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The Effects of Several Washings on Some Comfort Features of Denim Fabrics Made of Cotton and Coolmax Weft Yarns with and without Elastane

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Abstract

The performance of denim fabric under the influence of repeated home laundering techniques was investigated in this article. All fabrics have been produced from the same warp yarn (100% cotton) and four different weft yarns: 100% cotton (CT), 100% Coolmax (CM), Cotton & Elastane (CTE), and Coolmax & elastane (CME) and then subjected to one, ten, and twenty simulated home laundry cycles. Performance attributes such as air permeability, tearing strength, stiffness, drying performance, and color measurement were assessed. In addition, the significance of the washing effect on the parameters was determined using ANOVA and Tukey HSD multiple comparisons. In conclusion, frequent washing had a detrimental impact on air permeability, tearing strength, and stiffness, but did not affect drying performance. Aside from that, the successive washing has resulted in noticeable color changes.

Keywords: Stretch denim fabric, Coolmax, repeated laundering, air permeability

Çeşitli Yıkamaların Pamuklu ve Coolmax Atkı İpliklerinden Üretilen Denim Kumaşların Bazı Konfor Özelliklerine Etkisi

Öz

Bu çalışmada denim kumaşların tekrarlanan yıkamalar sonrasındaki performansı araştırılmıştır. Tüm kumaşlar aynı çözgü ipliğinden (%100 pamuk) ve %100 pamuk (CT), %100 Coolmax (CM), Pamuk & Elastan (CTE) ve Coolmax & elastan (CME) olmak üzere dört farklı atkı ipliğinden üretilmiştir: Ürtetilen kumaşlara 1, 10 ve 20 kez tekrarlı ev yıkaması uygulanmış ve sonrasında hava geçirgenliği, yırtılma mukavemeti, sertlik, kuruma performansı ve renk ölçümü gibi performans özellikleri değerlendirilmiştir. Ayrıca yıkama etkisinin parametreler üzerindeki önemi ANOVA ve Tukey HSD çoklu karşılaştırmaları kullanılarak tespit edilmiştir. Sonuç olarak, tekrarlı yıkamaların kumaşların hava geçirgenliği, yırtılma

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mukavemeti ve kumaş sertliği üzerinde olumsuz etkisi olduğu ancak kuruma performansını etkilemediği görülmüştür. Bunun dışında tekrarlı yıkamalar gözle görülür renk değişikliklerine neden olmuştur.

Anahtar Kelimeler: Streç denim kumaş, coolmax, tekrarlı yıkama, hava geçirgenliği

1. INTRODUCTION

Denim is a twill-woven fabric with indigo-dyed warps and grey or un-dyed wefts, with weft threads passing beneath two or more warp threads. One side of the fabric shows the blue warp threads, while the other side shows the white weft threads due to the warp-faced twill weaving [1]. Denim fabric's popularity is rising because of its versatility, durability, and affordability [2]. Usually, the fabric is rough and harsh when woven at first. Therefore, different washing treatments must be done to the material before being used in the final goods to change the fabric's surface and the look of denim products. So, denim washing is the core of denim finishing related to quality, aesthetic, and value of garments [3,4].

Coolmax is a modified polyester fiber with a tetra channel cross-section of benzene rings and a conjugated aromatic polymer chains system that absorbs UV radiation more effectively [5]. Ertekin observed that coolmax yarn fabrics have improved air permeability, heat resistance, and water vapor permeability indexes [6]. Coolmax's thermoregulation function is based on moisture management, thanks to the multi-channel cross-section of the fibers, which uses capillary theory to collect sweat and moisture from the skin's surface, move it to the fabric surface, and then evaporate it. Coolmax fabric has a decreased air permeability due to its increased thickness and the shape of its fibers [7]. Combining Coolmax fiber with regenerated cellulose fibers increased the wearing comfort and drying speed of sportswear [8]. Coolmax is hydrophobic, unlike hydrophilic cotton, which swells with solution absorption [9]. On the other hand, cotton absorbs and retains 14 times as much moisture as Coolmax [5].

