COMFORT AND PROTECTION PROPERTIES OF TENCEL/COTTON BLENDS

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<u>Abstract</u>

Good ultraviolet protection, thermal and moisture transport properties are quite important factors for knitted garments especially for sportswear, outerwear and underwear. These properties may offer higher flexibility in designing such garments with optimized comfort properties. There were few studies concerning knitted fabrics, in particular the influence of fiber materials on ultraviolet protection factor (UPF) and absorption properties. Accordingly, in this study, knitted fabric samples were produced with eight types of natural and regenerated cellulosic yarns using two different fabric types (i.e. single jersey and single jersey with Lycra fabrics). In doing so, Ne 30/1 yarns from cellulosic fibers: 50% Tencel LF / 50% cotton, 67% Tencel LF / 33% cotton, 67% Tencel STD / 33% cotton, 70% bamboo / 30% cotton, 100% bamboo, 100% Modal, 100% Micro Modal and 100% cotton were employed. After that, all fabric samples were subjected to a repeated laundering process (five cycles) under commercial conditions and then flat-dried. The results show that 67% Tencel LF / 30% cotton single jersey fabric has more flexural rigidity than 67% Tencel STD / 30% cotton fabric. Blending Egyptian cotton fibers with bamboo and Tencel as in 70 / 30% bamboo/cotton and 50 / 50% Tencel LF/cotton increase U.P.F characteristic of the produced fabric. Egyptian cotton fabric has the highest thermal insulation compared to the other regenerated cellulosic fabrics.

Introduction

Natural and synthetic cellulose fibres are important for the day-to-day performance of the textile industry. These fibres give apparels the highest comfort: softness, strength and good appearance (Ibbett et al. 2001, Valldeperas et al. 2000 and Nergis et al. 2000).

Cellulose fibres are included in the group of high comfort fibres. One of the essential developments in regenerated cellulosic fibre technology is "TENCEL Fibre Process" which is the recorded trademark of Courtaulds Fibres Ltd Company that uses N-methyl-morphine-N-oxide (NMMO) that is used to dissolve cellulose. The generic name for Tencel is Lyocell (Yilmaz 2010). The reason for its current emergence on the market is that Lyocell fibre has the advantage of being used in a less contaminant spinning process than the one for conventional viscose (Eichinger et al. 1999).

Lyocell is produced from wood pulp using a solvent spinning process. More than 99% of the solvent is recycled within the process, making the fibre production really environmentally accountable. The standard fibre produced is 1.4 dtex, 38 mm, but it can be produced in a range of linear densities and staple lengths. The fibre has a smooth surface and a round cross section, giving high luster in the raw state (Taylor 1998).

The cross-section of Tencel is circular and the surface smooth could be as a result of in the spinning process, the cellulosic fibers undergo quick and high penetration of solvent which consequences in consistent coagulation. The special spinning method of Tencel from conventional viscose fiber causes the forming of very long exclusive crystalline arrangement of its cellulose units which are extremely greatly oriented in the longitudinal axis of the fiber (Xul et al. 2007).

These factors cause significant differences in fibre properties. Tencel fibres have a high degree of crystallinity and are composed of elementary fibrils, oriented nearly parallel to the fibre axis. Between some of the fibrils are long thin voids. When the fibre as a whole in hydrated, swelling occurs, which change the void size shape and orientation. This leaves spaces in the structure across "filled amorphous regions" which the crystalline units are connected by hydrogen bonding (Crawshaw et al 2000 and Taylor 1998).

Lyocell fibres are characterized by their high strength in both dry and wet states. Standard Lyocell fibres, in comparison with other cellulose fibres (viscose), have a higher breaking strength, either wet or dry. In the wet state, Lyocell keeps 85 % of its dry strength and is the only man-made cellulosic fibre which is stronger than cotton at the wet state. Also, enormous differences exist between Lyocell and cotton in both thermal transmission and vapor permeability (Yilmaz 2010 and Eichinger et al. 1999).

Lyocell fibres absorb moisture and have a high modulus that causes small shrinkage in water. Like all cellulose fibres, Lyocell fibre absorbs water perfectly and gives hygienic properties to textile products. Tencel fabrics and garments exhibit superior stability when washed (Yilmaz 2010, Taylor 1998 and Eichinger et al. 1999).

