(REFEREED RESEARCH)

EFFECT OF WEFT YARN FIBER CONTENTS ON THE MOISTURE MANAGEMENT PERFORMANCE OF DENIM FABRICS WOVEN WITH DIFFERENT CONSTRUCTIONAL PARAMETERS

ATKI İPLİĞİ LİF İÇERİKLERİNİN FARKLI YAPISAL PARAMETRELERLE DOKUNAN DENİM KUMAŞLARIN NEM YÖNETİM PERFORMANSI ÜZERİNDEKİ ETKİLERİ

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ABSTRACT

The research presented in this paper assessed the effects of the properties of the weft yarns having different fiber contents (such as cotton, coolmax, cordura, thermocool and elastane) and ratios and the fabric constructional parameters on certain moisture management properties of denim fabrics. The correlation between fabric constructional parameters (such as fabric thickness, fabric weight, fabric bulk density and fabric cover factor) and moisture management properties (such as wetting time (top and bottom), spreading speed (top and bottom), accumulative one-way transport capability and overall moisture management capability) were examined in accordance with different weft yarn properties. A general overview of the results showed that moisture management property of denim fabrics was affected from fiber content ratios of weft yarns and fabric properties. In addition, while these effects were found to be related to fabric thickness, fabric weight and fabric bulk density, it was found that they were not related to fabric cover factor.

Keywords: Denim fabric, moisture management properties, fabric constructional properties.

ÖZET

Bu makalede sunulan araştırmada, farklı lif içeriğine ve oranlarına sahip olan atkı iplik özelliklerinin (pamuk, coolmax, cordura, thermocool ve elastan gibi) ve kumaş yapısal parametrelerinin denim kumaşlarının bazı nem yönetimi özelliklerine olan etkisi değerlendirilmiştir. Kumaş yapısal parametreleri (kalınlık, gramaj, yoğunluk ve örtme faktörü gibi) ve nem yönetimi özellikleri (ıslanma süresi (üst ve alt), yayma hızı (üst ve alt), kümülatif tek yönlü taşıma kabiliyeti ve genel nem yönetimi kabiliyeti) arasındaki korelasyon farklı atkı ipliği özellikleri ile ilişkili olarak değerlendirilmiştir. Genel olarak sonuçlar incelendiğinde, denim kumaşların nem yönetimi özelliklerinin atkı ipliklerinin lif içeriği ve içerik oranlarından etkilendiği ve bu etkilerin kumaş kalınlığı, kumaş gramajı ve kumaş yoğunluğu ile ilişkili olduğu gözlenirken, kumaş örtme faktörü değerleri ile arasında önemli derecede bir korelsyonun olmadığı gözlenmiştir.

Anahtar Kelimeler: Denim kumaş, nem yönetim özellikleri, kumaş yapısal parametreleri.

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1. INTRODUCTION

Denim has been the most widely preferred fabric by all generations, especially because of its properties such as having a high durability against the mechanical effect, longer washing performance, easy wear properties, and its ability to provide convenience in adapting to changing trends in culture and fashion (1, 2). The wide use of the denim has increased the importance of the comfort properties of denim fabrics. Also, in the clothing industry, the comfort that clothing provide has gained further importance. For this reason, proper fabric constructions have been designed and developed in terms of comfort features for clothes. Clothes must allow the water vapor evaporation from the body, to make the users, who wear these clothes, feel more comfortable.

Moisture management is one of the primary performance factors, which determine the comfort level of the fabric, in the clothing industry (3, 4). When any liquid is dropped on the surface of a textile material, it moves into multiple directions and its movement depends upon the chemical and physical structure of the material. The properties of the fabric regarding the liquid and moisture transport into multiple dimensions are called the moisture management properties. To improve the comfort of the clothing, it is important to know the liquid moisture management properties of the textiles for various end-uses (5-8).

According to previous studies, raw material type; yarn properties such as yarn count and yarn twist coefficient; fabric structural characteristics such as yarn densities, fabric weight, weave structure, fabric geometry etc.; and finishing processes mainly affect the moisture management properties as well as thermo-physiological comfort properties of fabrics (1, 9-22). Textile raw materials may be of hydrophobic or hydrophilic chemical characteristics in the nature. Natural and regenerated hydrophilic fibers absorb a higher amount of liquids and thus show higher moisture regain at a standard atmospheric condition (22, 23). Polyester fabrics have poor thermal properties when compared to cotton fabrics. Moreover, cellulosic and polyester blended fabrics provide better liquid absorption and transport efficiency (3, 22, 24).

Previous studies showed that fabrics with proper moisture management performance can be developed by using a blend of hydrophilic and hydrophobic yarns in the fabric structure. In the case of the inner side of the fabric, which would come directly in contact with the skin and which is predominantly covered by hydrophobic yarns, the amount of moisture absorbed would be less and also these yarns would provide a channel for the transfer of the moisture. Moreover, if the outer side of fabric is also predominantly covered by hydrophilic yarns, this will provide support in transporting the moisture from inner side to the outer side of the fabrics (7).

Polyester fibers have a hydrophobic character and this property limits their broad application. Therefore, it is necessary to design a kind of polyester fiber with both a good hygroscopic character and a quick dry property (25-27). Micro denier polyester spun yarns show better water absorbency than yarns spun from normal denier polyester. This is due to greater surface area of yarns spun from micro denier fibers (20, 28). Profiled fibers are widely used in applications that need to have water transfer instead of water absorption, and for quick dry feature. Profiled fibers have a bigger surface area which improves the wicking properties such as the multi-channel fiber (e.g. coolmax) (25, 29-31). Also, hollow core fibers provide great bulkiness with less weight and its hollow cross section offer insulation due to the entrapped air inside (32).

Denim fabric structures generally have twill weave construction. Previous studies report that twill weave fabrics produce better thermal insulation properties due to higher fabric thickness, and these fabric structures have better wicking properties due to improved moisture transport properties when compared to plain weave fabric structures. Overall moisture management capability (OMMC) of twill weave fabrics is greater than plain weave fabrics. Moreover, higher thread density improves fabric’s moisture absorbency, therefore, the OMMC value of these fabrics is higher at higher thread density and lower at lower thread density. Weave structures’ having longer yarn floats improves the fabrics’ overall moisture management capability (22, 33, 34).

In the literature, studies related to moisture management characteristics of denim fabrics have been performed on traditional denim structures, which are composed of 100% cotton, and novel denim structures, which are produced of the 100% cotton yarns in warp, while having different material in weft yarns (i.e. linen, polyester, polypropylene, elastane etc.). These studies have revealed that fabrics with enhanced moisture management capacity can be developed by using a blend of hydrophilic and hydrophobic yarns in the fabric structure. In denim fabrics, especially 3/1 twill weave design is a more suitable structure in such a way that the hydrophobic yarns are predominantly present in the weft direction, which would directly contact the skin, and the hydrophilic yarns are predominantly present in the warp direction (7, 41).

