.97	16	85% Cotton + 15% Modal + 78 Dtex Elastane	Rinse	402
MS4	9.97	16	85%Cotton + 15% Modal + 78 Dtex Elastane	Stone	406
TZ	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Untreated	340
TZ1	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Bleach	410
TZ2	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Enzyme	412
TZ3	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Rinse	411
TZ4	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Stone	418
TS	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Untreated	321
TS1	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Bleach	403
TS2	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Enzyme	376
TS3	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Rinse	397
TS4	9.97	16	85% Cotton + 15% Tencel + 78 Dtex Elastane	Stone	403

Note: * C = 100% Cotton elastane fabric, M = Modal included fabric, T = Tencel included fabric, Z = twill direction Z, S = twill direction S, 1 = bleach washing, 2 = enzyme washing, 3 = rinse washing and 4 = stone washing.

almost all fabric types, the lowest shrinkage values were measured for the untreated fabrics, except for rinse washings. The highest shrinkage values in the warp direction were observed in the fabrics produced with MZ2 and MZ4 coded Modal blended weft yarn, and in which enzyme and stone washing operations were performed (figure 1). When the shrinkage values in the weft direction were examined, the determining factor was found to be the weaving direction. The fabrics woven in the Z-twill direction exhibited more shrinkage than those woven in the S-twill direction, even though the weft yarn was the same. The SNK test of the shrinkage values is presented in table 3. The cotton/Modal elastane and cotton/Tencel elastane weft yarn woven fabrics exhibited significant differences in the warp direction, with the cotton/Tencel weft yarn woven fabrics exhibiting the lowest shrinkage values. When the effect of industrial washing on the shrinkage values in the warp and weft directions was examined, rinse washing showed statistically different results, and the lowest shrinkage values were measured for this washing. Previous studies have stated that the effect of rinse washing on the shrinkage value was higher than that of other washes [10]; however, the rinse-washed fabrics showed the lowest shrinkage value for all fabric types in this study. In another study, more shrinkage values were obtained by bleach washing in the warp direction and by enzyme washing in the weft direction [11]. It was observed that rinse washing reduces the shrinkage value of the fabric, while bleach washing increases this value.

Table 2

WASHING PROCESS CHEMICALS AND DETAILS						
Process No/Name	Step	Washing process details				
		Time (min.)	Temperature (°C)	Chemicals	Quantity	After treatment
1/Bleach washing	Bleaching	15	40–60	Hypo	2 g/l	Rinsing 1 min cold
	Neutralization	5	Cold	Sulphite	2 g/l	Rinsing 1 min cold
	Drying	35–40	80	-	-	Spray
2/Enzyme washing	Enzyme wash	40	40-60	Hot enzyme Dispergatör Sequestrants Surfactants	0.5 g/l 1 g/l 0.5 g/l 0.5 g/l	Rinsing 1 min cold
	Drying	35-40	80	-	-	Spray
3/Rinse washing	Pre-wash	10	50	Dispergatör Surfactants Sequestrants	1 g/l 0.5 g/l 0.5 g/l	Rinsing 1 min cold
	Drying	35–40	80	-	-	Spray
4/Stone washing	Stone washing	40–60	40–60	Hot enzyme Dispergatör Sequestrants Pumice stone	1g/l 0.5 g/l 0.5 g/l 10 kg	Rinsing 1 min cold and stone washing
	Rinsing	1	Cold	-	-	-
	Drying	35–40	80	-	-	Spray

Table 3

THE SNK TEST FOR WARP SHRINKAGE VALUES OF SAMPLES								
Warp shrinkage				Weft shrinkage				
Factors				Factors				
Weft yarn	N	Subset		Weft yarn	N	Subset		
		1	2			1	2	3
Cotton/Modal	24	–3.417		Cotton/Tencel	24	–17.271		
Cotton	24	–3.104	–3.104	Cotton/Modal	24	–17.125		
Cotton/Tencel	24		–2.875	Cotton	24	–17.062		
Washing type	N	Subset		Washing type	N	Subset		
		1	2			1	2	3
Bleach washing	18	–3.361		Bleach washing	18	–18.278		
Stone washing	18	–3.333		Enzyme washing	18		–17.500	
Enzyme washing	18	–3.306		Stone washing	18		–17.500	
Rinse washing	18		–2.528	Rinse washing	18			–15.333