Additionally, fabrics in Tencel are characterized by their silky handle, distinctive drape and fluidity. Tencel is an outstanding alternative to cotton and plays an important position in the textile market for fashion wear, bed linen, towels, etc. Tencel can be successfully used in the production of underwear and apparels. They can also be used in technical textiles, nonwovens and foils. Tencel fibers show huge advantages in adapting to the requirements of the end product both when spun alone and in different blends particularly with cotton. The additions of Tencel to cotton have also a positive impact on yarn mechanical properties specially tenacity and elongation, and on spinning stability (Yilmaz 2010, Eichinger et al. 1999 and website of Rieter lenzing).

Textile fabrics made of Lyocell staple fibres undergo controlled fibrillation and defibrillation by specific finishing processes. Fibrillation is one of the mainly essential physical properties of Tencel fibre. Lyocell fibres are distinguished by their specific ability to fibrillate in a wet state under the impact of external mechanical effects. Fibrillation means the detachment of fibrils along the fabric surface of individual fibres swollen in water, which is caused by mechanical aggression action.

Swelling of the porous regions of the fibre breaks the hydrogen bonds connecting the crystalline units and forces them away from each other. Mechanical action causes the external crystalline regions to break and peel away from the foremost fibre. These peelings are called fibrils. The fibrillation effect can be applied to benefit in generating fabrics of good-looking appearance and attractive handle "peach skin effect" (Ortlepp et al. 1999 and Morgado et al. 2000).

Dziworska et al. 2000 and Ibbett et al. 2001 studied the effect of liquid swelling on the structural rearrangement of Lyocell twill fabrics using different techniques. Fabrics with Tencel fibre wefts were distinguished by superior crease resistance in comparison with fabrics with cotton and viscose wefts. Furthermore, fabrics with Lyocell fibre wefts showed greater air permeability in comparison with fabrics with cotton and viscose wefts.

Bamboo fiber is a kind of regenerated cellulose fiber, generated from bamboo pulp. Bamboo fiber is famous as the natural, green and eco-friendly textile material. Bamboo fiber has some distinctive properties like natural antibacteria and breathable. Bamboo fibres are also important for clothes and other textile applications like filters and medical (Demiroz et al. 2008 and Erdumlu et al. 2008).

While some good studies have been made to investigate and evaluate the properties of Tencel fiber blended yarns, there is a lack of in depth study on the gamut of Tencel fabric properties. Consequently, the aim of this study was to produce knitted fabrics with better comfort properties by utilizing the excellent characteristics of Tencel fibers. The aim of this research is to explore the effect of Tencel fiber properties on some mechanical, ultraviolet protection, thermal and moisture transport properties of knitted fabrics.

Material and Methods

Material:

In this study, 30/1, 50% Tencel LF / 50% cotton, 67% Tencel LF / 33% cotton, 67% Tencel STD / 33% cotton, 70% bamboo / 30% cotton, 100% bamboo, 100% Modal, 100% Micro Modal and 100% Egyptian cotton yarns were used to knit single jersey and single jersey with Lycra knitted fabrics. The properties of the Egyptian cotton Giza 88 used in this research work are given in table 1. Also, the properties of the Tencel, Bamboo, Modal and Micro Modal fibers are cleared in table 2. Moreover, table 3 shows the properties of the yarns applied in this work.

Fabric Manufacture:

The single jersev and single jersev with Lycra samples were produced on the same knitting machine with 24 gauge. Santoni S.P.A., SJ-B model, 18-inch diameter, 54 feeders and with total number of needles equal to 1356. The loop length was kept constant at 2.8 mm value for the all knitted samples. Also, the varn input tension was kept constant at a value equal to 5 CN. After that, all fabric samples were subjected to a repeated laundering process (five cycles) under commercial conditions and then flat-dried. The specifications of all the knitted fabric samples are shown in table 4.

Methodology:

The influence of the experimental factors: fiber material and fabric structure on the fabric mechanical, ultraviolet protection, thermal and moisture transport properties was evaluated for significance using the analysis of variance.

Fabric Testing:

After leaving the finished samples 72 hours in standard conditions (Relative humidity = 65 + 2% - Temperature = 20 + 2 c'), the fabric properties were measured. The fabric flexural rigidity, abrasion resistance, ultraviolet protection factor, air permeability, thermal insulation and water vapor permeability was evaluated in accordance with the standards of ASTM D1388, ASTM D4158, AS/NZS 4399, ASTM D737, ASTM D1518 and ASTM E96 respectively.