The worldwide market is becoming more interested in apparel comfort with the advancement of civilization. Fabrics used to make summer and sports apparel must have outstanding thermal-wet performance. Air permeability, moisture management, and heat transfer performance are the major factors that impact comfort characteristics [10]. **Stretch denim fabric** has become increasingly popular due to its ability to perfectly fit the wearer's body [2]. Elastic yarn can be used in the warp or the weft, or both, of a stretch fabric. Usually, stretch denim fabrics are made by employing the core-spun cotton weft yarns incorporating elastane filament (Polyurethane) and cotton fibers. In addition to the elastane's linear density, its count and twist, the fabric weave and structure, and finishing techniques all have an impact on stretch textiles' mechanical properties [11-13]. Fabric weft stretchability is a significant factor in fabric comfort, mechanical and thermal properties, and the fabric's elongation [14]. There is a substantial difference in air and water vapor permeability between denim fabrics with cotton weft yarn and polyester and Lycra weft yarns [15]. On the other hand, elastane may affect the wearer's thermo-physiological comfort [7].

There is a lack of research on the comfort attributes of denim fabrics with various weft yarns, especially when it comes to the impact of regular home laundry. Moreover, no researcher paid attention to the drying performance of the denim fabric made by different weft yarns, specially coolmax and elastane core-spun yarn.

2. MATERIALS AND METHODS

This study produced four denim fabrics from the same & 100% cotton warp yarn and four different weft yarns. Weft yarns are 24 Ne cotton, 24 Ne Coolmax, 24 Ne cotton & elastane, and 24 Ne Coolmax & elastane. The properties of weft yarns have been depicted in Table 1.

The denim fabrics were made with a 3/1 twill weave by the Picanol Rapier weaving machine at the Bossa Denim Factory in Adana Industrial Area, Turkey. The specifications of the denim fabrics are shown in Table 2. After weaving, the fabric was passed through a singeing machine to burn the projecting fibers on the face side at 70 m/min and 12 mbar. Next, a regular wash was used to remove the ash from the fabric surface. Then, drum contact drying was carried out at a speed of 35 meters per minute and 110 °C. The softener was 3 g/l, the wetting agent was 1 g/l, and acetic acid was used to keep the pH constant between 4.5 and 5, with the speed of 24 m/min temperature was 140 °C. Finally, Sanforizing was completed at a rate of 30 meters per minute in the end.

Table 1. Properties of yarns from USTER TESTER 5-S800

Parameters	**Values**			
Count (Ne)	23.77	23.87	23.80	23.67
CV%	0.59	1.18	1.06	0.97
Elongation%	5.21	13.60	7.47	18.77
Sinlge yarn strength, Rkm	17.45	18.47	12.72	22.83
U%	12.38	3.16	12.97	7.73
Thin place (-50%km)	1	0	5	0
Thick place (+50%km)	48	0	523	1
Neps (+200%km)	21	0	324	4
Imperfections (IPI)	70	0	852	5
Hairiness	5.36	5.12	6.12	5.80

Table 2. The specifications of the denim fabrics

Sample code	**CT**	**CM**	**CTE**	**CME**
Weave	3/1 Z twill	3/1 Z twill	3/1 Z twill	3/1 Z twill
Mass/unit Area (gm/m^2)	215	203	226	202
Width	179 cm	180 cm	157 cm	140 cm
Warp material	Cotton: Indigo dyed	Cotton: Indigo dyed	Cotton: Indigo dyed	Cotton: Indigo dyed
Weft material	100% Cotton	100% Coolmax	92% Cotton, 8% elastane	92% Coolmax, 8% elastane
Warp density (ends/cm)	40	40	48	48
Weft density (picks/cm)	27	27	30	30
Warp linear density (Tex)	29.5 Tex	29.5 Tex	29.5 Tex	29.5 Tex
Weft linear density (Tex)	24.8 Tex	24.8 Tex	24.8 Tex + 78 dTex ela	24.8 Tex + 78 dTex ela

