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Fabric physical properties and clothing comfort

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Fabric physical properties and clothing comfort

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Abstract. The role of fiber content regarding the textile performance and physiological and sensorial comfort attributes of single jersey fabrics, typically used in skin-near applications such as underwear, was investigated. Fabrics made of 100% lyocell and 50:50 lyocell/polyester blends were compared to 100% polyester fabrics, typically used for institutional underwear. Blending polyester to the cellulosic fiber improved fabric tenacity and dimensional stability, while the 100% polyester fabric remained unmatched. While all tested fabrics showed low vapor transfer resistance and hence high breathability at a hotplate test, lyocell-containing fabrics proved superior in terms of vapor uptake as well as in skin sensorial aspects. A synergy effect was observed in the blended fabrics in terms of more efficient liquid transportation and faster fabric drying.

1. Introduction

Clothing comfort is one of the most important attributes of textile materials. It implies understanding the interrelationship between fiber material, yarn structure, fabric structure, transmission characteristics (air, heat and moisture) and tactile aspects of textile materials on thermo-physiologicall and neurophysiological processes [1]. Fabric performance in terms of better physiological and sensorial comfort ought to be an essential requirement of materials, which are used in contact with skin (i.e. lingerie, sportswear and bed clothing). Wear comfort has been listed as the most important property of clothing demanded by users and consumers according to recent studies [2].

An attribute essential to physiological comfort is the ability of the textile material to remove moisture generated by perspiration away from the skin surface, thus supporting the body cooling mechanism. Vapor uptake is decisive for the performance of textile under “comfort” conditions before the body comes into sweating, while liquid uptake, transportation and evaporation are the mechanism required for performance textiles [3].

Earlier works have shown the consequence of the enhanced moisture uptake of the wood-based cellulosic fibers lyocell and modal for the comfort properties in textile applications [4]. Moisture absorption has also an effect on the sensorial perception of the surface. Hygroscopic materials are known to provide a cool touch [5].

Thermo-physiological properties of clothing are often assessed by the hotplate test, where the “breathability index” is the ratio between evaporative resistance and thermal insulation. However, it is known, that a standard hotplate measurement, which is performed under equilibrium conditions, does not yield all information, especially when hygroscopic fibers are involved [6,7]. Under transient conditions, studies recommended considering moisture buffering function as an additional comfort characteristic [7,8].

A further important aspect is the skin-sensorial comfort. Various physical methods to assess fabric handfeel by mimicking hand actions have been developed in the last 50 years such as Kawabata, Phabrometer, drape coefficient etc. [9]. A new approach to assess fabric handfeel is offered by the Tissue Softness Analyzer (TSA) by Emtec Electronic GmbH. The method is based on measuring the sonic waves generated by applying a friction on the fabric. [10]. Originally established for the quality control in the hygiene tissue sector, this method is beginning to claim its place in nonwovens and textile sectors recently [11,12]. A rotating part of the TSA, while moving over the fabric surface, generates noise, which is recorded and analyzed into its amplitude signals. In the resulting sonic spectrum, the signal peak at 750Hz and is a measure for the fabric vibration under the rotating part, while the peak at 6500Hz occurs through the vibration on the rotating part moving above the fabric surface itself. Both are correlated with fabric surface parameters. The lower the generated noise, the smoother resp. softer is the fabric. A handfeel value (HF) can be calculated based on the TS values and the fabric weight and thickness.

The aim of this research is to investigate the role of fiber materials in fulfilling textile performance and physiological and sensorial comfort requirements in skin-near workwear clothing.

2. Materials and methods

Knitted fabrics of different construction as in table 1 were investigated.

Table 1. Single jersey fabrics used in this study.

	Blend	Weight [g/m²]	Thickness [mm]	Air permeability (50 Pa) [mm/s]	Drape [%]	R_{et} [m² Pa / W]	Fi [gVapor/ m²]
PES1	Polyester filament	132	0,48	617,9	20,8	1,46	0,1
PES2	Polyester filament	144	0,65	>835	24,3	1,57	0,7
CLY/ PES	Lyocell: Polyester 50:50	145	0,55	>835	22,7	2,13	4,5
CLY	Lyocell:Elastane 94:04	178	0,68	369	30,6	3,08	15,5

