(REFEREED RESEARCH)

A SURVEY OF COMFORT PROPERTIES OF SOCKS PRODUCED FROM CELLULOSE-BASED FIBERS

REJENERE SELÜLOZ ESASLI LİFLERDEN ÜRETİLEN ÇORAPLARIN KONFOR ÖZELLİKLERİ ÜZERINE BİR ARAŞTIRMA

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Received: 10.07.2013 Accepted: 04.02.2014

ABSTRACT

Customer satisfaction has become the main point and consumers have become more aware of their demands and are seeking more qualified products. This makes consumers' expectations get sophisticated about socks. Therefore, socks should be designed to meet customer satisfaction in accordance with fashion and functional needs; their performance should appeal to customer expectations and the fiber blend must not affect consumer health negatively. In this study, the effect of fiber blends on the comfort aspect of socks was investigated. Socks were knitted from traditional fibers like cotton and viscose and new regenerated fiber kinds like Bamboo, Modal®, Promodal®, Micromodal®, Linen-modal, Lyocell®. The effects of fiber types on the comfort and physical performances of socks were studied. So, parameters, which determine comfort in socks; like water vapor permeability, heat transfer, air permeability, liquid transfer, humidity management were determined. The findings were statistically evaluated with variance analysis by using SPSS 15.0 for Microsoft software.

Key Words: Sock, Comfort, Humidity management, Cellulosic fibers.

ÖZET

Günümüzde müşteri memnuniyeti sürekli ön plana çıkmakta ve buna paralel olarak da alıcılar taleplerinde daha bilinçli davranmakta, daha nitelikli ürünler aramaktadırlar. Bu da giyenlerin çoraplardan beklentilerini sürekli arttırmaktadır. Bu nedenle çoraplar; moda ve ihtiyaçlara uygun olarak müşteri memnuniyetini karşılayacak şekilde tasarlanmalı, üretim sonrası özelliklerini kaybetmeden kullanım performansları yüksek olmalı ve özellikle sağlık açısından kullanılan lif özellikleri insan sağlığını olumsuz yönde etkilememelidir. Bu çalışmada; pamuk ve viskon gibi geleneksel elyaflar ile Bambu, Modal®, Promodal®, Mikromodal®, Keten-modal, lyocell® gibi yeni rejenere elyaf cinsleri kullanılarak örülmüş çoraplar yardımıyla konfor özelliklerine elyaf cinsinin katkısı, yeni elyaf cinslerinin kumaş konfor özelliklerine katkıda ne kadar başarılı olduğu ve kumaşın fiziksel performanslarını ne şekilde etkilendiği araştırılmıştır. Bu doğrultuda, çorapların konfor performanslarını belirleyip karsılaştırmak için çoraplarda konforu belirleyen parametreler olan su buharı geçirgenliği, ısı transferi, hava geçirgenliği, sıvı transferi, nem yönetimi gibi özellikler belirlenmeye çalışılmıştır. Ayrıca SPSS 15.0 for Microsoft programı kullanılarak, bulguların varyans analizi ile istatistiksel değerlendirmeleri yapılmıştır.

Anahtar Kelimeler: Çorap, Konfor, Nem yönetimi, Selülozik lifler.

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1. INTRODUCTION

In today's conditions, with rising life standards and the effect of fashion trends, comfort has become an important factor in choosing clothing, beside their functional characteristics. Comfort is the state of feeling oneself good in an environment, which is also known as ease. Garments give this feeling when they do not restrict body movements nor prevent heat regulation mechanism of the body, to the contrary assist it. Body movement mainly depends on the garment and its fabric, whereas its body heat transfer takes place with the help of its comfort properties like its humidity, water and air permeability and heat transfer characteristics.

The quality of socks is affected by many factors. These factors may be given as the type and the properties of the yarn, knitting conditions and machine properties, dying techniques and the dyestuff used, and form giving processes. At the same time, socks are supposed to have elasticity, physiologic comfort and thermo physiologic features and resistance to wear. When physiologic comfort is stated, it means providing optimum heat, humidity and air transfer. Thermo physiologic features come to the point that fabric should give comfort over skin and positive feelings that affect warmness, coldness, wetness perception positively.

Slater (1) defines the term comfort as a mixture of physical, physiological and psychological satisfaction interaction between man and his environment. Sontag (2) with a similar expression, states that comfort is a state of feeling good and a state of balance between a person and his environment. Wang (3) claims that this balance, cited as Man – Garment – Environment, may be ruined because of different factors. According to Smith (4) comfort is the state of not feeling the garment nor pain when the garment has been put on and he adds that discomfort can be scaled between 'slight discomfort' and 'excessive pain'. Shivers (5) classifies comfort as psychological and physiological aspects.

