(REFEREED RESEARCH)

EFFECTS OF USAGE ACRYLIC YARN ON THERMAL COMFORT AND MOISTURE MANAGEMENT PROPERTIES OF WOVEN SHIRTING FABRICS

GÖMLEKLİK DOKUMA KUMAŞLARDA AKRİLİK İPLİK KULLANIMININ KUMAŞLARIN TERMAL KONFOR VE NEM İLETİM ÖZELLİKLERİNE ETKİLERİ

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ABSTRACT

In this study, comfort and moisture transmission properties of fine shirting fabrics produced by combining widely used fibre types of viscose, PES and cotton with acrylic fiber were investigated. For this purpose, 10 different fabrics were woven with viscose warp and cotton, PES, viscose, acrylic, cotton/acrylic, viscose/acrylic, and PES/acrylic weft yarns and with plain and etamine weaves. Thermal resistance, thermal conductivity, thermal absorbtivity, air permeability and moisture transmission properties of fabrics were measured and the results then evaluated statistically. According to the results obtained, thermal resistance, thermal conductivity, thermal absorbtivity and air permeability properties of fabrics were not affected by material type and addition of acrylic yarns, but weaving type showed a significant effect on these fabric properties. It was also seen that material type and acrylic yarn usage in the fabrics influenced moisture management properties of fabrics and increased OMMC values.

Keywords: Thermal comfort, air permeability, moisture management, acrylic, woven fabric.

ÖZET

Bu çalışmada, ince gömleklik dokuma kumaşlarda kullanılmayan bir elyaf türü olan akrilik iplikler ile yaygın olarak kullanılan pamuk, viskon ve PES ipliklerin birlikte kullanıldığı gömleklik dokuma kumaşların termal konfor ve nem iletim özellikleri incelenmiştir. Bu amaçla piyasada gömleklik olarak kullanılan viskon çözgü iplikleri ile atkıda, pamuk, viskon, PES, akrilik, pamuk/akrilik, viskon/akrilik ve PES/akrilik iplikler kullanılarak bezayağı ve etamin örgüde on farklı gömleklik dokuma kumaş üretilmiştir. Kumaşların termal direnç, termal iletkenlik, termal absorbsiyon ve hava geçirgenliği özellikleri ile nem iletim yetenekleri test edilmiş ve sonuçlar istatistiksel olarak değerlendirilmiştir. Elde edilen sonuçlara göre, kumaşların termal direnç, termal iletkenlik, termal absorbsiyon ve hava geçirgenliği özellikleri üzerinde kullanılan lif tipinin ve atkıda akrilik ilavesinin etkisi görülmezken, örgü tipinin bu özelliklere etkisinin olduğu görülmüştür. Deneysel kumaşlarda kullanılan lif tipinin ve akrilik iplik kullanımının kumaşların nem iletim özelliklerine etki ettiği ve OMMC değerlerini arttırdığı gözlenmiştir.

Anahtar Kelimeler: Termal konfor, hava geçirgenliği, nem yönetimi, akrilik, dokuma kumaş

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1.INTRODUCTION

In our daily life, shirts are one of the most used clothes in men's and women's clothing. Such features of shirts like keeping warm or cool as desired according to the condition, not making you sweat, not being wrinkle, not being fluff, not being wear quickly and easy maintenance are among the features that are required as much as color, pattern and model.

Clothing comfort is the satisfaction of psychological and physical harmony between the human body and the environment. Thermal comfort is related to the heat and moisture permeability properties of clothings. That the clothing provides a high level of thermal comfort is possible with protection of the body's thermal balance, ensuring body temperature and moisture balance. The clothes providing a good level of thermal comfort achieve the most important function in protecting the body's heat and moisture balance by transferring the changing temperature and moisture of the body depending on various environmental conditions and various physical activities [1]. Also, the environment, level of motion, fiber type, fabric and design of the clothing, the physiological and psychological state of the person are also influential in determining the comfort of clothing. For this reason, thermal comfort depends on the heat and moisture transmission properties of the clothings, the feeling on the skin created by clothings and the mechanical interaction between the skin and the clothing [2]. In studies related to thermal comfort, it is found that many parameters such as fiber and yarn properties, fabric structure, and finishing operations applied to the fabric have an effect on the thermal comfort properties.

