(REFEREED RESEARCH)

WICKING AND DRYING BEHAVIORS OF KNITTED FABRICS PRODUCED WITH DIFFERENT POLIAMIDE YARNS

FARKLI NAYLON İPLİKLERİNDEN MAMUL ÖRME KUMAŞLARIN ISLANMA VE KURUMA DAVRANIŞLARI

Sena CIMILLI DURU, Cevza CANDAN

Istanbul Technical University, Textile Technology and Design Faculty

Received: 06.10.2015 Accepted: 28.07.2016

ABSTRACT

The behavior of a textile during its contact with liquid and removal of this liquid from the body surface are the important parameters to determine the wearer comfort. In this study, drying and wicking properties of knitted fabrics made from meryl skinlife and tactel fibers were investigated. Conventional nylon fiber was also added to the study to compare the comfort properties of these special fibers. The samples were piece dyed under commercial conditions and then half of them washed five times and finally flat dried. Liquid transporting and drying properties of dyed samples were compared with dyed&washed ones. ANOVA evaluation and independent t-test were used to evaluate the results.

Keywords: Wcking, drying rate, meryl skinlife, tactel, nylon

ÖZET

Giysi konforu açısından, tekstil malzemesinin sıvı ile teması ve bu sıvıyı nasıl uzaklaştırdığı çok önemlidir. Bu çalışmada, meryl skinlife ve tactel liflerinden mamül örme kumaşların, kuruma ve ıslanma özellikleri araştırılmıştır. Bu liflerin konfor özelliklerini kıyaslamak adına standard naylon lifi de çalışmaya eklenmiştir. Üç farklı liften, üç farklı sıklıkta üretilmiş numuneler, aynı şartlarda boyanmış ve daha sonra her bir numune grubunun yarısı beş tekrarlı yıkamaya maruz bırakılmıştır. Böylelikle yıkamanın bahsi geçen özelliklere olan etkisi de çalışmada irdelenmiş ve ANOVA ve t-testi yardımıyla sonuçlar değerlendirilmiştir.

Anahtar Kelimeler: Kılcal ıslanma, kuruma, meryl skinlife, tactel, naylon

---

Corresponding Author: Sena Cimilli Duru, cimilli@itu.edu.tr

1. INTRODUCTION

Humans consider the evaporation of sweat to remain comfortable and prevent overheating in hot environments and during exercise. Discomfort results from the built-up of sweat on the skin and if it doesn't evaporate quickly, the body core temperature heats up producing more sweat exposing the wearer to potential afflictions such as post-exercise chill and even hypothermia [1]. This is more important especially for the sportswear garments. In a normal situation, human beings restore a correct balance of heat exchange, modifying the environment. However, outdoor activities are more demanding in terms of thermal balance, and the ability of recovering the thermal balance is more difficult to achieve [2]. For that reason, on physical comfort of active sport garments, liquid transporting and drying rate are the two vital factors to keep the skin dry and also with properly engineered dynamic or responsive fabrics less energy to cool the body is required resulting in increased performance and endurance [3].

For a fibrous material to effectively transport a liquid, the fibers must be easily and thoroughly wetted by the liquid. Water transport and absorbency in a fibrous material depend on the fiber-water interaction and the geometric configuration of the fibrous material. According to Tang et al [4] when textiles interact with a liquid the following procedures occur:

(1) wetting of the fiber surface by filling pores and rough pits at the surface,

(2) transport of the liquid into assemblies of fibers through capillaries, pores and cavities in the material,

(3) adsorption and migration along the fiber surface (radial spread), and

(4) diffusion of the liquid into the interior of the material.

Researchers generally agree that liquid transport properties are significantly affected by the size, shape, alignment and distribution of fibers, fiber combinations, yarn structure, fabric construction parameters, fabric position in a multilayer system, desizing, scouring, bleaching, alkaline hydrolysis, enzymatic treatments, plasma, UV and ozone treatments, the property of liquids, surfactants, type of finish, the use of electrolytes in disperse dyeing and the laundering of cotton [5-7]. The fiber length, width, shape and alignment all have a great influence on the quality of the capillary channels in the inter-fiber spaces and size of the pores present. The density and structure of yarns can greatly influence the dimensions and structure of inter- fiber and intra-yarn pores and, pore sizes and distribution are determined by the manner in which fibers are assembled into the woven, nonwoven, or knitted structure [1, 6, 8-10]. Larger liquid mass can be retained in larger pores, but the distance of liquid advancement is limited. Therefore, fast liquid spreading in fibrous materials is facilitated with small, uniformly distributed and interconnected pores, whereas high liquid retention can be achieved by having a large number of such pores or a high total volume so in fibrous structures, the sizes and shapes of the fibers as well as their alignment influence the geometric configurations and the topology of the interfiber spaces or pores, which are channels that have wide shape and size distributions and may not be connected [11]. Finishing treatment of the fabric surface and its surface roughness and the bulk properties of the liquid (i.e. viscosity, surface tension, volatility and stability) also play a significant role during wicking. Additional important variables which exert influence on wicking are the level of physical activity and environmental conditions such as the relative humidity of the atmosphere which combined with the ambient temperature, determine the water vapor pressure of the ambient atmosphere and hence the rate of water vapor transfer through clothing. [1].

