# CHARACTERISTICS OF THE YARNS SPUN FROM REGENERATED CELLULOSIC FIBERS

# REJENERE SELÜLOZ LİFLERİNDEN ÜRETİLEN İPLİKLERİN ÖZELLİKLERİ

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**ABSTRACT**

In today's textile industry, as an alternative to the fibers used for many years, many natural, regenerated or synthetic fiber types have emerged. Researches show that the use of new fiber and their blends provides positive results so that products with more comfortable and better properties can be obtained. At this point, it was seen that determining the yarn properties which affect the product characteristics before the production takes place has important advantages. In this study, regenerated fibers such as bamboo, viscose, modal, lyocell, promodal, micromodal were used. The yarns were spun 100 % and 50% cotton blends of these fibers and physical properties of the yarns were examined and statistically analyzed.

**Keywords:** Bamboo, viscose, modal, lyocell, promodal, micromodal, cotton, regenareted cellulosic fiber, yarn characteristics

**ÖZET**

Günümüzde tekstil alanında, yıllardır kullanılan liflere alternatif olarak gerek doğal gerek rejenere ya da sentetik birçok lif çeşidi ortaya çıkmıştır. Yapılan araştırmalar daha konforlu ve daha iyi özelliklere sahip ürünlerin elde edilebilmesi için yeni lif karışımlarından yararlanılmasının olumlu sonuçlar sağladığını göstermektedir. Bu noktada mamul özelliklerine etki eden iplik özelliklerinin, üretiminden önce belirlenmesinin önemli avantajlar sağladığı görülmektedir. Bu çalışmada, yeni nesil rejenere liflerden; bambu, viskon, modal, lyocell, promodal, mikromodal lifleri kullanılmıştır. Bu liflerden % 100 olarak ve 50% pamuk karışımlarından iplikler üretilmiş ve bu ipliklerin fiziksel özellikleri incelenerek istatistiksel olarak analiz edilmiştir.

**Anahtar Kelimeler:** Bambu, viskon, modal, lyocell, promodal, mikromodal, pamuk, rejenere selülozik lif, iplik özellikleri

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## 1. INTRODUCTION

As the fiber consumption rates are analyzed, different types of cellulosic regenerated fibers have been produced in recent years because natural fibers can not meet the demands of people because of increase in population and change of people's clothing needs. The importance of these fibers has been increasing due to the fact that textile materials produced from regenerated fibers have soft handling and aesthetic appearance, ease of workability, desired brightness, suitability to blend with other fiber types (1).

Cellulosic based regenerated fibers with different properties have been produced especially in recent years by improving production techniques. Regenerated fibers can be used by blending with natural fibers and can also be used alone depending on the application area. These fibers are used to reduce the inadequate quantity of natural fibers, they are also used to impart certain properties to textile products which can not be given with natural fibers (2).

Viscose was the first regenerated cellulosic fiber produced from wood pulp by viscose processes based on wet spinning. It has a lower dry and wet tenacity but higher elongation compared to cotton. The polymerisation degree of the macromolecules of the regenerated cellulose fibers is lower than that of the natural fibers. This situation causes the wet strength of these fibers to be lower than the dry strengths. Moreover, the short cellulose macromolecules of the regenerated cellulose fibers do not settle properly in the fiber, which causes 60-65% of the fibers to be amorphous regions, which leads to low breaking strengths (3).

Efforts are being made to overcome these disadvantages of cellulosic regenerated fibers. The production of new generation viscose fibers which have high tenacity to normal viscose fibers has become increasingly important. Normal viscose fibers are the first, modal fibers are the second, and lyocell fibers are the third generation representatives of the regenerated cellulose fibers (3).

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 (4). In the modal fibers, the fiber elements are more uniform and firmly located in the fiber cross -section and do not show the inner / outer difference. The average polymerization degree is higher than the normal viscose fibers, therefore modal has a higher dry and wet tenacity.

Lyocell fibers are produced by dissolving the cellulose raw material in NMMO solvent, which can be recovered completely after the process. In addition to environmentally friendly production methods of lyocell fibers, another positive aspect is that they have advantageous of mechanical properties (2). Lyocell fibers attract attention with high molecular orientation and high crystallinity grade, ecological production technique in comparison with viscose fibers (3). This special property is reflected in high wet and dry fiber strength and contrary to expectations in sorption properties similar to those of viscose fibers (4). It also has advantages such as warmth, softness and comfort; in addition to its good performance and dimensional stability (5).

