Industria Textilă

ISSN 1222–5347

5/2014

Revistă **cotată ISI** și inclusă în **Master Journal List** a Institutului pentru Știința Informării din Philadelphia – S.U.A., începând cu vol. 58, nr. 1/2007/
ISI rated *magazine, included in the* ***ISI Master Journal List*** *of the Institute of Science Information, Philadelphia, USA, starting with vol. 58, no. 1/2007*

Editată în 6 nr./an, indexată și recenzată în:
Edited in 6 issues per year, indexed and abstracted in:
Science Citation Index Expanded (SciSearch®), Materials Science Citation Index®, Journal Citation Reports/Science Edition, World Textile Abstracts, Chemical Abstracts, VINITI, Scopus, Toga FIZ technik ProQuest Central

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Recunoscută în România, în domeniul Științelor inginerești, de către
Consiliul Național al Cercetării Științifice din Învățământul Superior
(C.N.C.S.I.S.), în **grupa A** /
Aknowledged in Romania, in the engineering sciences domain,
by the ***National Council of the Scientific Research from the Higher Education*** *(CNCSIS), in* ***group A***

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Comfort-related properties of woven fabrics produced from Dri-release® yarns

EMİNE UTKUN

REZUMAT – ABSTRACT

Proprietăţile de confort ale ţesăturilor produse din fire Dri-release®

Scopul acestui studiu a fost de a produce ţesături pentru îmbrăcăminte sport cu un grad ridicat de confort, deci cu o valoare adăugată mare. În prima etapă a studiului a fost proiectată o ţesătură nouă cu structură bistrat pentru a fi utilizată pentru producerea îmbrăcămintei sport. Au fost create patru ţesături diferite utilizând firele de bumbac, Tencel LF®, bambus şi Modal®, precum şi firele Dri-release®. Ulterior, au fost analizate, verificate statistic şi comparate proprietăţile de confort termic ale acestor ţesături. La finalului studiului, au fost indicate ţesăturile cu proprietăţi optime de utilizare.

Cuvinte-cheie: Dri-release®, confort termic, ţesătură

Comfort-related properties of woven fabrics produced from Dri-release® yarns

The aim of this study was to manufacture active-wear fabrics that have a high clothing comfort, hence, a high added value. In the first stage of the study, a new double-layer woven fabric was designed to be used for active-wear and four different fabrics were manufactured by utilizing cotton, Tencel LF®, bamboo and Modal® yarns in addition to Dri-release® yarn. Then, thermal comfort properties of these fabrics were analyzed, statistically reviewed and compared to each other. At the end of the study, fabrics with optimum usage properties were suggested.

Key-words: Dri-release®, thermal comfort, woven fabric

Today, clothing comfort appears as a significant factor when people make their clothing selection. Researches conducted on this subject are important in terms of raising people's life standards. Clothing comfort is divided into sub-components as thermal comfort, sensory comfort, body movement comfort and psychological (aesthetical) comfort [1].

Thermal comfort is a property related to the ability of clothing to keep the body temperature within the required temperature limits and to transfer the produced sweat. Thermal comfort sense is the state where a person is satisfied with the temperature or moisture rate of the available environment and does not request any change in existing atmospheric conditions [2, 3, 4]. There is a common agreement in literature and the researchers of the subject consider that air permeability, water vapor permeability and liquid transfer properties as well as the thermal resistance and thermal conductivity properties are the most important properties of clothing in order to maintain thermal comfort [1, 3, 4, 5, 6, 7, 8, 9, 10].

Clothing with good thermal comfort has an efficient role in maintaining the heat and moisture balance of a person by transferring the heat and moisture of body that change under different atmospheric conditions and/or during different activities [11].