In addition to the traditional 100% cotton denim structure, in which the denim fabrics are based on a blend of cotton and the typical fibers with special cross-sections or holes (coolmax and thermocool, respectively) and the fibers giving the textile material a high abrasion resistance (e.g. cordura).

This paper assessed the effects of the weft yarns having different fiber contents (in other words, produced using different blended ratios of fibers such as cotton, coolmax, cordura, thermocool and elastane) and the effects of certain fabric constructional parameters (such as fabric thickness, fabric weight, fabric bulk density and fabric cover factor) on certain moisture management properties of commercially used denim fabrics.

2. MATERIAL AND METHOD

2.1. Material

Indigo dyed 100% cotton open-end warp yarns and open-end non-dyed weft yarns made of different fiber contents were used in denim fabric structures. Constructional parameters of the denim fabrics are given in Table 1 and the details regarding the fiber content properties of weft yarns are given in Table 2.

Measurement of Fabric Thickness

The thickness of a woven fabric is an important parameter that affects most of its physical properties. Therefore, thickness values of the fabrics were measured according to ASTM D1777-96 (2007) to observe the effects of different constructional parameters.

Table 1. Constructional parameters of denim fabrics

Fabric Group	Fabric Code	Yarn Count [Nm]		Yarn Density [thread/cm]		Yarn Crimp [%]		Fabric Thickness [mm]	Fabric Unit Weight [g/m^2]	Fabric Bulk Density [g/cm^3]	Fabric Cover Factor (K_f)	Weave
		Warp	Weft	Warp	Weft	Warp	Weft					
1th	1F-1	11	17	35	22	22	10	0.78	336.4	0.43	30.53	3/1 Z Twill
	1F-2	17	16	25	20	10	5	0.69	412.4	0.60	24.72	3/1 Z Twill
	1F-3	14	17	32	19	22	19	0.82	413.0	0.50	28.10	3/1 Z Twill
2nd	2F-1	21	30	40	23	15	20	0.65	310.5	0.48	28.41	3/1 Z Twill
	2F-2	22	23	39	20	21	36	0.71	328.5	0.46	27.72	3/1 Z Twill
	2F-3	16	19	34	20	18	10	0.75	355.2	0.47	28.02	3/1 Z Twill
3rd	3F-1	33	25	53	27	11	8	0.67	283.6	0.42	28.89	Special
	3F-2	33	17	52	20	12	15	0.71	321.8	0.45	28.80	4/1 S Satin
	3F-3	20	19	38	25	22	10	0.68	379.8	0.56	23.71	3/1 Z Twill

Calculation of Fabric Bulk Density

Fabric bulk density (*FBD*) was calculated according to Equation (1) (35, 36):

$$FBD\ (g/cm^3) = \text{Fabric unit weight}\ (g/cm^2)\ /\ \text{Fabric thickness}\ (cm) \quad (1)$$

Calculation of Fabric Cover Factor

For any fabric, there are two cover factors: warp cover factor (K_{wa}) and weft cover factor (K_{we}). Calculation of the warp (K_{wa}), weft (K_{we}) and fabric (K_f) cover factor are presented in Equations (2), (3) and (4), respectively (37-39):

$$K_{wa} = \frac{3{,}3\ x\ n_1}{\sqrt{Nm_1}} \quad (2)$$

$$K_{we} = \frac{3{,}3\ x\ n_2}{\sqrt{Nm_2}} \quad (3)$$

$$K_f = K_{wa} + K_{we} - \frac{K_{wa}\ x\ K_{we}}{28} \quad (4)$$

where; '*wa*' stands for warp, '*we*' stands for weft and '*f*' stands for fabric. n_1 and n_2 are warp and weft yarn density (thread/cm); Nm_1 and Nm_2 are warp and weft yarn count in Nm (metric count; length in meters for 1 g of yarn) respectively.

Table 2. Weft yarn content properties

Fabric Group	Fabric Code	Fiber Content Ratios of Weft Yarns
1th	1F-1	57% Cotton / 43% Coolmax
	1F-2	82% Cotton / 18% Cordura
	1F-3	99% Cotton / 1% Elastane
2nd	2F-1	67.5% Cotton / 30% Coolmax / 2.5% Elastane
	2F-2	62% Cotton / 35.5% Coolmax / 2.5% Elastane
	2F-3	64% Cotton / 35% Coolmax / 1% Elastane
3rd	3F-1	35% Cotton / 40% Thermocool / 23% Tencel / 2% Elastane
	3F-2	60% Cotton / 39% Thermocool / 1% Elastane
	3F-3	61% Cotton / 38% Thermocool / 1% Elastane

2.2. Methods

Definitions of Moisture Management Tester

The Moisture Management Tester (MMT) was developed to measure the dynamic liquid transport properties of textile materials in multi-dimensions. MMT instrument consists of upper and lower concentric moisture sensors. The specimen is held flat under fixed pressure between the sensors while standard test solution (0.9% sodium chloride solution mimics the human perspiration) is introduced onto the top surface of the fabric. Electrical resistance changes between the upper and lower sensors are then recorded dynamically on a computer. The fabric's side that was used as the 'top' side during test refers to the side of the fabric surface that would be directly in contact with human body skin while wearing the garment made of this fabric. The 'bottom' fabric side refers to the side of the fabric surface that would be the outer surface of a garment. (5, 6, 9, 12, 20, 29).

The following indexes of fabrics are tested with MMT according to AATCC Test Method 195 (2012):

(1) Wetting Time of the top surface (WT_T) and the bottom surface (WT_B) (sec): The time when the top and bottom surfaces of the specimen begin to be wetted, after the test is started.

(2) Absorption Rate of the top surface (AR_T) and the bottom surface (AR_B) (%/sec): The average speed of liquid moisture absorption for the top and bottom surfaces of the specimen, for the initial change of water content during a test.

(3) Maximum Wetted Radius of the top surface (MWR_T) and the bottom surface (MWR_B) (mm): The greatest ring radius measured on the top and bottom surfaces.

(4) Spreading Speed of the top surface (SS_T) and the bottom surface (SS_B) (mm/sec): The accumulated rate of the surface wetting from the center of the specimen where the test solution is dropped on the maximum wetted radius.

(5) Accumulative One-Way Transport Capability (OWTC): The difference between the area of the liquid moisture content curves of the top and bottom surfaces of a specimen with respect to time.