Together with wetting and wicking mechanisms, drying behavior of the garments are also important to provide user comfort. Not only is the drying time of garments during wear important, but also the drying time after wear. According to Lyons and Vollers [12] drying process of textile materials has three distinct stages. In the first stage, a wet fabric adjusts its temperature and moisture flows with its surrounding environment. The second stage is a ‘constant drying rate’ period, in which the drying rate remains constant as the rates of heat transfer and vaporization reach equilibrium. Liquid moisture moves within the fabric to maintain a saturation condition at the surface. The third stage is a ‘declined drying rate’, during which moisture flow to the surface is insufficient to maintain saturation and plane of evaporation moves into the fabric. Fourt et al [13] implied that the fabrics dried at the same rate, but the time of drying was dependent on the amount water held originally, so that some fabrics dries sooner than the others. They also stated that the rate governing factor was the thickness of the films of relatively still air near the fabric surface. Also Laining et al [14] added that drying time correlated positively both with fabric thickness and the mass of water retained in the fabric following the wetting treatment.

The people are paying more attention to sports activities and the market for sportswear continues to expand with a dramatic growth. Developing sportswear solutions in this field are invaluable in order to produce an adequate response to these increasingly demanding expectations [2]. Nylon fiber which was the first synthetic fiber to go into full-scale production, is mostly preferred for this kinds of garments. Nylon fiber is a kind of polyamide, and the recurring amide groups contain the elements carbon, oxygen, nitrogen and hydrogen. Nylon fibers differ in their chemical arrangement, accounting for slight differences in some properties. Also, the molecular chains of nylon are long, straight chains of variable length with no side chains or cross linkages. Cold-drawing aligns the chains so that they are oriented with the lengthwise direction and are highly crystalline [15]. The human skin normally has a bacteria presence, but a high level of bacteria, as well as a complete absence, creates various problems (allergy, odor, illness, etc.) [16]. When exercising, healthy skin microbes are transferred to the textile and, with normal nylon fibers, these bacteria can proliferate and grow very quickly, leading to bad smelling garments [17]. However, thanks to the presence of the exclusive bacteriostatic agent in the polymeric matrix of meryl skinlife fiber (which is inherent in the fiber, not deposited on the fabric's surface), there is no migration from fabric to skin (avoiding induction of allergy) and also this a kind of poliamide 6.6 fiber does not decrease the bacteria level lower than what is normally present on the skin. Due to the bacteriostatic agent present in the polymeric matrix, meryl skinlife is a permanent feature in the garments (it is present after more than 30 washes, or, to end of garment's life) [16, 17]. Also, tactel is a special type of nylon manufactured by the DuPont company and although originally used in manufacturing ski apparel, designers quickly discovered the fabric offered benefits for other types of garments as well [18, 19]. This fiber is produced from chemicals which are obtained from oil and it is easy to dye and finish. As this fiber contains only a low level of oils, yarns can be scoured at a low temperature (50 ^{0}C) and using mild, readily biodegradable detergent. Dying process is shorter consuming less energy and cheaper [20]. According to rigid testing, tactel fiber is at least twice as soft and 20 percent lighter than most other fibers. It also dries eight times faster than cotton. In addition to being soft and lightweight, it is very strong which makes this fiber to preferable by the consumers. [21, 22].

From this point of view, this study was conducted to investigate the transverse wicking and drying properties of garments made from merly skinlife and tactel fibers. Also, to compare the performances of these functional fibers, conventional nylon fiber was included to the study. During use, out-door and performance textiles fabrics are exposed to soiling which comes from two different sources, namely, from the body of the wearer and from the environment. Therefore, it is necessary at some stage to wash the fabrics [1]. Thus, it was also of our interest to study the effect of washing process on the wicking and drying behavior of fabric samples.