There are some publications in the literature related to comfort features of fabrics. As the proportion of cotton fiber decreases the fabrics make one feels warmer, and the thermal resistance value increases in cotton-angora and cotton- milk fiber blends [3, 4]. The thermal conductivity value of socks made from 100% acrylic yarns is higher than that of 100% wool socks. Knitted fabrics and socks made from 100% acrylic yarns have higher thermal conductivity and lower thermal resistance value than those produced from 50% wool-50% acrylic yarns. 50% acrylic- 50% wool blend stockings have lower thermal absorbance value than 100% acrylic stockings and gives a warmer feeling at the first contact [5-9]. The thermal resistance and thermal absorbtivity values decrease with decrease a yarn thickness [10]. The thermal conductivity is low at high jute mixing ratios in fabrics knitted from jute-cotton blended yarns and thermal conductivity decreases with increasing fabric thickness [11]. Futter fabrics have low thermal resistance and high air permeability and plain knitted fabrics have higher thermal resistance and lower air permeability [12]. In cotton woven fabrics, fabrics with a plain weave structure exhibit high thermal resistance and the fabrics with crepe and 2/2 panama weave structures exhibit low thermal resistance [13]. In fabrics used as garment, the air permeability decreases as the weft density increases. Also, the type of weft yarn, weft density and weft yarn number, the weave, weight per square meter and fabric thickness affect the fabric air permeability and air and water vapor permeability becomes higher in fine fabrics [14, 15]. Increase in thickness of fabrics increases the thermal resistance value and decreases the water vapor and air permeability values. Thickness in knitted fabrics are therefore associated with thermal resistance [2, 5, 11, 15, 16]. In plain weave woven fabrics produced from 100% cotton and 100% tencel yarns, 100% cotton fabrics have higher thermal conductivity and thermal absorbtivity values and lower air permeability compared to 100% tencel fabrics and also their thermal conductivity and thermal absorbtivity values are higher than canvas fabrics [17]. In woven fabrics for shirting, air and water vapor permeability of twill fabrics are higher than that of plain weave fabrics; air permeability decreases as the weft density increases [18]. The moisture transmission properties in wool-PES blended fabrics are improved as the percentage of wool fiber increases [19]. In 100% cotton knitted fabrics, single jersey knitted fabrics have better moisture management capacity and the highest air permeability than 1x1 and 2x1 rib knitted fabrics [20].

While acrylic yarns are widely used in knitted and upholstery fabrics, they are not used in woven outwear fabrics, especially in fine shirting production. In this study, the effect of acrylic fiber on the thermal resistance, thermal conductivity, thermal absorbtivity, air permeability and moisture transmission properties of woven fabrics are investigated. For this purpose, shirting woven fabrics are produced from viscose warp and combination of acrylic, cotton, viscose and PES weft yarns with two different weaves. Literature studies on this subject show that there is no comprehensive study about the effect of acrylic yarns on the comfort properties of woven fabrics used for shirting. Therefore, it is thought that this study will contribute to the literature in this field.

2. EXPERIMENTAL

Experimental fabrics used in the study were produced in HMK Textile Incorporated Company located in Bursa Gürsu Organized Industrial Zone under industrial conditions. 9, 84 tex (Ne 60/1) viscose yarns were used in the warp and 19, 68 tex (Ne 30/1) acrylic, cotton, viscose and PES weft yarns in the weft. Warp yarn, warp density (36 threads/cm) and weft density (24 threads/cm) remained the same. Fabrics were produced with plain and etamine weaves. The technical specifications of these fabrics are given in Table 1. Terms such as 1 viscose/1 acrylic or 1 cotton/1 acrylic used in Table 1 indicate that 1 acrylic weft is inserted after 1 viscose weft or 1 acrylic weft is inserted after 1 cotton weft during fabric production. Thus, in these fabrics, it was tried to achieve %50 acrylic ratio in the weft.

Thermal conductivity, thermal absorbtivity and thickness values of experimental fabrics were measured by Alambeta device and their air permeability values measured by SDL Atlas (Model M 021A) air permeability measuring device according to TS 391 EN ISO 9237 standard and the moisture transmission features were measured by SDL Atlas M 290 MMT moisture management test device according to AATCC 195 standard. The weights per square meter of the fabrics were obtained according to ISO 3801 standard. The fabric density was determined as the ratio of the weight in grams to the thickness of the fabric.

The results were evaluated statistically using SPSS 16 program by means of a correlation coefficient analysis which is a statistical method used to determine whether any linear relationship exists between two numerical measurements and direction of relation and closeness the relationship to linearity. Since the Shapiro-wilk normality test result showed a normal distribution (more than 0.05 significance value), Pearson's correlation coefficient was preferred. The Pearson correlation coefficient takes a value between -1 and 1. If this value is negative, it means that two parameters change in opposite direction and that the degree of closeness to -1 means that the relationship is strong at that direction. Also, factor analysis of variance (ANOVA) was used to evaluate the influence of material type, acrylic yarn usage and weaving type on thermal comfort and moisture management properties of woven shirting fabrics. The p-values for a three-way completely randomized ANOVA are presented in Table 3.

3.RESULTS AND DISCUSSION

The thermal comfort test results and the technical properties of fabrics are given in Table 1.