(6) Overall Moisture Management Capability (OMMC): An index of the overall capability of a fabric to transport liquid moisture calculated by combining three measured attributes of performance: the liquid moisture absorption rate on the bottom surface, the one-way liquid transport capability, and the maximum liquid moisture spreading speed on the bottom surface.

Moisture management properties of denim fabrics were tested with the SDL Atlas M290 Moisture Management Tester (MMT) instrument according to AATCC Test Method 195 (2012). Fabrics were conditioned at 65±2% relative humidity and 21±1°C for 24 hours in accordance with the ASTM D 1776-08 (2009) standards before measurements.

Wetting time (top and bottom), spreading speed (top and bottom), accumulative one-way transport capability and overall moisture management capability of the fabric samples were examined to determine the proper denim fabric structure for moisture transfer. MMT test results were evaluated using the grading scale, which is a 5-point scale, given a*ccording to AATCC Test Method 195* (2012).

Correlation coefficient analysis was conducted to determine the relationships between fabric constructional parameters (such as fabric thickness, fabric weight, fabric bulk density and fabric cover factor) and fabric moisture management properties (wetting time, spreading speed, accumulative one-way transport capability and overall moisture management capability).

The correlation coefficient analysis results (R-value) are given in Table 3. The correlation coefficients (R-value) higher than 0.3 were considered to be related, but with a weak relationship; and the correlation coefficients higher than 0.6 were considered to have moderate to strong relationship levels (17, 40).

3. RESULTS AND DISCUSSION

Wetting time (top and bottom), spreading speed (top and bottom), accumulative one-way transport capability and overall moisture management capability of the fabric samples were presented in Figs. 1-6. When the moisture management properties were examined, it was observed that these properties vary depending on fabric thickness, fabric weight, fabric bulk density and fabric cover factor that can be explained by the variety of weft yarn fiber contents.

Analysis of the Wetting Time of the Top Surface (WT_T)

WT_T range values were compared using the grading scale, which is a 5-point scale, *according to AATCC Test Method 195* (1-5). The grades of the indexes are: 1 (≥120) = non-wetting, 2 (20-119) = slow, 3 (5-19) = medium, 4 (3-5) = fast, 5 (<3) = very fast.

In Fig. 1, it was observed that all fabric samples had ‘medium’ WT_T values. When the structural properties of the 1F-3 fabric sample, which had the lowest WT_T value, were examined in Table 1 and Table 2, and it was observed that this fabric had the highest fabric weight and thickness values and had 99% cotton / 1% elastane weft yarn contents.

The fiber content properties of the 2F-2 fabric sample, which had the highest WT_T value, were examined in Table 2, it was observed that this fabric has cotton/coolmax/elastane weft yarn contents. This result showed that when the coolmax fibers were added to the cotton content of the weft yarn and at the same time the elastane ratio was increased (2.5 % elastane) (as in 2F-1 and 2F-2), the wetting time for the top side was increased.

WT_T values of the third group of denim fabrics (these fabrics have cotton/thermocool/elastane weft yarn contents), which have different fabric weights and weave structures, gave almost similar results to each other.

Table 3. Correlation coefficient analysis (R-value)

Fabric Group	Moisture Management Properties	Fabric Properties			
		Fabric Thickness	Fabric Weight	Fabric Bulk Density	Fabric Cover Factor
1st	WT_T	-0.38	-0.82	-0.35	0.33
	WT_B	-0.91	-0.21	0.38	-0.40
	SS_T	0.67	0.58	0.02	0.01
	SS_B	0.76	0.48	-0.11	0.13
	OWTC	0.77	0.46	-0.13	0.15
	OMMC	0.74	0.51	-0.07	0.09
2nd	WT_T	-0.37	-0.57	-0.73	-0.47
	WT_B	-0.96	-0.88	0.61	0.83
	SS_T	0.19	-0.03	-0.98	1.00
	SS_B	0.89	0.97	0.09	-0.23
	OWTC	0.56	0.36	-0.98	-0.99
	OMMC	1.00	0.98	-0.32	-0.61
3rd	WT_T	0.96	0.38	0.20	0.01
	WT_B	-0.13	-1.00	-0.98	0.92
	SS_T	-0.36	0.88	0.96	-0.51
	SS_B	-0.53	0.77	0.88	-0.96
	OWTC	1.00	0.07	-0.13	0.32
	OMMC	-	-	-	-

When the WT_T values of the first group of fabrics shown in Fig. 1 were analyzed, it was observed that the cotton and coolmax ratios used in the weft yarn constituting the fabric were close to each other and that the fabric having the lowest fabric weight value has the highest WT_T value. Although 1F-2 fabric had a high cotton ratio, it was observed that the cordura fibers in the content lowered the WT_T values. When the WT_T values of fabrics 1F-2 and 1F-3 having approximately the same fabric weight value were examined, it was observed that 1F-3 fabric having a ratio of 99% cotton had the lowest WT_T value. It was observed that the coolmax and thermocool fibers used in the blends in the 2nd and 3rd group fabrics increased the WT_T values of the fabrics.

According to the correlation coefficient analysis of the first group of denim fabrics in Table 3, WT_T values had a strong negative relationship with the fabric weight. In other words, the WT_T values of the first group of denim fabrics decreased, when the fabric weight was increased. Also, it was observed that, when the ratio of cotton in weft yarn content was increased, the WT_T values of the first group of denim fabrics decreased. The correlation coefficient of the first group of denim fabrics between WT_T and constructional parameters such as fabric thickness, fabric bulk density and fabric cover factor was very approximate to 0.3, therefore, there was no correlation.

According to the correlation coefficient analysis of the second group of denim fabrics, which have the cotton/coolmax/elastane weft yarn contents, WT_T values had strong negative relationships with the fabric weight and fabric bulk density. The correlation coefficient of the second group of denim fabrics between WT_T and constructional parameters such as fabric thickness and fabric cover factor was very approximate to 0.3, therefore, there was no correlation.

In the third group of denim fabrics, it was observed that the relationship between WT_T values and fabric constructional properties was different from other fabric groups. According to the correlation coefficient analysis, WT_T values of the third group of denim fabrics had strong positive relationships with fabric thickness. In the third group of fabrics having different blend ratios of cotton/thermocool in weft yarns, it was observed that the wetting time for the top side increased when the fabric thickness was increased, indicating that thermocool fibers in weft yarn contents could increase the WT_T values of denim fabrics. The correlation coefficient of the third group of denim fabrics between WT_T and constructional parameters such as fabric weight, fabric bulk density and fabric cover factor was positive, however, the R-values were very approximate to 0.3, therefore, there was no correlation.

The correlation coefficient of the all groups of fabrics between WT_T and especially fabric cover factor was very approximate to 0.3, therefore, there was no correlation. This result showed that WT_T values were not strongly affected by cover factor values of the denim fabrics.

