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EFFECT OF ELASTANE ON MOISTURE MANAGEMENT IN HIGH-PERFORMANCE SPORTSWEAR

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Abstract: *Nowadays, more and more articles for sportswear, but not only, include elastane yarns. Stretch clothing plays an important role in optimizing the performance of the wearer by providing freedom of movement, maximizing comfort, minimizing the risk of injury, and reducing friction. This study aimed to investigate the fabric moisture management properties with dependency on elastane yarn linear density. Experiments were conducted with two series of plated knitted fabrics. The ground yarns were: 30% Outlast®Viscose / 70% Cotton, 14.75 tex, and a Dacron® 702 WSD 1.7/38, 14.30 tex (Coolmax®). The plating yarns were 22 dtex, 44 dtex, and 77 dtex Creora®, plated at every feeder by using the electronic feeder. The Outlast®/Cotton material is superior in water vapour transmission and Colmax® in drying capacity, regardless of the fineness of the elastane yarn. In terms of liquid water management, correctly selecting the appropriate linear density of elastane yarn can optimize the functionality of sportswear.*

Keywords: knitted structure, stretch clothing, water absorption, vapour diffusion, drying capacity.

1. INTRODUCTION

Comfort in movement is a key feature of modern sportswear fabrics, and the use of elastic yarns to improve the elasticity of the fabric and increase comfort in movement is a very common method. Stretch clothing plays an important role in optimizing the wearer's performance by providing freedom of movement, maximizing comfort, minimizing the risk of injury or muscle fatigue, and reducing friction [1]. According to the literature, to improve fabric elasticity and shape retention, 2% of elastane is enough but for high-performance garments, such as swimwear and active sportswear, the elastane content can increase up to 30% [2]. Depending on the requirement of the level of the stretch of the clothing, it can be classified into two categories. The requirement of an elasticity level below 30% is called elastic comfort and the stretch level requirement above 30% is called power stretch and is relevant for certain types of sportswear such as swimwear and compression clothing [3].

Moisture transport in fabrics determines their functionality during activities that involve a high metabolic activity and that cause the human body to sweat. In this case, sweat must be eliminated in the form of water vapour that evaporates from the surface of the skin and through diffusion is transported by the clothes to the outside environment and/or in the form of liquid moisture through wicking. When liquid sweat is present, the moisture absorption by a fabric is characterized by in-plane and transplanar wicking [8]. Several relevant parameters, such as the geometrical properties of the pores formed by the fibers (intra-yarn) and yarns (inter-yarn), the surface properties of the fibers, and the fiber moisture absorption capacity have an influence on moisture transport in porous fabrics [4].

The present study investigates the effect of elastane yarn linear density on the moisture management properties of the knitted fabrics used in active sportswear.

2. MATERIALS AND METHODS

2.1 Materials

Two series of 3 knitted fabrics were produced using the 8-feed Single-Jersey Circular Knitting Machine MERZ – MBS. The ground yarns were: 30% Outlast®Viscose/70% Cotton, 14.75 tex, and a Dacron® 702 WSD 1.7/38, 14.30 tex (Coolmax®). The plating yarns were 22 dtex, 44 dtex, and 77 dtex Creora®, plated at every feeder by using an electronic feeder BTSR KTF 100 HP. The plating yarn input tension was 4 cN and for the main yarn 2 cN. The yarns selected for this study allow a comparison between two completely different types of materials (in terms of their affinity to water), the Outlast®/Cotton material being hydrophilic, while the Coolmax® material is hydrophobic. These materials were selected because they are used to produce high-performance sportswear, and due to the different approaches to achieving the thermo-regulating effect. Outlast®Viscose/Cotton yarn incorporates thermally active material, i.e., paraffinic phase change material (PCM) microcapsules within the viscose fiber structure (Fig. 1), according to the Outlast Technology, and the thermo-regulating effect results either from heat absorption or heat emission of the PCM [5], [6]. The thermoregulation effect of Coolmax® relies on moisture management due to the shape of the fibers, namely the multi-channel cross-section (Fig. 2), which applies the capillary theory and absorb sweat and moisture from the surface of the skin, transport it to the fabric surface and then evaporate [7], [8].