Results of rubbing fastness in dry and wet conditions

For rubbing fastness, a piece of white fabric was placed on the probe of the Crockmeter device, and the rubbing fastness value was determined from the colour change in the fabric as a result of the back-and-forth friction movement. For colour fastness to rubbing, grade 5 is the best and grade 1 is the worst [12]. The dry rubbing fastness values of all the untreated fabrics were measured as grade 4, and the wet rubbing fastness values of all the untreated fabrics were measured as grade 2 according to the scale. Figure 2 shows the results of colour fastness to rubbing of stretch denim fabrics for bleach, enzyme, rinse, and stone washes. When the test results under dry and wet conditions were compared, the highest fastness values were obtained for the bleach washing. In addition, it was concluded that the rubbing fastness values of enzyme-washed fabrics were lower than those of other fabrics under both industrially washed and untreated conditions (except TZ2). When the results were evaluated based on the grey scale, it was observed that all fabrics in the dry condition showed average to good rubbing fastness values and in the wet condition the washings had poor values (except bleach). The multiple comparisons of the factor levels are presented in table 4.

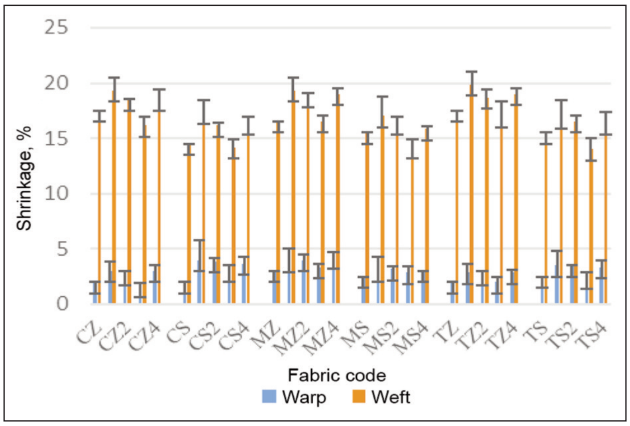

Fig. 1. Shrinkage values of fabrics

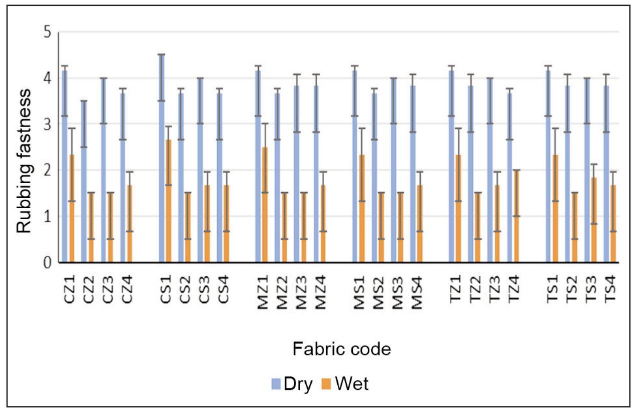

Fig. 2. The rubbing fastness values of industrially washed fabrics

Table 4

THE SNK TESTS FOR DRY AND WET RUBBING FASTNESS VALUES OF FABRICS								
Wet rubbing fastness				**Dry rubbing fastness**				
Factors				**Factors**				
Weft yarn	**N**	**Subset**		**Weft yarn**	**N**	**Subset**		
		1	**2**			**1**	**2**	**3**
Cotton/Modal	24	1.771		Cotton	24	3.896		
Cotton	24	1.813		Cotton/Modal	24	3.896		
Cotton/Tencel	24	1.854		Cotton/Tencel	24	3.937		
Washing type	**N**	**Subset**		**Washing type**	**N**	**Subset**		
		1	**2**			**1**	**2**	**3**
Enzyme washing	18	1.500		Enzyme washing	18	3.694		
	18	1.611		Stone washing	18	3.750		
Stone washing	18	1.722		Rinse washing	18		3.972	
Bleach washing	18		2.417	Bleach washing	18			4.222

Although it was stated in a previous study that the degree of dry and wet rubbing fastness for enzyme washing was relatively better than that of the others [13], the highest rubbing fastness values were measured in the case of bleach washing under dry and wet conditions in this study. In addition, it was observed that the dry and wet rubbing fastness values were higher than those of the untreated fabrics for bleach washing.