Testing Methods

Tearing strength was determined by ISO 9290:1990 with James H. Heal (Elmatear model) tester, stiffness by ASTM D4032-94 with circular stiffness tester, color by Minolta Spectrophotometer, and air permeability by ISO 9237: 1995 with EP08M ProWhite machine. The washing was done in a Type-A washing machine (Horizontal axis, Front loading). The detergent was reference detergent-3, and the mass of the washing sample and ballast was 1 kg/ 1 kg, with type-II ballasts consisting of 50% cotton and 50% polyester. The washing procedure was 3N (Temp: 30°C, Liquor level: 100 mm, wash time: 15 minutes, three rinses); the drying procedure was C (open air dry/flat dry).

3. RESULTS AND DISCUSSION

Before the measurements, the samples were put out on a level surface for a day in a normal atmospheric condition (20±2°C and 65±2% RH).

3.1. Air Permeability

Air permeability has an impact on how comfortable a garment feels. The fabric's ability to allow air to pass through when there is a differential air pressure on each side of the fabric's surface is an essential factor to consider when studying and comparing the breathability characteristic. The number of pores determines porosity, directly related to fabric permeability [6]. The porosity of a textile determines its air permeability. For the same fabric structure, increased filament fiber composition increases air permeability [16]. As the tightness of the fabric grew, the air permeability of the material decreased (Figure 1). The air permeability ratings of elastane-free materials CT & CM are greater than CTE & CME. The repeated washing negatively influences the air permeability values because the frequent washing leads the fabric structure to relax, enhancing its compactness.

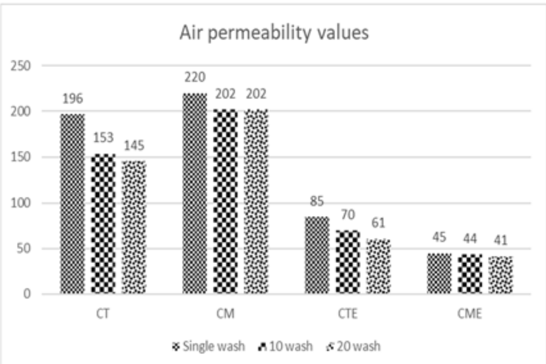

Figure 1. Air permeability values

Analysis of variance (Table 3) was done according to α=0.05 significance level to determine the effect of weft types on the air permeability due to repeated washing. The difference between weft types with Tukey HSD multiple comparisons has been depicted in Table 4 and found that the weft types had statistically significant on the air permeability values.

3.2. Drying Performance

The fibers' capillary capacity and moisture absorption determine the fabric's ability to regulate the moisture [15]. It was a simple procedure in which the fabric samples were weighed after being wet for a period, and the moisture loss percentage of the fabric samples was determined. After the washing procedure, the samples' weight was determined. Then, all the pieces were dried in a free environment. After every 1 hour, the samples' mass was measured, and the % of weight loss was determined. The same procedures were repeated until the difference in weight reduction was zero. These numbers have been used to evaluate the samples' fast dry characteristics. The results are presented in the Figure 2.

The formula for calculating the moisture loss

$$= \frac{Weight\ of\ wet\ sample - weight\ of\ dry\ sample}{Weight\ of\ wet\ sample} \times 100 \quad (1)$$

