

THE PROPERTIES OF KNITTED FABRICS FOR BIO-FUNCTIONAL TEXTILES

BY

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Abstract. “Bio-active” textiles belong to the so-called “Functional” textiles that in addition to their basic functions claim to take care of the health and hygiene of the consumer contributing to his well-being.

Fabric characteristics are usually dictated by a specified end-use. Understanding the relationship between the fabric end-use and fabric properties becomes fundamental for classification, selection, and proper utilization of apparel fabrics. This study focused on the effect of knitted structures on SeaCell active/Lycra yarn knitted fabric properties. In this work, we have used three structures: single jersey, single piqué and double piqué, for production of the knitted fabrics.

Key words: bio-active fibres, knitted fabric structure, thermal properties, air permeability, water vapour permeability.

1. Introduction

Customer desire for comfort, hygiene and well-being has created a large and rapidly increasing market for “Bio-active” textiles. “Bio-active” textiles belong to the so-called “Functional” textiles that in addition to their basic functions claim to take care of the health and hygiene of the consumer contributing to his well-being. These products use biocides as the active agents. Some biocides are applied at the finishing stage while in other cases the biocides can be incorporated into synthetic fibres during extrusion. The obtained products vary in their effectiveness and durability depending on the type of fabric, the biocide and the finishing method used [1].

Estimations have shown that the production of “Bio-active” textiles was in the magnitude of 30,000 tones in Western Europe and 100,000 tones worldwide in 2000. In 2005 “Bio-active” textile production was almost 175,000 tones and it was estimated that the production increased by more than 15% a

year in Western Europe in the next period, will making it one of the fastest growing sectors of the textile market [2].

In fact, the term “Bio-active” textiles cover the following products:

- *Anti-bacterial textiles* - products aim at reducing the proliferation of bacteria, including those responsible for microbial odours;
- *Anti-dust mite textiles* - products aim at eliminating the waste products of dust mite responsible for bronchial and asthmatic allergies;
- *Anti-fungal textiles* covering foot fungus (e.g. athlete's foot), black mildew in bathrooms, fungal contamination of mattresses and bed linen and products reducing mould and fungus in carpets and floor coverings. In practice, anti-fungal textiles generally provide anti-bacterial and/or anti-dustmite properties as well, so that these products can be included either under anti-bacterial or anti-dust mite properties, according to the main effect targeted [3].

Anti-bacterial textiles account for more than 70%, *versus* less than 30% for anti-dust mite textiles.

The main negative factor limiting the potential growth of “Bio-active” textiles is that the most biocides used on commercial textiles can induce bacterial resistance to these substances, which can lead to increased resistance to certain antibiotics in clinical use. Bacterial resistance may be a particular concern because large quantities of biocides are needed on the textiles to achieve adequate activity and durability [2].

An antimicrobial textile can act in two distinct ways:

- By contact: The antimicrobial agent placed on the fibre does not disperse and, to attain the antimicrobial action, micro organisms have to contact the fibre.
- By diffusion: The antimicrobial agent placed on the surface or in the fibre disperses more or less rapidly in a humid external medium to reach the micro organisms and inhibit their growth.

SEACELL[®] is a multifunctional cellulose fibre with bio-active properties. Seaweed is added as the active substance to protect the skin and have anti-inflammatory properties. The structure of Seacell[®] facilitates the active exchange of substances between the fibre and the skin – nutrients such as calcium, magnesium and vitamin E are released by the natural body moisture when the fibre is worn, thereby creating a complete sense of well-being [4]. The “active” version with added silver is for extra antimicrobial properties. 6,900 mg/kg silver ion in fibre, make the fibre hold forever antibiotic characteristic [5]. Trials with bacterial and fungal cultures at the University Hospital of Jena have established that the active fibre has antimicrobial properties. In addition to the antibacterial activity, tests were conducted to also evidence the antimycotic and fungicidal effect of SeaCell[®] active. The antimicrobial effect – while at the same time maintaining the typical skin-friendliness of cellulose fibres in SeaCell[®] active – was examined and confirmed by numerous tests, including those conducted at the Hohenstein research institute [4]. The bactericidal effect of silver ions on micro-organisms is very well known, but the bactericidal mechanism is only partially understood. It has been proposed that ionic silver

strongly interacts with thiol groups of vital enzymes and inactivates them [6], [7].