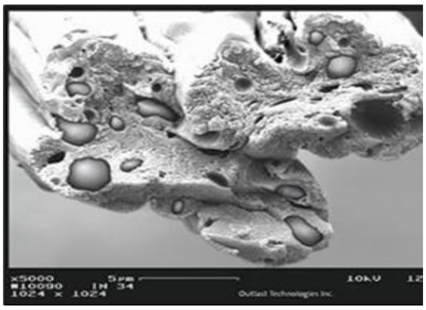

Fig. 1*: Outlast® Thermocules in viscose fiber [6]*

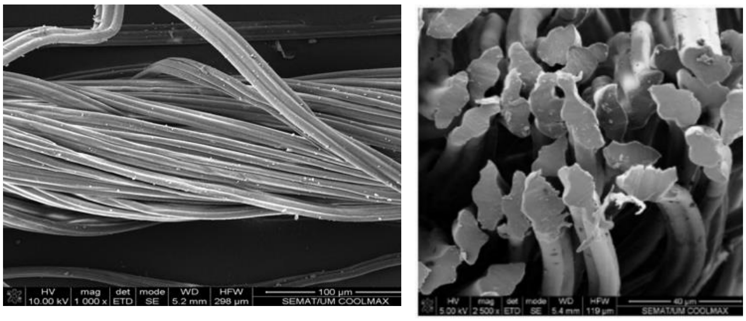

Fig. 2*: SEM image of Coolmax® yarn [9]*

2.2 Methods

Water vapour permeability

The ability of clothing ensembles to transport water vapour is an important factor of physiological comfort. When vapour passes through a textile layer, two processes are involved: diffusion and sorption-desorption. Water vapour diffuses through a textile structure in two ways, simple diffusion through the air spaces between fibers and yarns, and along the fiber itself. The factors associated with knitted fabric's thickness and construction determine moisture vapour transport properties, especially in low-density open textile structures. Das et al. [10]. concluded that, at a specific concentration gradient, the vapour diffusion rate along the textile material depends on the porosity of the material and also on the water vapour diffusivity of the fiber. Diffusivity of the material increases with the increase in moisture regain. In the same way, moisture transport through the sorption-desorption process will increase with the hygroscopicity of the material. Fiber-related factors, such as cross-sectional shape, do not play a significant role in water vapour transfer [11].

The water vapour permeability was determined on SDL Shirley Water Vapour Permeability Tester M – 261, according to the standard BS 7209-1990. The cup method is a very common method for testing the moisture transfer ability of fabrics. It is used to measure the rate of water vapour transmission perpendicularly through a known area of the fabric to a controlled atmosphere. In this method, a sample covers a cup containing distilled water and is placed in a controlled environment of 20 ºC and 65% relative humidity. By adjusting the initial weight of water in the cup to 46 cm3, a constant air gap was set between the water surface and the sample. The tests lasted for 16 hours and the weight of each cup was recorded initially and after 16 hours. The water vapour transmission rate (WVTR) in grams per hour per square meter was calculated by the following equation:

$$\mathrm{WVTR} = \frac{\mathrm{G}}{\mathrm{t \cdot A}} \quad (\mathrm{g/m^2/h}) \qquad \textbf{(1)}$$

where, G is the weight change of the cup with the fabric sample, in grams, t is the time during which G occurred, in hours, and A is the testing area in square meters.

The index of the water vapour transmission rate was calculated by the following equation:

$$\mathrm{I} = \frac{\mathrm{WVRT}}{\mathrm{WVRT_r}} \cdot 100\ (\%) \qquad \textbf{(2)}$$

where $WVTR_r$ is the water vapour transmission rate of the reference fabric.

