(REFEREED RESEARCH)

A STUDY ON THE MOISTURE TRANSPORT PROPERTIES OF THE COTTON KNITTED FABRICS IN SINGLE JERSEY STRUCTURE

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ABSTRACT

Moisture management is defined as the ability of a garment to transport moisture away from the skin to the garment's outer surface in multi-dimensions and it is one of the key performance criteria in today's apparel industry since it has a significant effect on the human perception of moisture sensations. Because of its good water absorbing property, cotton is often used for next-to-skin wear such as t-shirts and underwear. In scope of the study, cotton yarns, produced in different yarn counts (Ne 20, Ne 30, Ne 40) and different twist values (αe=3.2, 3.6, 4.0) were knitted as single jersey structure in the same production conditions. The moisture management properties of the fabrics were measured in "SDL-ATLAS Moisture Management Tester". Dynamic liquid transport properties of textiles such as wetting time, maximum absorption rate, spreading speed were measured and it was determined that the effects of yarn count and yarn twist coefficient on these properties were significant. According to the overall moisture management capacity of the fabrics calculated according to measured features, it was found that all the fabrics used in this study have good moisture management capability.

Key Words: Moisture transport, Single jersey fabric, Cotton yarn, Yarn count, Yarn twist coefficient.

ÖZET

Çokl yönlü nem iletim yeteneği, kişilerin nemi algılanmasında çok önemli bir etkiye sahip olduğu için günümüzün hazır giyim endüstrisinde giysilerin performansı belirleyen anahtar bir özelliktir. İyi nem absorbe etme yeteneği nedeniyle, pamuklu kumaşlar tişört ve iç çamaşırı gibi genellikle vücuda temas eden ürünlerde kullanılmaktadır. Bu çalışmada, farklı iplik numaralarında (Ne 20, Ne 30, Ne 40) ve iplik büküm katsayılarında (αe=3.2, 3.6, 4.0) üretilmiş olan pamuk iplikleri kullanılmış ve bu ipliklerden aynı üretim şartlarında süprem kumaşlar örülmüştür. Kumaşların nem iletim özellikleri "SDL-ATLAS Moisture Management Tester" cihazında ölçülmüştür. Islanma süresi, maksimum absorbsiyon hızı, yayılma hızı gibi dinamik sıvı iletim özellikleri ölçülmüş ve iplik numarası ile iplik büküm katsayının bu özellikler üzerine etkisinin önemli olduğu belirlenmiştir. Çok yönlü nem iletim kapasitesi değerlerine göre, çalışmada incelenen tüm kumaşların iyi nem iletim yeteneğine sahip olduğu belirlenmiştir.

Anahtar Kelimeler: Nem iletimi, Süprem örme kumaş, Pamuk ipliği, İplik numarası, İplik büküm katsayısı.

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1. INTRODUCTION

Moisture management often refers to the transport of both moisture vapor and liquid away from the body. Moisture vapor can pass through openings between fibers or yarns (1). This action prevents perspiration from remaining next to the skin. In hot conditions, trapped moisture may heat up and lead to fatigue or diminished performance. In cold conditions, trapped moisture will drop in temperature and cause chilling and hypothermia. Excess moisture may also cause the garment to become heavy, as well as cause damage to the skin from chafing (2).

The heat and moisture transmitting property of a fabric is a key factor that both affects textile and clothing comfort and decides handling quality of some special functional clothing (3,4,5). Moisture transmission through textiles has a great influence on the thermo-physiological comfort of the human body which is maintained by perspiring both in vapor and liquid form. The clothings should allow this perspiration to be transferred to the atmosphere in order to maintain the thermal balance of the body (6).

The flow of liquid moisture through textiles is caused by fiber-liquid molecular attraction at the surface of the fiber materials, which is mainly determined by the surface tension and the effective capillary pore distribution and pathways (6,7). Transport of liquid moisture across textiles increases their thermal conductivity and changes the heat transfer and moisture absorption of the fibers (8).

Moisture transport through a garment will have influence on the microclimate between the garment and the body beneath, the thermal contact feeling of the wearer, and the thermoregulatory response of the body (9,10,11). If liquid water (sweat) can not be dissipated quickly, the humidity of the air in the space between the skin and the fabric that contacts with the skin rises. This increased humidity prevents rapid evaporation of liquid water on the skin and gives the body the sensation of "heat" that triggered the sweating in the first place. Consequently, the body responds with increased sweating to dissipate excess thermal energy. Thus a fabric's inability to remove liquid water seems to be the major factor causing uncomfortable feelings for the wearer (12).