	Table 1. Cotton Fiber Properties								
	length	length Uniformity Strength Elongation MIC Rd +b Trash M							Maturity
		%		%				count	%
Cotton Giza 88	35.1	87.3	45	3.78	3.96	67.1	11.5	40	85

Table 2	. Regenerated Fibers Properties						
oer type	Fiber length	Fiber Fin					

Fiber type	Fiber length	Fiber Fineness
Tencel (LF-STD)	38mm	1.3 dtex
Bamboo	38mm	1.6 dtex
Modal	39mm	1.3 dtex
Micro modal	39mm	1 dtex

	Cotton 100%	Bamboo 100%	Modal 100%	Micro Modal	Bamboo / Cotton	Tencel LF/ cotton	TENCEL LF/ cotton	TENCEL STD/Cotton
				100%	(70:30%)	(50:50 %)	(67:33%)	(67:33%)
Ne	30/1	30/1	30/1	30/1	30/1	30/1	30/1	30/1
TPI	19.6	19	20.3	19.7	21.16	18.15	20.29	20.29
Irregularity (CV %)	9.52	9.23	10.8	11	12.93	8.00	11.65	9.41
Thin places (-50%)	2	0	0	0	0	0	0	0
Thick places (+50)	18	14	6	9	11	26.3	18	7
Neps	67	45	20	38	32	39.6	57	25
CN/Tex	17.16	13.11	26.4	27	14.61	20.53	21.59	20.19
Elongation (%)	5.22	12.66	11	11.5	7.26	4.73	5.04	7.04
Hairiness (H)	6.23	4.7	6.4	6	4.87	5.26	6.18	5.93

Table 3. Yarn Properties

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Sample		Fabric			Fabric 2	Thickness	Width		
no	Fiber Type	Structure	Courses/cm	Wales/cm	Weight "g/m "	''mm''	"cm"		
1	%50 Tencel LF %50 cotton	SJL	36	18.8	336.5	0.768	39		
2	100% Bamboo	SJL	37.6	21.2	346	0.917	34		
3	%67 Tencel STD %33 cotton	SJL	37.2	18.4	348.5	0.783	39		
4	%70 bamboo %30 cotton	SJL	38.4	18.8	364.5	0.81	38		
5	%67 Tencel LF %33 cotton	SJL	34.4	18	349.5	0.813	40		
6	100% Modal	SJL	34	20.4	398	0.785	36		
7	100% Cotton	SJL	34.4	18	295	0.726	40		
8	100% Micro Modal	SJL	38.4	20	411	0.826	36		
9	100% Micro Modal	SJ	20	16	141.5	0.4415	46		
10	100% Cotton	SJ	24	15.6	177	0.577	45		
11	100% Bamboo	SJ	22.8	16	154.5	0.4295	44.5		
12	100% Modal	SJ	21.2	14.8	133	0.559	45		
13	%70 bamboo %30 cotton	SJ	23.6	16.4	177.5	0.4326	44.5		
14	%67 Tencel STD %33 cotton	SJ	23.2	16.4	168.5	0.582	46.5		
15	%50 Tencel LF %50 cotton	SJ	22.4	16	160	0.502	45		
16	%67 Tencel LF %33 cotton	SJ	22.4	16.4	163	0.542	46		

Table 4.Specification and Properties of the Knitted Fabric Samples

Results and Discussion

The influence of the fiber material and fabric type on some fabric properties was discussed for significance using R statistical program by applying the ANOVA analysis as shown in table 5.

It is obvious from the statistical and experimental evaluation that all the studied properties: flexural rigidity, abrasion resistance, ultraviolet protection factor, air permeability, thermal insulation and water vapor permeability values are significantly affected at 5% significance level by fiber type and fabric type.

	Table 5. ANOVA test results								
_	Fabric Properties								
Process factors	Thermal	Air	U.P.F	Abrasion	Fabric Flexural	Water Vapor			
	Insulation	Permeability		Resistance	Rigidity	Permeability			
Fiber type	S	S	S	S	S	S			
Fabric Type	S	S	-	S	S	S			

S = Significant at 95% confidence level, NS = Non significant at 95% confidence level

Flexural Rigidity:

Single jersey fabric produced from 100% cotton has higher flexural rigidity values than the other studied fabrics, figure 1. Also, the variance analysis obviously clears that the fiber material does play an important role in influencing flexural rigidity of the studied fabrics. In addition, it's noticed that 100% bamboo, 100% modal and 100% micro modal fabrics have a lower flexural rigidity than 50% Tencel LF / 50% cotton, 67% Tencel LF / 30% cotton, 67% Tencel STD / 30% cotton and 70% Bamboo / 30% cotton. This case could be due to the blending regenerated fibers with cotton fibers decrease the flexural rigidity of the resultant fabric. As well, the cotton yarns have the greatest hairy level and flexural rigidity, so, the knitted loops cannot be compressed by far in this manner increasing the fabric thickness. Also, the fabrics produced from cotton fiber have a higher g/m2 and thickness than others knitted from other regenerated fibers. Furthermore, the Tencel, bamboo, micro modal yarns have the least hairy level and flexural rigidity than cotton.