Physiological comfort is related to establishing a thermo balance between gaining and losing body heat, while psychological comfort corresponds to comfort generating aspect of the garment. Baker (6) claims that comfort is not only about the physical properties of fabric and garment, but also is determined by the human's physiological and psychological state.

Avcı (7) had some studies in which he inspected the physical and comfort aspects of socks knitted from cotton, modal, viscose, bamboo, seacell and soy yarns. The results of water vapor conductivity testing showed that viscose gave the lowest values whereas bamboo-cotton and seacell provided the highest results. In terms of thermo-resistance findings, modal and soy gave the lowest and greatest thermo-resistance results, respectively. Cotton had the highest air-permeability values, whereas seacell and soy gave the lowest values. Results of wearing test showed that bamboo had the highest percent of mass loss, while viscose had the lowest.

Cimilli (8) investigated socks which were produced in three different densities of new fibers like modal, micromodal, bamboo, soy and chitosan. At the end, he found out that the most worn sample was micromodal. Cotton had the lowest air-permeability, whereas modal samples had the highest values. Modal samples gave the highest moisture recovery results. Cotton samples had the highest values in thermal conduction and heat convection.

Oğlakçıoğlu and Marmaralı (9) studied thermal comfort properties of garments with analyzing their thermal properties after sweating. For this aim thermal conductivity, thermal absorptivity and thermal resistance values of fabrics, knitted with different types of cotton yarn, were tested in both dry and wet states. The results indicate that there was not any significant difference between thermal comfort properties of the fabrics knitted with carded and combed yarns, whereas mercerization process affected to these properties significantly. After wetting, all fabric structures indicate cooler feeling and lower thermal insulation.

Namlıgöz et al (10) focused on the evaluation of indices of liquid moisture management properties, grading and classification methods of woven fabrics with various fibers by using MMT tester. It was found that unlike 100% Cellulosic and PES fabrics, Cellulosic/PES blended fabrics allowed the liquid absorption and transportation efficiently.

Ertekin and Marmaralı (11) investigated thermal comfort properties of fabrics which were produced in three different dial heights and two different spacer yarn on circular knitting machine by using spacer fabric production method. It was observed that, fabric weight, thermal conductivity, thermal resistivity, air permeability and relative water vapor permeability properties were affected by dial height and the type of spacer yarn significantly.

2. MATERIAL AND METHOD

2.1. Sample Preparation

In the experimental study, 8 groups of socks were knitted from cotton and regenerated cellulosic bamboo, modal, promodal, micromodal, linen-modal, lyocell, viscose fibers. Yarns were produced from the mentioned fibers by using ring spinning process. The cotton sock group was regarded as the control group. As the effects of fibers on the socks were investigated in terms of comfort and physical properties, other yarn and fabric parameters were kept constant. To achieve this, all socks were knitted on the same day, with the same yarn feeding and thread tension parameters and by using the same machine. An E18 fine, 3 inch-diameter, electronic single plated, Lonatti brand sock knitting machine was used. In these socks; plating knitting was applied and 70 denier Nylon+20 denier Lycra® yarn was used as the back thread. After tips were sewed, they were all put into the same dying machine and were dyed by reactive dying process which was followed by a forming (ironing) process before the socks became finished products. Before starting the experiments, all of the sock samples were conditioned at 22°C, 65% RH standard conditions.

2.2. Characterization

Finished products were tested in terms of water vapor permeability, heat transfer, humidity transfer, capillary wetting, moisture absorption, drying speed and air permeability. The collected data was statistically analyzed by using SPSS 15.0 for Microsoft software.

3. RESULTS AND DISCUSSION

3.1. uster testing results of threads used in socks

Uster quality testing results of the cellulosic threads of different raw materials, which have been used in knitted sample socks are given in Table 1.

3.2. course and wale densities

Sample socks were laid on a flat surface and then the number of courses and wales at 2.5 inches were counted. Average values of 5 different measurements for each sample were determined. Then, these average values were transformed to per cm units. Densities of courses and wales are presented in Table 2.

Table 1. Statistical Uster testing results of the cellulosic threads based on different raw materials.