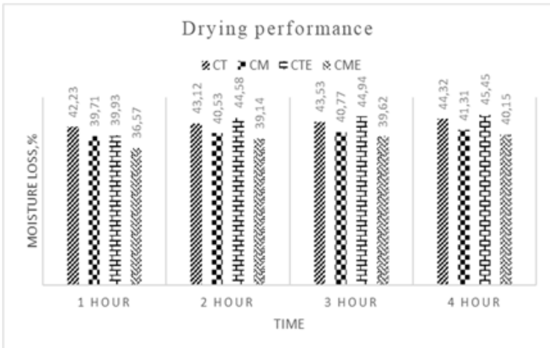

Figure 2. Moisture loss values

Cotton fibers are hydrophilic, which means that fabrics with a high proportion of CT absorb more water than CM fabrics. As a result, CM fabrics contained less water than cotton fabrics after washing. As a result, CM and CME drying performance in weight loss percentage is lower. Analysis of variance (Table 3) was done according to α=0.05 significance level to determine the effect of weft types on the drying performance due to repeated washing. The difference in moisture loss between weft types with Tukey HSD multiple comparisons has been depicted in Table 4 and found that the moisture loss percentage data was unaffected by differences in weft types between the groups.

3.3. Tearing Strength

Under specific conditions, the force necessary to begin or continue to rip a fabric in either the weft or warp direction is defined as tearing strength. It describes the gradual, thread-by-thread fabric rupture along a line, whereas all the yarns are broken during a tensile strength test. As a result, the tensile strength value (in kilograms) is larger than the tearing strength value. The results are presented in the Figure 3-4.

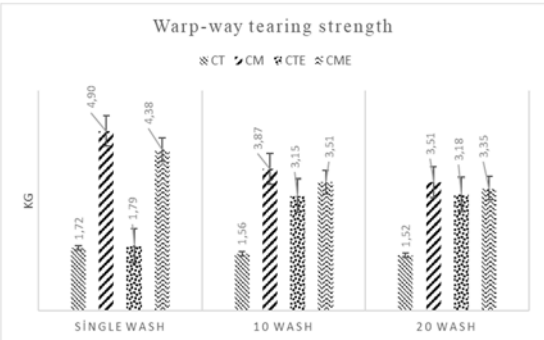

Figure 3. Warp-way tearing strength values

After every wash, the tearing strength of the fabric samples is as follows: CT<CM< CTE< CME. As we tried to find the effect of laundering on the fabric strength, the results demonstrated that the strength has a little decreasing trend from a single wash to 10 wash and 20 wash. The repeated laundry causes the yarns to lose their inter-cohesive force and become weaker.

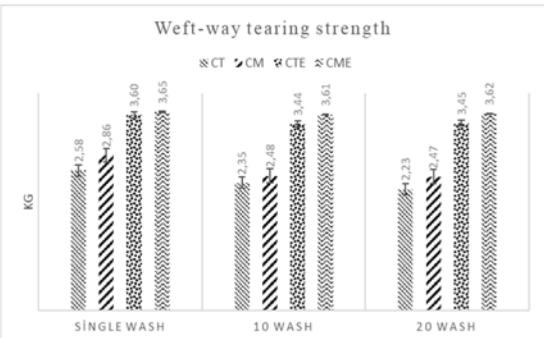

Figure 4. Weft-way tearing strength values

The values of the four denim fabrics differ because the weft threads are different. Because CTE and CME fabrics contain lycra, their strength is more substantial. There is also evidence of a decrease in tearing strength because of washing. To determine the effect of weft types on the tearing strength, analysis of variance (Table 3) was done according to α=0.05 significance level; the difference in tearing strength between weft types was examined with Tukey HSD multiple methods tabulated in Table 4 and found that the difference in weft types became significant when tearing strength values except for TS-WA_SW: CT/CTE (p = 0.362) and TS-WE_SW: CTE / CME (p = 0.450).

3.4. Stiffness

Fabric stiffness can affect the hand feel, draping effect, and comfort sensation while wearing. A fabric's stiffness is unique: the natural inclination to remain upright without any support. Therefore, it is crucial to understand the fabric's handle and drape properties. Laundry cycles progressively make the yarn more flexible, resulting in a decrease in stiffness in the materials. The CTE and CME fabrics have a high stiffness value because the elastane-cored yarn caused the fabric to be more compact and rigid. The results are presented in the Figure 5.

