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

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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 içerikleri ve oranlarına sahip olan atkı iplik özelliklerinin (pamuk, coolmax, cordura, thermocool ve elastan gibi) ve kumaş yapışal parametrelerinin denim kumaşlarının nem yönetimi özelliklerine olan etkisi değerlendirilmiştir. Kumaş yapışal parametreleri (kalınlık, gramaj, yoğunluk ve örtme faktörü gibi) ve nem yönetimi özellikleri (işlanma süresi (üst ve alt), yayılma hızı (üst ve alt), kümülatif tek yönlü taşıma kabiliyeti ve genel nem yönetimi kabiliyeti) arasındaki korelasyon farklı atkı ipliği özelliklerine iliskili 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 korelasyonun olmadığı gözlenmiştir.

Anahtar Kelimeler: Denim kumaş, nem yönetimi özellikleri, kumaş yapışal 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, cellulose 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). Profilled fibers are widely used in applications that need to have water transfer instead of water absorption, and for quick dry feature. Profilled fibers have a bigger surface area which improves the wicking properties such as the multichannel 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

<table>
<thead>
<tr>
<th>Fabric Group</th>
<th>Fabric Code</th>
<th>Yarn Count [Nm]</th>
<th>Yarn Density [thread/cm]</th>
<th>Yarn Crimp [%]</th>
<th>Fabric Thickness [mm]</th>
<th>Fabric Unit Weight [g/cm²]</th>
<th>Fabric Bulk Density [g/cm³]</th>
<th>Fabric Cover Factor (Kf)</th>
<th>Weave</th>
</tr>
</thead>
</table>
| 1
| 1F-1         | 11          | 17              | 35                       | 22             | 10                   | 0.78                        | 336.4                      | 0.43                   | 30.53 | 3/1 Z Twill |
| 1F-2         | 17          | 16              | 25                       | 20             | 10                   | 0.69                        | 412.4                      | 0.60                   | 24.72 | 3/1 Z Twill |
| 1F-3         | 14          | 17              | 32                       | 19             | 22                   | 0.82                        | 413.0                      | 0.50                   | 28.10 | 3/1 Z Twill |
| 2
| 2F-1         | 21          | 30              | 40                       | 23             | 15                   | 0.65                        | 310.5                      | 0.48                   | 28.41 | 3/1 Z Twill |
| 2F-2         | 22          | 23              | 39                       | 20             | 21                   | 0.71                        | 328.5                      | 0.46                   | 27.72 | 3/1 Z Twill |
| 2F-3         | 16          | 19              | 34                       | 20             | 18                   | 0.75                        | 355.2                      | 0.47                   | 28.02 | 3/1 Z Twill |
| 3
| 3F-1         | 33          | 25              | 53                       | 27             | 11                   | 0.67                        | 283.6                      | 0.42                   | 28.89 | Special     |
| 3F-2         | 33          | 17              | 52                       | 20             | 12                   | 0.71                        | 321.8                      | 0.45                   | 28.89 | Special     |
| 3F-3         | 20          | 19              | 38                       | 25             | 22                   | 0.68                        | 379.8                      | 0.56                   | 23.71 | 3/1 Z Twill |

Table 2. Weft yarn content properties

<table>
<thead>
<tr>
<th>Fabric Group</th>
<th>Fabric Code</th>
<th>Fiber Content Ratios of Weft Yarns</th>
</tr>
</thead>
</table>
| 1
| 1F-1         | 57% Cotton / 43% Coolmax  |
| 1F-2         | 82% Cotton / 18% Cordura       |
| 1F-3         | 99% Cotton / 1% Elastane        |
| 2
| 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 |
| 3
| 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 (WT₁) and the bottom surface (WT₂) (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 (AR₁) and the bottom surface (AR₂) (%/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 (MWR₁) and the bottom surface (MWR₂) (mm): The greatest ring radius measured on the top and bottom surfaces.

4. Spreading Speed of the top surface (SS₁) and the bottom surface (SS₂) (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.
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, according 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 (WTₜ)

WTₜ 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’ WTₜ values. When the structural properties of the 1F-3 fabric sample, which had the lowest WTₜ 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 WTₜ 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.