Vapor transfer resistance (R_{et}) was measured by a hotplate test according to ISO 110921 [13]. Additionally, moisture buffering capacity (Fi) was measured by the weight difference due to the vapor uptake of the fabrics before and during R_{et} measurement. To measure the drying rate, the fabric was placed on a scale connected to PC for digital weight registration. 500mg deionized water were dropped on the fabric surface and the weight loss by evaporation was measured every minute. Skin-sensorial aspects were investigated objectively using Tissue Softness Analyzer (TSA) as well subjectively by a handfeel panel of 7 female and 3 male experienced assessors. The fabrics were rated on a scale from 1 to 10 based on 3 descriptor pairs (rough/smooth; stiff/drapy; warm/cool) as well as on the over-all "softness" rating. Elasticity indicators of all fabrics were obtained according to EN 14704-1:2005 [14] for testing the elongation rate (%) which is a ratio of the extension of the specimen to its initial length, and the un-recovered elongation rate – the ratio of un-recovered extension after cycling [14]. Testing the changes in the linear dimensions of fabrics after laundering (30^{o} C; natural drying) was done according to the standard ISO 6330 [15].

3. Results & discussion

As shown in table 2 and figure 1, the indicators of elongation for all fabrics are estimated as sufficient for single jersey fabrics. The recovering of a material to its initial size and shape without permanent deformation is essential for product development – taking into account the potential deformations of fabrics and products after extension. Polyester fabrics show the permanent deformation only in weft direction, in turn lyocell blends show more significant deformation in both directions.

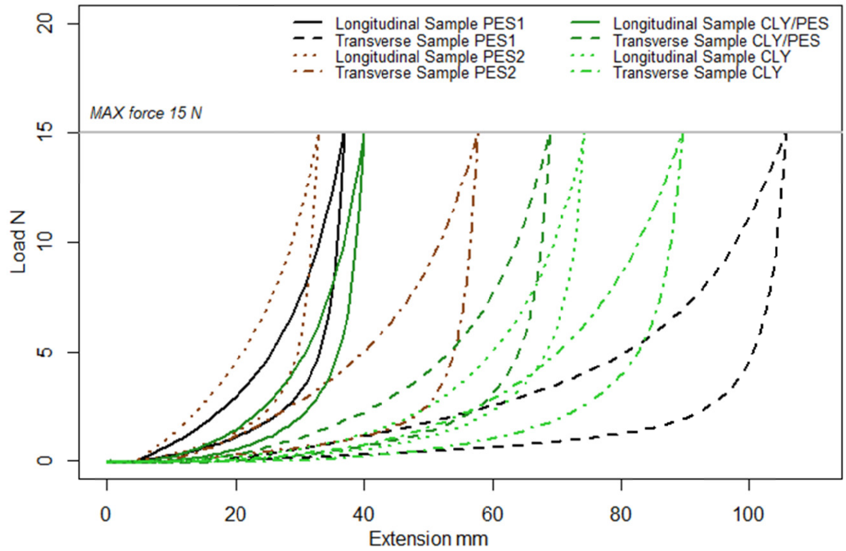

Figure 1. Extension at maximum force on the 5th cycle average 5 specimens.

Polyester materials show no significant shrinkage in either directions (warp and weft). The lyocell and elastane blend indicates 4,5 % of surface shrinkage (table 2). Significant shrinkage may cause the changes of products initial size and form.

Addition tests of fabric propensity to surface pilling were carried out according to ISO 12945 [16]. After certain visual assessment, both polyester fabrics reached 5 points - the highest rating: at all stages of the test no visual changes occurred. Lyocell blend specimens reached 4 points due to the slight surface fluffs (table 2) indicating a possible loss of visual appearance and fabric durability compared to polyester materials.

Table 2. Fabric testing results.

	Elongation [%]		Permanent deformation [%]		Shrinkage [%]	Pilling [7000 cycles]
	↕	↔	↕	↔		
CLY/PES	40%	69%	3%	6%	3,50%	4
CLY	75%	90%	6%	12%	4,50%	4
PES1	37%	106%	0%	6%	0,00%	5
PES2	33%	58%	0%	2%	0,00%	5

R_{et} measurements showed that all fabrics lay within the range of “very breathable” (R_{et}<6) as defined by Hohenstein Institute [17]. Fabrics containing absorbing fibers show slightly higher vapor transfer resistance, as the test typically doesn’t consider the amount of vapor absorbed inside the fabric. On the other hand, Fi values show the dependence of vapor absorption (buffering capacity) on the amount of the cellulosic lyocell fiber in the fabric.