Results of breaking strength in warp and weft directions

When the breaking strength values in the warp and weft directions were compared, the highest breaking strength values were observed for the rinse-washed fabrics in the warp direction. The lowest breaking strength values in the warp direction were measured for the bleach-washed fabrics (figure 3). The SNK test results for the warp and weft breaking strengths of the fabrics are listed in table 5. Considering the effect of the weft yarn on the warp-breaking strength values, the highest warp-breaking strength value was measured for the fabric woven with cotton/Modal elastane weft yarn. In previous studies, it was stated that fabrics woven with Modal had higher strength values than cotton and viscose [14]. When the breaking strength measurement results in the weft direction were compared, it was observed that weft yarn differences did not have a statistically significant effect on this value. The crystallisation value of the Tencel fibre is higher than that of the Modal fibre. For this reason, it is thought that water molecules entering the structure during washing change the structure of the Tencel fibre and break down weaker hydrogen bonds but cannot influence the regions of a high order, causing a decrease in strength values. Considering the impact of washing on the warp and weft breaking strengths, the highest breaking strength values were observed in the case of rinse washing in the warp direction. In the weft direction untreated fabrics and rinse-washed fabrics showed close strength values to each other which supports rinse washing reduced the strength value less than other types of washing [15]. In this study, the lowest breaking strength results were observed for bleach washing. Because the use of bleach reduces the strength value owing to the oxidant reaction [16].