Additionally, 67% Tencel LF / 30% cotton fabric has more flexural rigidity than 67% Tencel STD / 30% cotton fabric. The contribution of the fibers inside the yarn for the Tencel LF blend could be the reason of that trend.

On account of its higher thickness, the single jersey with lycra fabrics demonstrates extra flexural rigidity than single jersey samples. This tendency is clarified by the effect of the more material which contained in this fabric and makes the fabric thickness to be heightened.



Fig.1: Flexural rigidity at different fiber types for different fabric types.

Abrasion Resistance:

According to the statistical analysis and figure 2, there is a significant relationship between the fiber type and the fabric abrasion resistance. Figure 2 indicates the relationship between fabric abrasion resistance and fiber type. Where, it is observed that single jersey 70% Tencel LF /30 % cotton and 50% Tencel LF / 50% cotton have a higher abrasion resistance than 100% cotton fabrics. This is due to the highest tensile strength of Tencel fiber against cotton which makes it to be more durable during abrasion test. The Tencel fibers have merits of smoothness and softness against cotton fiber.

The surface fibers of standard Tencel STD are fibrillated to produce a luxurious, soft-touch fabric with a peach skin surface and this is the usual recognized quality of the fiber. So, Fibrillation features of Tencel STD are observed. As a result, during the abrasion resistance test, the resultant friction force between the abraded paper and the Tencel STD fabric will be high, which decreases the abrasion resistance of this fabric.

The micro fibers constitute the micro modal fabric affect negatively the abrasion sustainability of this finest fabric. These fibers are finer and as a result are more prone easily to be destroyed under abrasion force.

Single jersey with Lycra fabric has a higher abrasion resistance than single jersey fabric without Lycra. This is due to the higher density and thickness of this fabric.



Fig.2: Fabric abrasion resistance at different fiber types for different fabric types.

Ultraviolet Protection Factor (U.P.F):

From figure 3, it could be seen the values of U.P.F "ultraviolet protection factor" for single jersey with respect to fiber type. It is observed that blending Egyptian cotton with Tencel and bamboo fibers as obvious in all blended ratios, improves U.P.F characteristic of the final produced fabric. The possible reason of this is the the highest ultraviolet protection property of the *naturally Egyptian cotton*. Also, the higher thickness and cover factor of cotton fabricscould be enhanced this finding.

By investigating U.P.F of 70% Bamboo / 30% cotton with, 67% Tencel LF / 30% cotton and 67% Tencel STD / 30% cotton results, the Bamboo fibers have extra merits of resisting ultraviolet radiations compared to Tencel fibers. With comparing 100% bamboo with 100% modal and 100% micro modal values, the same conclusion could be reached.

Also, the fibrils covered the 67% Tencel STD / 30% cotton fabric gives more layer of protection against U.P.F than 67% Tencel LF / 30% cotton single jersey fabric.

There was no U.P.F chart for single jersey with Lycra fabric, because values of U.P.F are above the measuring limits of the device. The explanation of this behavior could be referred to the lycra fabrics have a higher cover factor and density than single jersey fabric.



Fig.3: U.P.F at different fiber types for different fabric types.

Air Permeability:

The results indicate that the air permeability of the single jersey 100% modal, 100% micro modal and 100% Bamboo samples is higher than the others produced from or blended with cotton as noticed in figure 4. Cotton convolutions are ribbon-like twists that characterize cotton. When cotton fiber matures, lumen dries out and collapses which makes secondary wall start to twist (Website of Physical Structure of Cotton Fiber). These fibers convolutions besides extra cotton yarn hairiness enhance the air resistance of the cotton samples. Furthermore, blending cotton with Tencel fibers worsen the air permeability level of the produced fabric with the knowledge that the Tencel fiber has it's naturally air conditioning.