Samples	Yarn Count (Ne)	Twist Coeff. (αm)	Tenacity RKM	Breaking Elangation (%)	Uneven ness (U%)	CV %	Thin Places (-50%)	Thick Places (+50%)	Neps (+200%)	Hairiness (H%)
Bamboo	30.0	3.8	18.93	16.12	9.67	12.21	1	13	46	5.56
Promodal	29.5	3.7	24.94	9.49	8.56	10.81	0	8	31	5.73
Modal	30.3	3.8	27.54	10.99	8.84	11.18	0	9	31	5.74
Micromodal	29.9	3.7	28.75	10.91	7.97	10.06	0	6	16	5.23
Viscose	30.3	3.9	20.57	14.15	9.62	12.12	1	9	23	5.22
Lyocell	29.8	3.7	23.80	7.12	9.76	12.42	0	37	89	7.29
Modal/linen	29.7	3.6	23.59	9.88	11.88	15.45	3	361	758	5.88

Table 2. Average values of course and wale densities number of courses per cm

Sample	Course Density (courses/cm)	Wale Density (wales/cm)
Cotton	15.47	10.55
Bamboo	15.87	10.75
Modal	15.83	10.31
Promodal	15.39	10.55
Micromodal	15.09	10.06
Modal Linen	15.47	10.91
Lyocell	15.91	10.94
Viscose	15.47	10.35

3.3. Air permeability

Air Permeability tests of the sock samples were carried out by using a Textest FX3000 testing machine in accordance with TS 391 EN ISO 9237 standard specifications. In the testing device, fabric was located under the test head which has a fixed space and the test head was pressed on the fabric and then air coming from the compressor was allowed to pass through the fabric. For each sample, 10 different measurements were carried out and their average values were calculated. The average air permeability values are given in Table 3.

Table 3. Average values of air permeability measurements of the sample socks

Sample	Average Air permeability (1/m^2/s)
Cotton	368
Bamboo	490
Modal	550
Promodal	520
Micromodal	500
Modal Linen	540
Lyocell	450
Viscose	480

According to air permeability testing results; cotton had the lowest air permeability values and modal had the highest values.

3.4. Water vapor permeability

In normal clothing conditions, human body always excretes water vapor through skin pores. Pressure difference, which is formed between the skin and the outer surroundings causes water vapor molecules to move to outer surroundings which have lower pressure (12).

Relative water vapor permeability is the ability of fabric to transfer water vapor in percentage scale. Especially, for products which are used in hot weather or for active sports when perspiring is maximal, water vapor permeability is one of the most important comfort parameters. Garments which have high water vapor permeability feature can easily ensure evaporation of moisture from body after sweating and enhance the sense of comfort (13).

Permetest water vapor conductivity testing machine was used to evaluate water vapor permeability values. For each sample, 10 different measurements were carried out and the relative water vapor permeability (L%) and the water vapor resistance (m^{2}Pa/W) are given in Table 4.

Table 4. Water vapor permeability values in socks

Sample	Relative Water Vapor Permeability (%)	Water Vapor Resistance (m^{2}Pa/W)
Cotton	39.7	14.3
Bamboo	37.5	15.6
Modal	41.8	7.5
Promodal	39.0	11.9
Micromodal	37.3	13.6
Modal-Linen	37.4	9.5
Lyocell	40.2	11.9
Viscose	38.1	13.7

In terms of relative water vapor permeability, micromodal sample had the lowest and modal sample gave the highest values. When the values are arranged in order from the lowest to the highest, the order is as follows; micromodal, modal-linen, bamboo, viscose, lyocell and modal samples.

3.5. Measurement of thermal properties

Heat insulation, which is provided by garments to keep human body temperature stable, affects body thermal comfort. Human body continuously produces thermo-energy because of its metabolism speed. To keep the body temperature stable, this produced energy must be sent away by conduction, convection or radiation mechanisms. The amount of transmitted heat energy changes depending on garment properties and outer surrounding conditions. In cold weather, people put on clothes so that the heat that is transmitted to outer surroundings should not be more than thermo-energy amount produced in body. In this case, heat insulation property of garment gains importance. In hot weather, heat transmission from body to outer surroundings becomes difficult. In hot weather, in order to boost heat transmission; garments which are lighter and have more thermo-conductivity are preferred. If body cannot send heat outside through usual ways, perspiration takes place. With mass diffusion through sweating, evaporation in hot weather increases the heat transmission from body to outer surroundings. In both cold and hot weather, the heat insulation and conductivity properties of the garment is of great importance (14).

Thermal properties of fabrics were measured according to ISO 11092 standard by using an Alambeta device. For each sample, 10 measurements were carried out and their averages were taken. At the end of the measurements, thermo-conductivity, thermo resistance, thermo-absorption and thickness values were determined. These values are given in Table 5.