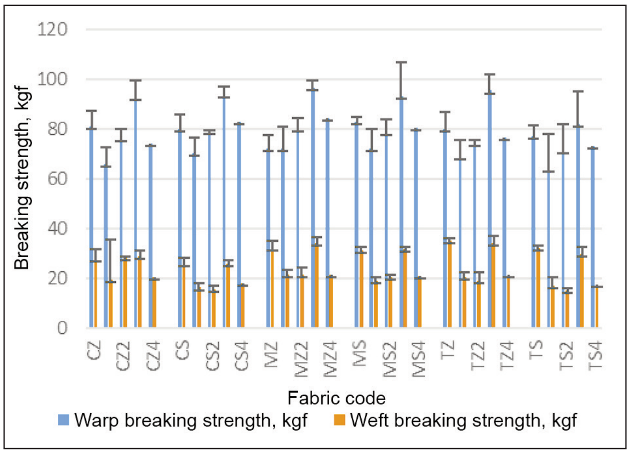

Fig. 3. Breaking strength values of fabric

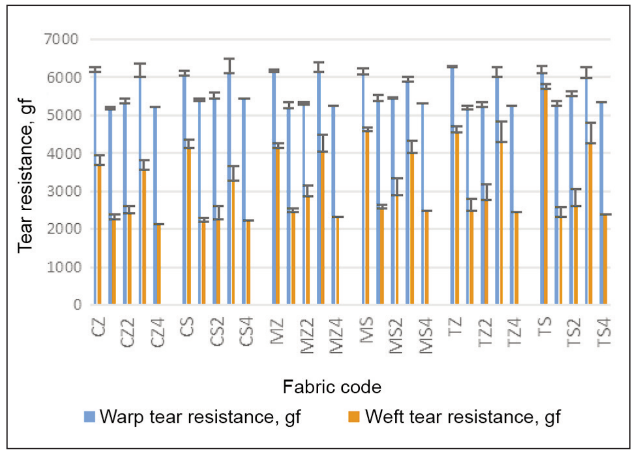

Fig. 4. Tear resistance values of fabrics

Table 5

THE SNK TEST FOR WARP AND WEFT BREAKING STRENGTH OF FABRICS									
Warp breaking strength					**Weft breaking strength**				
Factors					**Factors**				
Weft yarn	**N**	**Subset**			**Weft yarn**	**N**	**Subset**		
		1	**2**				**1**	**2**	**3**
Cotton/Tencel	24	75.67			Cotton	24	21.54		
Cotton	24	79.33	79.33		Cotton/Tencel	24	21.83		
Cotton/Modal	24		82.21		Cotton/Modal	24	23.87		
Washing type	N	**Subset**			**Washing type**	**N**	**Subset**		
		1	**2**	**3**			**1**	**2**	**3**
Bleach washing	18	68.89			Bleach washing	18	19.00		
washing	18		76.50		Stone washing	18	19.94		
Stone washing	18		78.67		Enzyme washing	18	20.06		
Rinse washing	18			92.22	Rinse washing	18		30.67	

Results of tear resistance in warp and weft directions

Tear resistance is defined as the force required for the continuation of an initiated tear on the fabric. The tear resistance of the denim fabrics in the warp and weft directions is shown in figure 4. One of the most important factors affecting tear strength is the mobility of the yarns in the fabric. The strength properties of the yarns affect the tear strength as well as the breaking strength. Considering the effect of weft yarn differences on tear strength, it was observed that the weft tear resistance of the Modal and Tencel included fabrics was higher than that of the 100% cotton elastane woven fabrics. Industrial washings reduced the tear resistance values of the fabrics compared to that of untreated fabrics. On the other hand, rinse washing yielded tear resistance results close to those of the untreated fabrics. The lowest tear resistance values in the warped way were seen in the fabrics that were treated with bleach washing (except MS4), and in the weft, way were seen in the fabrics that were treated with stone washing (except CS4 and TS4).

The SNK test results for warp and weft tear resistances are listed in table 6. When the impact of the weft yarn on the weft tear resistance value was investigated, it was observed that the 100% cotton fabric showed statistically different results from the others and the lowest weft tear resistance value was measured when cotton yarn was used in the weft. It was concluded that using Tencel and Modal blended yarns in the weft direction increased the tear resistance value in the weft direction. Previous studies have reported that Modal woven fabrics have higher tear strength values owing to their high tenacity and breaking strength [17] and the ratio of Tencel (Lyocell) fibre in the weft yarn increased, the tear strength value in the weft direction increased [18]. Considering the effect of industrial washing on warp and weft tear resistance values, there was a statistically significant difference between the rinse wash and other washes, and the highest warp and weft tear resistance values were measured in the case of rinse washing. The lowest weft tear resistance was measured in the case of stone washing.

Table 6

THE SNK TESTS FOR WARP AND WEFT TEAR RESISTANCE OF FABRICS								
Warp tear resistance				**Weft tear resistance**				
Factors				**Factors**				
Weft yarn	**N**	**Subset**		**Weft yarn**	**N**	**Subset**		
		1	**2**			**1**	**2**	**3**
Cotton/Modal	24	5467.83		Cotton/Tencel	24	2539.38		
Cotton	24	5482.67		Cotton/Modal	24		2946.92	
Cotton/Tencel	24	5512.54		Cotton	24		2948.67	
Washing type	**N**	**Subset**		**Washing type**	**N**	**Subset**		
		1	**2**			**1**	**2**	**3**
Bleach washing	18	5245.89		Bleach washing	18	2327.33		
Stone washing	18	5306.94		Enzyme washing	18	2371.89		
Enzyme washing	18	5366.06		Stone washing	18		2638.89	
Rinse washing	18		6031.83	Rinse washing	18			3908.50

