(REFEREED RESEARCH)

PERFORMANCE PROPERTIES OF REGENERATED CELLULOSE FIBERS

REJENERE SELÜLOZ LİFLERİNİN PERFORMANS ÖZELLİKLERİ

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ABSTRACT

Three generations of regenerated cellulose fibers, such as viscose, modal and lyocell fibers are among the most important fibers from the point of textile and environmental aspects due to the natural structures and properties. Different production process and production conditions for conventional viscose, modal and new lyocell fibers cause differences in the structure of the fibers in spite of the same chemical compositions. In this study, the structural properties of viscose, modal and lyocell fibers and yarns were investigated. Besides, the influence of structural characteristics of the fibers on the performance properties of knitted fabrics such as pilling, bursting strength, color efficiency and thermo physiological properties were determined. It was determined that due to the fiber structure, pilling tendency of viscose fabric is higher compared to lyocell and modal grey fabrics. Since the tensile strength of lyocell fiber is higher, fabric bursting strength of lyocell fabric is higher than the modal and viscose fabrics. As the thermal conductivity of lyocell fabric is higher, it gives cool feeling compared to viscose and modal fabrics. The highest colour efficiency is obtained from lyocell fabrics.

Key Words: Viscose, Modal, Lyocell, Performance properties, Thermo physiological property.

ÖZET

Viskon, modal ve lyocell lifleri rejenere selüloz liflerinin üç versiyonu olup, doğal yapıları ve özellikleri nedeniyle tekstil ve çevre açısından en önemli liflerdendir. Konvansiyonel viskon, modal ve yeni lyocell liflerinin farklı üretim prosesleri ve üretim koşulları, aynı kimyasal yapıya sahip olmalarına rağmen lif yapılarında farklılığa yol açmaktadır. Bu çalışmada, viskon, modal ve lyocel lif ve ipliklerinin yapısal özellikleri araştırılmıştır. Ayrıca, liflerin yapısal özelliklerinin, bazı örme kumaşların boncuklanma, patlama mukavemeti, renk verimliliği ve termo fizyolojik konfor özellikleri üzerine etkisi incelenmiştir. Viskon liflerinden üretilen kumaşların boncuklanma eğiliminin lif yapısal özellikleri nedeniyle lyocel ve modal liflerinden üretilen ham kumaşlara göre daha fazla olduğu belirlenmiştir. Lyocel liflerinin mukavemetinin daha yüksek olması nedeniyle kumaş patlama mukavemetinin de daha yüksek olduğu belirlenmiştir. Lyocell liflerinden üretilen kumaşların ısıl iletkenliği daha fazla olup, viskon ve modal liflerine göre ilk dokunuşta daha serin hissi verdiği belirlenmiştir. Renk verimliliği en yüksek lyocel liflerinden üretilen kumaşlarla elde edilmiştir.

Anahtar Kelimeler: Viskon, Modal, Lyocel, Performans özellikleri, Termo fizyolojik özellikler.

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1. INTRODUCTION

Due to the growing population, demand for the textile products and therefore textile raw material have been gradually increasing. As the life standards of the people change according to the new global world, the requirements of more quality and more various textile products are also improving. Due to the lack of natural fibers because of the growing fiber consumption per person, various researches were done in the field of manufacturing fibers similar to natural fibers with respect to chemical and physical structure and after these attempts; regenerated synthetic fibers were derived from the natural polymers by special chemical treatments.

The cellulosic regenerated fibers have come a long way. Cupro, acetate and viscose fibers were developed more than 100 years ago. The use of high tenacity viscose and modal fibers shows that these cellulosic regenerated fibers have not only come a long way but are well-established nowadays. This type of fiber - belonging to the third generation of cellulosic man-made fibers - enables the textile industry to expand its already wide range of applications in function (1).