Table 5. Results of thermal analyses of socks

Sample	Thermal Conductivity (W/mK)	Thermal Resistance (m²K/W)	Thermal Absorption (Ws½/m²K)	Thickness (m)
Cotton	0.070	0.024	147.1	0.001676
Bamboo	0.066	0.025	155.3	0.001641
Modal	0.071	0.022	169.1	0.001588
Promodal	0.066	0.024	164.1	0.001583
Micromodal	0.064	0.023	173.6	0.001477
Modal-Linen	0.067	0.024	163.3	0.001561
Lyocell	0.066	0.023	165.4	0.001537
Viscose	0.074	0.025	187.9	0.001814

Thermal Conductivity and thermal resistance are inversely proportional to one another. When thermal resistance declines, thermal insulation drops as well. When thermal resistance values are evaluated, it will be seen that the modal sample had the lowest, while the bamboo one had the highest value. In thermal absorption values; cotton gave the lowest and viscose gave the highest values. When the values are arranged in an order from the point of thermal absorption values, the order is as follows, as from the lowest to the highest; cotton, bamboo, modal-linen, promodal, lyocell, modal, micro-modal, viscose samples.

3.6. Moisture management measures

Sock samples were prepared for moisture management tests and measurements as stated in AATCC 195-2009 'Liquid Moisture Management Features of Textile Fabrics'. Tests and measurements regarding to inspect moisture management and comfort were held by using a MMT M290 testing device produced by SDL ATLAS (Fig. 1).

With the MMT device, thermal conductivity can be measured in three-dimensions. Thermo-resistance of textile materials (in the order of 1MΩ) is very high. When they get wet or a little damp, the resistance falls down to hundreds of KΩ. By using the way to measure resistance, the resistance difference through wetting, it is also possible to measure the difference in moisture content of 2 surfaces of the textile material (18). In the MMT device, working principle of measurement sensors is depending on measuring the resistance difference.

Figure 1. M290 Moisture management tester (ITC, 2005)

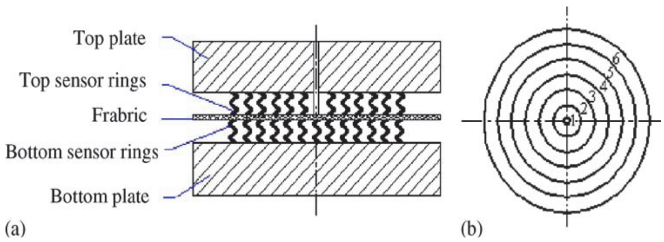


Figure 2. Figure of the MMT sensors a) Sensor structure, b) Measuring rings (16)

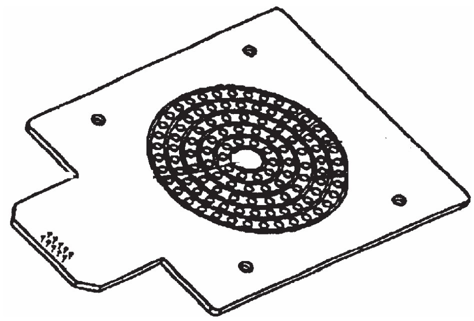
MMT is a device which makes a 3 dimensional testing of knitted and woven fabrics' dynamic liquid moisture management. The device includes upper and lower concentric circle profile moisture sensors which touch the fabric, when it is placed between them. The defined quantity of testing solution in methods and standards is poured onto the upper surface of the fabric by the device in the first 20 second period of 2 minute testing time. MMT senses and measures the transmitted behaviors of the testing solution in multi-direction. The device is controlled by the MMT system 3.06 version of its own software, some parameters which are defined to characterize the liquid moisture management performance of the testing sample, are calculated and recorded by this software.

MMT system software can evaluate and interpret measurement results on a scale of 5 by classifying fabric types in terms of their terminology. MMT permits the measurement of the following indexes:

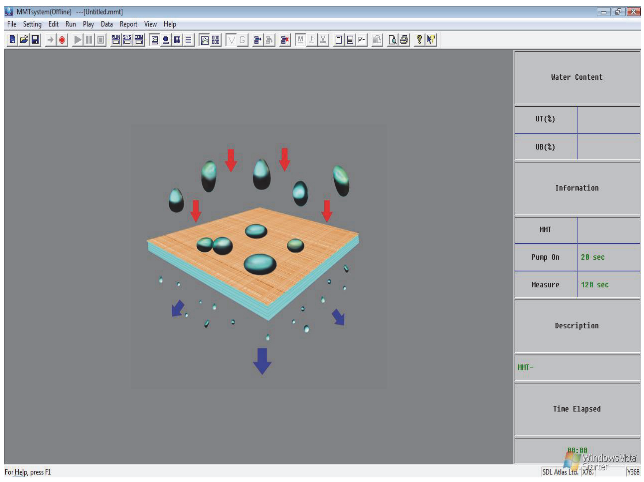
- Wetting time (s) (Separately for inner and outer face of the fabric),
- The degree of absorption (%/s) (for inner and outer face of the fabric, separately),

- Maximum wetted radius (mm) (for inner and outer face of the fabric, separately),
- Propagation velocity of the liquid (mm/s) (for inner and outer face of the fabric, separately)
- Uni-directional switch index of the accumulated liquid through the fabric (%),

The overall moisture management capacity of the fabric, the transition index (R) is explained in 3.1 equation in MMT terminology.