If considered isolated from other properties, a polyester fabric would be misleadingly expected to provide more “breathability” than a cellulosic (see ‘Figure 2’). Therefore, moisture buffering capacity (Fi) was also considered as a relevant criterion expressing the ability of the fabric material to absorb vapor off skin surface and hence supporting cooling mechanism.

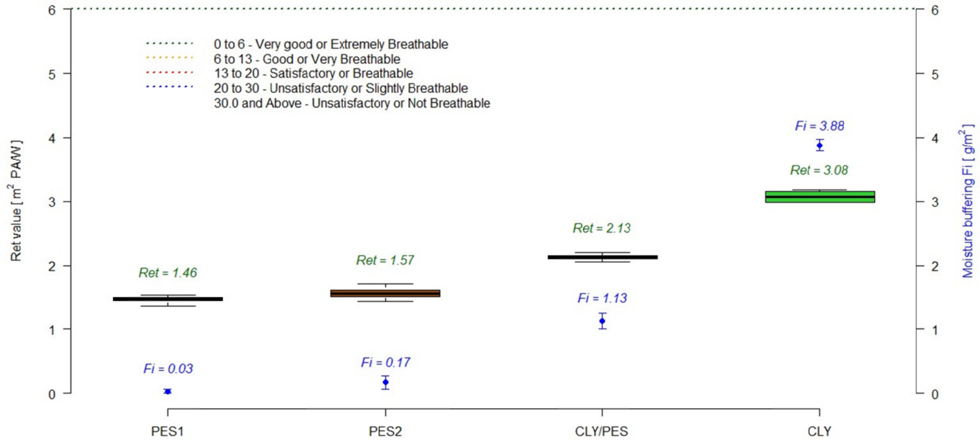

Figure 2. R_{et} values of samples.

The drying rate is shown in 'Figure 3'. This value is related to the evaporation surface provided by the transportation and spreading of the liquid in the fabric surface. Though hydrophilic and water absorbing, cellulosic material tends to swell and narrow the transpiration channels. Non-swelling polyester shows therefore faster drying.

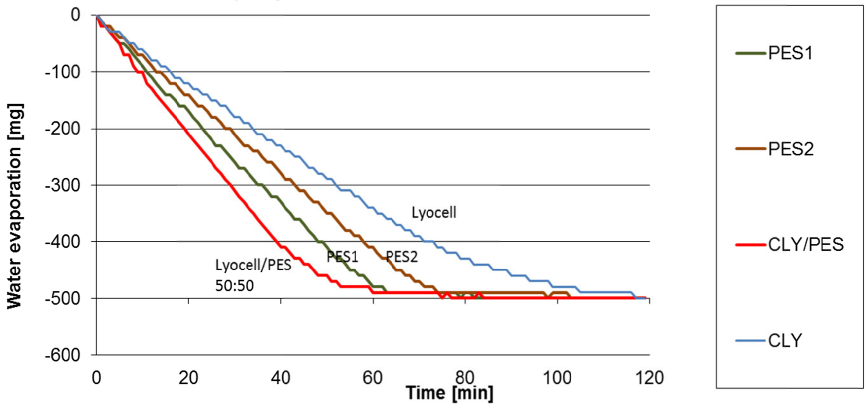

Figure 3. Drying rate.

Interestingly, the yarn blend of lyocell and polyester shows elevated liquid transportation and hence faster drying. This can be attributed to synergy effect of the absorbing cellulose and the polyester fiber acting as spacer between the swelling fibers and keeping transportation channels open. An explanation of this phenomenon is provided in 'Figure 4', where an environmental scanning electron microscopy (ESEM) imaging of the swelling shows the absorption inside the cellulose as a driving force and the spacer-role of the polyester to keep the capillaries open [18].

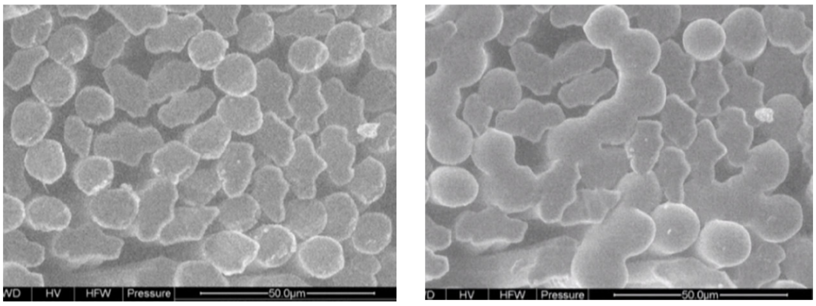

Figure 4. Electron microscopy (ESEM) imaging of a cross-section of a lyocell (round) and polyester (star form) blended yarn in in dry (left) and wet (right) condition [source: Lenzing AG].