Table 1. Technical properties of fabrics and results of thermal comfort test

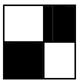
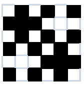
Type of weft yarn	Weaving type	Fabric thickness (mm)	Fabric weight (g/m²)	Fabric density (g/cm³)	Thermal conductivity (W/mK x 10^{-3})	Thermal resistance (m² K/W x 10^{-3})	Thermal absorbtivity ($Ws^{1/2}/m^2 K$)	Air permeability (l/m²/s)
Viscose		0,25	103	0,412	30,47	8,20	172	806
1Viscose/1 Acrylic		0,26	104	0,400	30,80	8,50	177	759
Cotton		0,28	106	0,378	33,60	9,04	158	626
1 Cotton/1 Acrylic		0,26	107	0,412	31,60	8,41	173	797
PES		0,27	107	0,396	31,90	9,10	154	976
1PES/1Acrylic		0,26	110	0,423	30,30	8,80	167	880
Acrylic	Plain	0,27	103	0,381	32,50	8,95	163	626
1Viscose/1 Acrylic		0,36	106	0,294	34,25	10,80	144	1271
1Cotton/1 Acrylic		0,38	103	0,271	33,92	11,10	139	1290
1 PES/1 Acrylic	Etamine	0,41	116	0,283	34,40	12,70	129	1235

Table 2. Correlation coefficients between fabric and comfort parameters

	Correlation coefficient	Sig. (2-tailed)
Fabric thickness - fabric density	-,972**	,000
Thermal absorbtivity - fabric density	,908**	,000
Thermal resistance - thermal conductivity	,821**	,004
Thermal resistance - fabric density	-,926**	,000
Thermal conductivity - fabric density	-884**	,001
Air permeability - fabric density	-824**	,003
Air permeability - fabric thickness	,-397	,377
Thermal resistance - fabric thickness	,984**	,000
Fabric thickness - thermal absorbtivity	-,938**	,000
Fabric thickness - thermal conductivity	,846**	,002

Table 3. Analysis of variance (ANOVA) p-values for thermal comfort properties of the fabrics

Parameters	Thermal resistance	Thermal conductivity	Thermal absorbtivity	Air permeability
Material type	,937	,957	,974	,822
Acrylic yarn usage	,482	,712	,849	,211
Weaving type	**,000***	**,002***	**,003***	**,000***

*statistically significant according to α=0.05 significant level

3.1. Thermal Resistance

Thermal resistance (m²K/W) (under stabilized condition): It is the magnitude of resistance to heat transfer, and it is defined by dividing the temperature difference between two sections of a material to the heat flow rate between the sections. Thermal resistance depends on the thickness and thermal conductivity of the fabrics [6].

The equation of thermal resistance is given below:

$$R=\sigma/ \lambda \quad (m^2\ K/W) \qquad (1)$$

where R is the thermal resistance, σ is the fabric thickness and λ is the thermal conductivity (w/mK).

According to the results obtained, the thermal resistance values of the fabrics woven with plain weave vary between 8,20 and 9,10 m² K/Wx10^{-3} (Figure 1). The highest thermal resistance values among the fabrics were observed in fabrics woven with PES, cotton, acrylic, PES/acrylic weft yarns respectively. These fabrics are followed by fabrics woven with viscose/acrylic, cotton/acrylic and viscose weft yarns. When the relationship between the thickness and the thermal resistance is statistically analyzed from the obtained data, it is seen that there is a strong and positive relationship (Table 2). This relationship shows that thermal resistance is low in fabrics with lower thickness. In addition, if the relationship between fabric density and thermal resistance is examined according to Table 2, it is seen that as the fabric density increases, the thermal resistance decreases. In the case of increase in fabric density, the amount of stagnant air decreases because there will be more fiber/yarn amount per unit volume. The decrease in the amount of stagnant air leads to a decrease in the thermal resistance value of the fabric.

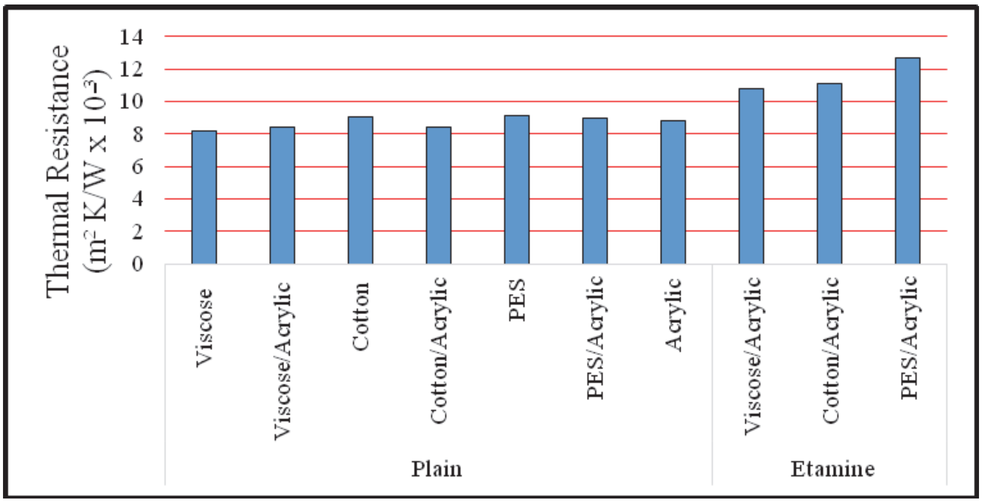


Figure 1. Thermal resistance values of the fabrics

It is also interesting result that the fabric with PES weft has the highest thermal resistance. However, when the thickness of this fabric is considered, it is seen that it is the second thickest among the fabrics woven with plain weave. It was also found that the thermal resistance values of PES knitted fabrics were higher than those of cotton fabrics in Kanat and Özdil's study. The researchers described this in the way that polyester fabrics keep air more in their structures due to the high thickness and porosity of them [21]. In this study, porosity of plain woven fabrics was calculated using three-dimensional (3-D) unit pore cell models developed by Turan [22]. Volumetric porosity of fabrics was calculated by Equation 2 and yarn diameter used in this equation was calculated by equation 3 developed by T.F. Peirce [23].