(a)



(b)

Figure 3. (a) Top view of table which has upper moisture sensors. (24)
(b) User interface of 3.06 version of MMT system software.

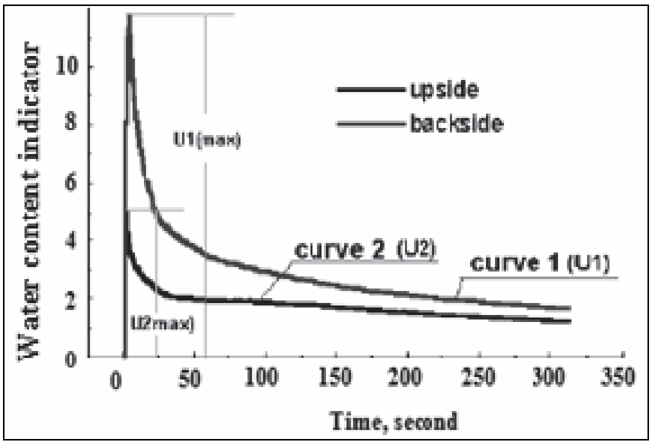


Figure 4. Definition of differential liquid transmission (23)

R= (Area(Uı) – Area(U2)) / Total Testing Period (3.1)

In equation (3.1), Uı means the amount of water in outer face of the fabric, and U_2 expresses the amount of water in the inner face. So it is possible to define 'transmission index' as 'the difference between upper and below parts of the face from the point of accumulated total liquid amount after the whole testing period per unit time'(23). As seen in Figure 4, liquid moisture amount of the fabric increases parabolically with liquid's spilling onto the fabric and decreases parabolically with fabric's liquid absorption and is expressed by Uı and U2 curves.

The transmission index values' being negative means U2 curve area is larger than the Uı one; namely there is little or no liquid moisture transmission from the upper part of the fabric to the under part (22).

Overall moisture management capacity (OMMC) is a parameter which the testing device calculates with its own terminology according to the equation (3.2).

OMMC:0.25*BAR ndv +0.5*Rndv 40.25*BSSndv (3.2)

In equation (3.2);

BAR; expresses liquid moisture absorption degree in under face of fabric,

BSS; drying rate of outer face of the fabric which is explained by the liquid propagation velocity,

Ndv; means these parameters are zero-dimensional (23).

Zero-dimensional BAR is calculated with R and BSS parameters according to equation (3.3).

$$BAR_{ndv} = \begin{cases} 1 & , BAR \geq BAR_{max} \\ \dfrac{BAR - BAR_{min}}{BAR_{max} - BAR_{min}} & , BAR \in [BAR_{min}, BAR_{max}] \\ 0 & , BAR \leq BAR_{min} \end{cases}$$

$$R_{ndv} = \begin{cases} 1 & , R \geq R_{max} \\ \dfrac{R - R_{min}}{R_{max} - R_{min}} & , R \in [R_{min}, R_{max}] \\ 0 & , R \leq R_{min} \end{cases}$$

$$BSS_{ndv} = \begin{cases} 1 & , BSS \geq BSS_{max} \\ \dfrac{BSS - BSS_{min}}{BSS_{max} - BSS_{min}} & , BSS \in [BSS_{min}, BSS_{max}] \\ 0 & , BSS \leq BSS_{min} \end{cases} \quad (3.3)$$

5 specimens in 8x8 cm^2 dimensions were cut through the fabric width in a diagonal layout for each sock samples. In the next step, samples were washed in distilled water for 5 minutes at room temperature. With this process, fabrics were purified from the chemicals applied on them. Washed samples were taken into an oven and dried at 105°C. To smooth wrinkles out in the samples and have the testing on

a plain fabric surface, all samples were ironed at high temperature with a household steam iron (covered with a gauze cloth). While working with the samples, care was taken to ensure that the sample keeps their physical conditions. Finally, before testing, samples were conditioned for 2 hours at 20 °C and 65% relative humidity. The testing solution was prepared from 9 g/l sodium chloride solution and distilled water and it was confirmed that fluid conductivity was 16±0,2 mS (16).

The MMT System scored the testing and measurement values out of 5 replications and classifies fabric types according to its own terminology. Values of wetting periods and absorption degrees of the finished stocking samples are illustrated in Tables below.

