PERFORMANCE AND THERMAL COMFORT PROPERTIES OF KNITTED FABRICS PRODUCED BY COTTON, ACRYLIC AND MIYABI YARNS

Gözde Ertekin, Arzu Marmaralı
Ege University, Faculty of Engineering, Department of Textile Engineering, Bornova, İzmir, Turkey
gozde.damci@ege.edu.tr

ABSTRACT

The performance characteristic of socks can vary depending on many factors such as yarn type, knitting process and finishing method etc. Cotton, acrylic, wool, viscose, polyester, nylon, elastomeric yarns and their blends are commonly used in sock production. Synthetic fibers with better wicking properties such as acrylic and polyester have replaced cotton fibers in most sock models. Cotton fibers are less conductive to moisture transport and have longer drying times. This research is focused on the comparative analysis between the most commonly used yarns in sock production (cotton and acrylic) and a new yarn type (miyabi) and the evaluation of physical and thermal comfort properties.

Key words: Miyabi, acrylic, cotton, socks, knitted fabrics, physical and thermal comfort properties

1. INTRODUCTION

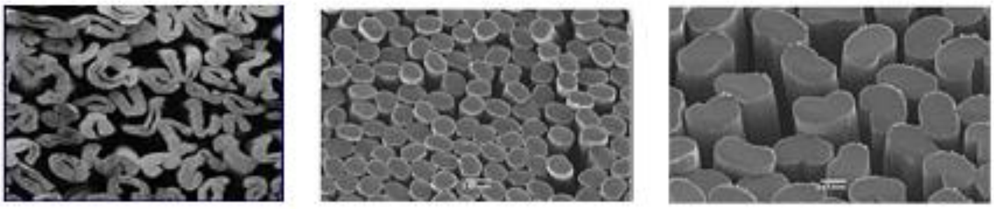
Due to stretchability, freedom of movement, good handle and comfort properties, knitted fabrics are commonly preferred for sportswear, casual wear, underwear and socks. Socks are critical for maintaining foot climate because it wicks sweat from the foot to the shoe upper for evaporation. The thermo-regulation of foot climate can be explained optimum heat, damp and air passing properties so called thermal comfort properties of socks. The expectations from socks are not only thermo-regulation of foot climate but also resistance against abrasion, elasticity and dimensional stability after several washing cycles are required.

The performance characteristic of socks can vary depending on many factors such as yarn type, knitting process and finishing method etc. Cotton, acrylic, wool, viscose, polyester, nylon, elastomeric yarns and their blends are commonly used in sock production. Synthetic fibers with better wicking properties such as acrylic and polyester have replaced cotton fibers in most sock models. Cotton fibers are less conductive to moisture transport and have longer drying times.

Cotton remains by far the most important natural fibre due to good water vapor, air permeability, softness and hygienic properties, despite all of the disadvantages listed above.

Acrylic fiber has a warm and soft handle like wool. It is about 30% bulkier than wool. It is also lightweight and highly resistant to sunlight; has high resilience and elastic recovery characteristic [1].

Miyabi fiber is a micro-fine acrylic yarn developed by Mitsubishi Rayon. It offers smoothness more superior to modal, viscose and silk. It is thinner, lighter and warmer as compared with wool and modal and is extremely comfortable to wear [2]. The cross sectional views of the fibres are given in Figure 1.



(a) (b) (c)

Figure 1. The cross sectional views of (a) Cotton, (b) Miyabi, (c) Acrylic fibers [3]

Extensive research has been carried out on the performance and thermal comfort properties of socks. Cimilli et. al. studied the thermal comfort properties of socks made from new yarns (modal, micro modal, bamboo, soybean and chitosan) and also conventional yarns (cotton, viscose). They noted that, the fiber type, together with regain and fabric properties such as thickness, appears to affect some comfort-related properties of the fabrics. Chitosan, modal, and viscose fabrics performed relatively better than the other fabrics so far as all the properties studied are concerned [4]. Özdil investigated the thermal comfort properties of the socks produced by wool, acrylic, cotton and PA. She reported that thermal conductivity values of wool socks are lower than acrylic socks. Thermal resistance values of wool-acrylic socks are higher than 100% acrylic socks and give warm sense at first contact. The socks which contain PA fibres give high thermal conductivity and thermal absorptivity values [5]. Akaydın and Can studied the abrasion resistance and air permeability properties of cellulose-based socks (modal, viscose, linen- modal, bamboo, cotton, tencel). They mentioned that fibers such as linen-modal and modal have quite high abrasion resistance and air permeability values [6]. Özdil et.al explained the yarn parameters and some finishing process that can affect the abrasion resistance of socks. They found that the use of coarse yarns, addition of polyester, polyamide fibers or elastane filaments to the structure and application of the mercerization process increase the abrasion resistance of the socks. However, the silicone softeners decrease this value. The resistance of wool socks is higher than acrylics [7]. Čiukas and Abramavičiūtė investigated the air permeability properties of socks manufactured using the yarns of new kinds of fibers, such as soybean, bamboo, cotton/Seacell and bamboo/flax. They noted that higher air permeability is characteristic for knits produced by natural yarns [8].