For liquid transport within fabrics, textile researchers distinguish two phenomena – wettability and wickability [12]. The term ‘wetting’ is usually used to describe the displacement of a solid–air interface with solid-liquid interface. Wicking is the spontaneous flow of a liquid in a porous substrate, driven by capillary forces. As capillary forces are caused by wetting, wicking is a result of spontaneous wetting in a capillary system. Wetting and wicking processes occurring during the wearing of clothes have a practical significance in clothing comfort [13], [14]. Many test methods have been developed to measure liquid water absorbency and water transport in fabrics. These methods measure different aspects of the moisture management characteristics of fabrics [12], [15].

Diffusion capacity

Diffusion capacity expresses the rate of water diffusing on the fabric surface and represents the fabric’s instantaneous water (perspiration) absorbency and transferring ability. To measure the diffusion ability, the sample fabrics were placed flat on a hydrophobic board with the outer surface facing down. The area (mm^2) was measured with water allowed to diffuse at 15, 30, and 60 seconds after dripping 0.2 ml of water using a precise dropper whose tip was 10 mm above the fabric surface. The measurement was repeated at five different points and the average of the diffusion area (mm^2) was taken to indicate the diffusion capacity of the fabrics.

Wicking - Transverse “plate” test or in-plane wicking test

In-plane wicking is a test method used to evaluate the ability of a textile structure to transport liquid moisture horizontally within the plane of the fabric. This test is used to determine the performance of a textile in applications where it is important for moisture to be distributed uniformly across the fabric surface, such as in sportswear, medical textiles, and outdoor clothing.

The apparatus used to determine the in-plane wicking consists of a horizontal glass plate fed from below with water through a capillary tube from a reservoir placed on an electronic balance. The sample is placed on the glass plate and is held in contact with it (and with water) applying another glass plate on top of it. The changing weight of the reservoir is measured by an electronic balance to determine the rate of liquid uptake by the textile material in the sample. Similarly, apparatus has been used by Buras, Hussain & Tremblay-Lutter, and McConnell [16].

Drying capacity

The drying capacity of textiles refers to the ability of a textile material to dry quickly after being wet, either through exposure to moisture or washing. It is an important property for textiles used in various applications, such as sportswear, outdoor clothing, and medical textiles, as it can affect the comfort and performance of the wearer. Textiles with high drying capacity can quickly wick away moisture and evaporate it, keeping the wearer dry and comfortable.

To determine the drying capacity, the fabrics cut into circular samples of 100 cm^2 were left on a flat surface under standard atmospheric conditions (temperature 20 ± 2°C, 65 ± 2% RH) and their weight (W_f) was determined. To determine the drying rate, 1 ml of water was dripped onto each sample using a precision dropper whose tip was 10 mm above the surface of the fabric, and the wet weight (W_0) at the initial stage was recorded. The weight change (W_i) was measured periodically at 10-minute intervals. The remaining water ratio (RWR) was calculated at each interval using the following equation:

$$\mathrm{RMR} = \frac{W_i - W_f}{W_0 - W_f} \cdot 100 \ (\%) \qquad \textbf{(3)}$$

The RWR was used to express the drying ability of the fabrics as wetted.

3. RESULTS AND DISCUSSION

Dry relaxation was performed for 48 hours by placing the samples on a flat surface in standard atmospheric conditions (20 ± 2°C and 65 ± 5% RH), before testing the properties.

Since the transfer of moisture through textile materials is strongly influenced by the inner structure of the material, the influence of the elastane yarn density on the dimensional properties of the knitted structures was also analyzed. The results can be summarized as follows [17]:

The higher the linear density the higher the tension of the elastomeric yarn, which makes stitches closer to each other and, consequently, stitch density increases. With an increased linear density of the elastane thread, the compactness of the fabric expressed by the tightness factor and density increases. The loop length of ground yarn decreases when the elastane yarn density increases - the tension applied by thicker elastane yarn is higher and consequently, the loop length is lower. The fabric weight per unit area increases with the increase of elastane linear density. The thickness of both types of fabrics slightly increases with the elastane yarn linear density.