Elasticity results of fabrics

Elasticity can be defined as the return of a material to its original shape without any deformation under a certain force and duration [19]. Garments with elasticity values between 5% and 30% are called easy-stretching garments, whereas those with elasticity values between 30% and 50% are called very stretchable garments [20]. When the impact of the weft composition on the elasticity property was examined, the highest elasticity values were observed in the Tencel weft yarn blended fabrics (figure 5). The highest elasticity value was measured in the fabric that had been treated with the bleaching process Tencel Z-twill direction fabric (58%). The lowest elasticity values were observed in the Modal S-twill woven fabrics. When the fabrics were compared in terms of the industrial washing process, the lowest elasticity values were observed in the fabrics subjected to rinse washing. It is also noteworthy that the elasticity values of rinse-washed fabrics were close to those of the untreated fabrics. Although the use of hydrogen peroxide and its derivatives in washing is a cheap method, it has some disadvantages. One of them is that it causes yellowing if good neutralization is not performed, and it interacts with cotton and decreases its strength [21]. In contrast, the highest elasticity values were observed in bleach washing for all fabrics in both the S and Z-twill directions (except MS1) in this study. This was attributed to the use of an appropriate amount of hydrogen peroxide and a good neutralization process. The SNK test results for the elasticity values of the fabrics are presented in table 7. The elasticity values of the cotton/Tencel elastane weft yarn woven fabrics were significantly different from those of the other fabrics, and the highest elasticity values were observed for these fabrics. A good fibre must have a certain amount of void volume. The void ratio decreases with increasing stretching of the fibres; therefore, the proportion of void ratio is greatest in viscose fibres, followed by lyocell (Tencel) fibres, and the smallest voids have the most stretched Modal fibres [22]. Therefore, it can be said that the fabric produced from the cotton/Tencel elastane yarn has higher elasticity than that produced from the cotton/Modal elastane yarn.