Clothing can serve as a buffer in the moisture transfer process. For evaporative cooling to occur, the moisture must transport through the fabric. Thicker fabrics, including traditional cotton fabrics, will absorb more liquid, and this will be roughly proportional to their thickness (11). In some cases, not only the total amount of liquid that can be absorbed is important, but also the speed of the absorption process is important (13).

A lot of scientists and technicians have made a great number of researches on this property of textile and clothing and have made great progress in the basic concept (3). Niwa (1968) stated that the ability of fabrics to absorb liquid water (sweat) is more important than water vapor permeability in determining the comfort factor of fabrics (12,14).

Galbraith et al (1962) compared cotton, water repellent cotton and acrylic garments through wearing tests and concluded that the major factor causing discomfort was the excess amount of sweat remaining on the skin surface (12,15).

Terry fabrics have a higher water absorption property compared to other types of textile fabrics, as the end uses of terry fabrics require this. The water absorption capacity of a terry fabric is dependent on yarn material, yarn type and fabric construction (16,17). Dynamic water absorption properties of terry fabrics were investigated experimentally using 216 various terry fabric samples of different construction by Su et al. It is shown that around 26% to 40% of water is absorbed during the first 10 seconds, depending on the fabric construction; the percentage of water absorption exceeds 50% in 30 seconds and reaches 75% in 100 seconds. Yarn type is found to have the most important effect on the dynamic water absorption properties of terry fabrics. The effect of pile length, warp and weft density on the percentage of water absorption remains limited compared to that of yarn type, and no significant effect of these parameters on water absorption is found for the last 100 seconds (17).

In a study conducted by Su et al., composite yarns were spun using profiled polyester fibers and cotton fibers at different blend ratios. The water absorption capacity, diffusion rate, and drying rate of knitted fabrics made from the three composite yarns were examined to shed light on their moisture absorption and release performance. Experimental results revealed that, the diffusion rate and drying rate become better with decreasing cotton content (18).

There have been a number of studies on the effect of different fiber types, fabric structure, fabric finishes, etc. on the moisture vapor transport properties. In one of the studies, the moisture vapor transport properties of cotton fabrics knitted from 31 different cotton fibers with different pedigrees grown over a three year period in three major cotton growing regions of US, Southwest (Texas), Mid-South (Mississippi) and Southeast (Georgia) were investigated. Preliminary analysis indicates a relationship between the basic sugar content such as verbascose of cotton and its moisture vapor transport (19).

In a study carried out by Hu et al, eight sets of sportswear knitted fabrics were tested with MMT instrument and the results showed that liquid moisture management properties were significantly different for these fabrics. The objective measurements were compared with subjective perceptions of moisture sensations during exercise. Twenty-eight females between ages 18 and 35 run on a treadmill while wearing a randomly selected garment for 20 minutes in an environmentally controlled chamber with temperature and humidity controlled conditions at 29 ± 1°C and 85 ± 2% RH for a psychological sensory wear trial. 7-point scale was used to rate two moisture sensations (*clammy* and *damp*) before (time = 0), during (time =5, 10, and 15), and at the end (time = 20) of the 20 minute running period. It was found that the ratings of both moisture sensations had increased as the running time increases. They reported that the fabric's one-way transport capacity and its overall moisture management capacity were significantly correlated with perceptions of clammy and damp sensations with increased exercise time. They also found that subjective perceptions of moisture sensations in sweating such as *clammy* and *damp* could be predicted by the measurements of the MMT (20).

Cotton fiber is a good moisture absorber. Contrary to synthetic fibers, it does not transport water from the surface by using the capillarity, but uses the absorption method, which let water to penetrate into the fiber. The effect of the yarn parameters on the moisture transport properties of the cotton knitted fabrics has not been researched systematically. Thus, in this study the effect of yarn count and yarn twist coefficients of the cotton yarns on the moisture properties of the knitted fabrics were investigated.

2. MATERIALS AND METHOD

In the study, cotton yarns were produced by using Agean cotton with the fineness of 4.00 microner index and the mean length of 28.90 mm in three yarn counts (Ne 20, Ne 30, Ne 40) and three yarn twist coefficients (α_e=3.2, 3.6, 4.0).