Promodal fiber is a new generation fiber with a homogeneous blend of 60% modal and 40% lyocell fibers. Lyocell fiber has higher fibrillation that is expressed in the form of fragmentation of microfibrils from the flament surface because of the separation of hydrogen bond molecules that form lateral ligaments of fibrils (6). The degree of fibrillation of modal fiber is lower than that of lyocell (7). For this reason, it is aimed to remove the adverse properties of lyocell by using modal in promodal fibers.

Micromodal fibers are produced as a new generation of regenerated fibers with a high durability of 1 dtex with a high degree of polymerisation. The luxurious appearance, softness and fullnes hand characteristics and high comfort of clothing compared to conventional fibers cause microfibers to be preferred in recent years.

Bamboo fiber is obtained from bamboo pulp, which is extracted from the bamboo stem and leaves by wet spinning, including a process of hydrolysis-alkalisation and multi-phase bleaching that is quite similar to that of viscose rayon fiber. A bamboo textile product provide the desirable properties. It is breathable, cool and extremely soft; it has a pleasant lustre; it rapidly absorbs water and is antibacterial. Bamboo and viscose rayon fiber properties are similar in terms of dry tenacity, elongation at break, and moisture absorption; on the other hand, the wet tenacity value of bamboo seems slightly higher than that of viscose rayon. Bamboo also has a lower tenacity than cotton both in dry and wet state. Modal has higher dry and wet tenacity than regular rayon and bamboo fiber. Contrary to cotton, the tenacity of all regenerated fibers decreases in wet state. Among all fibers subjected to comparative research, lyocell has the highest tenacity in both dry and wet states due to higher degree of crystallinity and molecular orientation compared to bamboo and viscose rayon fibers (8,9).

Many researchers investigated fiber properties of the regenerated cellulosic fibers (4, 7, 10, 11-14). Some of the papers are related with the yarn properties of the regenerated cellulosic yarns.

Gökdal (15) examined the properties of yarns and fabrics produced from regenerated cellulosic fibers obtained from bamboo plants. In the first part of the work, bamboo/cotton yarns at different blend ratios and different numbers were produced and the quality values of these yarns and the effect of blending ratios on yarn parameters were analyzed. They revealed that 100% bamboo yarns have the best quality. In bamboo / cotton fiber blended yarns, it has been found that as the amount of bamboo in the blend decreases, the quality values decrease.

Erdumlu and Özipek (9) investigated 100% regenerated bamboo yarns of six different counts produced from bamboo fiber using ring yarn spinning technology. The physical parameters of related yarns were tested, and the results were evaluated according to the parameters of 100% viscose rayon, as well as 100% carded and combed ring spun yarn in Uster statistics.

Canoglu and Yukseloglu (16) investigated the hairiness values of polyester/viscose blends in five blend ratios spun by using ring spinning system. As a result, within the produced yarns the worse hairiness was obtained on the viscose (100%) yarns.

Erdumlu et al. (17) investigated cotton, viscose and cotton-modal blended yarns spun on vortex, ring and open-end spinning systems. Yarn samples were converted into knitted fabrics to determine the physical performances of the yarns in knitted form. They revealed that vortex spun yarns have lower hairiness and better pilling resistance over ring and open-end rotor spun yarns. Viscose rayon yielded more satisfactory results in the vortex spinning system in terms of yarn strength, particularly in coarser yarn counts and hairiness.

Kılıç and Okur (18), compared structural, physical and mechanical properties of cotton-Tencel and cotton-Promodal blended ring, compact and vortex spun yarns. Effects of different blend ratios on a yarn's structural, physical and mechanical properties were examined by using 100% cotton, 100% regenerated cellulosic fiber and 67%–33%, 50%–50%, 33%–67% cotton-regenerated cellulosic fiber blended yarns. They found that an increasing ratio of regenerated cellulosic fiber content in the blend decreases unevenness, imperfections, diameter and roughness values; on the other hand it increases breaking force, elongation, density and shape values. They also resulted that effect of blend type was statistically significant for many yarn properties, mainly, while cotton-Promodal yarns have better physical properties, cotton-Tencel yarns have better mechanical properties.

Prakash et al. (19) investigated bamboo/cotton blended ring-spun yarn properties by spinning these yarns in three yarn counts in different blend ratios. It was revealed that the quality of 50%/50% bamboo/cotton blended yarn is most closely comparable with that of 100% cotton yarn. They found that the quality of the yarns decreases by increasing the bamboo content in the yarns.