Within the scope of this study, the aim was to manufacture active-wear fabrics that have high clothing comfort, hence, a high added value, considering the fact that different fibers and fabric structures can be used for active-wear. Accordingly, in the first stage of the study, a new double-layer woven fabric was designed to be used for casual wear and four different fabrics were manufactured by utilizing cotton, Tencel LF®, bamboo and Modal® yarns in addition to Dri-release® yarn. Then, thermal comfort properties of these fabrics were analyzed, statistically reviewed and compared to each other. At the end of the study, fabrics with optimum usage properties were suggested.

While designing a fabric, functional properties and basic structural parameters of fabrics must be fully understood [12]. A fabric consists of fibers and air. The still-air amount in fabric is more important than the fiber amount when thermal resistance is considered; still-air provides more thermal resistance in comparison to a great number of textile fibers [2, 13, 14, 15]. Regarding this matter, Cubric et al. (2012) put forward that the amount of still-air within the structure of knitted fabrics played an important role in terms of the thermal properties of fabric [16].

In the light of this information, the main idea of designing fabrics within the scope of the study was to form a double-layer structure and in this way, to preserve an air stratum between the fabric layers. In addition to that, multiple yarn types were used together in fabric manufacturing. Therefore, the aim was to utilize the properties of different fibers simultaneously.

The general properties of the fibers used within the study are as follows.

Dri-release®

Dri-release® is the trademark of Optimer. While 85–90% of this product consists of polyester fiber with hydrophobic properties, 10–15% of it consists of cotton, which is a hydrophilic fiber. In Dri-release® yarn, two different fibers are jointly used and they make a single yarn, thus, the properties of both fibers are separately utilized and the properties – mainly thermal comfort – of the manufactured goods are aimed to be improved. The natural fiber part absorbs the moisture on skin and transfers it inside the fabric. The synthetic fiber part wards off the moisture towards the upper part of clothing where it can easily vaporize by means of air current on the fabric. Dri-release® is a product which is used in active-wear, socks and underwear manufacturing [17, 18, 19, 20].

Cotton

Cotton fiber, which is a vegetable raw material of textile, has an extensive area of use. Cotton fiber is used especially in underwear and active-wear manufacturing due to its softness, its high resistance to wetness, its durability against washing, its hygiene property and its high capacity to hold moisture [21].

Tencel®

Tencel® fiber is the trademark of Lenzing. It is a tree-based fiber which is obtained via nano-fibril technology. Its most prominent feature is that it is soft due to its smooth fiber structure, that it is high-strength and that it provides quite high water absorption [22].

Bamboo

This fiber, which is obtained from the cellulose of bamboo plant, has good properties of moisture absorption, moisture vaporization and ventilation thanks to the micro gaps and micro holes [22, 23].

Modal®

Modal® is a fiber obtained from the cellulose of beech. It is the trademark of Lenzing. The most prominent feature of this fiber is that it is soft and radiant. Among the other properties, its low fiber hardness, smooth fiber surface, low yarn imperfection, high strength, natural softening material content and high chroma can be listed [22].

EXPERIMENTAL PART

Materials

Values related to the weft yarns of the fabrics within the scope of the study are shown in table 1, and values related to the warp yarns of the fabrics within the scope of the study are shown in table 2.

Table 1

CHARACTERISTICS OF THE WEFT YARNS OF THE FABRICS

Yarn Code	**Yarn Count** (Nm)	**Raw Material**	**Twist Coefficient (αe)**	**Direction of Twist**
Y1	20/1, ring	% 100 Dri-release® (%85 Polyester, %15 Cotton)	3,7	Z
Y2	20/1, ring	% 100 Tencel LF®	3,7	Z
Y3	20/1, ring	% 100 Rayon made from Bamboo	3,7	Z
Y4	20/1, ring	% 100 Modal®	3,7	Z

Table 2

CHARACTERISTICS OF THE WARP YARNS OF THE FABRICS

Yarn Code	**Yarn Count** (Nm)	**Raw Material**	**Twist Coefficient (αe)**	
			First Layer (Z)	**Second Layer (S)**
Y5	80/2, ring	% 100 Cotton	3,7	3,1

The fabrics were woven on a dobby weaving loom and kept in 50°C water for 90 minutes without adding any substance, and then, they were left to dry. The basis weight and thickness values, numbers of warp and weft yarns per unit area and the codes of warp and weft yarns are shown in table 3. In order that the fabric codes can be apprehended easily, the codes were prepared by using the numbers of yarn codes which are used in manufacturing the fabrics.