2. Experiments

The goal of the research was to study changes in the properties of knitted fabrics as a function of their structure. In this study, we changed only the knit structure of the samples, in order to isolate the effects of other variables.

2.1. Materials

The yarns used for knitting the fabrics were 20 SeaCell® pure/10 SeaCell® active/70 Combed Cotton, Ne 50 and Lycra 70D. Adding Lycra to a fabric gives it stretch and recovery and these properties are important particularly in active sportswear and outdoor activities where body flexing and stretching occur. Also, Lycra supports muscles, delaying fatigue and extending the endurance.

Table 1
Yarn Characteristics: SeaCell

No.	Parameters	Unit of measure	Average value
1.	Linear density, T_{tex}	g/km	11.93
2.	CV of yarn count	%	1.246
3.	Twist	Tpm	1284
4.	CV of Twist	%	3.66
5.	Uster Irregularity	%	13.9
6.	Thin places/1000 m of yarn	Num	105
7.	Thick places/1000 m of yarn	Num	456
8.	Neps/1000 m of yarn	Num	367
9.	Tenacity	cN/tex	10.15
10.	CV of Tenacity	%	11.13
11.	Breaking Elongation	%	3.849
12.	CV of Breaking Elongation	%	12.97

Table 2
Yarn Characteristics: Lycra

No.	Parameters	Unit of measure	Average value
1.	Linear density, T_{den}	g/9km	70
2.	Tenacity	cN/tex	16.85
3.	CV of Tenacity	%	8.41
4.	Breaking Elongation	%	526
5.	CV of Breaking Elongation	%	11.7

The USTER Irregularity and Imperfections were determined using the Uster Tester 3. The Tensile Properties were determined using a HOUNSFIELD Tensile Tester and twist of the yarn with the Twistronic Mesdan.

Single jersey and its derivative fabrics Single Piqué and Doppel Piqué

were selected for this study, since they are widely used.

The fabrics have been produced on the 8-feed Single-Jersey Circular Knitting Machine MERZ – MBS. The details of machine: gauge – 28 E, diameter – 13”, speed – 50 rpm, number of needles – 1152. The loop length for all the fabrics was the same (2.5 mm).

2.2. The Properties of Knitted Fabrics

All tests were carried out after the samples were conditioned in standard atmospheric conditions (temperature $20 \pm 2^\circ\text{C}$, $65 \pm 2\%$ relative humidity), according to the standard ISO 139:1973 – Textiles - Standard atmospheres for conditioning and testing.

Table 3
The Properties of the Fabrics

	Single jersey	Single piqué	Doppel piqué
Thickness, [mm]	1.16	1.29	1.36
CV of the thickness, [%]	2.93	3.55	1.5
Fabric weight, [g/m^2]	301.80	318.98	330.56
Fabric density, [g/cm^3]	0.260	0.247	0.243
Air permeability, [mm/s]	850.9	821.97	781.97
Thermal conductivity, (W/mK) $\times 10^{-3}$, (CV %)	51.76 (2.26%)	50.74 (2.7%)	49.86 (2.07%)
Thermal resistance, ($\text{m}^2\text{K}/\text{W}$) $\times 10^3$, (CV %)	22.48 (3.76%)	25.42 (3.16)	27.27 (2.22%)
Thermal absorptiveness, $\text{W s}^{1/2}/\text{m}^2\text{K}$, (CV %)	142.2 (3.67%)	138.36 (2.25%)	134.8 (3.0%)
Water vapour transmission rate, [$\text{g}/\text{m}^2/\text{h}$]	30.406	29.90	29.73
Index of water vapour transmission rate, [%]	99.8	98.19	97.63

The thickness of the fabric depends on the yarn count, knitted structure and relative closeness of the loops. The fabrics thickness was determined with SDL – Digital Thickness Gauge M034A, according to the standard EN ISO 5084. From Table 3, it can be seen that the thickness was higher for the double piqué fabrics and reduced for single piqué and single jersey, respectively. The tuck-knit combination fabrics showed higher thickness than that of plain knit fabric, because of tuck stitch accumulation.