This research is focused on the comparative analysis between the most commonly used yarns in sock production (cotton and acrylic) and a new yarn type (miyabi) and the evaluation of physical and thermal comfort properties.

2. EXPERIMENTAL

Single jersey fabrics were knitted using 100 % Cotton, Acrylic, Miyabi yarns in the same yarn count (36 Ne) and with the same twist coefficient ($\alpha e = 3{,}6$) and same tightness values. The knitting process was performed on an experimental 3 ¾” diameter circular knitting machines “Lab Knitter”, with 240 needles. The knitting process was completed with constant machine settings and the samples were kept under the standard atmospheric conditions for 24 hours for the relaxation.

Some physical properties (weight, thickness, stitch density, abrasion and bursting strength) and comfort properties (thermal conductivity, thermal resistance, thermal absorptivity, relative water vapor permeability, air permeability) of the fabrics were measured.

Alambeta instrument was used to measure thermal conductivity, fabric thickness, thermal resistance and thermal absorptivity values; relative water vapor permeability was measured on Permetest instrument working on similar skin model principle as given by the ISO 11092 and air permeability was measured according to the TS 391 EN ISO 9237 using tester FX3300 (Table 1). Martindale abrasion resistance and pilling tester and hydraulic bursting tester were used for measurement of abrasion resistance and bursting strength values according to ISO 12947-2 and TS 393 EN ISO 13938-1, respectively. All measurements were repeated five times. The results of the tests were evaluated statistically and the importance levels of the relationship between the measured parameters were determined.

3. RESULTS AND DISCUSSION

The performance and thermal comfort values of the fabrics are given in Table 1. In these tables, the mean values are marked with the letters ‘a’, ‘b’ and ‘c’. Any levels marked by the same letter showed that they were not significantly different (‘a’ shows the lowest value and ‘c’ shows the highest value).

Table 1. Measured performance and thermal comfort properties of the knitted fabrics

Properties		Miyabi	Cotton	Acrylic
Yarn count		36 Ne	36 Ne	36 Ne
Yarn twist coefficient (αe)		3,8	3,8	3,8
Stitch density	**Course/cm**	15	15	15
	Wale/cm	13	13	13
Thickness (mm)		0,7704 (c)	0,7368 (b)	0,6703 (a)
Weight (g/m^2)		97,3 (a,b)	95,37 (a)	100,4 (b)
Air permeability (%)		2511 (b)	2625 (b)	2247 (a)
Thermal conductivity		0,0380 (a)	0,0467 (c)	0,0405 (b)
Thermal resistance		0,0203 (b)	0,0158 (a)	0,0166 (a)
Thermal absorptivity		78,17 (a)	90,70 (b)	88,20 (b)
Relative water vapor permeability (%)		52,46 (b)	51,17 (a)	50,24 (a)
Bursting strength (kPa)		396,13 (a)	374,83 (a)	344,5 (a)
Abrasion resistance		22.500	26.000	12.500

3.1. Air Permeability

Air permeability is the rate of air flow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material. The results indicate that the air permeability values increase while the weight values of the fabrics decrease. The 100% cotton and 100 % Miyabi fabrics have the highest values and there aren’t any significantly differences between them. The amount of air passed through the fabric increases when the fabrics become lighter as expected.