Şekerden (20) studied on the properties of the 100% bamboo yarn, which was ring-spun under industrial conditions, bamboo/cotton with varying blend ratios and 100% cotton yarns. The unevenness, tenacity and elongation at break of the yarns were measured. The effect of yarn type on these properties was analysed. Their results indicated that the ratio of bamboo fiber in the blend had an effect on the properties of yarn.

In this study, unlike the previous researchs, most of the regenerated cellulose fibers were produced by 100% and blending 50% cotton in ring spinning system. The physical properties of the yarns were compared with each other to determine how the properties of the yarns have changed when cotton blend was used.

## 2. MATERIALS AND METHODS

In this study bamboo, viscose, lyocell, modal, promodal, micromodal and cotton fibers were used. They were provided in sliver form. After two passage drawing frame they were brought to roving form using by Ingolstadt F4301 roving frame machine. Blending process with cotton fiber was done at the drawing frame machine. Ne 30 yarns in 100% regenerated and blended 50 % with cotton fiber were spun in Rieter G30 spinning machine at 10000 rpm. 13 type of yarns with twist coefficient value of $\alpha_e$= 3,6 were produced. The fiber properties were given in Table 1 and yarn production line was given in Table 2.

**Table 1.** Fineness and lenght values of the fibers used in the study

| Material | Fiber fineness (dtex) |
|---|---|
| Cotton | 1,70 |
| Bamboo | 1,40 |
| Viscose | 1,65 |
| Lyocell | 1,40 |
| Modal | 1,30 |
| Promodal | 1,30 |
| Micromodal | 1,00 |

**Table 2.** Yarn production machine line

| Machine | Technical properties | |
|---|---|---|
| 1.passage draw frame | Rieter SB-D 15 Draw frame | Speed: 800 m/min<br>Sliver count: 4,5 ktex<br>Doubling: 6, draft:6,4 |
| 2.passage draw frame | Rieter RSB-D 35 Draw frame | |
| Roving frame | Ingolstadt Zinsel FL 670 Roving frame<br>Roving Ne: 1,18-1,42 - T/m: 45-46<br>Speed: 2400 rpm<br>Draft: 7,6 | |
| Yarn spinning machine | Rieter G30 Ring spinning machine (230 spindle)<br>Spindle speed: 10.000 rpm Draft : 26,5 T/m :772 | |

All the yarns were conditioned in standard atmosferic conditions (20 °C and 65 ±4% relative humidity). The breaking tenacity and elongation values of the yarns were measured by using Lloyd LRX according to the TS EN ISO 2062 standards. The unevenness values of the yarns were measured by an Uster Tester 5 S800. The tests were performed at 400 m/min speed for 1000 m yarn. The measured values are mass coefficient variation (CVm), thin places (-%40), thick places (+%35), neps (+%200), yarn diameter (2DØ) (mm) and hairness (H).