3.7. Results of the moisture management test

The presence of liquid particles on the skin, whether they come out of the body or they are taken from outside, is accepted as least healthy and least comfortable state (17-21). To have healthy conditions and humidity comfort, the liquid particles on the body must be sucked by the inner face of fabric before they touch the fabric, then be driven outside of the outer face of the fabric and then they must evaporate (22). To activate evaporation quickly, the liquid must spread to the outer side of fabric at top level (16).

In Table 6, the values of finished samples' wetting time results are given. Upper parts of socks get wet in 20 s. which is the time of liquid dripping.

Moisture transmission from inside of micromodal socks to outside was quite fast as the period is short. When this result and conditions to provide moisture comfort and health are surveyed, it is seen that micromodal samples had the most moisture comfort raw material type, whereas modal, promodal and viscose gave the least level of comfort.

Table 6. Average values of finished samples' wetting time

Finished Sample	Inner Face Wetting Time (sec.)	Outer Face Wetting Time (sec.)
Cotton	17.828	55.284
Bamboo	18.917	081.745
Modal	19.288	119.953
Promodal	19.097	119.953
Micromodal	10.690	010.709
Modal Linen	18.934	106.678
Lyocell	19.320	086.160
Viscose	19.418	119.953

Absorption value is the amount of maximum absorption that the fabric has got in dripping period of testing solution on the fabric (23,24).

Degrees of absorption values of finished samples are given in Table 7.

Amount of moisture absorbed per second in both outer and inner parts to meet health and moisture comfort must be at top level. In this way, liquid in skin can be sucked by inner and outer surfaces of the sock and the humid surrounding which quickens microbial formations with body heat in skin is prevented. When absorption degrees for inner and outer face of the fabric are searched separately, it is evaluated that in inner side of the stocking, promodal was the most comfortable and healthiest, and in outer side the best one was cotton. However, the inner and outer faces of socks should be regarded together, an optimum degree for both of them should be obtained, to do it; average absorption values of inner and outer face of the fabric should be taken into consideration (Table 8).

Table 7. Average degrees of finished samples' absorption values (%/sec.)

Sample Product	Inner Face Absorption Value	Outer Face Absorption Value
Cotton	91.372	66.788
Bamboo	35.539	7.160
Modal	89.759	0.000
Promodal	99.364	0.000
Micromodal	76.416	66.563
Modal Linen	58.590	55.303
Lyocell	77.946	49.043
Viscose	93.513	0.000

Table 8. Average absorption degrees for inner and outer face of fabric

Sample Product	Average Absorption Degree (%/sec.)
Cotton	79.080
Bamboo	21.349
Modal	44.879
Promodal	49.682
Micromodal	71.489
Modal Linen	57.126
Lyocell	63.519
Viscose	46.756

As shown in Table 8, cotton has the highest average degree so that a sock knitted by using cotton has the best liquid moisture absorption degrees for both inner and outer face of the fabric. Cotton has been detected as the best fiber in terms of supplying moisture comfort and highest level of health.

To meet the highest health and moisture comfort conditions, liquid transmission velocity should be low in the inner part of the sock through the fabric width, and it should be high in the outer part to provide rapid evaporation (17). When maximum wetting radius values are inspected, it is possible to see that micromodal was the least comfortable for the inner face of the fabric (inside the sock), and it is the most comfortable for the outer face of the fabric (outside the sock). But when the sock is evaluated as a whole, an evaluation as illustrated in Table 10 is appropriate. According to this evaluation, wetting radius values of inner face of fabrics were taken negative as they are required to be minimal and those of outer face of fabrics which are required to be maximal were taken in their positive sign and these two values were added up for each corresponding sample.

The only raw material, namely cotton, the value of which was not negative, was the most suitable kind of fiber for socks with respect to maximum wetted radius analysis.

Modal, viscose and promodal were not considered suitable fiber kinds.

Table 9. Average values for wetting radius of sample products

Sample Product	Inner Part Max Wetting Radius (mm)	Outer Face Max Wetting Radius (mm)
Cotton	5.000	5.000
Bamboo	5.000	3.333
Modal	5.000	0.000
Promodal	5.000	0.000
Micromodal	13.333	11.667
Modal Linen	5.000	3.000
Lyocell	5.000	3.750
Viscose	5.000	0.000

Table 10. Total wetting radius values of the whole socks

Sample Product	Maximum Wetted Radius (mm)		
	Inner face of the fabric	Outer Face of the fabric	TOTAL
Cotton	-5.000	5.000	0.000
Bamboo	-5.000	3.333	-1.667
Modal	-5.000	0.000	-5.000
Promodal	-5.000	0.000	-5.000
Micromodal	-13.333	11.667	-1.666
Modal Linen	-5.000	3.000	-2.000
Lyocell	-5.000	3.750	-1.250
Viscose	-5.000	0,000	-5.000

Average liquid transmission values of the sample products are given in Table 11.