$$P(\%)=\frac{p_1p_2t-\frac{\pi}{4\left(d_1^2l_1+d_2^2l_2\right)}}{p_1p_2t} \qquad (2)$$

$$d=2\sqrt{\frac{V_y}{\pi N 100}} \text{ (cm)} \qquad (3)$$

Where;

p: Distance betwen two yarn centers,

t: Fabric thickness,

l: Yarn length within the pore cell

V_y : Yarn specific volume,

N : Metric yarn count.

1 and 2 indices: Represent warp and weft yarns respectively.

Yarn specific volume is given as $V_y=1/(0{,}59\rho_f)$ where 0,59 is packing constant of fibres in the yarn and ρ_f is fibre density. Fibre density values are 1,54 gr/cm^3 for cotton, 1,50 gr/cm^3 for viscose, 1,38 gr/cm^3 for PES and 1,18 gr/cm^3 for acrylic. Fabric porosity values are calculated with these data as %61,2 for cotton weft plain weave fabrics, %57,9 for viscose weft fabrics, %56 for PES weft fabrics, %54,4 for acrylic weft fabrics, %56 for viscose /acrylic weft fabrics, %55,8 for cotton/acrylic weft fabrics and %54,8 for PES/acrylic weft fabrics. According to porosity results, the highest porosity is obtained with fabric having %100 cotton weft. Fabrics with viscose, PES and viscose /acrylic weft yarns follow the cotton weft fabric with decreasing porosity. It is seen from the analysis of data that cotton and PES weft fabrics showing the highest thermal resistance have higher volumetric porosity and fabric thickness and lower fabric density values compared to other test fabrics. These conditions cause fabrics to keep more air in the structure and hence to show more thermal resistance.

When the thermal resistance values of the fabrics woven with the etamine weave are examined, it is seen that the thermal resistances of the fabrics with all yarn types increases compared to the fabrics woven with plain weave. The reason is that the thickness of etamine weave fabrics is higher than that of fabrics woven with plain weave and the density of etamine weave fabrics is lower than the density of fabrics woven with plain weave.

ANOVA p-values for thermal comfort properties of the fabrics are presented in Table 3. According to the statistical analysis, weaving type has a significant effect on thermal resistance values of the fabrics, while the effect of material type and acrylic yarn usage on thermal resistance is found to be insignificant.

3.2. Thermal Conductivity

Thermal conductivity (W/mK): Measure of the amount of heat passing through a material at a unit temperature difference of 1 ° K. It occurs when two surfaces of the material are exposed to a unit temperature difference [6].

Thermal conductivity measurement is based on the equation given below:

$$\lambda= Q\,\sigma/\Delta T \text{ (W/mK)} \qquad (4)$$

where λ is the thermal conductivity, Q is the amount of conducted heat (W/m^2), σ is the thickness (m) and ΔT is the heat difference (K).

The thermal conductivity values of the fabrics are shown in Figure 2. According to the measured data, the thermal conductivity values of the fabrics woven with plain weave vary between 30,30 and 33,60 W/mK x 10^{-3}. While the highest thermal conductivity value was obtained in cotton weft fabrics, this was followed by the fabrics woven with acrylic and PES weft yarns respectively. Thermal conductivity value of cotton fibre (71 mW/mK) is lower than thermal conductivity values of PES (140 mW/mK) and acrylic (200 mW/mK) fibres [24, 25] and among the plain weave fabrics, highest porosity has been obtained in the fabric woven with cotton weft yarn. Thermal conductivity of air is lower than those of all the fibers used in this study. It is expected in this case that thermal conductivity of the fabric woven with cotton weft is measured lower compared to other fabrics because high porosity value causes more air to be hold inside the fabric. Highest thickness and lowest density of plain weave cotton weft fabric could be the reason for measuring higher thermal conductivity in opposite to the expectation as the statistical evaluation has indicated an increase in the thermal conductivity with increasing fabric thickness and decreasing fabric density (Table 2).

It is seen that the thermal conductivity values of the woven fabrics produced by adding acrylic weft yarns to cotton, PES and viscose weft yarns decreases in comparison with the thermal conductivity values of fabrics woven with 100% cotton, 100% viscose and 100% PES weft yarns.