Water vapour permeability

For both types of raw materials, the structures are relatively tight and the compactness is similar for a certain value of the linear density of the elastane yarn. Differences in water vapour transmission are due to the diffusion of water vapour through the fibers. Outlast®/Cotton fabrics have higher water vapour permeability (Fig. 3). This result is attributed to the fact that Outlast®/Cotton fabrics have higher moisture regain than Coolmax® fabrics, causing higher diffusivity. Hygroscopic Outlast®/Cotton fabric facilitates better water vapour transfer from the humid air close to the sweating skin and releases it in dry air.

When comparing fabrics made of the same yarn, the WVTR is primarily a function of fabric thickness and porosity. Fabric thickness is an important factor because it determines the distance through which moisture vapour traverses from one side of the fabric to the other, and the transportation of water vapour through a thin fabric will be easier. Also, fabric density plays a significant role in influencing behaviour. The diffusion of vapour molecules through air space in a fabric is a major contributor to total water vapour transport. The higher water vapour transmission rate for fabrics with lower elastane yarn linear density might be attributed to the comparatively higher porosity of these fabrics.

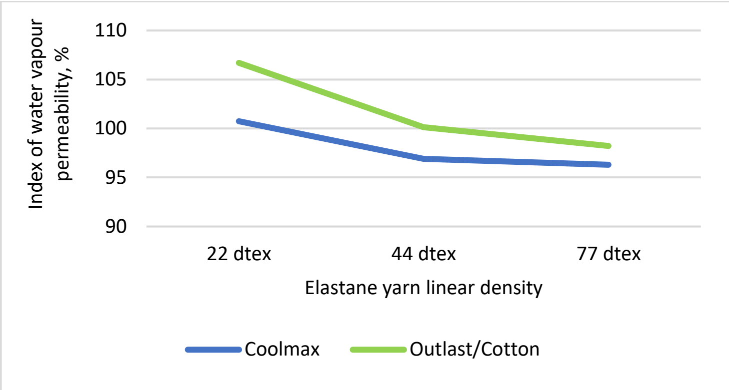

Fig. 3*: Influence of elastane linear density on fabric water vapour transmission rate*

Diffusion capacity

In the Coolmax® fabrics, the hydrophobic character and special morphology of the fibers are the main factors promoting water diffusion by capillary action. Capillary action is the process by which liquid is drawn into narrow spaces, such as the gaps between fibers, due to the combined forces of adhesion and surface tension. The larger surface area of the fibers and more channels on the surface (Figure 2) facilitate the diffusion of water through capillarity. The water diffusion capacity for 15, 30, and 60 seconds is plotted in Fig. 4. When 44 dtex elastane yarn is used the best diffusion capacity was obtained. For more open structures (22 dtex elastane yarn) the diffusion area reduces, probably due to the increase in inter-yarn open space that reduces the capillary action. For structures with a higher tightness factor (77 dtex elastane yarn), the diffusion area is also reduced, and the higher bulk density reduces the rate of capillary migration. So, in this case, the best conditions for water diffusion are achieved neither by the most compact nor by the most open structures, but rather by structures that fall between the two extremes. There is an optimal balance between the level of openness and the level of compactness in textile structures that allows the best water diffusion capacity. This concept is important for the development of textiles that are designed to manage moisture, such as sportswear.

For Outlast®/Cotton fabrics, in addition to the transfer of water through capillarity, there is also the absorption of water in the fibers which have a strong hydrophilic character. Due to this phenomenon of water absorption into the fibers, the spreading of water (diffusion area) is slower for samples with greater thickness and weight. Thus, structures with lower density and lower thickness (22 dtex elastane yarn) have the highest water diffusion capacity (Fig. 5).