Fabric weight per unit area. The double piqué fabrics showed a higher weight per unit area value and it reduced with single piqué and single jersey, respectively. So, it can be concluded that the knit-tuck combination showed a higher weight per unit area value than plain knit fabrics.

The density of the tuck-knit structures is slightly reduced compared with the single jersey fabric.

Fabric Comfort Properties. Clothing comfort is an extremely complex phenomenon resulting from the interaction of various physical and non-physical stimuli on a person wearing given clothing under given environmental conditions. One of the basic variables that have a great influence on comfort is fabric construction. A lot of thermo-physiological comfort properties, such as air permeability, thermal resistance, water vapour permeability, water absorbency and so on, can be altered by fabric construction.

a) *Air Permeability.* The air permeability of the fabric depends on the shape and value of the pores and the inter-thread channels, which are dependent on the structural parameters of the fabric. The effects of knit structures with spandex on the air permeability of fabric have been analyzed by Çeken [8].

The air permeability of the samples was measured according to standard ISO 9237 with a Textest FX-3300 air permeability tester. The air permeability measurements of the fabrics were carried out 10 times, and the average and standard deviation of the test values were calculated.

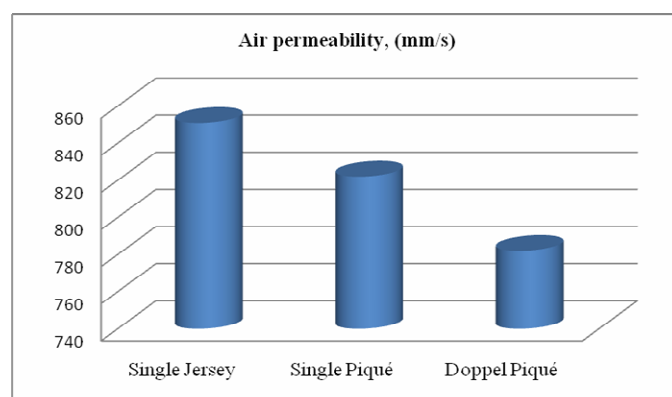


Fig. 1 – The air permeability of the fabrics.

As we can see from Fig. 1, single jersey fabric showed the highest air permeability and double piqué fabric showed the lowest air permeability. In between these came single piqué fabric. This evolution is determined by reduced thickness and weight of the single jersey fabric compared with piqué fabrics.

According to the literature the tuck stitch can be employed to produce openwork effects on knitted fabrics [9] but, because of the stretched structure of the Lycra yarn the openwork effects is reduced and that determines a more compact and closer structure.

b) *Thermal properties.* The thermal properties of the samples are presented in Table 3. The thermal properties of the fabrics were measured by the ALAMBETA instrument according to standard ISO EN 31092-1994. The measurements were repeated 5 times on randomly chosen parts of the fabrics, and average values were calculated. The coefficients of variation of all properties are also indicated. The measuring head temperature of the ALAMBETA is

approximately 32°C, and the contact pressure is 200 Pa in all cases.

Thermal conductivity, λ , [W/mK], is considered to be dominant in determining the heat transfer through fabrics and garments.

The single jersey structure has higher thermal conductivity. This situation can be explained by the amount of entrapped air in the fabric structure. The amount of fibre in the unit area increases and the amount of air layer decreases as the fabric density increases. As it is known, thermal conductivity values of the fibres are higher than the thermal conductivity of entrapped air [10]. So, fabrics that contain less still air have higher thermal conductivity values.

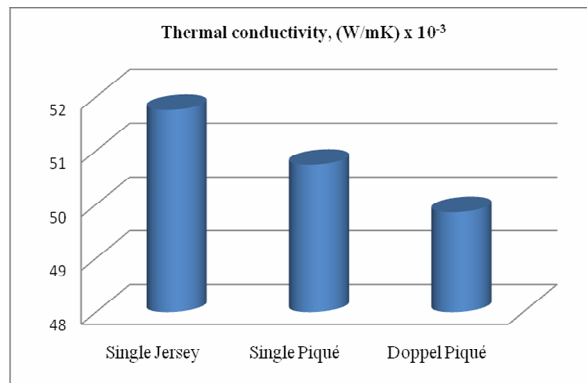


Fig. 2 – Thermal conductivity.