The thermal conductivity values of the fabrics woven with the etamine weave vary between 33,92 and 34,40 x10^{-3} W/mK. While the fabric with the highest thermal conductivity value is woven with PES/acrylic weft yarn, this is followed by fabrics woven with viscose/acrylic and cotton/acrylic weft yarns respectively. The thermal conductivity values of the etamine weave fabrics are higher than those of the plain weave fabrics. Even though the thickness of the etamine weave fabrics is higher and the density is lower than those of the plain weave fabrics, the increase in the thermal conductivity shows that weaving type has an effect on thermal conductivity.

When the relationship between thermal resistance and thermal conductivity is examined statistically, it is seen that a positive and strong relationship is exists (Table 2). Most of the previous studies showed that the thermal conductivity value was inversely proportional to the thermal resistance value [12, 17] but, Özdil's study [9], the thermal conductivity increased as thermal resistance increased.

According to the statistical analysis (Table 3), the weaving type showed a significant effect on thermal conductivity values of the fabrics, while the effect of fibre type and acrylic yarn usage is found to be insignificant. When the relationship between thermal conductivity-fabric thickness and thermal conductivity-fabric density is examined statistically, it is seen that there are a positive and negative relationships respectively (Table 2).

3.3. Thermal Absorbtivity

Thermal absorbtivity ($Ws^{1/2}/m^2$ K) (In transition period): Thermal absorbtivity is a sudden heat flow that occurs when two parts of materials with different temperatures come into contact with each other. Thermal absorbtivity (b) can be expressed as:

$$b = (\rho \lambda c)^{1/2} \ (Ws^{½}/m^2 \ K) \quad (5)$$

where ρ is the density (kg/m^3), λ is the thermal conductivity (W/mK), c is the specific heat of the fabric(J/kg K).

Thermal absorbtivity refers to the sensation of warmth and coldness of the garment, that is, feelings in the first contact with the fabric. It is numerical value of the heat transfer rate between the fabric and the skin. If the thermal absorbtivity value is low, the fabric gives a hot feeling and if it is high it gives a cold feeling at the time of first contact. Especially on cold days, this parameter varies in direct proportion to the thermal conductivity, density and specific heat values of the material [6, 26].

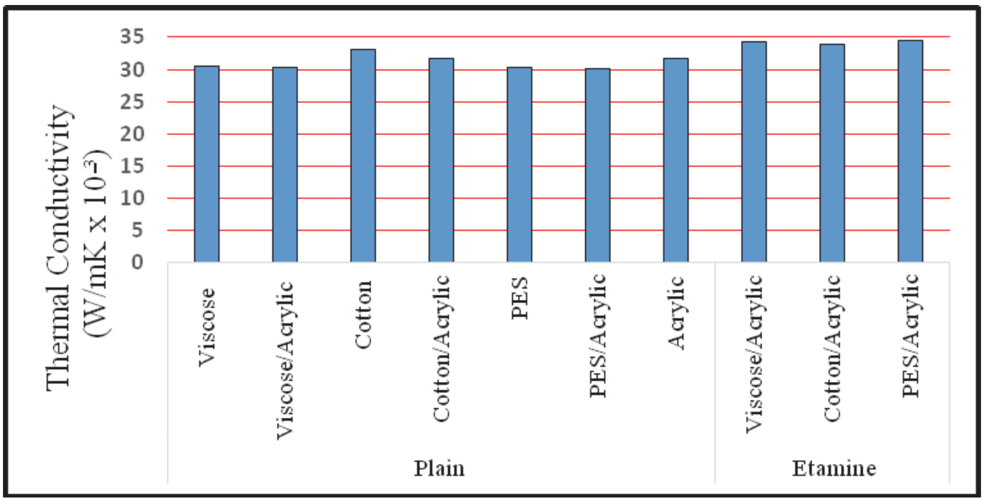


Figure 2. Thermal conductivity values of the fabrics

The thermal absorbtivity values of the fabrics are shown in Figure 3 and range between 154 and 177 Ws $^{1/2}$/m^2 K for plain weave fabrics. Fabrics with the highest thermal absorbtivity values are listed as the fabrics woven with viscose/acrylic, cotton/acrylic, viscose, PES/acrylic weft yarns, respectively. These fabrics are followed by fabrics woven with acrylic, cotton and PES weft yarns. It is seen that the thermal absorbtivity values of the woven fabrics by adding acrylic weft yarns to cotton, PES and viscose weft yarns increased in comparison with the thermal absorbtivity values of fabrics woven with 100% cotton, 100% PES and 100% viscose weft yarns. The thermal absorbtivity of fabrics with etamine weave vary between 129 and 144 Ws $^{1/2}$/m² K. Generally, they are lower than the thermal absorbtivity values of fabrics woven with plain weave. Because, as shown in Table 1, the thicknesses of the fabrics woven with etamine weave are higher than those of the fabrics with the plain weave. When the relationship between thickness and thermal absorbtivity is statistically analyzed (Table 2), it is seen that there is a strong negative relationship between these two parameters. As the thickness decreases, the thermal absorbtivity increases and vice versa. The lowest thermal absorbtivity value was obtained in fabric woven with 100% PES weft and plain weave. This fabric has higher thickness and lower density. It is seen that there is a positive and strong relationship between thermal absorbtivity and fabric density (Table 2). As the fabric density decreases and fabric thickness increases, thermal absorbtivity also decreases.