Analysis of the Wetting Time of the Bottom Surface (WT_B)

WT_B range values were compared using the grading scale, which is a 5-point scale, *according to AATCC Test Method 195* (1-5). The grades of the indexes are: 1 (≥120) = non-wetting, 2 (20-119) = slow, 3 (5-19) = medium, 4 (3-5) = fast, 5 (<3) = very fast.

In Fig. 2, it was observed that the majority of denim fabric samples (1F-3, 2F-2 and 2F-3, 3F-1, 3F-2 and 3F-3) had 'medium' WT_B values. 1F-1, 1F-2 and 2F-1 fabrics which had 'slow' WT_B values.

When Fig. 2 was examined, it was observed that the fabric with the highest WT_B value was obtained from the 1F-2 fabric, in which the cordura fibers were used in the weft yarn blend. It was observed that the cotton and coolmax ratios in the blend were close to each other and the elastane-free, 1F-1 fabric had a high WT_B value. It was observed that 1F-3 fabric having a ratio of 99% cotton had the lowest WT_B value. 2F-1 fabric, which has the highest WT_B value in the second group fabrics, has a lower fabric weight and fabric thickness values than the other two fabrics.

When the WTB values of the third group of fabrics, which have almost the same WTT values, were examined, it was observed that the 3F-1 fabric, whose cotton ratio and fabric weight were low, and whose cotton fiber ratio in the content was similar to the thermocool fiber ratio, had the highest WTB value in the third group of fabrics.

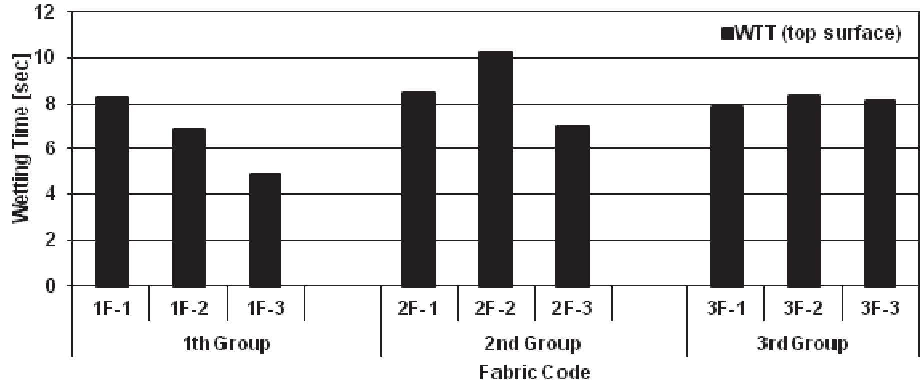

Figure 1. Changing of the wetting time of the top surface (WT_T)

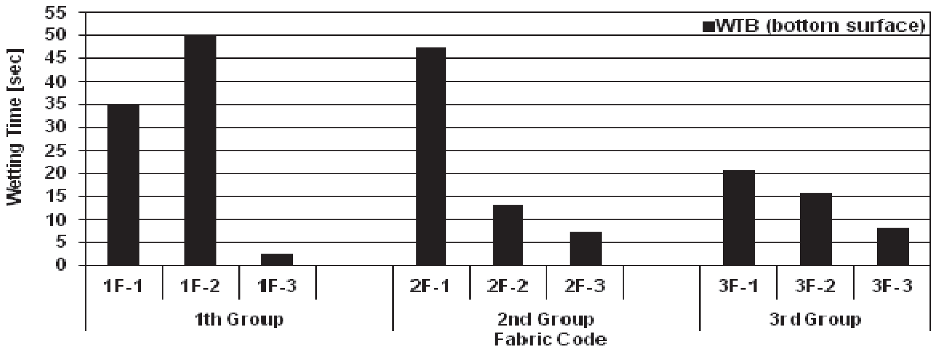

Figure 2. Changing of the wetting time of the bottom surface (WT_B)

According to the correlation coefficient analysis of the first group of denim fabrics in Table 3, WT_B values had strong negative relationships with fabric thickness. In other words, the WT_B values of the first group of denim fabrics decreased when the fabric thickness was increased. The correlation coefficient of the first group of denim fabrics between the WT_B and the other constructional parameters such as fabric weight, fabric bulk density and fabric cover factor was very approximate to 0.3, therefore, there was no correlation.

In the second group of denim fabrics, WT_B values had strong negative relationships with fabric thickness and fabric weight, while it had strong positive relationships with fabric bulk density and fabric cover factor. These results showed that the WT_B values of the second group of denim fabrics having cotton/coolmax/elastane fiber contents in weft yarns decreased when the fabric thickness and fabric weight were increased; while the WT_B values of fabrics increased when the fabric bulk density and fabric cover factor were increased.

When Table 3 was examined, it was considered that the decrease in the WT_B values with the increase in fabric thickness and fabric weight might be a result of the decrease in the WT_T values, which also decreases with increasing fabric thickness and fabric weight. The decrease in WT_T values due to the rapid absorption of the liquid with the increase in fabric thickness and fabric weight might be caused by the liquid's being transferred to the bottom surface rapidly, resulting in a decrease in the WT_B values.

According to the correlation coefficient analysis of the third group of fabrics in Table 3, WT_B values had a strong negative relationship with fabric weight and fabric bulk density while it had strong positive relationship with fabric cover factor. These results represented that when the fabric weight and fabric bulk density were increased, the WT_B values of the third group of denim fabrics with thermocool fiber contents decreased; while the WT_B values of these fabrics increased when the fabric cover factor was increased.

It has been observed that the increase in fabric weight and fabric bulk density of the fabric caused a decrease in the wetting time for the bottom side, and in this case, the cotton/thermocool blended yarns may have caused a high rate of liquid transfer to the outer surface.

Analysis of the Spreading Speed of the Top Surface (SS_T)

SS_T range values were compared using the grading scale, which is a 5-point scale, *according to AATCC Test Method 195* (1-5). The grades of the indexes are: 1 (0.0-0.9) = very slow, 2 (1.0-1.9) = slow, 3 (2-2.9) = medium, 4 (3-4) = fast, 5 (>4) = very fast.

In Fig. 3, it was observed that all fabric samples, except for 2F-2, had 'very slow' SS_T values. When the constructional properties of the 2F-2 fabric sample with the highest SS_T value (>4 = very fast) were examined in Table 1, it was observed that this fabric had the highest weft yarn crimp values, which were different from other samples. This result has shown that the amount of the yarn crimps in the fabric structure could have a significant effect on the SS_T value. Also, it was observed that SS_T values increased considerably when the cotton ratio in weft yarn content was increased.