2. Material and Method

The plain jersey fabrics for the study were produced on an 8 system, 14 gauge Santoni SM8-TOP 2 seamless machine of 1248 needles (see Figure 1). All the samples were knitted according to plaiting technique. In doing so, 78/68/1 denier yarns from tactel, merly skinlife and nylon fibers were employed as face yarn whereas 33 denier 34 filament nylon, which was intermingled with 17 dtex spandex yarn, was utilized as the plaiting yarn.

The fabrics were also produced at three knitting settings (i.e. slack, medium, tight). All of them were dyed and finished under the commercial conditions, and then they were conditioned at the standard atmospheric conditions (21 0C, 65 % relative humidity) for one week. Half of the samples were washed 5 times at 40 °C for 30 minutes and then they were flat dried. The details regarding the properties of the samples are given in Table 1.

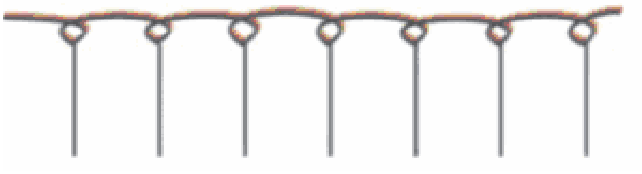

Figure 1. Knitting notation of fabrics

The samples were coded such that the first letter shows the fiber type, the second letter(s) refers to the process (dyed, dyed&washed), and finally the last one stands for the stitch length (T-tight, M-medium, and S-slack).

Fabric weight, thickness and dimensional stability were tested in accordance with the standards TS 7128 EN ISO 5084, BS EN ISO 5084:1997 and ISO 3759 in turn. The overall porosity is defined as the ratio of open space to the total volume of the porous material and accordingly it was calculated from the measured thickness and weight per unit area values using the following equations [6]:

$$\text{Porosity (\%)} = \left[1 - \frac{\text{Density of fabric (g/cm}^3\text{)}}{\text{Density of fiber (g/cm}^3\text{)}}\right] * 100 \qquad 1$$

$$\text{Density of fabric (g/cm}^3\text{)} = \left[\frac{\text{Fabric weight(g/cm}^2\text{)}}{\text{Fabric thickness (cm)}}\right] \qquad 2$$

Measurement of transverse wicking test was based on Zhuang et. al.s' method [23] with a difference that the pressure applied was kept constant at 15,6 kg/m^2. Fabric samples were cut into 74,5 mm diameter circles, which were the same size as the dish placed on the fabrics. The amount of water initially held in the wet fabric was controlled by completely soaking the sample in distilled water and then removing the excess water with a paper towel. The wet fabric was weighed periodically. As soon as the dry layer fabrics, which was the same fabric as the wet layer, was placed on the top of wet layer, liquid transfer was continuously allowed for a certain period of time, then the amount of liquid transfer was measured by weighing the dry fabric layer at 5, 10, 15, 20, 25 and 30 minutes. The test for each sample was repeated three times.

The research of Coplan [24] and Fourt et al. [13] tests was used to measure drying rates of fabrics. Each specimen was soaked in distilled water for 30 minutes. When no air bubbles were produced upon squeezing under water, the fabrics were considered wet-out. Wet-out fabrics were suspended vertically for 15 seconds and then laid flat on a double thickness of dry paper towel for 2 minutes on each side. The samples were weighed at half-hour and 1 hour intervals as drying progressed. When the measurement value was 105% of the dry weight, the test was ended. Drying rates were expressed as average weight loss over the initial water content per unit area per unit hour.

The statistical evaluation of the data obtained was performed with the SPSS 18 software package. As a method, one way-ANOVA was employed and the factors were considered to be significant at a p-value less than 0,05. Also t-test was used to evaluate the results of the washed and unwashed samples.

Table 1. Properties of the fabrics

	TYPE	Weight (g/m^2)	Stitch Density (loops/cm^2)	Thickness (mm)	Porosity (%)	Dimesional stability widthwise (%)	Dimesional stability lengthwise (%)
Tactel	**T-D-T**	219	522	0,833	76,95	-2,53	-5,90
	T-D-M	208	468	0,893	79,58	-1,77	-6,20
	T-D-S	203	352	0,953	81,32	-1,07	-5,50
	T-WD-T	216	512	0,847	77,62	0,07	0,20
	T-WD-M	204	480	0,893	79,97	0,27	0,07
	T-WD-S	201	368	0,950	81,44	0,23	0,17
Meryl skinlife	**MS-D-T**	230	544	0,773	73,91	-2,93	-4,40
	MS-D-M	219	450	0,850	77,40	-2,17	-5,07
	MS-D-S	204	406	0,873	79,51	-1,43	-4,23
	MS-WD-T	227	480	0,737	72,97	0,70	0,13
	MS-WD-M	218	364	0,803	76,20	0,13	0,10
	MS-WD-S	204	336	0,873	79,51	0,07	0,10
Nylon	**N-D-T**	227	561	0,753	73,57	-3,07	-3,40
	N-D-M	216	405	0,840	77,44	-2,23	-3,80
	N-D-S	207	325	0,873	79,21	-1,90	-3,83
	N-WD-T	230	551	0,767	73,68	0,30	0,20
	N-WD-M	221	432	0,830	76,64	0,60	0,27
	N-WD-S	209	336	0,877	79,09	0,67	0,50