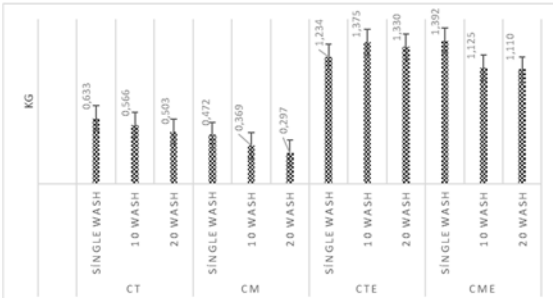

Figure 5. Stiffness values

To determine the effect of weft types on the fabric stiffness, analysis of variance was done (Table 3) according to α=0.05 significance level; the difference between weft types was examined with Tukey HSD method tabulated in Table 4 and discovered that the difference between the weft types became meaningful on the stiffness values due to repeated washing.

Table 3. Effect of weft types on different tests for repeated washing (ANOVA results)

Test	Dependent variable	F	Sig.
Air permeability (AP)	AP_SW	513.104	0.000
	AP_10W	535.504	0.000
	AP_20W	198.477	0.000
Moisture loss percentage (MLP)	MLP_1H	6.265	0.004
	MLP_2H	6.397	0.003
	MLP_3H	6.538	0.003
	MLP_4H	7.163	0.002
Tearing strength (TS)	TS-WA_SW	999.213	0.000
	TS-WE_SW	137.794	0.000
	TS-WA_10W	353.998	0.000
	TS-WE_10W	208.211	0.000
	TS-WA_20SW	489.349	0.000
	TS-WE_20W	134.145	0.000
Stiffness (ST)	ST_SW	286.199	0.000
	ST_10W	222.127	0.000
	ST_20W	267.134	0.000

SW: single wash, 10W: 10 washes; 20W: 20 washes, WA: Warp, and WE: Weft

Table 4. The results (p values) of multiple comparisons for each test according to weft types

Tests	CT:CM	CT:CTE	CT:CME	CM:CTE	CM:CME	CTE:CME
AP_SW	0.002	0.000	0.000	0.000	0.000	0.000
AP_10W	0.000	0.000	0.000	0.000	0.000	0.000
AP_20W	**0.118**	0.000	0.000	0.000	0.000	**0.215**
MLP_1H	0.000	**0.096**	**0.07**	0.019	0.027	**0.867**
MLP_2H	0.009	**0.299**	**0.075**	0.001	**0.326**	0.008
MLP_3H	0.009	**0.309**	**0.055**	0.001	**0.404**	0.006
MLP_4H	0.005	**0.400**	0.033	0.001	**0.390**	0.005
TS-WA_SW	0.000	**0.362**	0.000	0.000	0.000	0.000
TS-WE_SW	0.001	0.000	0.000	0.000	0.000	**0.450**
TS-WA_10W	0.000	0.000	0.000	0.000	0.000	0.000
TS-WE_10W	0.041	0.000	0.000	0.000	0.000	0.016
TS-WA_20SW	0.000	0.000	0.000	0.000	0.011	0.009
TS-WE_20W	0.035	0.000	0.000	0.000	0.000	**0.052**
ST_SW	0.001	0.000	0.000	0.000	0.000	0.001
ST_10W	0.000	0.000	0.000	0.000	0.000	0.000
ST_20W	0.000	0.000	0.000	0.000	0.000	0.000

* The mean difference is significant at the 0.05 level

3.5. Color Measurement

Under the illuminant D65, the color of the fabric samples was measured. The instrument was calibrated initially, and then spectral reflectance values were collected at 10 nm intervals from 400 nm to 700 nm in the visible spectrum. All the color measurements and visual evaluations were conducted in the same direction. The single, 10, and 20 washed samples' CIELab coordinates (L*, a*, b*, c*, and h), K/S values, and color difference values were measured and compared in Tables 5 and 6. The color yield (K/S) was measured at a wavelength of 560 nm. Because the values of L* are negative, all the fabric samples have become darker. Furthermore, the fabric samples got more reddish after washing since the a* values were generally positive.