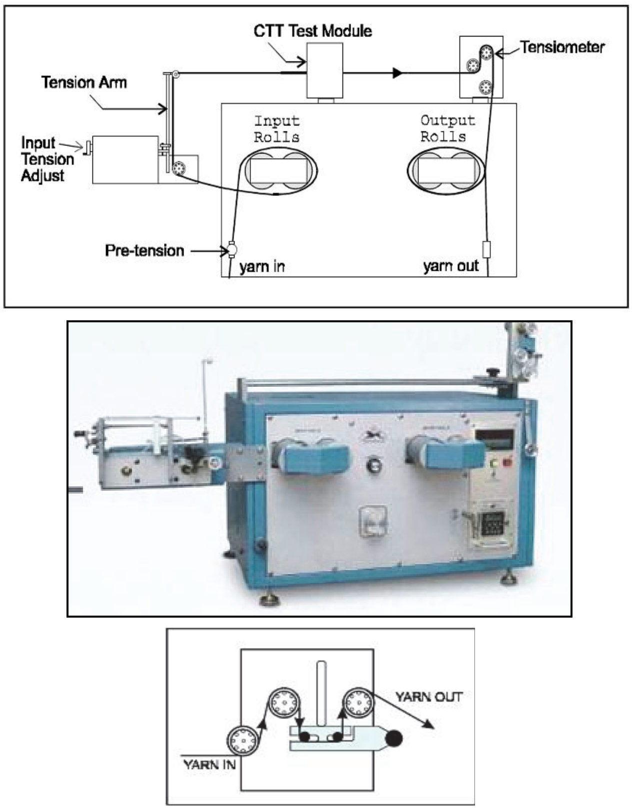


**Figure 1.** CTT instrument (a), its elements (b) and the placement of yarn during the yarn to pin friction test(c)

Friction properties of the yarns were tested by using CTT (Constant Tension Tester) instrument (Figure 1). The machine provides constant input tension on the yarn as it runs during the test. In Yarn-to-Pin Friction Test the test yarn is allowed to run at a certain test speed over friction surfaces such as stainless steel or ceramic pin with a specified wrap angle. The yarns are passed through over the stainless steel with a specified wrap angle 180° at a 100 m/min test speed (21-22). The coefficient of yarn to pin friction (μ) is calculated according to the following formula (23). Since input tension ($T_{in}$) and the wrap angle (θ) are constant and during the test, the coefficient friction changes with the change in the output tension ($T_{out}$). Therefore, the factors which influence the output tension of the yarn, also affects the coefficient of yarn to pin friction of the yarn (24-25)

$$\mu = \frac{\ln(\boldsymbol{T}_{out} - \boldsymbol{T}_{in})}{\theta}$$

After all measurements, Student–Newman–Keuls (SNK) tests (a nonparametric post-ANOVA test) were conducted to determine whether the efects of fiber type on the yarn properties are statistically significant at the 95% confidence level (p<0.05).

## 3. RESULTS AND DISCUSSION

### 3.1 Breaking load and elongation results

Yarn breaking load and elongation test results were given in Figure 2 and Figure 3 and statistical evaluation of the values according to the yarn type was given in Table 3 and Table 4 respectively.

As the breaking load values are examined; the yarn produced from the bamboo fiber has the lowest values whereas lyocell yarns highest. The bamboo yarn also has the highest elongation due to the high elasticity of this fiber. Bamboo fiber has lower crystallinity compared to viscose and lyocell. Therefore, the higher ratio of the amorphous regions in the structures causes the lower strength value.

The breaking load values of the yarns produced from viscose and cotton fiber are very close to each other; however, there was a large difference between the breaking elongation values. This is due to the fact that viscose fiber has a higher elastic structure than cotton. The main reason why the viscose yarn has lower strength is that the amorphous region in the macromolecular structure is larger than the crystalline region.

Modal yarns have higher breaking load than viscose yarns as expected. Lyocell fibers have a high degree of polymerisation compared to modal and viscose fibers due to their long molecular chains, so that the strength of the yarns produced from these fibers is high. The elongation value of lyocell yarns is lower than those of other regenerated fibers, as the molecular orientation and the fiber length ratio are inversely proportional.

When the the breaking load values of the blended yarns were examined, given in Table 3, it has been found that the yarns other than the lyocell blend exhibit similar behavior to 100% regenerated yarns. While the lowest breaking load value appears in the cotton-bamboo blend yarn, it was determined that the yarn spun from the cotton-micromodal mixture had the highest value. All the blended yarns strenght values were found to be lower than 100 % regenerated yarns.

It has been observed that the cotton-modal blended yarn has the highest elasticity value and the cotton-lyocell has the lowest. Similiar to the breaking load results elongation test values were found lower for blended yarns because of lower elongation of cotton fiber than all of regenerated fibers.

**Table 3.** Student–Newman–Keuls test results related with yarn breaking load

| Type | | Subset | | | | | | | | Subset | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | 1 | 2 | 3 | 4 | 5 | 6 | | N | 1 | 2 | 3 | 4 |
| Bamboo | 50 | 2,3930 | | | | | | 50%Cotton-50% Bamboo | 50 | 1,9857 | | | |
| Viscose | 50 | | 2,5916 | | | | | 50%Cotton-50% Viscose | 50 | | 2,1204 | | |
| Cotton | 50 | | | 2,7566 | | | | 50%Cotton-% 50 Lyocell | 50 | | 2,1779 | | |
| Promodal | 50 | | | | 3,0983 | | | 50%Cotton-50% Promodal | 50 | | | 2,3764 | |
| Micromodal | 50 | | | | | 3,4540 | | 50%Cotton-% 50 Modal | 50 | | | | 2,4990 |
| Modal | 50 | | | | | 3,5612 | | 50%Cotton-50% Mikromodal | 50 | | | | 2,582 |
| Lyocell | 50 | | | | | | 4,0212 | | | | | | |
| Sig. | | 1,000 | 1,000 | 1,000 | 1,000 | 1121 | ,000 | Sig. | | 1,000 | ,321 | 1,000 | ,150 |