WTₜ 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>
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<tr>
<th>Table 3. Correlation coefficient analysis (R-value)</th>
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When the WT\textsubscript{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\textsubscript{T} value. Although 1F-2 fabric had a high cotton ratio, it was observed that the cordura fibers in the content lowered the WT\textsubscript{T} values. When the WT\textsubscript{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\textsubscript{T} value. It was observed that the coolmax and thermocool fibers used in the blends in the 2\textsuperscript{nd} and 3\textsuperscript{rd} group fabrics increased the WT\textsubscript{T} values of the fabrics.

According to the correlation coefficient analysis of the first group of denim fabrics in Table 3, WT\textsubscript{T} values had a strong negative relationship with the fabric weight. In other words, the WT\textsubscript{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\textsubscript{T} values of the first group of denim fabrics decreased. The correlation coefficient of the first group of denim fabrics between WT\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{T} values and fabric constructional properties was different from other fabric groups. According to the correlation coefficient analysis, WT\textsubscript{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\textsubscript{T} values of denim fabrics. The correlation coefficient of the third group of denim fabrics between WT\textsubscript{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\textsubscript{T} and especially fabric cover factor was very approximate to 0.3, therefore, there was no correlation. This result showed that WT\textsubscript{T} values were not strongly affected by cover factor values of the denim fabrics.

**Analysis of the Wetting Time of the Bottom Surface (WT\textsubscript{B})**

WT\textsubscript{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\textsubscript{B} values. 1F-1, 1F-2 and 2F-1 fabrics which had ‘slow’ WT\textsubscript{B} values.

When Fig. 2 was examined, it was observed that the fabric with the highest WT\textsubscript{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\textsubscript{B} value. It was observed that 1F-3 fabric having a ratio of 99% cotton had the lowest WT\textsubscript{B} value. 2F-1 fabric, which has the highest WT\textsubscript{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\textsubscript{T})](image-url)
According to the correlation coefficient analysis of the first group of denim fabrics in Table 3, WTB values had strong negative relationships with fabric thickness. In other words, the WTB 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 WTB 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, WTB 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 WTB 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 WTB 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 WTB values with the increase in fabric thickness and fabric weight might be a result of the decrease in the WTT values, which also decreases with increasing fabric thickness and fabric weight. The decrease in WTT 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 WTB values.

According to the correlation coefficient analysis of the third group of fabrics in Table 3, WTB 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 WTB values of the third group of denim fabrics with thermocool fiber contents decreased; while the WTB 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 (SST)**

SST 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' SST values. When the constructional properties of the 2F-2 fabric sample with the highest SST 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 values. Also, it was observed that SS values increased considerably when the cotton ratio in weft yarn content was increased.
According to the correlation coefficient analysis of the first group of fabric samples in Table 3, SS\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{T} values had a strong positive relationship with fabric weight and fabric bulk density.

**Analysis of the Spreading Speed of the Bottom Surface (SS\textsubscript{B})**

SS\textsubscript{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\textsubscript{B} values, while 1F-3 and 2F-2 fabric samples had 'slow' SS\textsubscript{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\textsubscript{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\textsubscript{B} values of the fabrics with high SS\textsubscript{T} values were also high.

According to the correlation coefficient analysis of the first and second group of fabrics in Table 3, SS\textsubscript{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\textsubscript{B} values had a strong positive relationship with fabric weight and fabric bulk density while it had strong negative relationship with fabric cover factor.

The correlation coefficient analysis showed that SS\textsubscript{T} and SS\textsubscript{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\textsubscript{T} and SS\textsubscript{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\textsubscript{T} and SS\textsubscript{B} values of all fabrics were examined, it was observed that fabrics with low weft yarn values had the lowest spreading speed values. The SS\textsubscript{T} and SS\textsubscript{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, according 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 the 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.
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).
It has been found that the OMMC values of the third group fabrics 3F-1, 3F-2 and 3F-3, 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 cellulose fibers having good moisture transmission properties were used in the yarn composition.

![Figure 7](image)

**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**