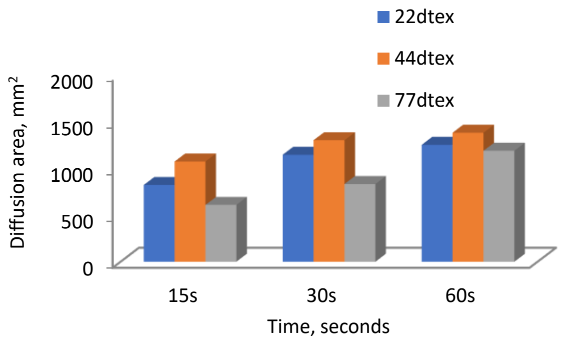

Fig. 4*: Influence of elastane linear density on diffusion capacity of Coolmax® fabrics*

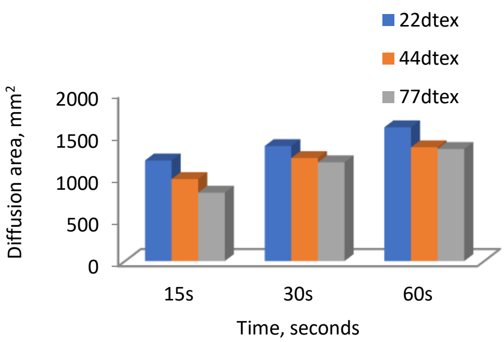

Fig. 5*: Influence of elastane linear density on diffusion capacity of Outlast®/Cotton fabrics*

Wicking - in-plane wicking test

The amount of water (ml) absorbed by the fabrics with time in the case of the in-plane wicking test is shown in Fig. 6 and Fig. 7. Using those data, the polynomial curves have been fitted for all the fabrics (with r^2 values higher than 0.99). In-plane wicking rate (rate of water uptake) has been calculated from the fitted curves. The water absorption rate gradually became constant after about 3 minutes.

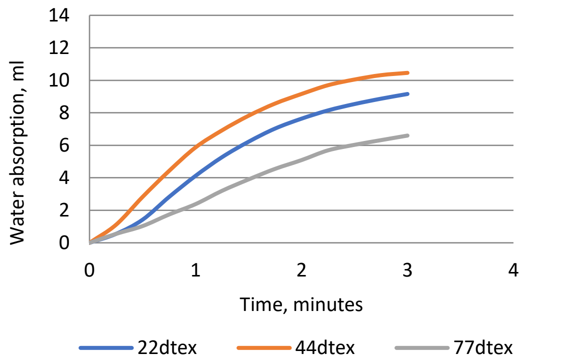

Fig. 6*: In-plane wicking test of Coolmax® fabrics*

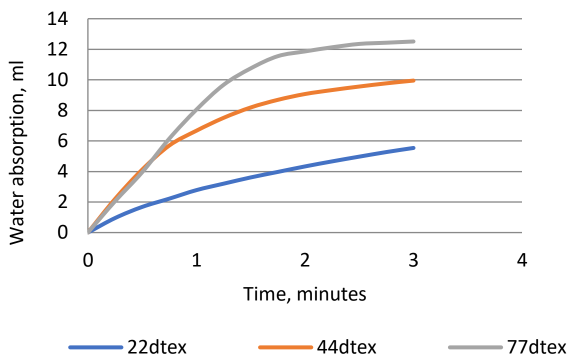

Fig. 7*: In-plane wicking test of Outlast®/Cotton fabrics*

Outlast®/Cotton knit fabrics have a better capacity and water absorption rate compared to Coolmax® knit fabrics. These results can be explained by the hydrophilic character of viscose and cotton fibers.