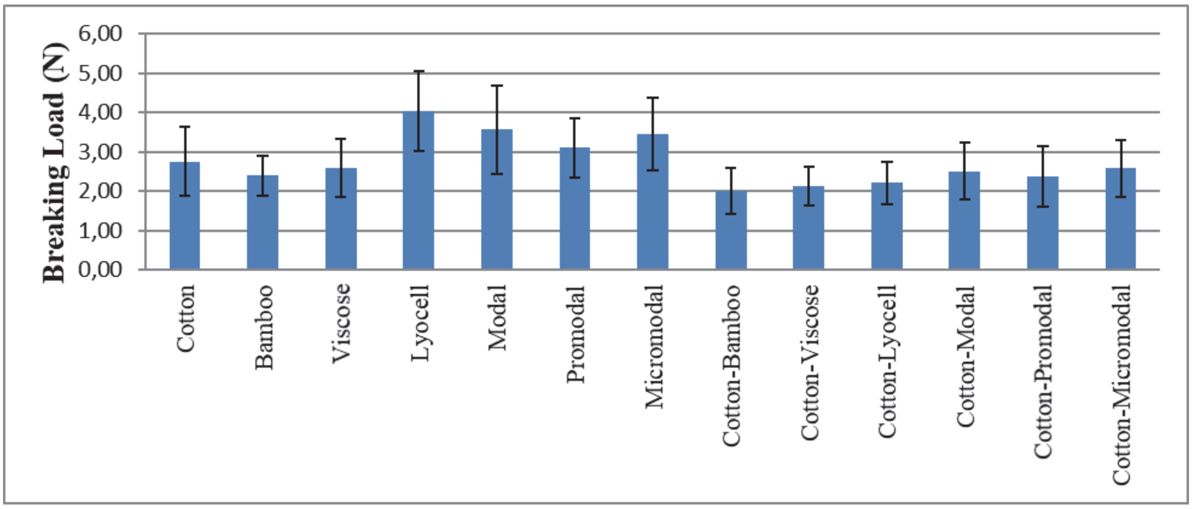


**Figure 2.** Breaking load values of the yarns

**Table 4.** Student–Newman–Keuls test results related with yarn elongation

| Type | N | Subset 1 | 2 | 3 | 4 | 5 | | N | Subset 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cotton | 50 | 7,8236 | | | | | % 50 Cotton-50% Lyocell | 50 | 8,2767 | | |
| Lyocell | 50 | | 12,4832 | | | | % 50 Cotton-50% Promodal | 50 | 8,7065 | 8,7065 | |
| Promodal | 50 | | 12,6815 | | | | % 50 Cotton-50% Bamboo | 50 | | 9,0309 | |
| Micromodal | 50 | | | 14,0400 | | | % 50 Cotton-50% Viscose | 50 | | | 9,5729 |
| Modal | 50 | | | 14,7594 | | | % 50 Cotton-50% Micromodal | 50 | | | 9,6919 |
| Viscose | 50 | | | | 21,4732 | | % 50 Cotton-50% Modal | 50 | | | 9,7777 |
| Bamboo | 50 | | | | | 22,8840 | | | | | |
| Sig. | | 1,000 | ,686 | ,144 | 1,000 | 1,000 | Sig. | | ,073 | ,175 | ,667 |