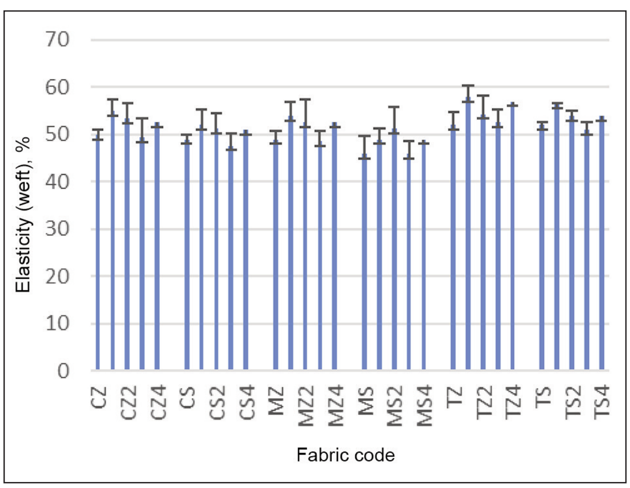

Fig. 5. Elasticity values of fabrics

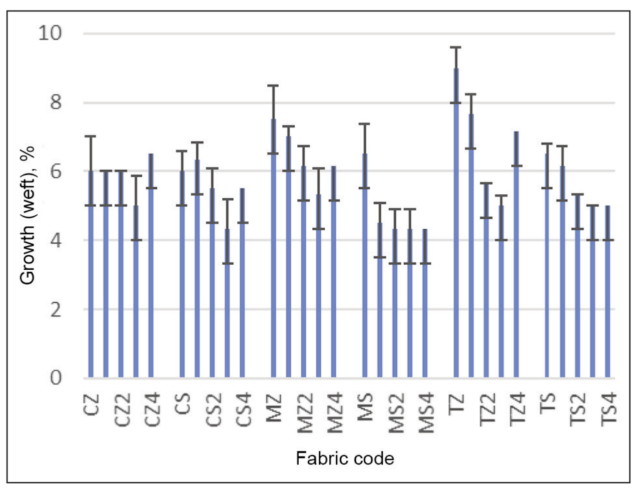

Fig. 6. The growth values of fabrics

Table 7

THE SNK TESTS GROWTH AND ELASTICITY OF FABRICS								
Growth					**Elasticity**			
Factors					**Factors**			
Weft yarn	**N**	**Subset**			**Weft yarn**	**N**	**Subset**	
		1	**2**				**1**	**2**
Cotton/Modal	24	5.271			Cotton/Modal	24	50.42	
Cotton	24		5.646		Cotton	24	51.54	
Cotton/Tencel	24		5.875		Cotton/Tencel	24		54.71
Washing type	**N**	**Subset**			**Washing type**	**N**	**Subset**	
		1	**2**	**3**			**1**	**2**
Rinse washing	18	4.833			Rinse washing	18	49.22	
Enzyme washing	18		5.500		Stone washing	18		52.72
Stone washing	18		5.778		Enzyme washing	18		52.83
Bleach washing	18			6.278	Bleach washing	18		54.11

Growth results of fabrics

Fabric manufacturers and designers want the growth value of the fabrics used in garment production to be as low as possible. This is because, as the growth value increases, bagging also increases. When the growth values of the fabrics were investigated, it was observed that the growth value was between 4–9%. It was observed that the growth values of all the rinse-washed fabrics were lower than those of the other fabrics (figure 6). The highest growth values were observed for the cotton/Modal elastane and cotton/Tencel elastane untreated fabrics. In addition, TZ1 and TZ4 coded Tencel Z-twill weave bleach and stone-washed fabrics showed the highest growth value after untreated fabrics. Because the polymerization degree of the Tencel fibre is higher than that of the other fibres, it can be said that the deterioration in the crystalline region causes an increase in the growth value of the fabrics made from this fibre. The growth value increased in the case of bleach washing in the Modal and Tencel weaved fabrics, whereas an increase in this value was observed in the case of stone washing in the cotton Z-twill fabrics. The SNK test results for the growth values of the fabrics are presented in table 7. The results demonstrated that there was a significant difference between the cotton/Modal elastane weft woven fabric and other fabrics, and the lowest growth value was observed in this fabric. Considering the effect of washing, the lowest growth value was observed in the case of rinse washing, and the highest growth value was observed in the case of bleach-washed fabrics after untreated fabrics. In previous studies, it was stated that the growth value of rinse wash was lower than that of other washes because of the lower washing time and temperature [23]. Therefore, it can be concluded that rinse washing decreases the growth value of denim fabrics more than other industrial washing methods. Although subjecting the fabrics to stone washing for a long time and adding bleach after stone washing deteriorates the elastane fibre, which reduces the recovery value and increases the growth value of the fabric. It can be concluded that industrial washing decreases the growth value of fabrics compared with untreated fabrics.

CONCLUSIONS

In this study, the effects of three different factors (weft yarn, twill direction, and washing) on the performance properties of denim fabrics were investigated. When the untreated fabric and industrially washed fabrics were compared, it was observed that the shrinkage, elasticity, and weft-breaking strength values of rinse-washed fabrics were close to those of the untreated fabrics, the rubbing fastness values of the untreated fabrics were lower than those of the bleach washed fabrics, and the highest tear strength values were measured in the untreated fabrics. In addition, it can be said that industrial washing processes reduce the growth values of untreated fabrics and reduce the bagging occurring during use. The rinse-washed fabrics showed the lowest shrinkage, elasticity, and growth, and the highest warp-breaking values because chemicals are not used in rinse washing (such as hypo and enzyme), washing temperatures, and duration are low. The highest shrinkage, elasticity, rubbing fastness values, and lowest breaking strength were measured for the bleach washing. Considering the effect of the weft yarn on the measured parameters, the highest elasticity, growth, and rubbing fastness were observed in the fabric woven with the cotton/Tencel elastane weft yarn. The highest weft and warp breaking strengths and weft tearing resistances were measured in fabrics woven with cotton/Modal elastane weft yarn. Thus, it can be concluded that the use of Modal fibre with cotton in the fabric structure increased the strength more than the Tencel fibre, and the use of Tencel yarn with cotton increased the elasticity and rubbing fastness values more than the Modal fibre. In addition, it was observed that twill direction only affected the shrinkage and elasticity values, and Z-twill fabrics exhibited higher shrinkage and elasticity values.

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