The fabrics were manufactured in original modified twill structure (figure 1). Modified twill structure was double-layered. While a double-layer structure was

Table 3

CHARACTERISTICS OF THE FABRICS

Fabric No	**Weight** (g/m²)	**Thickness** (mm)	**Warp Density** (warp/cm)	**Weft Density** (weft/cm)	**Code of Warp Yarn**	**Code of First-Layer Weft Yarn**	**Code of Second-Layer Weft Yarn**
1-1	121	0,55	22	28	Y5	Y1	Y1
1-2	123	0,52	23	29	Y5	Y1	Y2
1-3	140	0,56	23	29	Y5	Y1	Y3
1-4	128	0,53	23	30	Y5	Y1	Y4

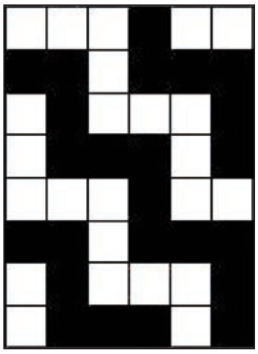

Fig. 1. Modified twill texture report

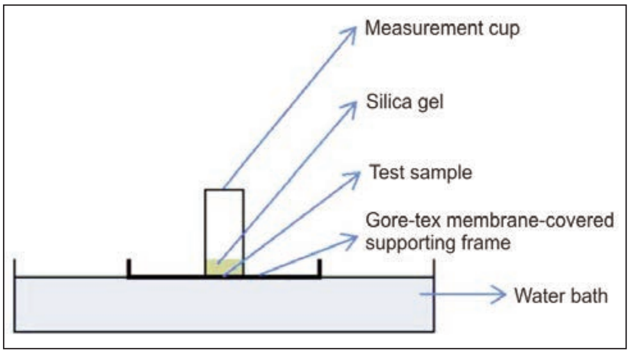

Fig. 2. Testing apparatus of Gore cup method

developed in the fabrics, among the self-tie methods, weft joining method was used. The texture reports of the fabrics are equal, however, their junction points were changed in order to use different yarns on front and reverse sides.

Method

All of the experimental studies in this section except water permeability test were conducted in the Textile Laboratories in Tampere Technical University, Faculty of Automation, Mechanical and Material Engineering, Department of Fiber Materials Science. Water permeability test was conducted in the Textile Laboratories in Technical Administration of TSI Denizli Textile Laboratory. All of the fabric samples were conditioned by keeping under standard atmospheric conditions (20 ± 2°C temperature and 65% ± 5 relative humidity) for 24 hours before the experimental studies. The data obtained were analyzed by utilizing the SPSS 15.0 statistical package software. The measurements are described as follows. The weight values of the fabrics were identified according to SFS 3192:1974 standard, and the thickness values of the fabrics were identified according to SFS-EN ISO 5084:1997 standard.

Thermal resistance – Thermal conductivity

Thermal resistance and conductivity of the fabrics were measured via thermal resistance measuring device according to ISO 5085-1:1989 standard and double plate method [24]. Test samples with diameter of 33 cm were prepared for each fabric sample.

Water vapor permeability

Water vapor permeability of the fabrics was measured according to Gore cup method. Test samples with diameter of 9 cm were prepared for each fabric sample. The materials used during the test were measurement cup, rubber ring, silica gel, Gore-tex membrane-covered supporting frame and water bath. The testing apparatus is shown in figure 2.