Cellulose is a raw material with a wide variety of uses in the chemical industry for producing man-made textile fibers. Commercial methods of manufacturing man-made cellulosic fibers include viscose, cuprammonium, and several new alternative processes. Conventional regenerated cellulosic, that is viscose fibers are generally produced by the indirect viscose process, while high tenacity modal fibers are produced using a modification of the basic procedure. Viscose production is based on deriving cellulose with carbon bisulphide. Only recently have new processes appeared, mainly due to considerable environmental problems with the viscose process. New regenerated cellulosic fibers that is lyocell fibers are produced with a more environmentally friendly procedure from a solution of non-derivative cellulose in a solvent spinning process, where the cellulose is dissolved directly in the organic solvent N-methylmorpholine-Noxide, without the formation of derivatives. Therefore, lyocell process includes considerably less production steps and the tedious production of viscose spinning mass is avoided. Although all regenerated cellulosic fibers have the same chemical composition, they differ in density, molecular mass, degree of polymerization, supermolecular arrangement, degree of crystallinity and orientation (2,3).

Attributes of lyocell include good drape, diverse range of tactile properties, ease of blending with other fibers, high wet modulus, good wash stability resulting in low shrinkage and environmental friendliness (4).

Thermal properties belong to the most important features of textiles. For instance, thermal insulation determines the elementary function of garments. However, most of the studies characterizing thermal properties of textiles are focused on steady-state thermal properties such as thermal conductivity and thermal resistance. Just recently, attention is being paid also to transient thermal properties like thermal diffusivity and thermal absorbtivity. Effective thermal insulation properties are determined not only by the mentioned thermo physical parameters of fabrics, but also by their structural parameters such as bending and shearing rigidity, which in complex characterize the fabric drape. (5).

In this study, it was aimed to conduct a comparative study of the performance properties such as pilling, bursting strength, color efficiency and thermo physiological properties of the 1x1 interlock knitted fabrics produced from viscose, modal and lyocell yarns. The yarns were produced in the same linear density (20 tex). The utilized regenerated cellulose fibers were also in the same linear density (1.3 dtex) and cut length. In order to explain the differences between the measured properties of the fabrics, cristallinity and mechanical and cross sectional properties of the fibers were also determined.

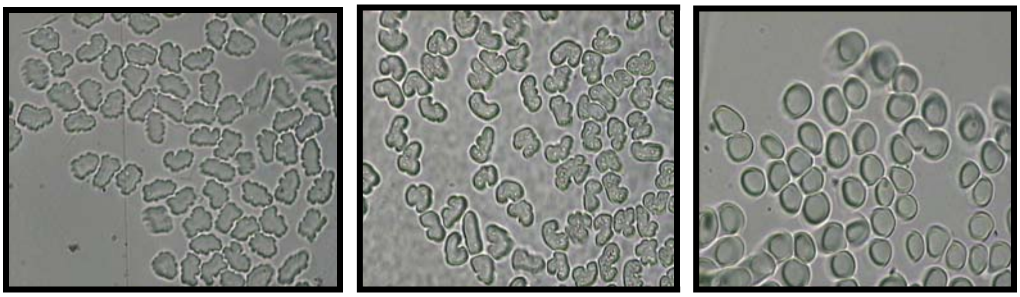
2. EXPERIMENTAL

Regenerated cellulosic fibers (viscose, modal, lyocell) used in the study which differ structurally due to the different production processes are all staple fibers produced by Lenzing AG Austria, and the specifications of the fibers are given in Table 1.