According to the statistical analysis (Table 3), weaving type has a significant effect on thermal absorbtivity values, while the effect of material type and acrylic yarn usage on thermal absorbtivity is insignificant.

3.4. Air permeability

Air permeability (1/m^2/s): It is the amount of air passing between two surfaces of a material at a certain pressure difference through a unit surface and in a unit time. It describes the ability of air to pass through the fiber, yarn and fabric structure. This parameter, which makes the transfer of heat easier and determines the breathability feature, has an important place among the thermal comfort features [27, 28].

The air permeability values of the experimental fabrics used in this study are shown in Figure 4. The air permeability values of fabrics woven with plain weave vary between 626 and 976 l/m²/s. The ones with the highest air permeability among these fabrics are fabrics woven with PES, PES/acrylic, viscose and cotton/acrylic weft yarns respectively. These fabrics are followed by fabrics woven with viscose/acrylic, cotton and acrylic weft yarns. It is seen that the air permeability values of the woven fabrics by adding acrylic weft yarns to PES and viscose weft yarns decreased in comparison with the air permeability values of woven fabrics with 100% PES and 100% viscose weft yarn. In the case of adding acrylic to the cotton weft yarn, air permeability increases compared to the fabric woven with 100% cotton weft yarn. Reason for the increase in air permeability in cotton/acrylic weft fabrics could be due to its lower thickness than fabric woven with cotton weft yarn. According to correlation analysis of the data in Table 2, air permeability decreased with increasing fabric thickness. Cotton and acrylic weft fabrics have volume porosity values of % 61,2 and % 54,4. Compared to other fabrics, these two fabrics have the lowest air permeability values. Low porosity of acrylic weft fabric is thought to be the reason for its lower air permeability. But, lower air permeability of cotton fabric despite its lower porosity can be explained by its higher thickness value. Cotton weft fabric has the highest thickness among the fabrics used in the experiments. Volumetric porosities of PES and PES/acrylic weft fabrics are calculated as %56 and %54,8. Air permeabiliy of these fabrics are the highest among the experimental fabrics. Their lower thickness values compared to cotton weft fabrics are considered to be the reason for their higher air permeabilities.