The measurement cup is filled with silica gel and the brim of the cup is covered with samples via rubber rings. This apparatus is weighed on a precision scale and the m_0 value is obtained. On the other hand, water bath is prepared and the Gore-tex covered supporting frame, which is a highly permeable membrane in terms of water vapor, is placed on this water bath. Previously prepared sample is placed on this frame. This testing apparatus is kept for four hours and the m_1 value is obtained by measuring the cup weight again at the end of these four hours. The m_1 and m_0 values, which are obtained from the test results, are subtracted from each other and the water vapor permeability value is calculated.

Air permeability

Air permeability of the fabrics was measured according to SFS-EN ISO 9237:1996 standard [25] The measurements were conducted via Karl Schröder D-6940 air permeability measuring device by applying 100 Pa pressure on a surface area of 20 cm^2.

Water permeability

Water permeability of the fabrics was measured according to TS 257 EN 20811/T1 – Textile Fabrics-Determination of Resistance to Water Penetration-Hydrostatic Pressure Test standard [26]. The measurements were conducted via Textest FX 3000 Hydrostatic Head Tester measuring device by applying 60 mbar/minute water pressure rate of increase.

RESULTS AND DISCUSSION

The mean values, standard deviations and measurement units of thermal comfort property, which were obtained from the standard measurements conducted on the fabrics, are shown in table 4.

The significance value within the study was acknowledged as (p) 0.05. If significance value (p) of a parameter was higher than 0.05 ($p > 0.05$), it was interpreted that the parameter did not make a statistically significant difference.

Fabric 1-1 was considered as the control group in interpretation of the analysis. One-way Analysis of Variance (ANOVA) was conducted on the independent samples in order to determine if different yarn types used in conjunction with Dri-release® yarn have a statistically significant difference on the thermal resistance, thermal conductivity, water vapor permeability, air permeability and water permeability values of the fabrics.

Table 4

RESULTS OF THE STANDARD MEASUREMENTS OF THE FABRICS															
Fabric code	**Thermal resistance** ($m^2 \cdot K/W$)			**Thermal conductivity** W/(m·K)			**Water vapor permeability** ($g/m^2 \cdot 24h$)			**Air permeability** ($l/m^2 \cdot s$)			**Water permeability** (mbar)		
	N	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**	**N**	**Mean**	**Standard deviation**
1-1	4	0,008	0,001	4	0,110	0,007	4	4868	112	5	1770	148	5	10,2	0,3
1-2	4	0,009	0,001	4	0,090	0,008	4	4812	96	5	1770	57	5	6,5	0,4
1-3	4	0,003	0,001	4	0,338	0,075	4	4817	104	5	1230	27	5	7,3	0,6
1-4	4	0,008	0,001	4	0,114	0,012	4	4899	89	5	1660	129	5	9,2	0,3

The hypotheses of ANOVA analysis, which were conducted for each property, are as follows.

"H0": There is no difference between the fabrics in terms of thermal comfort property.

"H1": There is a difference between the fabrics in terms of thermal comfort property.

Before the variance analysis, Levene Test was conducted and variance homogeneity was tested. It was interpreted that the variances were homogeneous if the result was $p > 0.05$, and that the variances were not homogeneous if the result was $p < 0.05$ in Levene Test. In order to define the relationship between the fabrics, Tukey HSD multiple comparison test was conducted in the cases that the variances were homogeneous, and Games-Howell multiple comparison test was conducted in the cases that the variances were not homogeneous. The results obtained are described in the provided tables.

Thermal resistance

According to the results of Levene Test, $F = 0,105$ and significance level was $p = 0,955$; in this case, it was observed that distribution variances were homogeneous. According to the results of ANOVA, $F = 71,636$ and $p = 0,000$. Therefore, "H1" hypothesis was accepted; in other words, there was a statistically significant difference between the thermal resistance values of the fabrics. According to Tukey HSD multiple comparison test, which was conducted after ANOVA test, while the fabrics 1-1, 1-2 and 1-4 made a group, the fabric 1-3 made another group.