The fabrics were knitted in single jersey structure by using Mesdan Lab Knitter in the same machine tightness factors. In order to extract natural hydrophobic characteristics of cotton fabrics, the samples were treated in a bath contained 1% NaOH, 1% Na_2CO_3, and wetting agent with concentration 1g/l and 90ºC bath temperature. After washing, the fabrics were neutralized with acid and dried.

Fabric thickness was measured on SDL digital thickness gauge according to ISO 5084 standard. The structural properties of the fabrics, such as thickness (mm) and weight per unit area (g/m^2) are given in Table 1.

Table 1. Fabric properties used in the experiment

Yarn count (Ne)	**20**			**30**			**40**		
Yarn twist coefficient (α_e)	**3,2**	**3,6**	**4**	**3,2**	**3,6**	**4**	**3,2**	**3,6**	**4**
Fabric thickness (mm)	0,74	0,76	0,78	0,73	0,75	0,78	0,72	0,74	0,76
Fabric weight per unit area (g/m^2)	124	125	125	115	121	124	102	103	111

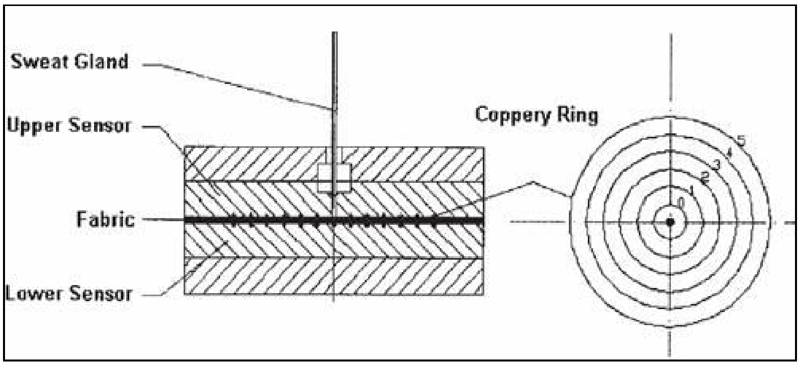
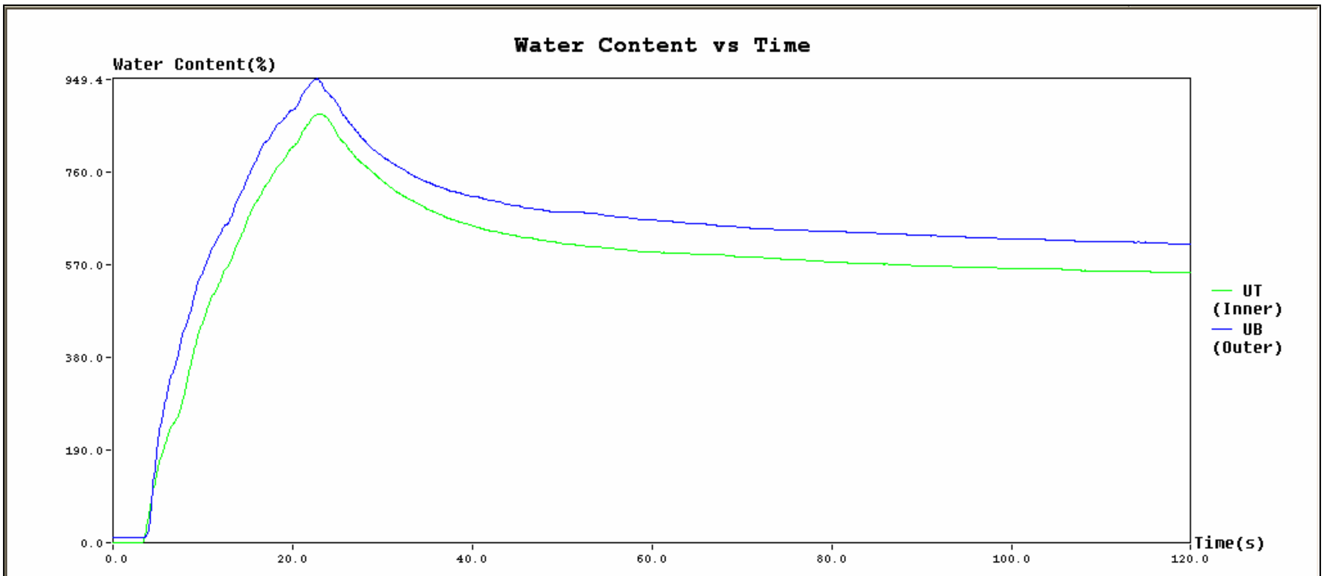