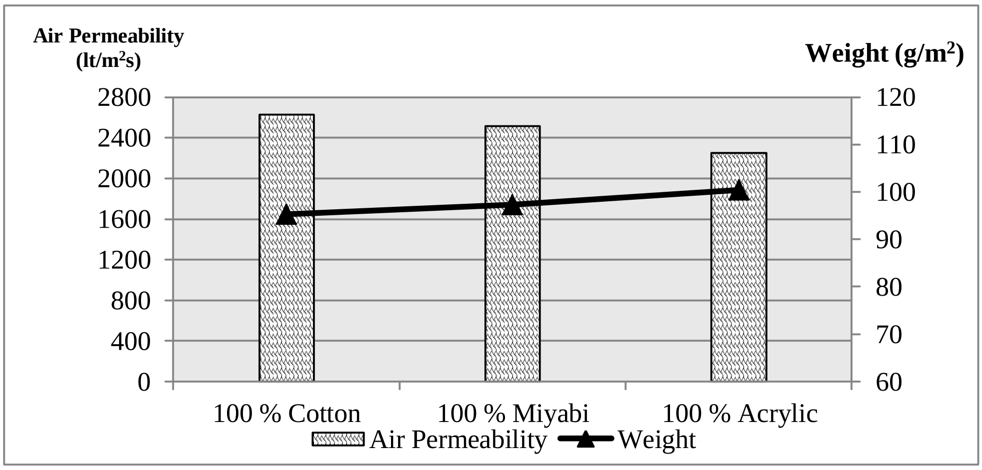


Figure 2. Air permeability and weight values

3.2. Thermal Resistance and Thermal Absorptivity

Thermal resistance is an indication of how well a material insulates and thermal absorptivity determines the contact temperature of two materials.

100 % Cotton and 100 % Acrylic fabrics have similar comfort properties (statistically same thermal resistance and thermal absorptivity values). Thermal conductivity value of Miyabi fabric is significantly lower and thermal resistance value of Miyabi fabric is higher than these two fabrics. So Miyabi fabric provides better thermal insulation and warmer feeling at the initial touch with lower thermal absorptivity value.

These situations might be explained by the thermal conductivity which is a property of materials that expresses the heat flux that will flow through the material if a certain temperature gradient exists over the material. The thermal conductivity values are significantly higher in 100 % Cotton and 100 % Acrylic fabrics. Therefore with increasing of thermal conductivity, thermal resistance will decrease and thermal absorptivity will increase as it is given in equation 1 and 2 respectively.

$$Rct = \frac{h}{\lambda}(m^2 K / W) \tag{1}$$

where:
h: thickness (m)
λ: thermal conductivity (W/m K)

$$b = (\lambda \rho c)^{1/2} (Ws^{1/2} / m^2 K) \tag{2}$$

where:
λ: thermal conductivity (W/m K)
ρ: fabric density (kg m^{-3})
c: specific heat of fabric (J/ kg K)