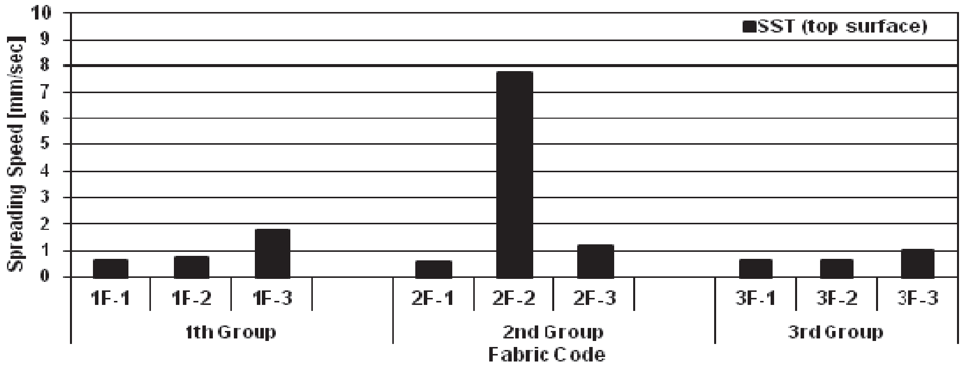

Figure 3. Changing of the spreading speed of the top surface (SS_T)

According to the correlation coefficient analysis of the first group of fabric samples in Table 3, SS_T values had a strong positive relationship with fabric thickness and fabric weight while it had no relationship with fabric bulk density and fabric cover factor. In contrast to the tendency observed in the first group of fabrics, SS_T values of the second group of denim fabrics had no relationship with fabric thickness and fabric weight. In the second group of denim fabric samples, SS_T values had a strong negative relationship with fabric bulk density while it had strong positive relationships with fabric cover factor. In the third group of denim fabric samples, SS_T values had a strong positive relationship with fabric weight and fabric bulk density.

Analysis of the Spreading Speed of the Bottom Surface (SS_B)

SS_B range values were compared using the grading scale, which is a 5-point scale, *according to AATCC Test Method 195* (1-5). The grades of the indexes are: 1 (0.0-0.9) = very slow, 2 (1.0-1.9) = slow, 3 (2-2.9) = medium, 4 (3-4) = fast, 5 (>4) = very fast.

In Fig. 4, it was observed that most fabric samples had ‘very slow’ SS_B values, while 1F-3 and 2F-2 fabric samples had ‘slow’ SS_B values. When the constructional properties of the 1F-3 and 2F-2 fabric samples were examined in Table 1 and Table 2, it was observed that 1F-3 fabric had the highest cotton ratio in weft yarn and 2F-2 fabric had the highest weft yarn crimp values. These results showed that SS_B values increased considerably when the cotton ratio in weft yarn content was increased and the yarn crimp ratio in fabric structure was increased. It was observed that the SS_B values of the fabrics with high SS_T values were also high.

According to the correlation coefficient analysis of the first and second group of fabrics in Table 3, SS_B values had a strong positive relationship with fabric thickness and fabric weight while it had no relationship with fabric bulk density and fabric cover factor. In the third group of denim fabric samples, SS_B values had a strong positive relationship with fabric weight and fabric bulk density while it had strong negative relationship with fabric weight and fabric cover factor.

The correlation coefficient analysis showed that SS_T and SS_B properties of denim fabrics changed in different manners according to the changes in fabric constructional properties, especially as the correlation with weft yarn content properties. Also, it was observed that SS_T and SS_B values of fabrics were considerably affected by the cotton ratio in weft yarn content and the yarn crimp ratio in fabric structure.

When SS_T and SS_B values of all fabrics were examined, it was observed that fabrics with low weft crimp values had the lowest spreading speed values. The SS_T and SS_B values of the fabrics, such as 1F-3 fabric with high cotton ratio and 2F-2 fabric with the highest weft crimp value, were found to be higher.

Analysis of the Accumulative One-Way Transport Capability (OWTC)

OWTC range values were compared using the grading scale, which is a 5-point scale, a*ccording to AATCC Test Method 195* (1-5). The grades of the indexes are: 1 (<-50) = very poor, 2 (-50-99) = poor, 3 (100-199) = good, 4 (200-400) = very good, 5 (>400) = excellent.

In Fig. 5, it was observed that all fabric samples had ‘excellent’ OWTC values. When the fiber properties of the 1F-3 fabric sample which had the highest OWTC value, were examined in Table 2, it was observed that this fabric had the highest cotton ratio (99% cotton/1% elastane) in weft yarn content. Also, it has been found that OWTC values of denim fabrics containing coolmax (2F-2) and thermocool (3F-2) fibers in weft yarns can be close to those of fabric (1F-3) having a high cotton ratio in weft yarn.

When cotton/cordura blended weft yarns were used in fabric such as 1F-2, the obtained OWTC value was found to be decreased, although the cotton ratio and fabric weight values were high.

Fabric 1F-1, which is among the fabrics with a cotton/coolmax blend ratio, and which does not contain elastane, has a lower OWTC value than the second group of fabrics (cotton/coolmax/elastane blends). It has been found that the ratio of cotton in the weft yarn constituting the 1F-1 fabric is less and the ratio of the coolmax in the weft content is about the same as cotton ratio, and that the 1F-1 fabric, which does not contain elastane, also has low OWTC value. As in the second group of fabrics, it was observed that the cotton fiber ratio of the weft yarn content was remarkably higher than the coolmax fiber ratio, and when there was elastane content, the fabrics had better OWTC values. Similarly, it was observed that the fabrics with the highest fabric weight and thickness values had better OWTC values in the second group of fabrics’ content with cotton/coolmax/elastane.

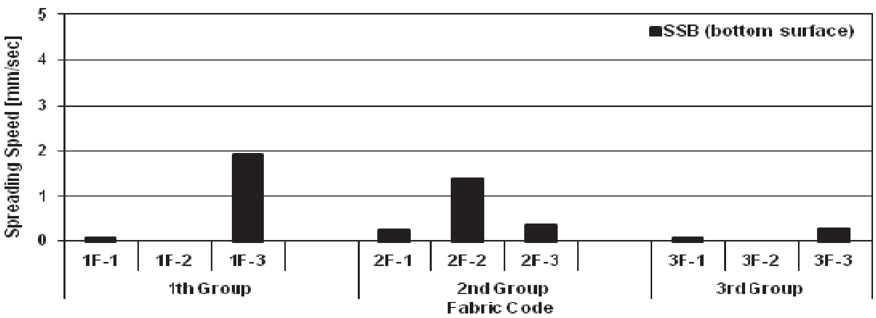

Figure 4. Changing of the spreading speed of the bottom surface (SS_B)

When the OWTC values of 2F-3 (cotton/coolmax/elastane blends) and 3F-3 (cotton/thermocool/elastane blends) fabrics having approximately similar blend percentage ratios, were examined, it was observed that 2F-3 fabric content with coolmax had a higher OWTC value. When the OWTC values of 3F-2 and 3F-3 fabrics, having approximately similar blend percentage ratios, were examined, it was seen that 3F-2 fabric with satin weave structure had a higher OWTC value.