Thermal absorptiveness, b , [Ws^{1/2}/Km²], is the heat flow q , [W/m²] which passes between the human skin and the contacting textile fabric.

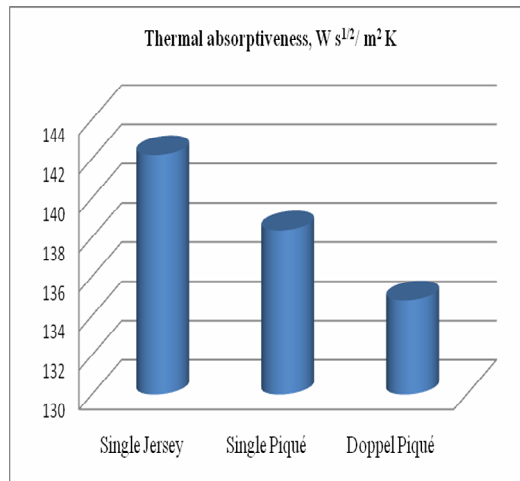


Fig. 3 – Thermal absorptiveness.

Thermal absorptiveness is the objective measurement of the warm-cool feeling of fabrics. When a human touches a garment that has a different temperature than the skin, heat exchange occurs between the hand and the fabric. If the thermal absorptiveness of clothing is high, it gives a cooler feeling at first contact [11]. The surface character of the fabric greatly influences this sensation. A rough fabric surface reduces the area of contact appreciably, and a smoother surface increases the area of contact and the heat flow, thereby creating a cooler feeling [10].

The single jersey structure has a smoother surface compares with single piqué and double piqué structures as can be seen from Figs. 4 and 5. As consequence, the single jersey structure presents a higher thermal absorptiveness.

So the tuck-knit structure is recommended for a warmer filling at the contact with the skin and the plain single jersey structure must be preferred for a cooler feeling.

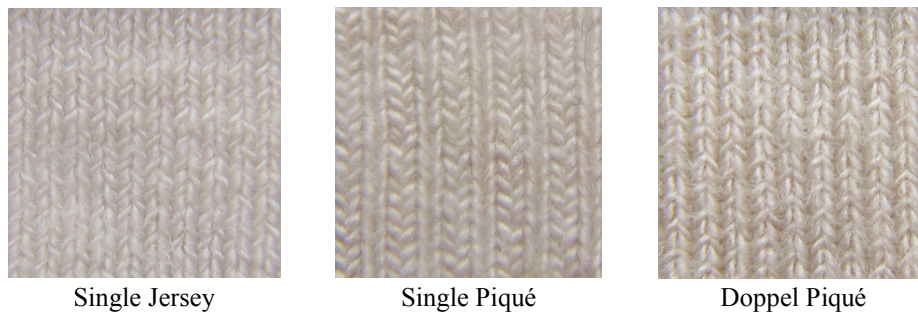


Fig. 4 – Aspect of the knitted structures – technical face.

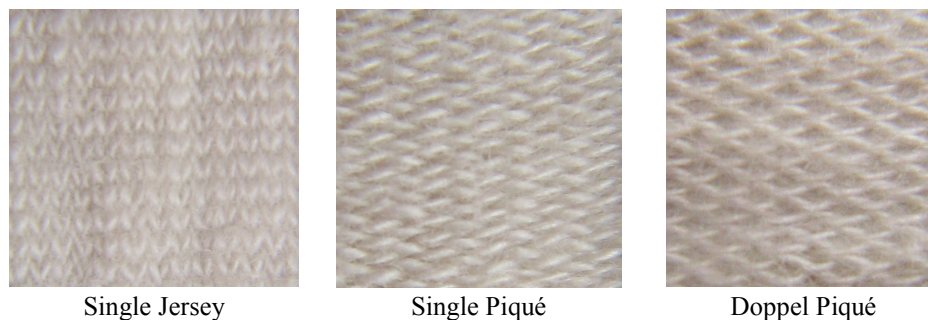


Fig. 5 – Aspect of knitted structures – technical back.