Table 11. Average liquid transmission velocity values of sample products

Sample Product	Transmission Velocity of Liquid at Inner Face (mm/sec.)	Transmission Velocity of Liquid at Outer Face (mm/sec.)
Cotton	0.278	0.090
Bamboo	0.263	0.053
Modal	0.257	0.000
Promodal	0.260	0.000
Micromodal	1.257	1.405
Modal Linen	0.262	0.033
Lyocell	0.256	0.054
Viscose	0.255	0.000

Viscose was found to be the most suitable fiber kind for the inner face of socks which requires a liquid transmission speed close to 0 mm/sec or no transmission at all. In contrary, micromodal was suitable for outer face of socks which requires fast transmission speed and evaporation. But, when socks are considered as a whole as cited in Table 12, the most suitable kind of fiber is micromodal. Promodal was the fiber kind which had the most negative points among other fiber kinds.

Average values of uni-directional transmission indices were gathered for sample products and overall moisture management indices are given in Table 13.

Table 12. Liquid diffusion velocity results for the socks as a whole

Sample Product	Liquid diffusion velocity (mm/s)		
	Inner face of the fabric	Outer Face of the Fabric	TOTAL
Cotton	-0.278	0.090	-0.188
Bamboo	-0.263	0.053	-0.210
Modal	-0.257	0.000	-0.257
Promodal	-0.260	0.000	-0.260
Micromodal	-1.257	1.405	0.148
Modal Linen	-0.262	0.033	-0.229
Lyocell	-0.256	0.054	-0.202
Viscose	-0.255	0.000	-0.255

When transmission index parameter is evaluated for socks; the increase in the negative degree of transmission index means that the amount of liquid accumulated inside the sock (over fabric) increases and the liquid is imprisoned inside the sock which is an undesired case for health and comfort. This case was mostly observed with modal linen. So this product type is not suitable for socks since this parameter is more important than other parameters. Relatively; viscose, promodal, modal, bamboo and lyocell are not good raw materials for socks, either. Micromodal and cotton were found to be more suitable to make socks.

Table 13. Uni-directional transmission index values and overall moisture management index values of liquid accumulated on sample products.

Sample Product	Uni-directional Transition Index of Accumulated Liquid %	Overall Moisture Management Index
Cotton	-046.296	0.187
Bamboo	-406.720	0.005
Modal	-414.884	0.000
Promodal	-418.842	0.000
Micromodal	221.974	0.493
Modal Linen	-468.490	0.053
Lyocell	-239.651	0.168
Viscose	-430.105	0.000

According to Table 13, micromodal was the kind of fiber which had the highest moisture management capacity; and modal, promodal and viscose had the lowest.

3.8. Statistical evaluation of measured values

Statistical evaluation results of findings with respect to variance analysis are given in Table 14 and Table 15.

The symbol of “+” expresses a situation where a change in raw material causes a statistically significant change in the feature it addresses, The symbol of “-“ expresses the situation where a change in raw material causes no statistically significant change in the feature it addresses.

Shown as p1 – 15 in Table 14 were given respectively as topics in dependent variable column in Table 15. Parameters which resulted in ‘‘-’’ according to Post Hoc Test are insignificant and were not evaluated in any manner. Parameters marked as ‘‘+’’ are only meaningful according to Post Hoc test and therefore they needed to be considered when results of the test were being evaluated.

Table 14. Results of statistical evaluation with post hoc test

		Sum of Squares	df	Mean Square	F	Sig.
p1	Between Groups	.000	7	.000	12.765	.000
	Within Groups	.000	16	.000		
	Total	.000	23			
p2	Between Groups	.000	7	.000	1.139	.388
	Within Groups	.000	16	.000		
	Total	.000	23			
p3	Between Groups	3093.400	7	441.914	3.632	.015
	Within Groups	1947.007	16	121.688		
	Total	5040.406	23			
p4	Between Groups	.000	7	.000	7.039	.001
	Within Groups	.000	16	.000		
	Total	.000	23			
p5	Between Groups	55.240	7	7.891	1.631	.197
	Within Groups	77.393	16	4.837		
	Total	132.633	23			
p6	Between Groups	149.925	7	21.418	16.586	.000
	Within Groups	20.661	16	1.291		
	Total	170.586	23			
p7	Between Groups	31179.257	7	4454.180	10.223	.000
	Within Groups	6970.942	16	435.684		
	Total	38150.199	23			
p8	Between Groups	11440.776	7	1634.397	.637	.719
	Within Groups	41037.744	16	2564.859		
	Total	52478.520	23			
p9	Between Groups	22548.632	7	3221.233	4.506	.006
	Within Groups	11437.583	16	714.849		
	Total	33986.215	23			
p10	Between Groups	182.292	7	26.042	25.000	.000
	Within Groups	16.667	16	1.042		
	Total	198.958	23			
p11	Between Groups	323.958	7	46.280	11.107	.000
	Within Groups	66.667	16	4.167		
	Total	390.625	23			
p12	Between Groups	2.602	7	.372	100.919	.000
	Within Groups	.059	16	.004		
	Total	2.661	23			
p13	Between Groups	4.971	7	.710	68.000	.000
	Within Groups	.167	16	.010		
	Total	5.138	23			
p14	Between Groups	1288423.901	7	184060.557	11.415	.000
	Within Groups	257999.120	16	16124.945		
	Total	1546423.022	23			
p15	Between Groups	.675	7	.096	7.804	.000
	Within Groups	.198	16	.012		
	Total	.873	23			