When the OWTC value of 3F-1 fabric was examined, it was observed that it has almost close OWTC value to that of 1F-1 fabric. It has been observed that this was due to the fact that the proportion of cotton in the content of weft yarns constituting the 3F-1 fabric was low and was about the same as other fiber groups forming the content, as in 1F-1 fabric. If the proportion of cotton used in the yarn blends was higher than the other fiber groups in the blend, the fabrics showed better OWTC values.

According to the correlation coefficient analysis in Table 3, accumulative one-way transport capability values of all fabric samples had strong positive relationship with fabric thickness, which represented the fact that when the fabric thickness was increased the OWTC values also increased. The correlation coefficient of fabric samples, except for the second group of fabrics, between OWTC and other constructional parameters such as fabric weight, fabric bulk density and fabric cover factor was very approximate to 0.3, therefore, there was no correlation. However, the OWTC values of the second group of fabrics (these fabrics have the cotton/coolmax/elastane weft yarn contents) had strong negative relationship with fabric bulk density and fabric cover factor.

Analysis of the Overall Moisture Management Capability (OMMC)

OMMC range values were compared using the grading scale, which is a 5-point scale, *according to AATCC Test Method 195* (1-5). The grades of the indexes are: 1 (0.0-0.19) = very poor, 2 (0.2-0.39) = poor, 3 (0.4-0.59) = good, 4 (0.60-0.80) = very good, 5 (>0.80) = excellent.

In Fig. 6, it was observed that all fabric samples had 'good' OMMC values. Also, it was observed that the OMMC values of denim fabrics increased when the cotton ratio in weft yarn content was increased (e.g. 1F-3 and 2F-3).

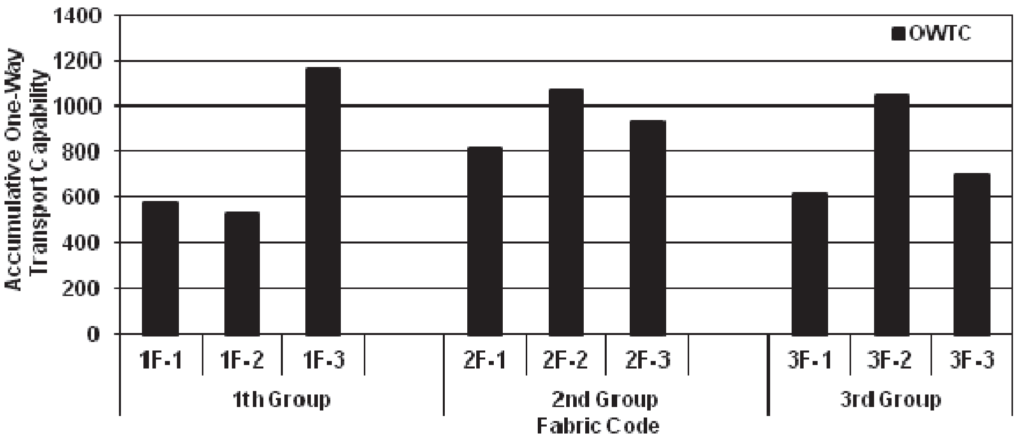

Figure 5. Changing of the accumulative one-way transport capability (OWTC)

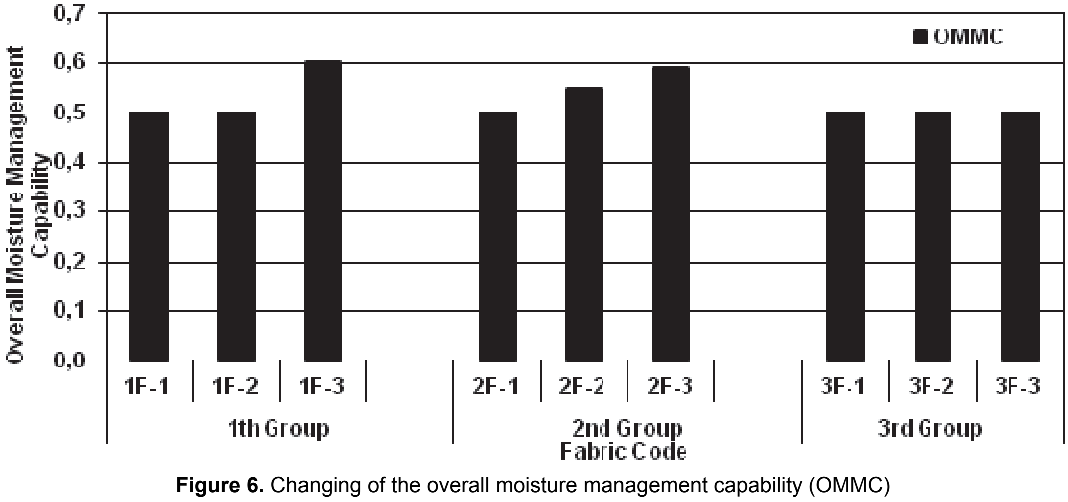

Figure 6. Changing of the overall moisture management capability (OMMC)

It has been found that the OMMC values of the third group fabrics 3F-1, 3F-2 and 3-F3, which have different structural parameters and weave structures (Fig. 7), were approximately the same. When the fiber contents of these fabrics were evaluated (Table 2), it was found that 3F-2 and 3F-3 fabrics had about 60% cotton content, while 3F-1 fabrics had about 35% cotton and 23% tencel content, among the third group fabrics having almost the same thermocool ratio; and that they had cotton/thermocool/ elastane composition.

The fact that the 3F-1, 3F-2 and 3F-3 fabrics, which have different fabric weight and thickness values, have the same OMMC values, have shown that the OMMC values of these fabrics were affected by the weave structure of the fabrics and the tencel content in the weft yarn. The 3F-1 fabric, which has the lowest fabric weight and thickness value and having tencel fiber content (because of the good moisture transfer properties of the cellulose derivative fiber like tencel (42)) in the weft yarn composition, and which is among the third group of fabrics, was produced in a special weave pattern (Fig. 7-a).