For Coolmax® fabrics, as with water diffusion capacity, the knitted fabric with 44 dtex elastane yarn has the best water absorption capacity and the highest rate of water absorption, followed by those with 22 dtex yarn. The structure with the highest bulk density (with 77 dtex elastane yarn) presents the lowest water absorption capacity. All the curves show an inflection point, corresponding to a 10 % - 15 % water ratio in the fabrics above 100 % RH equilibrium moisture regain. The wicking starts right at the beginning of the measurement, and until this concentration of water (10 % - 15 %), must be due to intra-yarn water transport (as opposed to inter-yarn) because capillary forces are larger inside the yarns. Due to the relatively low water concentration at the beginning, it will first fill the smaller intra-yarn voids. For a higher water concentration, the inter-yarn wicking starts, and the rate of the wicking process increases. This result is consistent with that obtained by Birrfelder P. et al [8].

For Outlast®/Cotton fabrics, the structure with the highest thickness and mass per unit area (with 77 dtex) has the highest water absorption capacity and rate of water uptake, due to the hydrophilic character of the cellulose fibers. The greater the weight and thickness, the more water will be absorbed. In this case, the ranking of the samples is exactly the opposite compared to that of water diffusion capacity.

Drying capacity

The Coolmax® fabrics dried completely faster than Outlast®/Cotton fabrics. The drying time for Coolmax® fabric structures was between 130-160 minutes and for all Outlast®/Cotton fabric structures was about 240-250 minutes (Fig. 8 and Fig. 9).

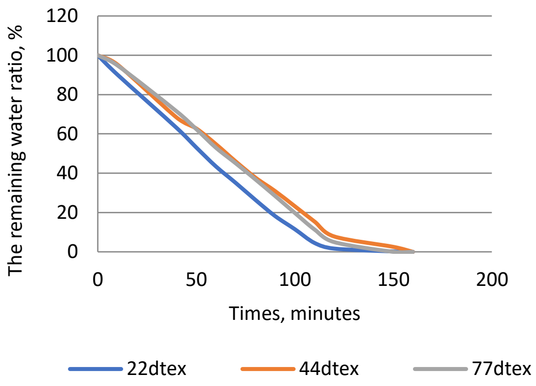

Fig. 8*: Drying rate of Coolmax® fabrics*

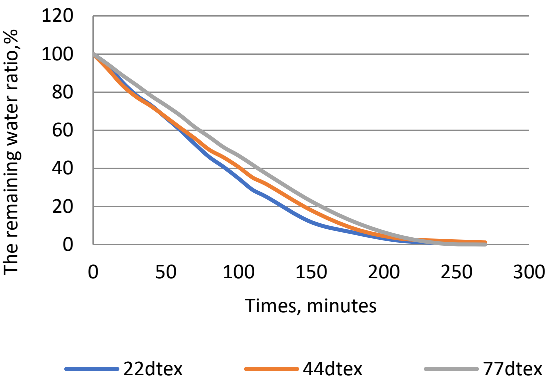

Fig. 9*: Drying rate of Outlast®/Cotton fabrics*

The results showed that the drying rates of the fabrics from Coolmax® were higher, which can be attributed to their lower moisture regain values. Also, probably, due to the Coolmax® fiber multi-channel cross-section (Fig. 2), the rate of capillary migration is higher, and that enhances the water transmission to the fabric surface and release.

When fabrics of the same material are considered, thickness and density appear to be the factors that most influence the drying rate. For both Coolmax® and Outlast®/Cotton, fabrics with the thinnest elastane yarn, 22 dtex, (respectively lower thickness and lower density) have the higher drying rate. The drying rate has significantly slowed down after 100 - 110 minutes for Coolmax® fabrics and after about 150 minutes for Outlast®/Cotton fabrics. Thus, the curves show an inflection point, corresponding to about 10 % remaining water ratio in the fabrics above 100% RH equilibrium moisture regain for all fabrics. The first part of the curve, having a higher slope, corresponds to the moisture released from the void spaces between yarns, and the second part of the curve with a lower slope corresponds to the release of moisture retained in interfiber capillaries in the case of Coolmax® fibers and in interfiber capillaries and within fibers in case of Outlast®/Cotton fabrics.