Thermal conductivity

According to the results of Levene Test, $F = 6,725$ and significance level was $p = 0,007$; in this case, it was observed that distribution variances were not homogeneous. According to the results of ANOVA, $F = 37,321$ and $p = 0,000$. Therefore, "H1" hypothesis was accepted; in other words, there was a statistically significant difference between the thermal resistance values of the fabrics. According to Games-Howell multiple comparison test, which was conducted after ANOVA test, there was a significant difference between the thermal conductivity of the fabric 1-3 and the thermal conductivity of the fabrics 1-1, 1-2, 1-4. In addition to that, there was a significant difference between the thermal conductivity values of the fabrics 1-1 and 1-2.

Water vapor permeability

According to the results of Levene Test, $F = 0,301$ and significance level was $p = 0,824$; in this case, it was observed that distribution variances were homogeneous. According to the results of ANOVA, $F = 0,698$ and $p = 0,571$. Therefore, "H0" hypothesis was accepted; in other words, there was no statistically significant difference between the water vapor permeability values of the fabrics.

In addition, according to the correlation analysis conducted between the thickness and water vapor permeability values of fabrics, Pearson correlation coefficient was measured as –0.953 at 0.05 significance level. In other words, while the thickness value of fabrics increases, the water vapor permeability value decreases.

Air permeability

According to the results of Levene Test, $F = 1,877$ and significance level was $p = 0,174$; in this case, it was observed that distribution variances were homogeneous. According to the results of ANOVA, $F = 30,889$ and $p = 0,000$. Therefore, "H1" hypothesis was accepted; in other words, there was a statistically significant difference between the air permeability values of the fabrics. According to Tukey HSD multiple comparison test, which was conducted after ANOVA test, while the fabrics 1-1, 1-2 and 1-4 made a group, the fabric 1-3 made another group.

In addition, according to the correlation analysis conducted between the air permeability and thermal resistance values of fabrics, Pearson correlation coefficient was measured as 0.893 at 0.05 significance level. In other words, while the air permeability value of fabrics increases, the thermal resistance value increases as well.

Water permeability

According to the results of Levene Test, $F = 1,431$ and significance level was $p = 0,271$; in this case, it was observed that distribution variances were homogeneous. According to the results of ANOVA, $F = 96,222$ and $p = 0,000$. According to these results, “H1” hypothesis was accepted; in other words, there was a statistically significant difference between the water permeability values of the fabrics. According to Tukey HSD multiple comparison test, which was conducted after ANOVA test, each of the fabrics 1-1, 1-2, 1-3 and 1-4 made a separate group.

Besides these analyses, according to the correlation analysis conducted between the water vapor permeability and water permeability values of fabrics, Pearson correlation coefficient was measured as 0.922 at 0.05 significance level. In other words, while the water vapor permeability value of fabrics increases, the water permeability value increases as well.

CONCLUSIONS

Thermal and moisture transfer properties of active-wear fabrics must be very good in order that they can have optimum properties. Thermal conductivity, water vapor permeability, air permeability and water permeability values of the fabrics, which were developed within the scope of the study, were aimed to be high. At the end of the assessment of the measurements and analysis which were conducted on the fabrics, table 5 was generated.

It is observed that the thermal properties of the fabric 1-1, which is considered as the control group, are higher in comparison to the other fabrics. It follows the fabric 1-3 only in terms of thermal conductivity value. It is assumed that this is because of the micro holes which are available in the structure of bamboo fiber.

Considering the obtained results, if the fabrics should be sorted out according to their preferability as an active-wear fabric, the final listing is as follows.

Table 5

EVALUATION OF THE MEASUREMENTS

Fabric code	Thermal resistance	Thermal conductivity	Water vapor permeability	Air permeability	Water permeability
1-1	1	2	1	1	1
1-2	1	3	1	1	4
1-3	2	1	1	2	3
1-4	1	2	1	1	2

Note: While the figure 1, which is used in the table, indicates that the fabric provides the highest value for the mentioned property, an increase on the figure indicates that the mentioned value lowers.