The weft yarn composition proportions of 3F-2 and 3F-3 fabrics were about the same, while they are denim fabrics woven in different weave structures. The 3F-2 fabric has a lower fabric weight than the 3F-3 fabric and has a 4/1 satin weave structure, while the 3F-3 fabric has a 3/1 twill weave structure with a higher fabric weight. As the result of the comparison of the properties of these three fabrics (3F-1, 3F-2 and 3F-3), it was obviously observed that OMMC value of the fabrics with low fabric weights had approximately the same values as the OMMC values of the high weighted 3/1 twilled fabrics, when the yarn floating lengths inside the weave pattern were increased.
According to the correlation coefficient analysis in Table 3, it was seen that there was a positive correlation between the fabric weight values and the OMMC values, regarding the results of correlation analysis of the 1st and 2nd group fabrics. In other words, as the fabric weight is increased, the OMMC values of the fabric also increase. The fact that the denim fabric, which is woven in 3/1 twill weave structure with the highest fabric weight value, and the other two fabrics (3F-1 and 3F-2) give approximately the same OMMC value shows that the parameter that brings the OMMC values of the 3F-1 and 3F-2 fabrics close to the 3F-3 fabric may be because of the weaving structures, in the third group of fabrics. As the result, in low fabric weight values, it was seen that the OMMC values of the fabrics were improved, when the yarn floating lengths and numbers were increased, and when regenerated cellulosic fibers having good moisture transmission properties were used in the yarn composition.

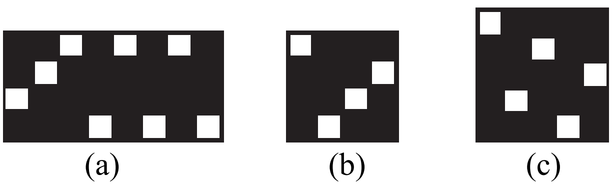

Figure 7. a) Special Weave b) 3/1 Z Twill Weave c) 4/1 S Satin Weave

From the data obtained from the experimental study, it was observed that the fabric structure with the highest OMMC and OWTC values was obtained with the highest cotton content ratio, fabric weight and fabric thickness values.

The correlation coefficient analysis revealed that OMMC properties of denim fabrics showed various changes according to the changes in fabric constructional properties, especially in correlation with weft yarn content properties. Also, it was observed that the OMMC values of the fabrics were highly affected by the cotton ratio in weft yarn content and the yarn floating lengths in weave structure.

CONCLUSION

It is important to develop moisture management properties, to ensure the continuity of the comfort when using the denim fabrics, in accordance with their features. Generally, the basic principle used in the moisture management of fabrics is to form multi-layered fabric structures and to transmit the liquid to the upper layer by using fibers that do not absorb moisture in the parts of the fabrics contacting with the skin, and to transmit the liquid to the outer environment by using moisture absorbing fibers in the upper layer.

It should also be taken into account that, in the case of using 100% hydrophobic structured yarns in a dominant way in the inner surface of the fabric, which contacts the skin, the cloth may have a negative psychological impact on the user. For this reason, moisture transmission performances of denim fabrics, in which fibers of various characteristic are used, and which provide rapid transfer of the moisture to the outer surface by being used in the form of a mixture with cotton in the weft yarns constituting denim fabrics, have gained importance.

The research presented in this paper assessed the effects of weft yarns having different fiber contents (produced with different blend ratios of fibers such as cotton, coolmax, cordura, thermocool and elastane) on certain moisture management properties (such as wetting time, spreading speed, accumulative one-way transport capability and overall moisture management capability) of denim fabrics woven with different constructional parameters. Experimental results showed that all denim fabric samples had 'good' OMMC values. Also, it was observed that the OMMC values of denim fabrics also increased when the cotton ratio in weft yarn content was increased.

According to the test results, the OWTC values of the fabrics having cotton/coolmax blended weft yarns were generally higher than the other fabric groups, however, these results were affected from blend ratios of fibers in weft yarns. OWTC values of denim fabrics decreased as the coolmax ratio in weft yarn content was increased. Results showed that OWTC values of denim fabrics also increased as the cotton ratio in weft yarn content was increased. For this reason, it's necessary to change the coolmax percentage in the yarn blend in order to determine the ideal blend proportion for producing fabrics that require a higher moisture transport capability. In the case of denim fabrics made of cotton/thermocool blended weft yarns, the OWTC values of fabrics were higher at higher cotton ratio in weft yarn content. OWTC values of denim fabrics decreased as the thermocool ratio in weft yarn content was increased. In the case of denim fabrics made of cotton/cordura blended weft yarns, even though this fabrics' cordura fiber ratio in weft yarn content was low, the lowest OWTC value was examined.

Experimental results showed that the fabric parameters which were effective in evaluating the moisture management properties of fabrics were found to be fabric thickness, fabric weight, fabric bulk density and also crimp and floating length of yarns in the weave structure. It has been observed that the use of the fabric cover factor in the moisture management evaluations may not be suitable; because the correlation between the fabric cover factor and the moisture management parameters generally is not significant.