Figure 1. Schematic view of the tester sensors (20)



	Top Surface	Bottom Surface
Wetting time(sec)	2.844	3.234
Absorption rate(%/sec)	43.1541	47.6109
Max wetted radius(mm)	20.0	20.0
Spreading Speed(mm/sec)	4.3884	4.4699
One way transport capability	62.9673	
Description	MMT-	

Figure 2. Water content versus time curve for the fabric sample produced with Ne 30, α_e= 3.6 yarn

The Moisture Management Tester (MMT) is an instrument used to test the liquid moisture management capabilities of textiles such as knitted and woven fabrics dynamically. This instrument consists of upper and lower concentric moisture sensors. The fabric sample is placed between the two sensors (Figure 1). MMT is designed to sense, measure and record the liquid moisture transport behaviors in multiple directions (21).

When moisture is transported in a fabric, the contact electrical resistance of the fabric will change and this change will depend on two factors: the components of the water and the water content in the fabric. When the influence of the water components is fixed, the measured electrical resistance is related to the water content in the fabric (20,22).

The electrical resistance of textiles is usually very large when placed in a closed circuit. Thus, no electric current can be detected, and the voltage on the reference resistor of 1 MΩ is almost zero. However, when a fabric is wet or contains a certain quantity of moisture, the resistor will be reduced to the hundreds KΩ level. Therefore, voltage change can be detected on the reference resistor of 1 MΩ. The method used in the experiment, measure changes in the moisture content on the two surfaces of textiles (20,21).

In order to simulate sweating 0.15 g special solution (including NaCl) introduced onto the fabric's top surface automatically by the instrument.

A series of indexes are defined and calculated to characterize liquid moisture management performance of the test sample by using moisture management tester, such as wetting time, absorption rate, spreading speed, accumulative one-way transportation index and overall moisture management capacity.

Wetting time (WTT-top surface, WTB-bottom surface) is the time period in which the top and bottom surfaces of the fabric just start to get wetted after the test commences, which are defined as the time in second (s) when

Table 2. The p values of variance analysis

Parametres	TOP				BOTTOM			
	Top Wetting time	Top Absorption rate	Top Max wetted radius	Top Spreading Speed	Bottom Wetting time	Bottom Absorption rate	Bottom Max wetted radius	Bottom Spreading Speed
Yarn count	0,000*	0,000*	0,000*	0,000*	0,000*	0,000*	0,000*	0,000*
Yarn twist	0,019*	0,005*	0,063	0,000*	0,007*	0,041*	0,333	0,000*

*statistically important according to α=0.05

the slope of total water contents at the top and bottom surfaces become greater than tan 15° respectively.

Absorption rate (TAR-top surface, BAR-bottom surface) is average moisture absorption ability of the fabric in the pump time.

Maximum wetted radius (MWR_{top}, MWR_{bottom}) is defined as the maximum wetted ring radii at the top and bottom surfaces, respectively, where the slopes of water content become greater than tan 15° for the top and bottom surfaces, respectively.

Spreading speed (SS_{top} and SS_{bottom}) is defined as the accumulative spreading speed (mm/sec) from the centre to the maximum wetted radius. SS_t and SS_b are the speeds of the moisture spreading on the top and bottom fabric surfaces to reach the maximum wetted radius, defined as:

$SS_t = MWR_t / t_{wrt}$ $SS_b = MWR_b / t_{wrb}$, where t_{wrt} and t_{wrb} are the times to reach the maximum wetted rings on the top and bottom surfaces, respectively.

Overall moisture management capacity (OMMC) is an index to indicate the overall ability of the fabric to manage the transport of liquid moisture, which includes three aspects of performance: moisture absorption rate of the bottom side (*BAR*), one-way liquid transport capacity (*OWTC)*, and spreading/drying rate of the bottom side (SS_b) which is represented by the maximum spreading speed (20,21). The overall moisture management capacity (OMMC) is defined as:

$$OMMC=0.25BAR+0.5OWTC+0.25SS_b$$

The larger the *OMMC is* the higher the overall moisture management ability of the fabric (20).