Table 15. Results of statistical evaluation

Independent Variable Feature (Dependent Variable)	Change in raw material	
Thermal Conductivity	+	
Thermal Resistance	-	
Thermal Absorption	+	
Thickness	+	
Relative Water Vapor Permeability	-	
Water Vapor Resistance	+	
Wetting Time (Outer face)	+	
Absorption degree	Inner face of the fabric	-
	Outer face of the abric	+
Maximum wetted radius	Inner face of the fabric	+
	Outer face of the abric	+
Liquid trasmission velocity	Inner face of the fabric	+
	Outer face of the abric	+
Uni-directional transmission velocity of accumulated liquid throuh the fabric	+	
OMMC	+	

It was detected that a change in raw material resulted in a statistical change in all physical properties except for thermal resistance, relative water vapor conductivity and the absorption degree of the inner face of the fabric.

4. CONCLUSION

Regarding socks which were knitted from the yarns of the same linear densities but different raw materials by the same knitting machines, in the same conditions, processed through the same wet treatments;

- ✓ According to air conductivity test; socks knitted from cotton had the lowest results whereas modal gave the highest results. When the values are put in an order from the highest to the lowest; the order is as follows; cotton, lyocell, viscose, bamboo, micromodal, modal-linen and modal samples.
- ✓ According to their relative water vapor percentages; the micromodal sample had the lowest result and the modal sample had the highest result. When samples are put in an order beginning with the highest, the order is; micromodal, modal-linen, bamboo, viscose, promodal, cotton, lyocell, modal.
- ✓ In water resistance values; modal sample had the worst result and bamboo had the highest value. When the results are put in an order from the worst to the best, the order is like; modal, modal-linen, promodal, lyocell, micromodal, viscose, cotton, bamboo.
- ✓ The greater the thermal conductivity, the greater heat transmission from the skin to the fabric. The viscose sample gave the highest values in this category, and the micromodal sample had the lowest values.
- ✓ Thermal absorption is related to thermal resistance. The increase in thermal absorption of textile materials leads to a cold feeling at first touch. Among the samples, cotton sample gave the lowest, whereas viscose gave the highest results. The order of the samples from the lowest to the highest in terms of thermal absorption is: cotton, bamboo, modal-linen, promodal, lyocell, modal, micromodal and viscose.
- ✓ Cotton, which was the only sample that gave a positive value in terms of wetted radius, was found to be the most suitable material for sock production. Modal, promodal and viscose was found to be inappropriate ones.
- ✓ In order to provide highest health and comfort standards, the liquid should not be transmitted in the inner part of the sock or should have a velocity close to 0 mm/s, whereas a fast transmission and vaporization is needed for the outer part of socks. Accordingly, viscose and micromodal were found to be the most suitable fibers for the production of the inner and outer parts of socks, respectively.
- ✓ With respect to transmission index parameter, an increasing negative value means an increase in the liquid amount accumulated in the inner part of the sock (over the fabric) and that the liquid is enclosed in the sock. This is an unwanted condition in terms of health and comfort aspects. This situation was observed mostly for the modal-linen sample. When it is considered that this parameter is a more decisive factor among other performance characteristics with respect to liquid – humidity transfer, it can be said the mentioned sample is not suitable for sock production. Viscose,

promodal, bamboo and lyocell, in the given order, which had a similar negative sign were not regarded as suitable materials for socks. Micromodal and cotton, in the given order, is more appropriate to use in socks.

- ✓ As can be seen in the total moisture management index results, the best three fibers were found to be micromodal, cotton and lyocell.

ACKNOWLEDGEMENT

This study was composed from a Master of Science thesis research which was pursued in the Department of Textile Engineering in Pamukkale University. Sample characterizations were carried out in the laboratories of Ege University and Pamukkale University Textile Engineering Departments. We acknowledge the laboratory assistants and staff who contributed during laboratory work.

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