The air permeability reduces with the increase of the fiber fineness. Therefore, the air permeability for the 100% micro modal fabrics is lower than the100% modal fabrics having the coarsest fibers. It is normally acknowledged that the air permeability of a fabric depends on the air porosity that affects its openness. The more porosity the fabric, the extra the porous fabric is acquired. For the 100% micro modal, the space inside the yarn reduces due to the existence of the high number of fibers /yarn cross-section. Thus, the fabrics knitted from these yarns have less open and permeable structures and consequently less air permeability values.

The air permeability value of the 100% bamboo fabric is lower than that of the modal sample. This may be partly attributed to the fact that bamboo fibers have some striated cracks distributed over the longitudinal surface, and they have many voids in their cross section (Xu1Y. et al). This might have heightened the friction between the fiber surface and the air, creating a reduction in the air permeability of fabrics knitted from these fibers.

Single jersey with Lycra fabrics has less air permeability than normal single jersey fabric. This is because Lycra reduces air gabs in fabric.



Fig.4: Air permeability at different fiber types for different fabric types

Thermal insulation:

The relation between the fabric thermal insulation after fifth wash with the fiber type is shown in figure 5. The high hairiness degree of cotton fiber can result in high thermal insulation for the single jersey samples. The higher hairiness level of cotton yarns makes air pockets inside the fabric which as a result decrease the thermal conductivity of these fabrics. Also, blending Tencel, bamboo with cotton fibers lessens thermal insulation of the produced fabric.

The thermal insulation of 70% Bamboo / 30% cotton is higher than 67% Tencel LF / 30% cotton and 67% Tencel STD / 30% cotton and 50% Tencel LF / 50% cotton. The Bamboo fibers have feature of insulating property compared to Tencel fibers. Also, it could be noticed that the 100% micro modal fabric has the least thermal insulation which gives an indication of its coolness sensation.

Besides, single jersey with Lycra fabric has less thermal insulation than single jersey sample which related to the highest quantity of material contained in these fabrics. the Lycra threads reduces the air gabs in the fabric, where the fabric thermal insulation property depends on the air quantity contained inside the fabric, "the more air gabs in fabric, the more thermal insulation".



Fig.5: Thermal insulation at different fiber types for different fabric types.

Water vapor permeability:

Water vapor permeability is the ability of the fabric to transfer the perspiration in the form of moisture vapor throughout it. This property is measured by observing the amount of water vapor passing through a square meter of fabric per twenty four hours. A fabric with less water vapor permeability is incapable to transfer enough moisture, leading to sweat accumulation and discomfort. From figure 6, it could be seen the values of fabric water vapor permeability with respect to fiber type for different fabric types. It is observed that as the knitted fabric produced from 100% micro modal single jersey fabric has the highest water vapor permeability. This fiber type is the best to get the superior water vapor permeability.

The one of the possible clarification for this may be that the fiber fineness of the micro modal affects the smoothness of its fabrics. The decrease in the fiber fineness guarantees smoother fabrics. A smooth surface increases the contact area of a fabric with a skin and consequently it influences on its sensation level and provides cool feeling effect.

The overall water vapor transport is a sum of the water vapor transmission throughout air space existing as voids formed at yarn interstices, and air between fibers and yarns and moisture absorbed by fibers (Prahsarn, C). In a fabric composed of significantly finer fibers, more fibers can be accommodated in a given space than an equal volume of coarse fibers (Chaudhari S. S., et al). The hydrophilic nature of the Tencel fibers for the 67% Tencel LF / 30% cotton and 67% Tencel STD / 30% cotton against 70% Bamboo / 30% cotton yarns might have enhanced the easy passage of water vapor molecules through the yarn interior. This might be the reason for the high water vapor transfer rate obtained for these Tencel blended fabrics.

Moreover, the water vapor transfer rate was mainly affected regain of the fabrics. Accordingly, the highest water vapor transfer rate, obtained for 100% Bamboo fabric, could be attributed to its highest regain. Also, single jersey with Lycra fabrics has less water vapor permeability than single jersey fabric.



Fig.6: Water vapor permeability for different fiber types at different fabric types.

Summary

In this research paper, some mechanical, ultraviolet protection and absorption properties of single jersey and single jersey with Lycra knitted fabric produced from 50% Tencel LF / 50% cotton, 67% Tencel LF / 33% cotton, 67% Tencel STD / 33% cotton, 70% bamboo / 30% cotton, 100% bamboo, 100% Modal, 100% Micro Modal and 100% cotton fibers.