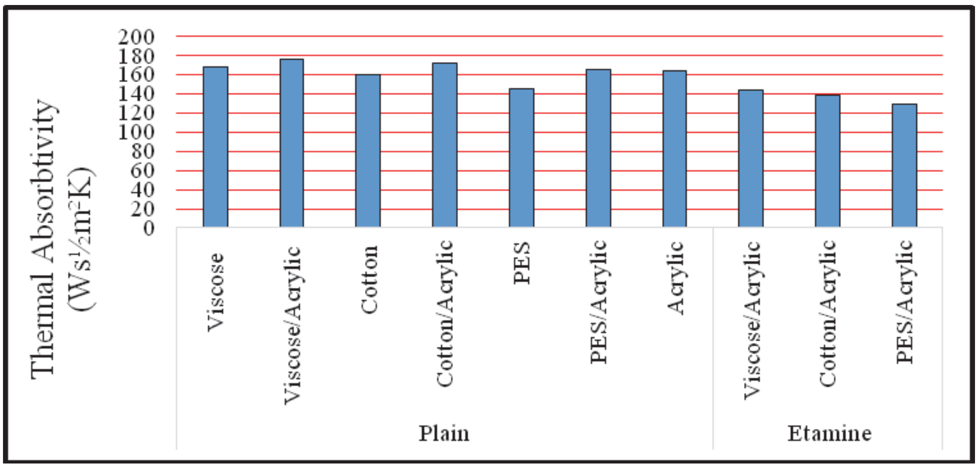


Figure 3. Thermal absorbtivity values of the fabrics

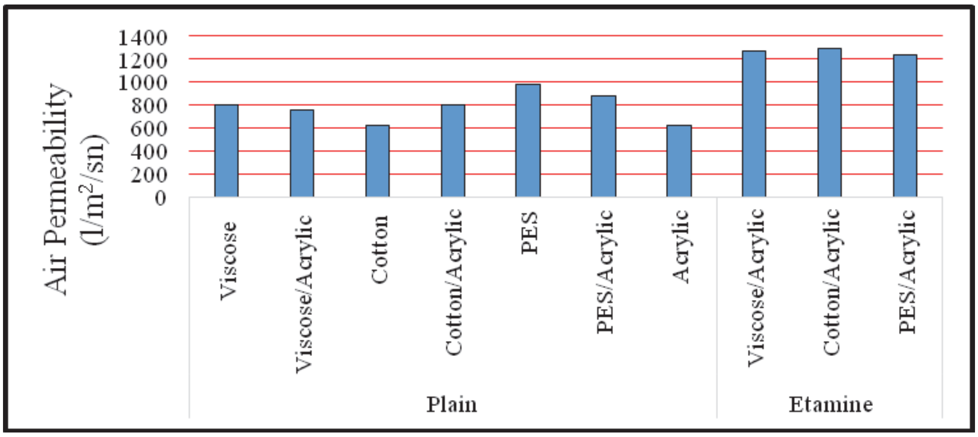


Figure 4. Air permeability values of the fabrics

When the air permeabilities of the fabrics woven with the etamine weave are examined, it is seen that the air permeabilities of the fabrics woven with cotton/acrylic, viscose/acrylic and PES/acrylic weft yarns increases in comparison with the air permeabilities of the fabrics woven with plain weave using the same yarns. The fabric woven with cotton/acrylic weft yarn has the highest air permeability in this weave. This fabric is followed by fabrics woven with viscose/acrylic and PES/acrylic weft yarns. Previous studies shows that fabrics woven with plain weave are more resistant to air passage than fabrics woven by other weaves with the same yarn count and densities [28]. Hence our study, that the air permeability values of the fabrics woven with the etamine weave are higher than the air permeability values of the fabrics woven with the plain weave, supports this result. In addition, although the thickness of the etamine weave fabrics is high, the reason for high air permeability is that the fabric porosity is higher in etamine weave. This result shows that the weaving type affects air permeability.

According to the statistical analysis (Table 3), weaving type has a significant effect on air permeability of the fabrics, while the effect of material type and acrylic yarn usage on air permeability values is not significant.

3.5. Moisture Transmission Feature

In order to determine the effect of acrylic addition on the moisture management performance of experimental fabrics, the mean values of the measurements taken from the plain weave fabrics in the MMT moisture controller are compared with the values on the MMT evaluation scale [29]. MMT results of the fabrics are presented in Table 4.

Table 4. MMT results of the fabrics

Type of weft yarn		Viscose	Viscose-Acrylic	Cotton	Cotton-Acrylic	PES	PES-Acrylic	Acrylic
Top	Wetting Time (sec)	9,3127	2,343	9,656	2,719	8,9997	2,438	6,843
	Absorbency Rate (%/sec)	67,944	46,171	13,7711	39,8719	11,0883	29,966	30,5244
	Max Wetted Radius (mm)	10	15	13,3	15	8,333	15	15
	Wetting Speed (mm/sec)	0,7297	3,8269	1,3831	7,7769	1,9182	3,0167	3,0003
Bottom	Wetting Time (sec)	8,188	4,218	5,75	3,094	5,25	6,281	5,437
	Absorbency Rate (%/sec)	17,2486	49,9171	12,5245	24,1201	21,1436	28,5331	15,279
	Max Wetted Radius (mm)	23,3333	25	10	30	23,3333	20	10
	Wetting Speed (mm/sec)	2,8642	3,6417	2,4964	6,0375	8,0996	6,5421	2,7437
Accumulative one-way transport index(%)		1853,8926	553,6636	1941,2	994,1692	1682,1163	1668,308	2123,8264
OMMC		0,6817	0,831	0,6374	0,7892	0,7664	0,8015	0,66
Moisture management category		Very good	Excellent	Very good	Very good	Very good	Excellent	Very good
0-0.2: very poor, 0.2-0.4: poor, 0.4-0.6: good, 0.6-0.8: very good, >0.8: excellent [29]								

When the test results of cotton, viscose and PES weft fabrics are compared with acrylic/cotton, acrylic/viscose and acrylic/PES weft fabrics, it is found that while the top-wetting period is at 'middle' level, and the wetting periods with adding acrylic weft reaches a "very fast" wetting level. While the bottom-wetting periods are again at the "middle" level, it reaches "very fast" level in the acrylic/viscose and acrylic/cotton weft fabrics and it remains at the "middle" level in the acrylic/PES fabrics.

According to their absorbency values, the viscose weft fabrics have the highest top-absorbency rate with degree of "very good". The result did not change with adding acrylic weft. In cotton woven fabrics, while the top-absorbency ratio has been "slow" it increases to "middle" level by acrylic addition. While the top-absorbency rate is "slow" in the PES weft fabrics, there is no change after the acrylic weft addition. While the values of the bottom-absorbency ratios are at the "slow" level in all fiber groups, they increases to "middle" level in the viscose-acrylic weft fabrics by the addition of acrylic weft, and the level did not change in cotton-acrylic and PES-acrylic weft fabrics.

According to the results of the wetting speed; while the top-wetting speed of viscose weft fabrics is "very slow", the values of the fabrics produced by acrylic weft addition are "fast" level. While the top-wetting speed of cotton and PES weft fabrics are "slow", it reaches at "fast" level in cotton-acrylic weft fabrics and at "slow" level in PES-acrylic weft fabrics. The results at the bottom-wetting speeds are "very fast" in PES and PES-acrylic weft fabrics and while it is at "middle" level in cotton and viscose weft fabrics, it reaches at "very fast" level in cotton-acrylic weft fabrics and at "fast" level in viscose-acrylic weft fabrics.