The tenacity of the fibers increases from viscose to lyocell fibers, whereas the highest elongation values belong to the viscose fibers. The wet tenacity is extremely important for processing cellulosic regenerated fibers. Viscose fibers show the lowest wet tenacity level. This means that for pretreatment and dyeing processes, viscose fabrics cannot be processed on machines which exert strong tensile stress on the material. Modal fiber is considerably more stable, but the residual shrinkage

Table 1. Specifications of the regenerated cellulose fibers

	Viscose	Modal	Lyocell
Lineer density (dtex)	1.3	1.3	1.3
Tenacity (cN/tex)	24	34	40
Elongation (%)	18	12	15
Tenacity in wet state (cN/tex)	12	20	34
Elongation in wet state (%)	21	13	17
Water retention ability (%)	90	60	70
Natural moisture content (%)	13	12.5	11.5
Volume swelling in water (%)	88	63	67
Cristallinity (%)	25	25	40



(a) (b) (c)

Figure 1. Cross sections of the (a) viscose, (b) modal and (c) lyocell fibers

Table 2. Cross sectional parameters of the fibers

	Viscose	Modal	Lyocell
Area (μm^2)	119.209	107.7548	103.1005
Equivalent diameter (µm)	12.19916	11.49585	11.40661
Perimeter (µm)	45.50421	44.84851	37.42616
Circularity (%)	74.6441	69.0249	92.8869

values would also be too high. Lyocell fibers show the highest wet tenacity level among the cellulosic regenerated fibers, and could be processed without any problems on such machines. As the water retention ability is the highest in viscose fibers, swelling occurs too much compared to the modal and lyocell fibers.

The cross sections of the fibers were taken by using microtone and Leica optical microscope with the magnification of 100. The area, equivalent diameter, perimeter and circularity of the fibers were calculated by LUCIA software by using the cross sectional pictures of the fibers as shown in Figure 1 and Table 2.

The ring spun yarns were produced from viscose, modal and lyocell fibers in the same linear density, 20 tex and at the same production conditions. The knitted 1x1 interlock fabrics were manufactured at the same knitting machine and by using the same production settings in order to eliminate the production effects. The knitted fabrics were dyed with the same reactive dyeing recipe.

The produced knitted fabrics were investigated with respect to their performance properties. All tests were done after conditioning the fabrics in standard atmospheric conditions (20°C±2, %65±2 relative moisture). The pilling tendencies of the grey and dyed fabrics were tested according to ISO 12945-2 standard on Martindale pilling & abrasion tester and the test samples were evaluated according to EMPA standard photographs (SN 198525-K3) by five textile-related people and 1-5 evaluation scale was used, where 1 means "excessive pills formation" and 5 means "no pills". The pilling test was repeated 5 times. Bursting strengths of the grey and dyed fabrics were tested according to ISO 13938-2 with 5 repetitions by using James Heal Truburst instrument.

Thermal resistance, thermal conductivity and thermal absorptivity of the knitted fabrics produced with regenerated cellulose fibers were measured by means of the computer controlled ALAMBETA commercial instrument, which enables fast measurement of both steady state and transient state thermal properties of any plain compressible non-metallic materials like textile fabrics, plastic or rubber foils, paper products etc (6,7,8). Five measurements were done from the different parts of the grey fabrics. The instrument measures directly transient and steady-state heat flow density passing through the tested fabric, as well as the fabrics thickness. The rest of the thermal parameters like thermal conductivity, thermal resistance, thermal absorptivity and thermal diffusivity are calculated form the mentioned basic parameters using a special program (6,7). Six parameters were determined: stich as thermal conductivity λ, thermal resistance *r*, thermal diffusivity *a*, thermal absorptivity *b*, the ratio of maximal to stationary heat flow density p, and the peak heat flow density q_{max} measured after the contact of the fabric with a skin.

Thermal conductivity λ (W/m.K) is a measure of heat flow density passing through the material in case of 1°C temperature difference between the sides of the material. Thermal conductivity can be expressed as:

$$\lambda = \frac{q.h}{\Delta T}(Wm^{-1}K^{-1})$$

Where q = heat flow density (W m^{-2}), ΔT = temperature difference (K), h = thickness (m).