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'Figure 5' shows the handfeel objective assessment as received by TSA. Based on the acoustic signals and fabric weight and thickness a handfeel value (HF) is calculated. For this assessment, the basic Algorithm Q1 (light tissues) as provided by the device was used. Lyocell knit showed lower acoustic signal intensity and hence the "softest", the highest HF values, followed by the lyocell/polyester blend. Polyester showed lower HF values.

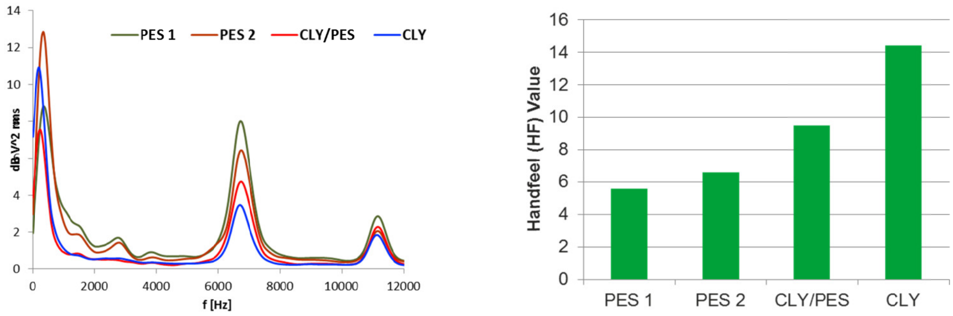

Figure 5. TSA skin sensoric assessment: Sonic spectrum of the fabric surface (left) and the resulting calculated handfeel values HF (right).

Subjective handfeel assessment ('Figure 6') results are more complex. Though abstract smoothness and drape evaluations show no significant differences between the cellulosic and the polyester fabrics, human hand seems to recognize synthetic as such and assessors provide higher all-over ratings for cellulosic materials. This recognition and preference seem to be mostly influenced by the warm/cool perception of the fabric. Moisture absorbing surfaces remove vapor from the hand surface and provide a cool impression at first contact. The polyester non-absorbent surface feels warm.

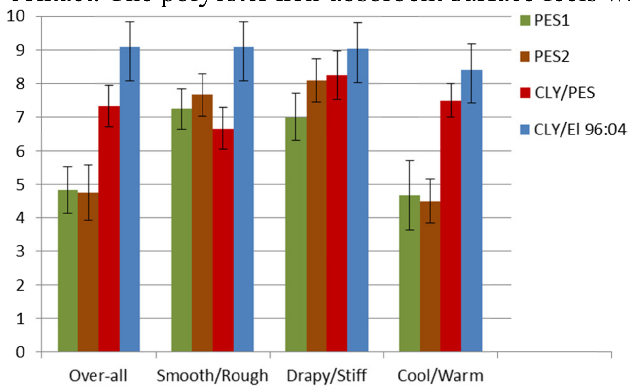

Figure 6. Subjective handfeel assessment by expert handfeel panel.

4. Conclusions

Workwear requirements foresee high textile performance properties of the used fabrics, while comfort and skin sensorial aspects receive less consideration. The requirements for underwear also do not take into account the period of the effective wearing down (months of usage, frequency of washing).

Taking vapor transfer resistance as measured by the hotplate as the sole criterion for "comfort" can be misleading, as it doesn't consider dynamic conditions, where the immediate reaction of the textile on vapor development is relevant. While polyester fabrics are superior in terms of dimensional stability and mechanical resistance and hard to be matched by cellulosics, the lyocell fabrics are superior in terms of moisture buffering and sensorial comfort. An optimum of mechanical performance and physiological and sensorial comfort can be reached in yarn blends. In such blends, an additional benefit is the received synergy effect observed on liquid transportation and drying speed.

To determine the level of comfort, objective as well as subjective methods must be used to determine the correct psychological, physiological and physical factors. It is not possible to obtain a complete quantitative assessment of comfort using isolated test methods. The effects of all five senses, the environment and textiles can have a significant effect on individual perception of clothing comfort.

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