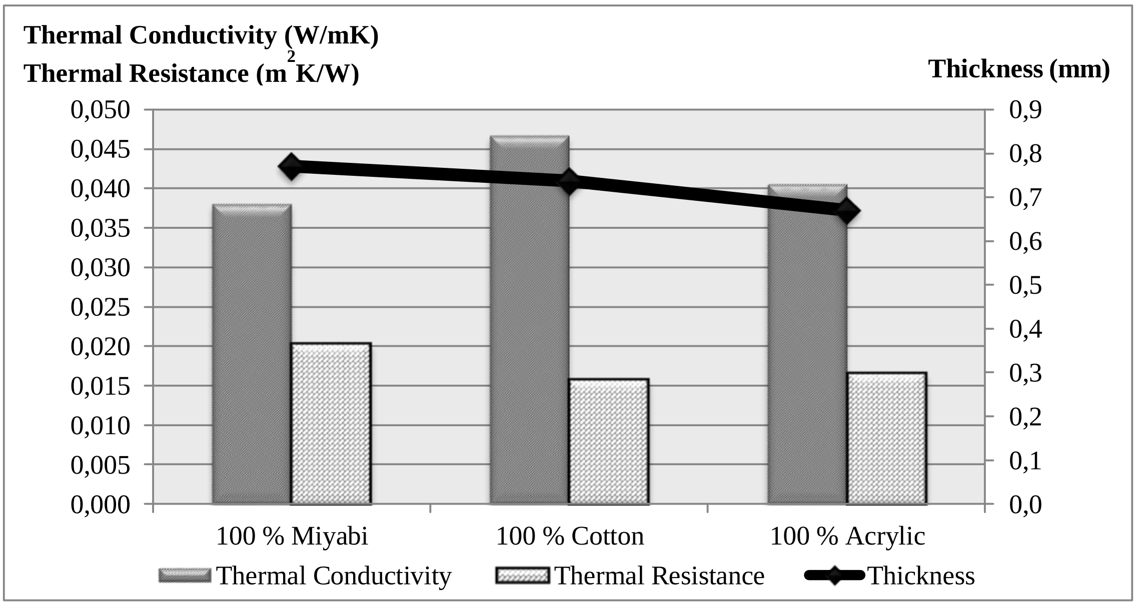


Figure 3. Thermal conductivity and thermal resistance values

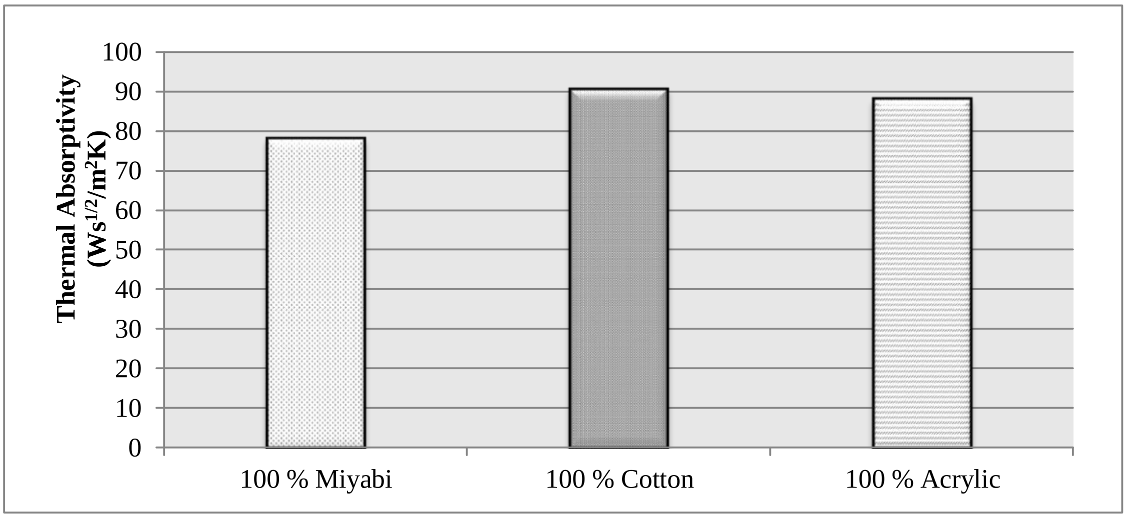


Figure 4. Thermal absorptivity values

3.4. Relative Water Vapor Permeability

Relative water vapour permeability is the rate of water vapour transmission through a material. Relative water vapor permeability is given by the relationship:

$$q[\%] = 100 \times \frac{q_s}{q_0} \tag{2}$$

where q_s is the heat flow value with a sample (W/m^2) and q_o is the heat flow value without sample (W/m^2).

As it is seen from Fig.5, 100 % Miyabi fabric has the highest water vapor permeability values and the statistical analysis show that there is a significant difference between 100% Miyabi and 100% Cotton, 100% Acrylic fabrics.

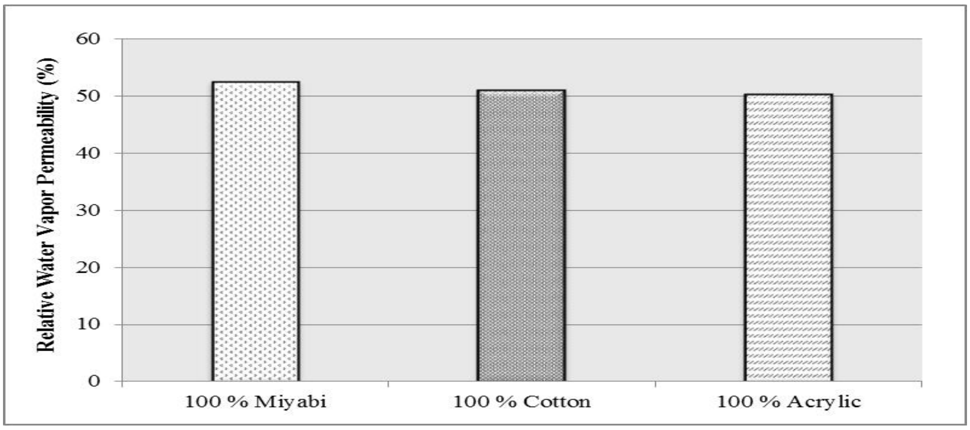


Figure 5. Relative water vapour permeability values

3.5. Abrasion Resistance and Bursting Strength

Bursting strength is the force that must be exerted perpendicularly on the fabric surface to break off the fabric. On the basis of the obtained results, there isn't any difference in bursting strength among the tested fabric samples.