Thermal diffusivity a (m^2/s) characterizes the velocity of propagation of thermal impulse through the material, and can be expressed as follows:

$$a = \frac{\lambda}{\rho.c}(m^2s^{-1})$$

Here, ρ means density (kg m^{-3}) and c is specific heat of fabric (J/ kgK)

As already mentioned, in last decades, most of the studies dealing with thermal comfort properties of textiles were devoted to the measurement of steady-state thermal properties such as thermal conductivity and thermal resistance, but later, Kawabata & Yoneda pointed out the importance of new transient property, so-called 'warm-cool feeling' also (5). This property tells us whether a user feels 'warm' or 'cool' at the first short contact of the fabric with human skin. In 1987, Hes introduced the term of 'thermal absorptivity' as a measure of the 'warm-cool feeling' of textiles (9).

Thermal absorptivity b ($Ws^{1/2}/m^2K$) can be expressed as:

$$b = \sqrt{\lambda\rho c} \quad (Ws^{1/2}m^{-2}K^{-1})$$

The heat flow passing between the textile samples and measuring head during thermal contact is measured by a special sensing system, of which thermal inertia is similar to that of human skin. The thermal contact feeling is strongly affected by fabric structure and composition.

Thermal resistance r (m^2K/W) is connected with fabric thickness by the following relationship:

$$R = \frac{h}{\lambda}(m^2KW^{-1})$$

The color efficiencies of the reactive dyed knitted fabrics were tested via a spectrophotometer under daylight D65 conditions.

3. RESULTS AND DISCUSSION

Pilling tendency

The pilling tendencies of the grey and dyed knitted fabrics were evaluated subjectively by using 1-5 scale and with five textile related people and the average values are given in Table 3.

Table 3. Pilling degrees of the grey and dyed knitted fabrics

Fiber type	Grey knitted fabric	Reactive dyed knitted fabric
Viscose	1-2	3
Modal	2	2
Lyocell	2-3	2-3

Pill formation is a common problem, mainly in knitted fabrics made from both synthetic and natural fibers, man-made cellulosics, and their blends because consumers will not accept undesirably pilled garments (10).

Comparing the pilling degrees of the three grey fabrics out of regenerated cellulose fibers, it can be stated that fabrics made of viscose yarns have the most pilling tendency and fabrics made of modal and lyocell fabrics have the pilling values 2 and 2-3 respectively. The pilling degrees of the grey and reactive dyed knitted fabrics are the same for the fabrics made of modal and lyocell yarns which means lower pilling tendency. As all the yarn and fabric production conditions are all same, the differences of the pilling tendencies of the fabrics are due to the fiber characteristics and especially due to the fiber cross section. Since the circularity of the viscose fibers is less among the regenerated cellulose fibers, the viscose fibers are prone to curl and form pills on the fabric surface much more compared to modal and lyocell fibers. After dyeing process, due to the compensating effect of the mechanical actions, which causes more fuzz formation and high fiber-

fiber friction in wet state, which retards pill formation; there is no change after reactive dyeing in the pilling degrees of fabrics made of lyocell and modal fibers.

Bursting strength

The bursting strength values of the fabrics measured by pneumatic method are given in Figure 2. As it can be seen from Figure 2, the fabrics made of first generation regenerated cellulose fibers have the lowest bursting strength. The second and third generation regenerated cellulose fibers are superior to viscose fibers with respect to tenacity and therefore the bursting strength values of the modal and lyocell fabrics are also higher compared to viscose fabrics.

Color Efficiency

The color efficiencies of the knitted fabrics were tested via a spectro-photometer under daylight conditions (D65). The CIELAB coordinates (L,a,b), color remission and color efficiencies of the dyed fabrics are given in Table 4.

Although the fabrics were dyed in the same dyeing conditions, the brightness of the fabrics increases in turn of lyocell, viscose and modal fabrics. Despite of the high cristallinity of the lyocell fibers, the most color efficiency is obtained with lyocell fabrics due to the higher circularity of the lyocell fiber structure.

Thermal properties

The thermal related properties measured by the ALAMBETA instrument are given in Table 5.