Another feature that can be obtained from the instrument is the water content versus time curves. The typical water content change versus time on the fabric's top and bottom surfaces is given in Figure 2.

All the measurements were carried out in the controlled laboratory conditions that are 20±2ºC, % 65±4 relative humidity. For the evaluation of the statistical importance of the parameters (yarn count and yarn twist coefficient) on the moisture management properties of the cotton knitted fabrics, one way variance analysis was performed. In order to determine the statistical significance of the variables on the related properties, SPSS statistical program was used. To deduce whether the parameters are significant or not, p values were examined according to significant level of α=0.05. If the p value of a parameter is greater than 0.05 (p>0.05), it means that the parameter is not important and should be ignored.

3. RESULTS AND DISCUSSION

The moisture management performances of the fabrics measured by MMT instrument are evaluated individually. In order to determine whether the effects of yarn count and yarn twist on the measured parameters are significant or not, one way variance analysis was carried out and the related p values are given in Table 2.

As it can be seen from Table 2, except from the effect of yarn twist coefficient on maximum wetted radius of the top and bottom surfaces, yarn count and twist factor significant for all the parameters. The influence of yarn count on the features measured by MMT instrument is more obvious compared to the effect of yarn twist on the related properties.

The wetting time values of the top and bottom surfaces of the fabrics are given in Figure 3.

As it can be seen from Figure 3, the wetting time changes according to the yarn count and twist coefficient on the top and bottom surfaces. The results indicate that generally wetting time of the bottom surfaces is higher than the top surfaces for all the fabrics as expected. In the scope of this explanation, it can be stated that, the wetting time value is related with the water absorbency of the fabric.

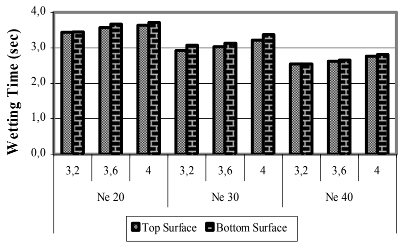


Figure 3. Wetting time (sec) values of the fabrics

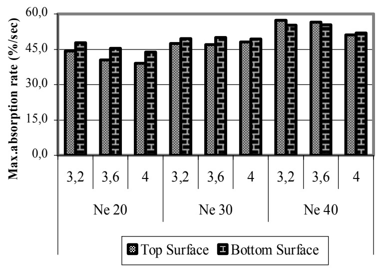


Figure 4. Maximum absorption rates (%/sec) of the fabrics

It can be stated that the finer the yarn, the lower the wetting time is. As the yarns get finer, the thickness of the fabric decreases. When the results of the thin and thick fabrics from same type of material compared, it can be stated that thinner fabrics has shown faster wetting than thicker ones, when equal amounts of water are applied. Since the number of fibers in finer yarns is less than coarse yarns, time of the wetting decreases as well. So the fabric can be easily wetted by the liquid. As the twist factor increases, the diameter and hairiness of the yarn decreases, yarn becomes more compact. This lead to the increment of the wetting time of the fabrics.

The absorption rates of the top and bottom surfaces of the fabrics are given in Figure 4. As it can be seen from the figure, the absorption rate values change according to yarn count and twist coefficient.

The absorption rate is the average moisture absorption ability (%/sec) of the top and bottom surfaces of the fabric in the pulp time (20 sec). Be-

Table 3. OMMC values of the fabrics

Yarn count (Ne)	20			30			40		
Yarn twist coefficient (α_e)	**3,2**	**3,6**	**4**	**3,2**	**3,6**	**4**	**3,2**	**3,6**	**4**
OMMC value	0,4414	0,4299	0,4029	0,4523	0,4635	0,4340	0,4298	0,4294	0,4350
Moisture management category	Good	Good	Good	Good	Good	Good	Good	Good	Good