3. Results

3.1. Transverse Wicking

3.1.1. Before washing

The results revealed that the meryl skinlife slack samples had the highest transverse wicking values whilst tactel tight ones had the lowest ones. Also, in the first five minutes of the test, the transverse wicking of the all samples showed a steep increase which then became more gradual as may be seen from Figure 2.

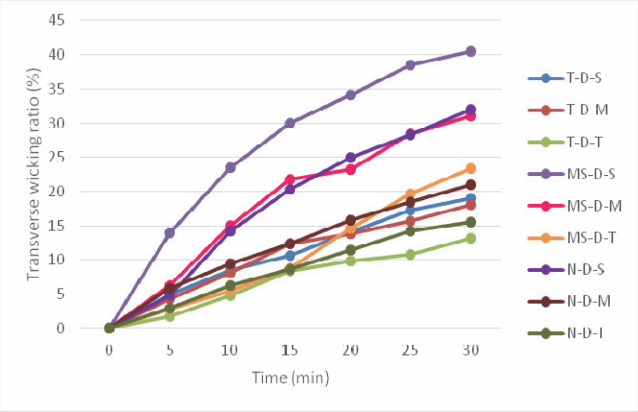

Figure 2. Transverse wicking ratio of dyed fabrics against time

The results obtained suggest that the liquid transfer properties of the fabrics showed significant variation in accordance with fiber type. The literature survey presented that the governing factors for liquid transport are thickness, porosity and the free surface energy, as well as the size and shape of fibers [23-27]. The fiber fineness of meryl skinlife is less than 10 µ [21] with round cross section. Liquid transport is suppressed as the number of fibers in the yarn decreases, may be the reason of the highest wicking ratio of samples made from merly skinlife fiber for all stitch lengths [28]. On the other hand, tactel fabrics, in fact, gave the lowest wicking value of all the samples although they had the highest thickness and porosity values. This may have been the result of the trilobal cross-section of the tactel fiber which might have narrowed the gaps between the fibers and yarns and consequently made it difficult for the water to be transferred in the traverse direction. Figure 3 shows the transverse wicking ratios of the dyed samples.

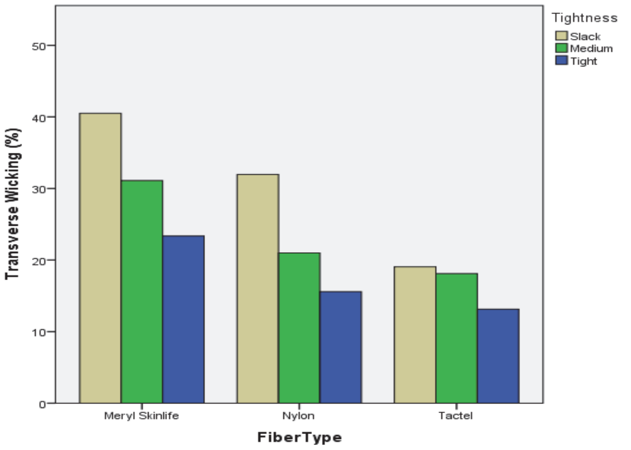

Figure 3. Transverse wicking ratio of dyed fabrics

Also, according to ANOVA results, fiber type had a statistically important parameter on transverse wicking ratios of dyed samples (95% significant level F=13,150 p= 0,000). Moreover, irrespective of fiber type, slack samples showed higher transfer wicking values. All the wet slack samples had the highest water content and this finding helps to answer why slack samples had the highest transfer ratios, which is compatible with the literature finding saying that the greater amount of water initially held in the wet fabric, the greater the amount of liquid water transferred to the dry layer [23] (see Figure 3). Furthermore, a proper channel is needed for the water to pass through and slack samples had the highest porosity values. Also, the location and form of the channels (or capillary) in the fabrics made from tight fabrics might be more random than the channels in the slack ones, and accordingly this might be the reason for lower transfer wicking of tight samples (see Table 1) [11, 23]. ANOVA evaluation of data showed that irrespective of fiber type, there is significant difference between slack and medium sample (p=0,076).