It is obvious from the statistical and experimental evaluation that all the studied properties: flexural rigidity, abrasion resistance, air permeability, thermal insulation and water vapor permeability values are significantly affected by fiber type and fabric type. Ultraviolet protection factor is significantly only by only

The single jersey fabrics produced from 100% bamboo, 100% modal and 100% micro modal fabrics have a lower flexural rigidity than 50% Tencel LF / 50% cotton, 67% Tencel LF / 30% cotton, 67% Tencel STD / 30% cotton and 70% Bamboo / 30% cotton. Also, blending regenerated fibers with cotton fibers decrease the flexural rigidity of the resultant fabric. The cotton yarns have highest flexural rigidity; so, the knitted loops cannot be compressed by far in this manner increasing the fabric thickness. Moreover, the Tencel, bamboo, micro modal yarns have the least hairy level and flexural rigidity than cotton.

Additionally, 67% Tencel LF / 30% cotton fabric has more flexural rigidity than 67% Tencel STD / 30% cotton fabric. The contribution of the fibers inside the yarn for the Tencel LF blend could be the reason of that trend. Because of its higher thickness, the single jersey with lycra fabrics gives extra flexural rigidity than single jersey samples. The more material contained in this fabric could be the reason.

70% Tencel LF /30 % cotton and 50% Tencel LF / 50% cotton have a higher abrasion resistance than 100% cotton fabrics. The highest tensile strength of Tencel fiber against cotton makes it to be more durable during abrasion test.

Fibrillation features of Tencel STD are observed. Consequently, during the abrasion resistance test, the resultant friction force between the abraded paper and the Tencel STD fabric will be high, which decreases the abrasion resistance of this fabric.

Blending Egyptian cotton with Tencel and bamboo fibers improves U.P.F characteristic of the final produced fabric. The *naturally Egyptian cotton*, higher thickness and cover factor of cotton fabrics could be enhanced this finding. Bamboo fibers have extra merits of resisting ultraviolet radiations compared to Tencel fibers as cleared in all studied 70/30 blended ratios. The same conclusion could be reached for all 100% studied fibers. Fibrils covered the 67% Tencel STD / 30% cotton fabric gives more layer of protection against U.P.F than 67% Tencel LF / 30% cotton fabric.

There was no U.P.F chart for single jersey with Lycra fabric, because values of U.P.F are above the measuring limits of the device. The Lycra fabrics have a higher cover factor and higher density than plain single jersey fabric.

Air permeability of the 100% bamboo, 100% modal and 100% micro modal samples is higher than the others produced from cotton. Cotton fiber convolutions besides extra cotton yarn hairiness lessen the air permeability of the cotton samples. Furthermore, blending cotton with Tencel fibers decreases the air permeability level of the produced fabric although the merit of the Tencel fiber for its naturally air conditioning.

The air permeability reduces with the increase of the fiber fineness. Therefore, the air permeability for the 100% micro modal fabrics is lower than the100% modal fabrics having the coarsest fibers.

The high hairiness degree of cotton fiber can result in high thermal insulation for the single jersey samples. Also, blending Tencel, bamboo with cotton fibers reduces thermal insulation of the knitted fabric.

The thermal insulation of 70% Bamboo / 30% cotton is higher than 67% Tencel LF / 30% cotton and 67% Tencel STD / 30% cotton and 50% Tencel LF / 50% cotton. The Bamboo fibers have feature of insulating property compared to Tencel fibers. Also, it could be noticed that the 100% micro modal fabric has the least thermal insulation which gives an indication of its coolness sensation.

Besides, single jersey with Lycra fabric has less thermal insulation than single jersey sample which related to the highest quantity of material contained in these fabrics.

A fabric with less water vapor permeability is incapable to transfer enough moisture, leading to sweat accumulation and discomfort. Knitted fabric produced from 100% micro modal single jersey fabric has the highest water vapor permeability. This fiber type is the best to get the superior water vapor permeability.

The hydrophilic nature of the Tencel fibers for the 67% Tencel LF / 30% cotton and 67% Tencel STD / 30% cotton against 70% Bamboo / 30% cotton yarns enhanced the easy passage of water vapor molecules through the yarn interior. This might be the reason for the high water vapor transfer rate obtained for these Tencel blended fabrics.

Acknowledgements

I am thankful to the co-operation of El-Nasr Clothing and Textile Company (*KABO*) for the contribution to the experimental part of the study and the realization of it. Special thanks to Mediterranean Textile Company "MTC", CSA textile and the Egyptian Spinning & Weaving Company, for providing us with the regenerated cellulosic yarns.

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