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REFERENCES

1. Khushbu, P. and Thakkar, A. (2015). Effect of fabric construction parameters on air permeability and thermal resistance of commercially produced denim fabric. IJSRD-International Journal for Scientific Research & Development, 3, 767-769.
2. Midha, V., Kumar, S. S. and Kumar, M. N. (2017). Investigation on permeability and moisture management properties of different denim fabrics after repeated laundering. The Journal of The Textile Institute, 108, 71–77.
3. Maqsood, M., Hussain, T., Malik, M. H. and Nawab Y. (2016). Modeling the effect of elastane linear density, fabric thread density and weave float on the stretch, recovery and compression properties of bi-stretch woven fabrics for compression garments. The Journal of The Textile Institute, 107, 307–315.
4. Chinta, S. K. and Gujar, P. D. (2013). Significance of moisture management for high performance textile fabrics. International Journal of Innovative Research in Science, Engineering and Technology, 2, 814–819.
5. SDL ATLAS MMT Moisture Management Tester. (2005). Retrieved from http:// www.sdl.atlas.com.
6. Venkatesh, J. and Gowda, K. N. N. (2013). Effect of plasma treatment on the moisture management properties of regenerated bamboo fabric. International Journal of Scientific and Research Publications, 3, 1-8.
7. Mangat, M. M., Hussain, T. and Bajzik, V. (2012). Impact of different weft materials and washing treatments on moisture management characteristics of denim. Journal of Engineered Fibers and Fabrics, 7, 38-49.
8. Hu, J., Li, Y., Yeung, K. W., Wong, A. S. W. and Xu, W. (2005). Moisture management tester: a method to characterize fabric liquid moisture management properties. Textile Research Journal, 75, 57-62.
9. Özgen, B. and Altaş, S. (2014). The investigation of thermal comfort, moisture management and handle properties of knitted fabrics made of various fibres. Tekstil ve Konfeksiyon, 24, 272-278.
10. Özdil, N., Süpüren, G., Özçelik, G. and Pruchova, J. (2009). A study on the moisture transport properties of the cotton knitted fabrics in single jersey structure, Tekstil ve Konfeksiyon, 3, 218-223.
11. Öner, E., Atasağun, H. G., Okur, A., Beden, A. R. and Durur, G. (2013). Evaluation of moisture management properties on knitted fabrics. The Journal of The Textile Institute, 104, 699-707.
12. Selli, F. and Turhan, Y. (2017). Investigation of air permeability and moisture management properties of the commercial single jersey and rib knitted fabrics. Tekstil ve Konfeksiyon, 27, 27-31.
13. Li, Y., Zhu, Q. and Yeung, K. W. (2002). Influence of thickness and porosity on coupled heat and liquid moisture transfer in porous textiles. Textile Research Journal, 72, 435-446.
14. Sharabaty, T., Biguenet, F., Dupuis, D. and Viallier, P. (2008). Investigation on moisture transport through polyester / cotton fabrics. Indian Journal of Fibre & Textile Research, 33, 419-425.
15. Namligoz, E. S., Coban, S. and Bahtiyari, M. I. (2010). Comparison of moisture transport properties of the various woven fabrics. Tekstil ve Konfeksiyon, 20, 93-100.
16. Onofrei, E., Rocha, A. M. and Catarino, A. (2011). The influence of knitted fabrics' structure on the thermal and moisture management properties. Jounal of Engineered Fibres and Fabrics, 6, 10-22.
17. Mansor, A., Ghani, S. A. and Yahya, M. F. (2016). Knitted fabric parameters in relation to comfort properties, American Journal of Materials Science, 6, 147-151.
18. Ravandi, S. H. and Valizadeh, M. (2011). Properties of fibers and fabrics that contribute to human comfort. In: Song G (ed.) Improving Comfort in Clothing, Philadelphia: Woodhead Publishing Series in Textile, 61-78.
19. Bedek, G., Salaün, F., Martinkovska, Z., Devaux, E. and Dupont, D. (2011). Evaluation of thermal and moisture management properties on knitted fabrics and comparison with a physiological model in warm conditions. Applied Ergonomics, 42, 792-800.
20. Umair, M., Hussain, T., Shaker, K., Nawab, Y., Maqsood, M. and Jabbar, M. (2016). Effect of woven fabric structure on the air permeability and moisture management properties. The Journal of The Textile Institute, 170, 596–605.
21. Kandhavadivu, P., Rathinamoorthy, R. and Surjit, R. (2014). Thermoregulatory characteristics of bamboo / lyocell union fabrics. Indian Journal of Fibre and Textile Research,39, 386-393.
22. Maqsood, M., Nawab, Y., Shaker, K., Umair, M., Ashraf, M., Baitab, D. M., Hamdani, S. T. A. and Shahid, S. (2016). Modelling the effect of weave structure and fabric thread density on mechanical and comfort properties of woven fabrics. AUTEX Research Journal, 16, 160-164.
23. Das, B., Das, A., Kothari, V., Fanguiero, R. and Araujo, M. D. (2009). Moisture flow through blended fabrics – Effect of hydrophilicity. Journal of Engineered Fibers and Fabrics, 4, 20–28.
24. Nayak, R. K., Punj, S. K., Chatterjee, K. N. and Behera, B. K. (2009). Comfort properties of suiting fabrics. Indian Journal of Fibre & Textile Research, 34, 122–128.
25. Wang, F., Zhou, X. and Wang, S. (2009). Development processes and property measurements of moisture absorption and quick dry fabrics. Fibres & Textiles in Eastern Europe, 17, 46-49.
26. Ansari, N., Nosraty, H. and Rahmani, F. (2007). Measurement of capillary spaces of woven fabric by wicking determination of water into samples. The 9th Asian and the Pacific International Conference on Textiles, Taiwan.

27. Zhang, Y. and Wang, H. (2007). Modeling of capillary flow in shaped polymer fibre bundles. Journal of Materials Science, 42, 8035-8037.

28. Srinivasan, J., Ramakrishnan, G., Mukhopadhyay, M., and Manoharan, M. (2007). A study of knitted fabrics from polyester microdenier fibers. The Journal of The Textile Institute, 98, 31–35.

29. Baltušnikaitė, J., Abraitienė, A., Stygienė, L., Krauledas, S., Rubežienė, V. and Žuravliova, S.V. (2014). Investigation of moisture transport properties of knitted materials intended for warm underwear. Fibres & Textiles in Eastern Europe, 22, 93-100.

30. Hasan, M. M. B., Calvimontes, A., Synytska, A. and Dutschk, V. (2008). Effects of topographic structure on wettability of differently woven fabrics. Texttile Research Journal, 78, 996–1003.

31. Kajiwara, K., Nori, R. and Okamoto, M. (2000). New fibres from Japan. The Journal of Textile Institute, 91, 32-78.

32. Manshahia, M. and Das, A. (2014). High active sportswear – A critical review, Indian Journal of Fibre & Textile Research, 39, 441-449.

33. Raj, S. and Sreenivasan, S. (2009). Total wear comfort index as an objective parameter for characterization of overall wearability of cotton fabrics. Journal of Engineered Fibers and Fabrics, 4, 29-41.

34. Malik, Z. A., Malik, M. H., Hussain, T. and Arain, F. A. (2011). Development of models to predict tensile strength of cotton woven fabrics. Journal of Engineered Fibers and Fabrics, 6, 46-53.

35. Hsieh, Y. L. (1995). Liquid transport in fabric structures, Textile Research Journal, 65, 299-307.

36. Hsieh, Y. L. and Cram, L. A. (1998). Enzymatic hydrolysis to improve wetting and absorbency of polyester fabrics, Textile Research Journal, 68, 311-319.

37. Peirce, F. T. (1937). The geometry of cloth structure, The Journal of The Textile Institute, 28, T45–T96.

38. Seyam, A. M. (2002). The structural design of woven fabrics: theory and practice, The Textile Institute, Textile Progress, 31, 11-19.

39. Hearle, J. W. S., Grosberg, P. and Backer, S. (1969). Structural mechanics of fibers, yarns and fabrics, Wiley-Interscience, New York, USA.

40. Mukaka, M. M. (2012). A guide to appropriate use of correlation coefficient in medical research, Malawi Medical Journal, 24, 69-71.

41. Ponda, K. and Thakkar, A. (2015). Effect of Fabric Construction Parameters on Air Permeability and Thermal Resistance of Commercially Produced Denim Fabric, International Journal for Scientific Research & Development, 3, 767-769.

42. Kumari, A. and Khurana, K. (2016). Regenerated Cellulose-Based Denim Fabric for Tropical Regions: An Analytical Study on Making Denim Comfortable, Journal of Textiles, Volume 2016, 1-10.