3.1.2. After repeated washing

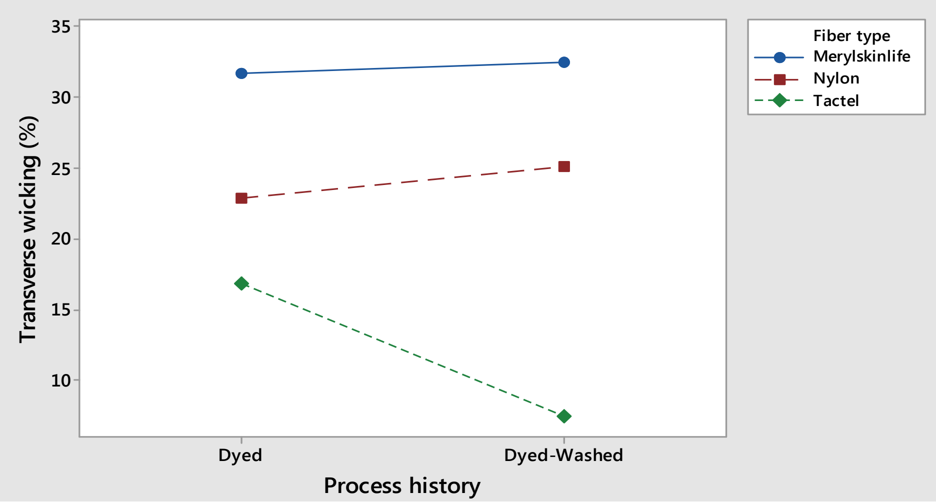

Figure 4. Interaction plot for transverse wicking (%)

After five repeated washing cycle, it is apparent that transverse wicking rates of merly skinlife and nylon garments had a tendency to increase whilst tactel ones decreased as can be from Figure 4. This result suggested that washing process did not lead to any changes in the capillary behavior of the fabric, but resulted in the re-arrangement of the capillaries due to the relaxation of the structure. However, the independent t-tests conducted between unwashed and washed fabrics made from meryl skinlife and nylon ones showed that there was no significant difference between their wicking ratios (Meryl skinlife: t=-0,253p= 0,803, Nylon t=0,737 p=0,49) whilst tactel ones were different (Tactel: t=8,157 p=0,00).

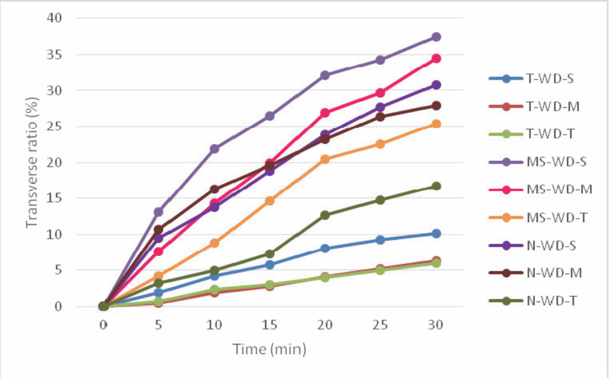

Figure 5. Transverse wicking ratio of dyed&washed fabrics against time

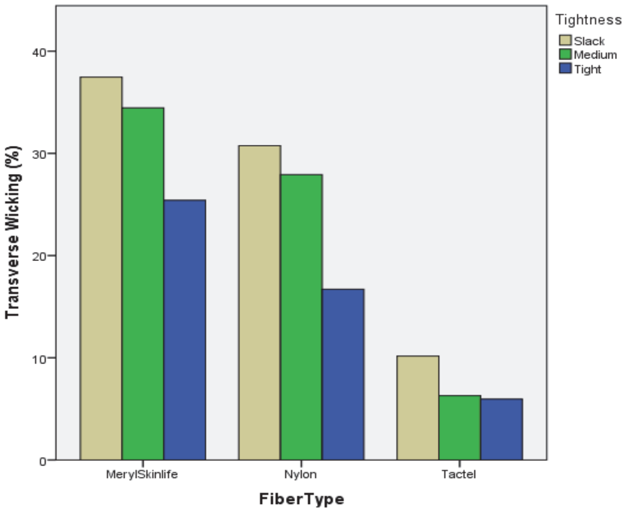

Figure 6. Transverse wicking ratio of dyed&washed fabrics

Similar to the unwashed fabrics, the washed meryl skinlife ones had the highest transverse wicking rations for all the stitch lengths, and they were followed by nylon and tactel samples, in turn (see Figure 5). ANOVA evaluation of the data presented that fiber was an influential factor so far as the wicking ratios of the fabrics which were subjected to repetitive washing cycle (F=59,388 p= 0,000), was concerned. Moreover, the slack washed fabrics which held the highest water in the beginning of the test and had the highest porosity values, performed the highest transfer wicking ratios (see Figure 6). ANOVA evaluation also supported this very results that irrespective of fiber type stitch length affected the transfer ratios of the samples (F=1,859 p=0,178).