Abrasion resistance is the ability of a material to withstand mechanical action such as rubbing, scraping, that tends progressively to remove material from its surface. To test the abrasion resistance of the fabrics, the determination of specimen breakdown by the Martindale method according to the standard ISO 12947-2:1998 was used. The number of cycles to wear a hole in the specimen is measured. According to the results, a certain difference between the fabric samples is noticeable. The highest abrasion resistance (highest number of cycles) records 100% Cotton fabric followed by 100 % Miyabi and 100% Acrylic (Fig. 6).

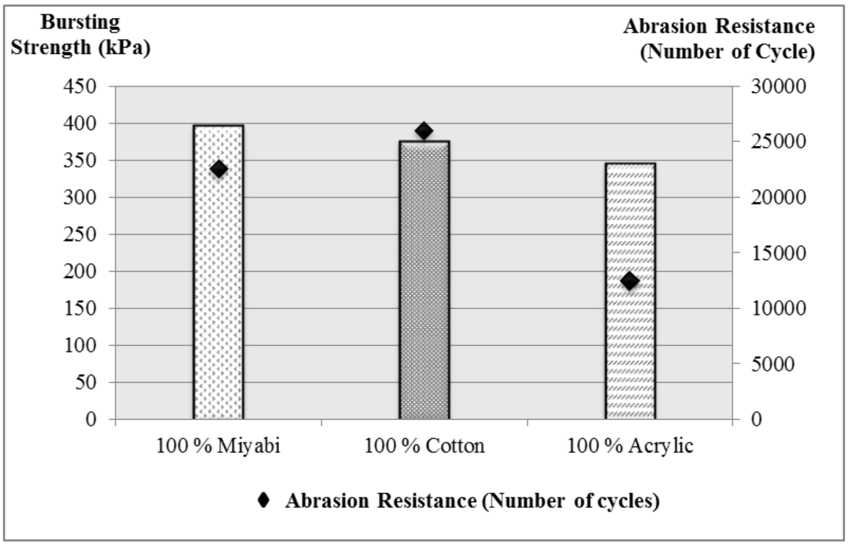


Figure 6. Bursting strength and abrasion resistance values of the fabrics

4. CONCLUSION

This study performs a quantitative investigation of various fabric characteristics, such as fabric weight, air permeability, thermal conductivity, thermal resistance, relative water vapor permeability, abrasion resistance and bursting strength properties of fabrics produced by different materials.

The results indicate that Miyabi fabric has higher air permeability, thermal resistance and relative water vapor permeability values as compared with 100 % Cotton and 100% Acrylic fabrics. So Miyabi fabric provides better thermal insulation and warmer feeling at the initial touch with lower thermal absorptivity value. Miyabi fabric has also good resistant to abrasion.

According to these results, it is recommended to use Miyabi fabric for summer or high activity garments with high thermal resistance, air permeability and relative water vapor permeability to ensure better moisture management.

ACKNOWLEDGEMENTS
The authors would like to thank to Gülle Entegre Tekstil İşlt. Tic. ve San. A.Ş. for providing Miyabi yarn.

5. REFERENCES

[1] http://www.aksa.com/en-US/OurProducts/Pages/WhatIsAcrylicFiber.aspx
[2] http://www.mrchk.com.hk/en/product_c_04.php
[3] EDİS, E.T., 2010, Miyabi Mikroakrilik Lifleri, Çorapland Dergisi, Mayıs- Haziran, 52-53s.
[4] CİMİLLİ, S., NERGİS, B.U., CANDAN, C. and ÖZDEMİR, M.,2010, A Comparative Study of Some Comfort-related Properties of Socks of Different Fiber Types, Textile Research Journal, 80: pp.948-957
[5] ÖZDİL, N., 2008, A Study on Thermal Comfort Properties of the Socks, Tekstil ve Konfeksiyon, 2, pp.154-158.
[6] AKAYDIN, M., CAN, Y., 2012, A Research of Strength Properties of Socks Knitted from New Cellulose- Based Fibers, Tekstil Teknolojileri Elektronik Dergisi, Cilt: 6, No: 2, (28-36).
[7] ÖZDİL, N., MARMARALI, A., OĞLAKCIOĞLU, N., 2009, The Abrasion Resistance of Socks, International Journal of Clothing Science and Technology, Vol. 21 Iss: 1, pp.56 – 63.
[8] ČIUKAS, R., ABRAMAVIČIŪTĖ, J., 2010, Investigation of the Air Permeability of Socks Knitted from Yarns with Peculiar Properties, FIBRES & TEXTILES in Eastern Europe, Vol. 18, No. 1 (78) pp. 84-88.