Thermal resistance, r , [m²K/W], mainly depends on thickness and air porosity nature in the fabric. Double piqué fabric had a higher thermal resistance than the others due to its higher thickness. It then decreased from single piqué and single jersey, respectively. Fabrics from tuck-knit combination stitches showed higher thermal resistance than the fabrics from plain stitches.

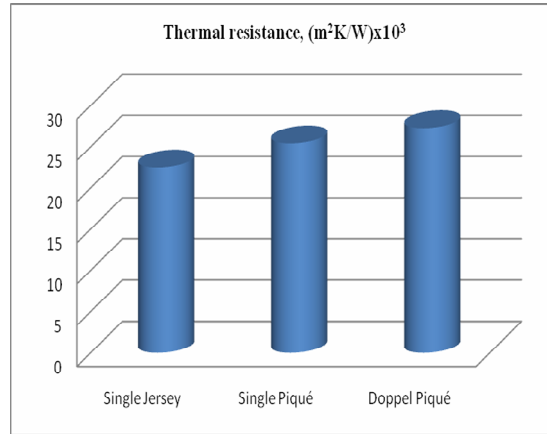


Fig. 6 – Thermal resistance.

c) *Water vapour permeability*. The ability of clothing ensembles to transport water vapour is an important factor of physiological comfort. The water vapour permeability was determined using a SDL Shirley Water Vapour Permeability Tester M – 261, according 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 a fabric to a controlled atmosphere. In this method, a sample covers a cup containing distilled water and placed in a controlled environment of 20°C and 65% relative humidity. By adjusting the initial weight of water in the cup to 46 ml, a constant air gap was set between the water surface and the sample. The tests lasted for 16 h and the weight of each cup was recorded initially and after 16 h. The water vapour transmission rate (*WVTR*) was calculated by the following equation:

$$(1) \quad WVTR = \frac{G}{tA}, \text{ [g/m}^2\text{/h]}$$

where: G is weight change of the cup with fabric sample, [g]; t – the time during which G occurred, [h]; A – the testing area, [m²].

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

$$(2) \quad I = \frac{WVTR}{WVTR_r} \times 100, \text{ [%]}$$

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

The index of water vapour transmission rate of the single jersey structure is slightly higher than for the other structures. The existence of this

difference is most probably a consequence of the thinner structure of single jersey fabrics. The transportation of water vapour through a thin fabric will be easier.

3. Conclusions

In order to achieve the ideal clothing comfort, it is necessary to consider the end-use of the garment when selecting the fabric. According to the results knit-tuck structures, due to their high thermal resistance values, could be preferred for winter garments in order to protect from cold and for a warmer feeling at first contact.

On the other hand, single jersey structures should be chosen for active sports or summer garments for better moisture management properties, air permeability and for a higher thermal absorptiveness, that gives a cooler feeling at first contact with the skin.

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R E F E R E N C E S

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PROPRIETĂȚILE STRUCTURILOR TRICOTATE CU DESTINAȚIE
ARTICOLE BIO-FUNCȚIONALE

(Rezumat)

Cerințele consumatorilor pentru confort și igienă au determinat o rapidă dezvoltare a pieții de textile „bio-active”. Textilele „bio-active” aparțin așa numitelor textile „funcționale” care, în plus față de funcția lor de bază, contribuie la menținerea sănătății și igienei consumatorului, completând sentimentul de confort. Caracteristicile produselor textile sunt impuse, în general, de destinația acestora. Înțelegerea relației dintre destinația și proprietățile textilelor este fundamentală pentru clasificarea, selecția și utilizarea corectă a acestora. În lucrare s-a studiat efectul structurii tricoturilor asupra proprietăților tricoturilor din bătătură, realizate din fire bio-active SeaCell și Lycra. S-au utilizat trei structuri diferite: glat, piqué și doppel piqué pentru realizarea tricoturilor.