1) Fabric 1-1
2) Fabric 1-4
3) Fabric 1-3
4) Fabric 1-2

As it is obvious from the results, high-comfort fabrics can be manufactured by using cotton and Dri-release® yarns. This combination is followed by the fabric 1-4, which is a mix of cotton-Dri-release®-Modal® and by the fabric 1-3, which is a mix of cotton-Dri-release®- bamboo. It can be proposed that these fabrics can be used as active-wear fabrics. However, it was observed that the results were not as good as expected although the fabric 1-2, which is a mix of cotton-Dri-release®-Tencel LF®, was designed as an active-wear fabric, and it is not recommended to use for active-wear items.

Acknowledgements

My profound thanks to M.Sc. Minna VARHEENMAA, to Teija JOKI from Tampere Technical University, and to the Technical Direction of Denizli Textile Laboratory of Turkish Standards Institution that helps to carry out the experimental studies, and to Kaçanoğlu Textile in the presence of Selahattin KAÇANOĞLU in the production of the fabric samples.

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Mark	Rank	Abbreviated Journal Title (linked to journal information)	ISSN	JCR Data: Total Cites	JCR Data: Impact Factor	JCR Data: 5-Year Impact Factor	JCR Data: Immediacy Index	JCR Data: Articles	JCR Data: Cited Half-life	Eigenfactor® Metrics: Eigenfactor® Score	Eigenfactor® Metrics: Article Influence® Score
	1	AATCC REV	1532-8813	215	0.254	0.321	0.034	29	8.9	0.00020	0.065
	2	AUTEX RES J	1470-9589	196	0.618		0.038	26	7.4	0.00019	
	3	CELLULOSE	0969-0239	4238	3.033	3.925	0.530	268	4.8	0.00746	0.719
	4	COLOR TECHNOL	1472-3581	787	1.173	1.170	0.155	58	6.8	0.00093	0.200
	5	DYES PIGMENTS	0143-7208	8559	3.468	3.255	0.951	387	6.0	0.01092	0.553
	6	FIBER POLYM	1229-9197	1502	1.113	1.361	0.112	313	4.3	0.00313	0.236
	7	FIBRE CHEM+	0015-0541	313	0.167	0.227	0.013	80	>10.0	0.00030	0.044
	8	FIBRES TEXT EAST EUR	1230-3666	832	0.541	0.712	0.050	120	5.6	0.00114	0.110
	9	IND TEXTILA	1222-5347	85	0.475	0.310	0.302	53		0.00010	0.029
	10	INDIAN J FIBRE TEXT	0971-0426	512	0.778		0.062	64	5.5	0.00092	
	11	INT J CLOTH SCI TECH	0955-6222	329	0.333	0.493	0.031	32	9.8	0.00031	0.135
	12	J AM LEATHER CHEM AS	0002-9726	467	0.714	0.739	0.087	46	8.7	0.00044	0.118
	13	J ENG FIBER FABR	1558-9250	247	0.778	1.150	0.042	48	3.8	0.00076	0.252
	14	J IND TEXT	1528-0837	326	1.200	1.680	0.119	42	5.8	0.00060	0.370
	15	J NAT FIBERS	1544-0478	135	0.512	0.558	0.034	29	6.0	0.00021	0.103
	16	J SOC LEATH TECH CH	0144-0322	283	0.414	0.392	0.056	36	9.3	0.00020	0.064
	17	J TEXT I	0040-5000	1253	0.770	0.764	0.139	144	>10.0	0.00143	0.158
	18	J VINYL ADDIT TECHN	1083-5601	451	1.000	1.208	0.056	36	6.5	0.00070	0.236
	19	SEN-I GAKKAISHI	0037-9875	292	0.164	0.164	0.016	127	>10.0	0.00025	0.028
	20	TEKST KONFEKSIYON	1300-3356	104	0.245	0.313	0.024	42	4.1	0.00027	0.063