4. CONCLUSIONS

The Outlast®/Cotton material is superior in water vapour transmission and Colmax® in its drying capacity, regardless of the fineness of the elastane yarn. Regarding the wicking properties (water absorption ability and area of diffusion of water) it can be concluded that by selecting the appropriate linear density of the elastane yarn the fabric can be optimized for its ability to absorb and distribute moisture, which is important for comfort and performance during physical activity.

Overall, the results of this study are an important tool in the design of sportswear products adapted to the requirements of effective sweat management, emphasizing the importance of material selection and design for achieving optimal performance.

REFERENCES

[1] M. Vidhya, K. Parveen Banu, D. Vasanth Kumar, C. Prakash and V. Subramaniam, *"Study on single jersey knitted fabrics made from cotton/polyester core spun yarns. part II: moisture management properties"*, Tekstil ve Konfeksiyon, 32(1), pp. 37-46, 2022

[2] J. Voyce, P. Dafniotis and S. Towlson, "*Elastic textile" in* Textiles in sport, R. Shishoo Ed. Woodhead Publishing Limited and CRC Press LLC©, Cambridge England, 2005, pp. 204-230.

[3] A. Mukhopadhyay and V. P. Shaw, *"Reliability analysis of stretchable workwear fabric under abrasive damage: influence of stretch yarn composition"*, Journal of Natural Fibers, 20(1), 2022, Advance online publication, https://doi.org/10.1080/15440478.2022.2134262.

[4] P. Birrfelder, M. Dorrestijn, C. Roth R. M. and Rossi RM, *"Effect of fiber count and knit structure on intra-and inter-yarn transport of liquid water"*, Textile Research Journal, 83(14), pp.1477-1488, 2013.

[5] G. Erkan, *"Enhancing the thermal properties of textiles with phase change materials"*, Research Journal of Textile and Apparel, 8(2), pp. 57-64, 2004.

[6] Outlast®, https://www.outlast.com/.

[7] COOLMAX®, https://www.lycra.com/en/coolmax-business.

[8] D. Li and M. Ni, *"Moisture properties of Coolmax fiber blended with regenerated cellulose fibers"*, in Second International Conference on Information and Computing Science, Vol. 2, pp. 129-131, IEEE, 2009.

[9] E. Onofrei, A. M. Rocha and A. Catarino, *"Thermal comfort properties of knitted fabrics made of elastane and bioactive yarns"*, Journal of Materials Science and Engineering. A, 1(3A), p. 428, 2011.

[10] B. Das, A. Das, V. Kothari, R. Fanguiero, M. D. Araujo, *"Moisture flow through blended fabrics-Effect of hydrophilicity"*, Journal of Engineered Fibers and Fabrics, 4(4), pp. 20-28, 2009.

[11] C. Prahsarn, R. L. Barker and B.S. Gupta, *"Moisture vapor transport behavior of polyester knit fabrics"*, Textile Research Journal, 75(4), pp. 346-351, 2005.

[12] K. Ghali, B. Jones and J. Tracy, *"Experimental techniques for measuring parameters describing wetting and wicking in fabrics"*, Textile Research Journal, 64(2), pp.106-111, 1994.

[13] M. G. Çil, U. B. Nergis and C. Candan, *"An experimental study of some comfort-related properties of cotton-acrylic knitted fabrics",* Textile Research Journal, 79(10), pp. 917-923, 2009.

[14] N. Pan and W. Zhong, *"Fluid transport phenomena in fibrous materials"*, Textile Progress, 38(2), pp.1-93, 2006.

[15] Cotton Incorporated. *"100% Cotton moisture management"*, J. Textile Apparel, Technol. Manage., 2(3), 2002.

[16] M. Sarkar, J. Fan and X. Qian, *"Transplanar water transport tester for fabrics"*, Measurement Science and Technology, 18(5), p.1465, 2007.

[17] E. Codau and T. C. Codau, *"Effect of elastane on dimensional and thermal properties of sportswear fabrics"*, Annals of the University of Oradea, Fascicle of Textiles, vol. 24, pp. 27-24, 2023.