As it can be seen from Table 5, the lyocell fibre structure exhibits the coolest warm-cool feeling (the highest level of thermal absorbtivity of b). Nevertheless, the thermal results the fibers do not differ too much.

4. CONCLUSION

In this paper, selected properties of interlock knitted fabrics produced from viscose, modal and lyocell yarns were investigated. Since all the yarn and fabric production conditions are same, the results reveal the effects of fiber structures on the performance properties of the fabrics. The following conclusions can be drawn on the basis of the study:

- Despite of the same chemical composition of all regenerated cellulose fibers, cross sectional and physical properties differs from each other, which affect the yarn and fabric performances.
- The pilling tendency of the viscose fabric is higher since the circularity of the viscose fibers is the less among the regenerated cellulose fibers, the viscose fibers are prone to curl and form pills on the fabric surface much more compared to modal and lyocell fibers.
- Due to the better tenacity of modal and lyocell fibers compared to viscose fiber, bursting strength values of the modal and lyocell fabrics are higher respectively.
- Due to the higher circularity of lyocell fibers, the most colour efficiency is obtained with lyocell fibers.
- As regards the thermal comfort properties, just relatively small differences among the studied knitted fabrics were found. However, it can be stated that the coolest feeling belongs to lyocell fabric and therefore for summer cloths it can be preferred much more compared to other regenerated cellulosic fabrics.

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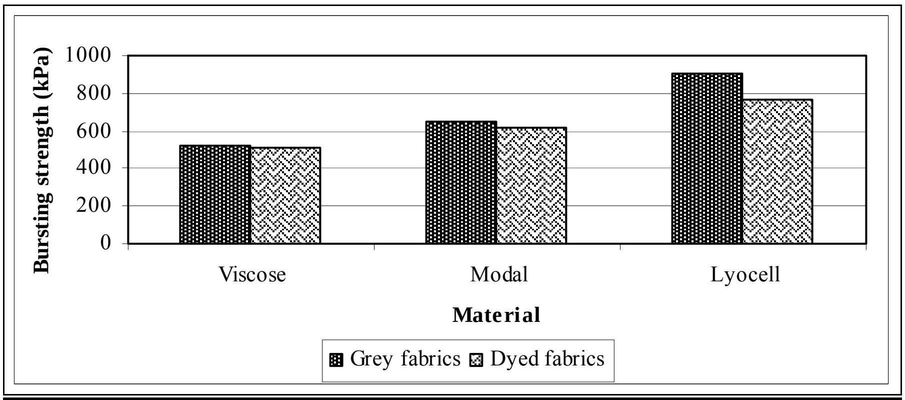

Figure 2. Bursting strength values of the fabrics

Table 4. CIELAB colour coordinates and efficiencies of the dyed fabrics

	L	a	b	R %	K/S
Viscose	46.63	-9.86	-35.69	5.17	8.69
Modal	47.89	-9.07	-34.14	6.36	6.88
Lyocell	43.09	-6.30	-35.55	4.92	9.18

Table 5. Results of the thermal insulation properties of the knitted fabrics

	Viscose	**Modal**	**Lyocell**
Thermal conductivity coefficient - λ ($W.m^{-1}.K^{-1}$)	36.10 $x10^{-3}$	35.26$x10^{-3}$	38.60 $x10^{-3}$
Thermal diffusivity coefficient – a ($m^2.s^{-1}$)	0.094 $x10^{-6}$	0.099$x10^{-6}$	0.099 $x10^{-6}$
Thermal absorptivity - b ($W.m^{-2}.s^{1/2}.K^{-1}$)	120	112	123
Thermal resistance - r ($K.m^2.W^{-1}$)	16.30$x10^{-3}$	17.42$x10^{-3}$	16.40$x10^{-3}$
Thickness - h (mm)	0.59	0.61	0.63
Peak heat flow density- q_{max} ($KW.m^{-2}$)	0.79	0.73	0.77

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