3.2. Drying Rate

3.2.1. Before washing

Drying properties of the samples are given by Table 2.

According to Table 2 and Figure 7, tactel fabrics had the highest drying rates in terms of g/m^2/hour, and they were followed by nylon and merly skinlife respectively. It was found that for each fiber type and tightness studied, the drying rates of the samples were related to the initial amount of liquid water in a fabric, which was in agreement with literature [13, 24, 26, 29-31]. Table 1 showed that tactel fabrics had the highest thickness and porosity values which helped to swell more initial water amount, so their drying time were longer than the other fibers (see Table 2). As it is defined in the literature [26], there are two factors for the absorption of water: one is the total amount that can be absorbed regardless of time, and the other is the speed of water uptake. These properties are not necessarily related, as fabrics of similar structures but different rates of uptake may ultimately hold similar amounts of water if enough time is allowed for them to reach equilibrium. These two facts can explain why the fabric samples having the same dimensions and structures had different amounts of water at the beginning of the drying test, as the wetting process and time was identical for each sample. On the other hand, ANOVA results revealed that drying rates of the tactel and nylon samples behaved in the same manner (p= 0,178). From Table 2, it can also be said that drying rate was independent of stitch length, which was confirmed by ANOVA results stating that there was no significant difference between the slack-tight samples (p=0,314).

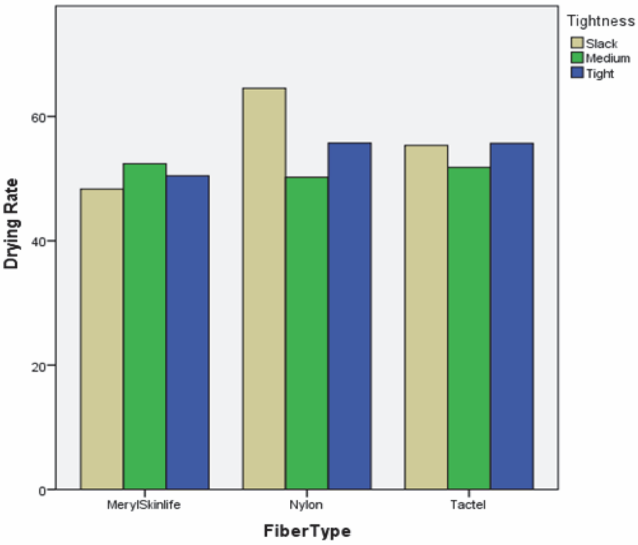

Figure 7. Drying rates of dyed fabrics

Table 2. Drying properties of dyed fabrics

	Dry fabric weight (g)	Initial wet-out fabric weight (g)	Initial water amount (g)	Drying Time (h)	Drying Rate $(g/h/m^2)$
Tactel dyed					
T-D-T	2,91	7,754	4,841	6,59	55,67
T-D-M	2,84	8,299	5,458	8,02	51,81
T-D-S	2,70	8,505	5,803	8,00	55,35
Merry skinlife dyed					
MS-D-T	2,92	7,521	4,597	6,89	50,47
MS-D-M	2,91	7,736	4,824	6,97	52,41
MS-D-S	2,83	7,799	4,969	7,81	48,32
Nylon dyed					
N-D-T	3,05	7,481	4,432	6,00	55,72
N-D-M	2,90	7,956	5,061	7,65	50,22
N-D-S	2,79	7,887	5,097	6,00	54,55

3.1.2. After repeated washing

Table 3 represents the drying properties of the washed fabrics.