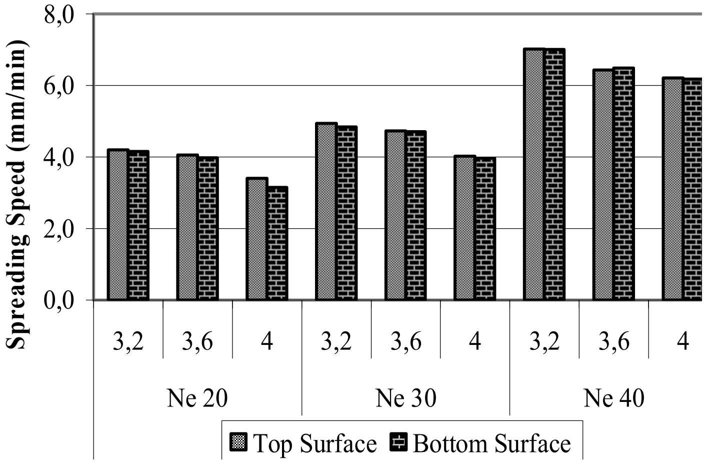


Figure 5. Spreading speed (mm/min) values of the fabrics

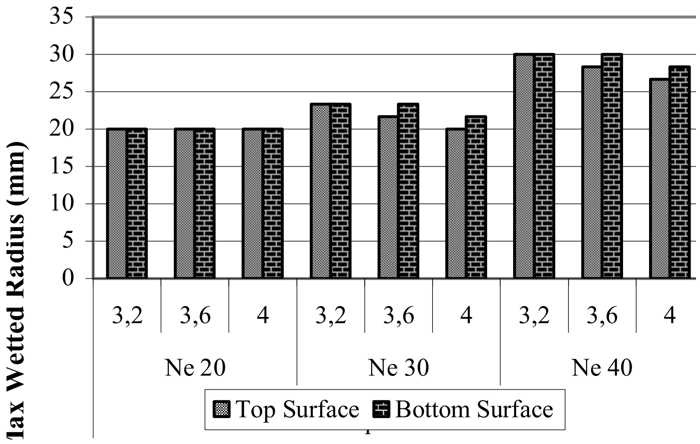


Figure 6. Maximum wetted radius (mm) values of the fabrics

cause of the same reasons as explained for the wetting times of the fabrics, as the yarn gets finer, the thickness of the fabric decreases. Therefore the absorption rate values of the thinner fabrics become higher. Maximum absorption rate values generally decrease, as the twist factor increases. It is due to the more compact structure of the yarns having higher twist per unit length. According to Figure 4, the bottom absorption rates of the fabrics are generally higher than top surfaces. This indicates that the liquid (sweat) diffuse from the next-to-skin surface to the opposite side and is accumulated on the bottom surface of the fabric.

Spreading speed test results are given in Figure 5. It is associated with the moisture transport, which occurs parallel to the fabric surface. As the spreading speed values are compared, it can be clearly seen that, higher the yarn count, higher the spreading speed is. When the yarns are finer, the wetting time decreases as mentioned before, consequently spreading speed for the wetting of the finer fabric are higher compared to the fabric knitted with coarser yarn. The spreading speed results in terms of yarn twist are similar with absorption rate results. The higher the yarn twist, the lower the spreading speed is.

In the study, maximum wetted radius of the fabrics wetted with the same amount of liquid is also investigated. Maximum wetted radius results of all the fabrics are also given in Figure 6.

According to maximum wetted results, it can be seen that the value increases for the fabrics made from finer yarns and yarns having lower twist values. However the differences for the fabrics produced with the yarns in α_e= 3.2 and α_e= 3.6 is not apparent.

Overall moisture management capacity (OMMC) values of the fabrics are given in Table 3 and the values are compared with the grading scale given by the manufacturing company (0-0.2: very poor, 0.2-0.4: poor, 0.4-0.6: good, 0.6-0.8: very good, >0.8: excellent) (21). According to the results, it can be stated that all the fabrics are in the "good" category in terms of moisture management capacity.

4. CONCLUSION

The paper mainly focuses on the moisture management properties of the single jersey knitted fabrics produced by using cotton yarns in three different yarn counts and twist coefficients. According to the results, it can be stated that, as the higher twist coefficient value creates a compact structure, maximum absorption rate, spreading speed and maximum wetted radius decrease whereas the wetting time of the fabrics increases. On the contrary, as the yarn gets finer, maximum absorption rate, spreading speed and maximum wetted radius increase whereas the wetting time of the fabrics decreases.

According to the overall moisture management capacity (OMMC) values which can be used as an indication of moisture behavior of the fabrics, even the yarn counts and yarn twist coefficients are different, all the cotton fabrics have been found in the same category and they were evaluated as "good" in moisture management.

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