The cumulative one-way transport index represents the difference in moisture content between the two sides of a fabric. That the fabrics transfer rapidly the liquid from their one face to the other face shows that they transfer it to the surface which is in contact with the environment without holding liquid in their structure and feeling wet. The cumulative one-way transport index is excellent in all of the experimental fabrics.

The Overall moisture management capacity (OMMC) is an index that determines the total transfer capacity of the liquid moisture in a fabric. The high overall moisture management capacity value means that the moisture transfer is high. According to OMMC results, moisture transfer of experimental fabrics increases for all type of fibers when acrylic yarn is added. When compared the values obtained with the standard evaluation scale, it is seen that very good values are obtained with viscose, cotton, cotton-acrylic and PES weft fabrics, and excellent moisture transmission values are recorded for PES-acrylic and viscose-acrylic weft fabrics (Table 4). The cotton weft fabric has the lowest moisture management value. In their study, Özkan and Kaplangiray states that cotton fabrics exhibit lower moisture control features than PES and therefore these fabrics may be called as fast absorbing slow-drying fabrics [19].

According to the Selli, while PES has the ability to quickly perform liquid transfer due to their hydrophobic feature, cellulosic fabrics (cotton and viscose) absorb the liquid quickly but do not transfered and hold its structure instead. Therefore, when compared to other fabrics, PES fabrics have the highest OMMC values, the best moisture management features and the ability to transfer liquid fast. Cotton fabrics have the lowest OMMC values. Cotton fabrics cause a greater sense of wetness than other fabrics [20]. According to the results obtained, it is seen that the acrylic yarn usage increases the OMMC values of the fabrics.

ANOVA p-values for moisture management properties of the fabrics are presented in Table 5. According to the statistical analysis, material type has a significant effect on all moisture management properties of the fabrics. While the effect of acrylic yarn usage on top- absorbency rate, top and bottom maximum wetted radius is insignificant, the effect of acrylic yarn usage on other moisture management properties of the fabrics is found to be significant.

Table 5. Analysis of variance (ANOVA) p-values for moisture management properties of the fabrics

	Top Surface				**Bottom Surface**				**Accumulative one-way transport index(%)**	**OMMC**
Parameter	**Wetting time**	**Absorbency rate**	**Max. wetted radius**	**Wetting speed**	**Wetting time**	**Absorbency rate**	**Max. wetted radius**	**Wetting speed**		
Material type	**,000***	**,000***	**,001***	**,000***	**,000***	**,000***	**,000**	**,000***	**,000***	**,003***
Acrylic yarn usage	**,000***	**,102**	**,772**	**,011***	**,001***	**,003***	**,332**	**,009***	**,019***	**,011***

*****statistically significant according to α=0.05 significant level

4. CONCLUSION

In this study, effect of using acrylic yarns in combination with cotton, viscose and PES as weft yarn on thermal comfort and moisture transmission properties in shirting woven fabrics were investigated. For this aim, fabrics were produced with viscose warp and %100 viscose, %100 cotton, %100 PES, %100 acrylic, %50 PES-%50 acrylic, %50 cotton-%50 acrylic, %50 viscose -%50 acrylic weft. Different weft yarns were inserted one after the other to obtain %50 weft mixing. Thermal resistance, thermal conductivity, thermal absorbtivity, air permeability and moisture transmission tests were applied to the fabrics and results were evaluated statistically. Following results were obtained.

- It was seen that material type did not show any significant effect on thermal resistance, thermal conductivity, thermal absorbtivity and air permeability of fine shirting fabrics, but it affected moisture transmission property. It was shown that top-absorbency rate was obtained with viscose weft, lowest top-wetting speed was obtained with cotton weft fabrics and highest bottom-wetting speed was obtained with PES and PES/acrylic weft fabrics. Highest moisture management capacity was reached with PES weft fabric and the lowest with cotton weft fabric.
- Usage of acrylic yarns did not show any significant effect on thermal resistance, thermal conductivity, thermal absorbtivity and air permeability of fabrics, but it increased bottom-absorbency rate, top and bottom-wetting speed, top and bottom-wetting time, accumulative one-way transport index (%) and moisture management capacity of fabrics. According to the results, addition of acrylic weft yarn transmitted the moisture from one side of the fabric to the other side quickly without keeping it in the structure. Hence it made the user feel wetness less.
- Weaving type showed to be effective on thermal resistance, thermal conductivity and thermal absorbtivity. Fabrics woven with etamine weave had a higher thermal resistance and air permeability and a lower thermal absorbtivity compared to fabric woven with plain weave. Therefore etamine fabrics are expected to give more warm feeling.
- Fabric thickness was also observed to be a parameter affecting thermal comfort properties of fabrics. Thermal resistance and thermal conductivity increased and thermal absorbtivity decreased with increasing thickness of fabrics used in the experiments.
- Correlation analysis showed that fabric density had an effect on thermal comfort and water vapour management properties of the fabrics. Decreasing fabric density increased thermal resistance, thermal conductivity and air permeability of fabrics, but it decreased thermal absorbtivity and moisture management capacity.

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