The negative b* values show that the samples became increasingly blueish because of continuous washing. The K/S values of elastic-containing fabrics are greater than those of elastic-less fabrics. Color changes were determined compared to single wash samples, and assessments were done. Any international standard does not define the entire color difference. The manufacturer's quality standards and customer criteria establish this value. The absolute color difference tolerance was believed to be 1.0 in this experiment. As a result, All samples received a fail remark since ΔE is more prominent than 1 (Table 6).

Table 5. Measured CIELab values of denim fabrics

Sample	Process	Color values					
		L*	C	a*	b*	h	K/S
CT	SW	28.7	2.84	0.14	-2.83	272.9	7.96
	10W	21.72	4.92	0.24	-4.91	272.79	14.08
	20W	22.82	5.28	0.07	-5.28	270.73	12.87
CM	SW	26.01	6.2	-0.05	-6.2	269.5	10.11
	10W	21.82	7.09	0.06	-7.09	270.49	14.4
	20W	21.85	7.71	0.06	-7.71	270.43	14.4
CTE	SW	27.61	2.97	0.43	-2.94	278.27	8.66
	10W	19.17	4.71	0.85	-4.64	280.43	17.74
	20W	17.3	5.16	1.02	-5.05	281.38	21.14
CME	SW	24.82	6.25	0.24	-6.24	272.23	11.19
	10W	18.31	6.19	0.71	-6.15	276.63	19.67
	20W	17.56	7.11	0.52	-7.09	274.2	21.33

Table 6. The color difference between SW and 10W & 20W samples

Sample	Process	Color differences						Assessment
		ΔL*	Δa*	Δb*	ΔC*	Δh*	ΔE	
CT	10W	-6.973	0.095	-2.075	2.077	0.007	7.28	Fail (darker, reddish, bluer, brighter)
	20W	-5.877	-0.076	-2.447	2.444	0.146	6.37	Fail (darker, greener, bluer, brighter)
CM	10W	-4.195	0.115	-0.883	0.883	0.115	4.29	Fail (darker, reddish, bluer, brighter)
	20W	-4.163	0.112	-1.51	1.51	0.113	4.43	Fail (darker, reddish, bluer, brighter)
CTE	10W	-8.442	0.425	-1.691	1.738	0.141	8.62	Fail (darker, reddish, bluer, brighter)
	20W	-10.308	0.589	-2.11	2.181	0.213	10.54	Fail (darker, reddish, bluer, brighter)
CME	10W	-6.51	0.471	0.095	-0.059	0.477	6.53	Fail (darker, reddish, yellower, duller)
	20W	-7.258	0.277	-0.847	0.861	0.229	7.31	Fail (darker, reddish, bluer, brighter)

ΔL*= Difference in lightness or darkness value, Δa*= Difference in red/green axis, Δb*=Differences in yellow / blue axis, ΔC= Difference in chroma, Δh*= Difference in hue, ΔE= Color difference value

4. CONCLUSION

The present research fotanveercuses on the comparative performances of denim fabrics with the same cotton warp and different weft yarns, typically cotton, coolmax with or without elastane yarn. Frequent washing causes the fabric structure to relax, increasing its compactness. Thus it has a detrimental impact on the air permeability values. There is also evidence of tearing strength being reduced because of washing. Laundry cycles gradually make the yarn more flexible, resulting in a reduction in fabric stiffness. The moisture loss percentage data had a substantial influence when viewed with time. However, the differences in weft types between groups had no noticeable effect on the moisture loss percentage data. The tearing strength dropped marginally as the washes increased from one to ten and twenty. All the fabric samples were found darker, reddish, and blueish due to repeated washing.

5. ACKNOWLEDGMENTS

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