Table 3. Drying properties of dyed&washed fabrics

	Dry fabric weight (g)	Initial wet-out fabric weight (g)	Initial water amount (g)	Drying Time (h)	Drying Rate $(g/h/m^2)$
Tactel dyed&washed					
T-DW-T	2,89	7,675	4,781	7,70	47,02
T-DW-M	2,77	7,790	5,020	8,01	47,62
T-DW-S	2,65	8,462	5,811	9,85	45,02
Merry skinlife dyed &washed					
MS-DW-T	2,93	7,265	4,333	6,54	50,02
MS-DW-M	2,88	7,897	5,022	7,81	48,82
MS-DW-S	2,73	8,018	5,289	7,79	51,67
Nylon dyed &washed					
N-DW-T	2,95	7,487	4,536	6,70	51,14
N-DW-M	2,82	7,858	5,037	7,00	54,64
N-DW-S	2,73	7,796	5,062	7,46	51,55

Table 3 showed that, repeating washing cycle had a singular effect on the drying rates of the samples. Unlike the unwashed samples, the washed nylon fabrics had the highest drying rates while the merry skinlife ones followed them. The tactel samples, on the other hand, had the lowest drying rates. Figure 7 shows the drying rates of dyed&washed fabrics. Also, according to the ANOVA results, fiber type was an effective parameter on the drying rate of the samples (F=42,004 p=0,000). Also as may be seen from Table 2&3, after repetitive washing process, the drying rates of all the fabrics tended to decrease, irrespective of fiber type from which they were made. However, the independent t-test revealed that the repetitive washing cycle influenced only the drying rates of the tactel fabrics while no effect was observed on merry skinlife and nylon ones (Tactel: t=10,541 p=0,00- Merly skinlife: t=0,319 p=0,754- Nylon: t=2,032 p=0,059). The repetitive washing cycle changed the fabric properties (see Table 1) and this also may have affected capillary property and liquid movement and retention properties of the samples. The repeated washing process may change the inter-yarn and inter fiber pore sizes and volumes as well as pore tortuosity of tactel fiber more significantly due to its trilobal cross section. Different from these findings, irrespective of fiber type, there was no significant difference between the drying rates of the samples produced at different settings (i.e slack, medium and tight) (F=0,332 p=0,72).

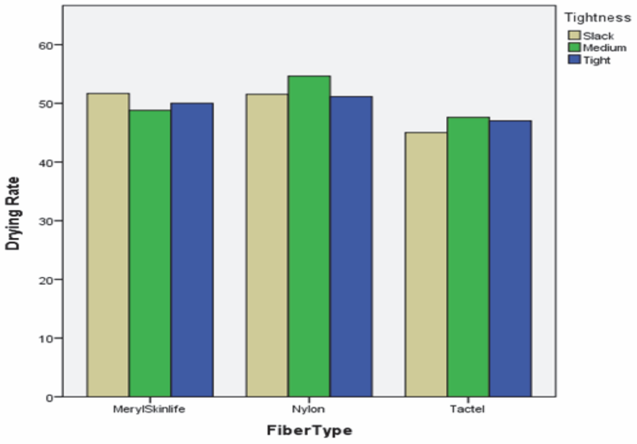

Figure 7. Drying rates of dyed&washed fabrics

4. Conclusion

Drying and wicking properties of fabrics made from tactel, meryl skinlife and conventional nylon fibers were investigated in the study. The fabrics were produced by seamless technology at three different stitch lengths using plaiting technique. According to the obtained results, it may be concluded that:

- ✓ Fiber type had a statistically important parameter on transverse wicking ratios of dyed samples.
- ✓ Transverse wicking rates of merly skinlife and nylon garments had a tendency to increase whilst tactel ones decreased by washing process. However, this process did not change the order of the transverse wicking ratios of fibers that merly skinlife fabrics were the highest and they were followed by nylon and tactel in turn.
- ✓ Transverse wicking of slack samples had the highest values for all conditions irrespective of fiber type.
- ✓ Drying rates of tactel fabrics were the highest in terms of g/m^2/hour, and they were followed by nylon and merly skinlife respectively. On the other hand, washing process changed this tendency such that the washed nylon fabrics had the highest drying rates while the tactel ones were the lowest.
- ✓ After washing process, the drying rates of fabrics decreased.
- ✓ Irrespective of fiber type, drying rate was independent of stitch length.

REFERENCES

1. Abraham Babs Nyoni. 1970, "Liquid transport in nylon 6.6 woven fabrics used for outdoor performance clothing", *Advances in Modern Woven Fabrics Technology*, Dr. Savvas Vassiliadis (Ed.), InTech: pp. 211-240.
2. Özdil N., Anand S., 2014, "Recent developments in textile materials and products used for active wear and sportswear", *Electronic Journal of Textile Technologies* Vol. 8, No.3, pp. 68-83.
3. Fangueiro, R., Filgueiras, A., Souinho F. 2010, "Wicking behavior and drying capability of functional knitted fabrics", *Textile Research Journal* Vol.80, No.15, pp.1522-1530.
4. Maggie T. K.P., Kan, C.V., Fan, J. T. 2014. "Evaluation of water absorption and transport property of fabrics" *Textile Progress* Vol.46, No.1 pp.1-132.
5. Patnaik, A., Rengasamy, R. S., Konthari, V. K., and Ghosh, A. 2008. "Wetting and wicking in fibrous materials" *Textile Progress,* Vol.38, pp. 1–105.
6. Kissa, E. 1996. "Wetting and wicking", *Textile Research Journal,* Vol.66, No. 10, pp.660-668.
7. Çil, M.G., Nergis, U.B., Candan C. 2009, "An experimental study of some comfort-related properties of cotton-acrylic knitted fabrics", *Textile Research Journal*, Vol.79, No. 10, pp.917-923.
8. Hatch, K.L., Woo, S.S., Barker, R.L., Padhakrishnaiah, P. Markee, N.L., Maibach, H.I.. 1990. "In vivo cuteneous and perceived comfort response to fabric Part 1: Thermophysiological comfort determinations for three experimental knit fabrics" *Textile Research Journal,* July, pp.405-412.
9. Yoon, H. N., Buckley, A. 1984. "Improved comfort polyester Part 1: Transport properties and thermal comfort of polyester/cotton blend fabrics", *Textile Research Journal*, May, pp.289-298.
10. Adler, M. M., Walsh, W. K. 1984, "Mechanisms of transient moisture transport between fabrics" *Textile Research Journal*, May, pp.334-342.
11. Hsieh Y.L. 1995, "Liquid transport in fabric structures", *Textile Research Journal,* Vol. 65, No.5, pp.299-307.
12. Layton, J.M., Li, Y. 2001, "The science of clothing comfort", *The Textile Institute*, Oxford.
13. Fourt, L., Sookne, A. M., Frishman, D., Harris M. 1951, "The rate of drying of fabrics", *Textile Research Journal*, Vol. 21, pp. 26–32.
14. Laing R. M., Wilson C. A., Gore S. E., Carr D. J., Niven B. E. 2007. "Determining the drying time of apparel fabrics", *Textile Research. Journal*, Vol.77, No. 8 pp.583–590.
15. Kadolph, S. J 2010. "Textiles", 11. Edition, Boston : Pearson, pp.1588-166
16. Information on http://www.textileweb.com/doc/meryl-skinlife-0001
17. Information on http://www.nylstar.com/brochures/Nylstar_Meryl_Skinlife_2014.pdf
18. Information on http://www.wisegeek.com/what-is-tactel.htm
19. Twine C., Ruckman J.E. "Fibre brand promotion and consumer product awareness: case study of Tactel" *Journal of Fashion Marketing and Management* Vol. 9 No. 3, 2005 pp. 330-341
20. Information on http://www.janmarsport.pl/en/yarn/tactel
21. Information on http://www.textile-tech.com.tw/web_en/product-info.php?id=56
22. Information on http://www.invista.com/en/brands/tactel.html
23. Zhuang, Q., Harlock, S. C., Brook D. B. 2002, "Transfer wicking mechanism of knitted fabric used as undergarment for outdoor activities" *Textile Research Journal* , Vol. 72, No.8, pp.727–734.
24. Coplan, M. J.1953. "Some moisture relations of wool and several synthetic fibers and blends", *Textile Research Journal,* Vol. 23, pp.897–916.
25. Ramachandran T., Kesavaraja, N. 2004. "Study on influencing factors for wetting and wicking behavior" *IE (I) Journal*, Vol.84, pp. 184–186.
26. Cimilli, S., Nergis, B. U., Candan, C., Özdemir, M. 2010, "Comparative study of some comfort-related properties of socks of different fiber types" *Textile Research Journal* Vol. 80, No.10, pp. 948-957.
27. Nyoni, A. B., Brook, D. 2006, "Wicking mechanisms in yarns-the key to fabric wicking performance", *Journal of Textile Institute* Vol.97, No.2, pp.119-128.
28. Jhanjia, Y. Gupta, D., Kothari V.K. 2015, "Effect of loop length and filament fineness on thermo-physiological properties of polyester-cotton plated knit structures", *The Journal of The Textile Institute* Vol.106, No. 4, pp.383–394.
29. Crow, R. M., Osczevski, R. J. 1998, "The interaction of water with fabrics", *Textile Research Journal* Vol. 68, No. 4, pp. 280-288.
30. Layton, J. M., Li, Y. 2001, "The science of clothing comfort", *The Textile Institute,* Oxford.
31. Benltoufa, S., Fayala, F., Nasrallah, S. B. 2008, "Capillary rise in macro and micro pores of jersey knitting structure", *Journal of Engineered Fibers and Fabrics,* Vol.3, No. 3, pp. 47-54.