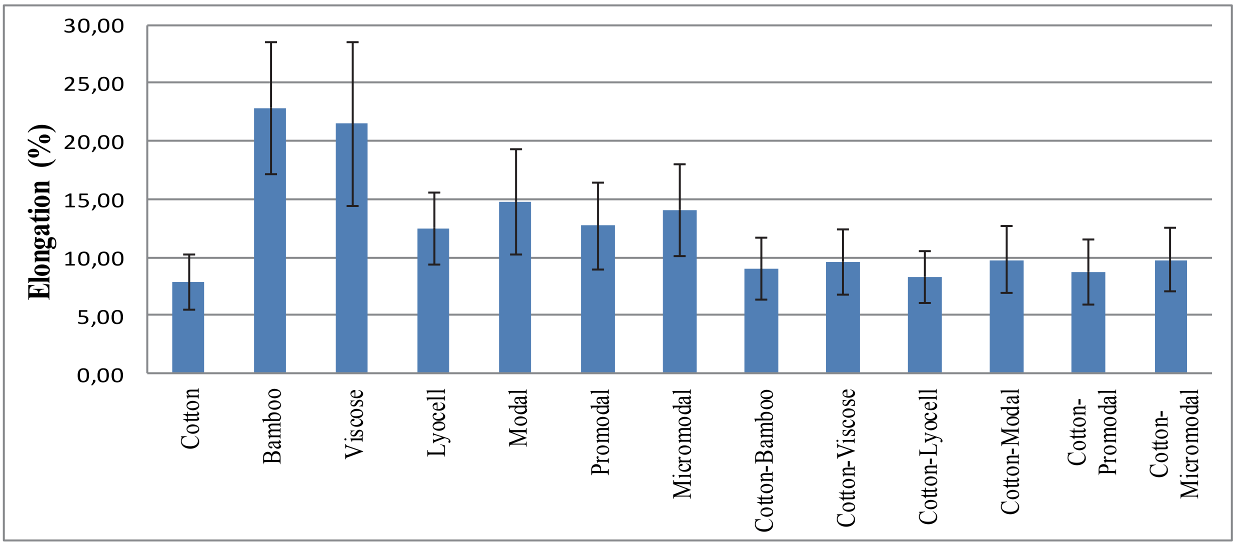


**Figure 3.** Elongation values of the yarns

### 3.2 Yarn irregularity test results

#### 3.2.1. Unevenness (CVm)

Yarn irregularity test results were given in Figure 4 and statistical evaluation of the coefficient of variation in mass (CVm) values according to the yarn type was given in Table 5.

As Table 5 was examined, it was found that the yarn produced from the micromodal fiber (1 dtex fineness) had the lowest unevenness, while the yarn produced from bamboo and cotton fibers showed the highest unevenness. Unevenness in yarns spun from fine fibers is low. Here, the unevenness values of the yarns produced from the thin fibers are found to be lower than those produced from the thick fibers.

**Table 5.** Student–Newman–Keuls test results related with yarn CVm values

| Type | N | Subset 1 | 2 | 3 | 4 | | N | Subset 1 |
|---|---|---|---|---|---|---|---|---|
| Micromodal | 10 | 10,1590 | | | | 50% Cotton-50% Viscose | 10 | 11,4160 |
| Modal | 10 | | 11,0070 | | | 50% Cotton-50% Micromodal | 10 | 11,5280 |
| Promodal | 10 | | 11,2820 | | | 50% Cotton -50% Modal | 10 | 11,9880 |
| Viscose | 10 | | 11,5820 | 11,5820 | | 50% Cotton -50% Promodal | 10 | 12,2750 |
| Lyocell | 10 | | | 11,9360 | 11,9360 | 50% Cotton -50% Bamboo | 10 | 12,6950 |
| Cotton | 10 | | | 12,0680 | 12,0680 | 50% Cotton -50% Lyocell | 10 | 12,7320 |
| Bamboo | 10 | | | | 12,4800 | | | |
| Sig. | | 1,000 | ,054 | ,121 | ,072 | Sig. | | ,250 |

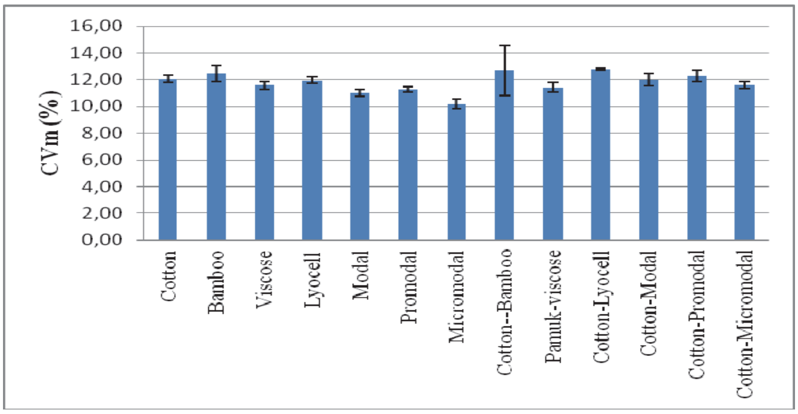


**Figure 4.** CVm values of the yarns

The difference between modal and promodal was not found statistically significant. At the same time there is no statistically significant difference between viscose, lyocell and cotton yarns. As the blended yarn values were examined, the differences between the CVm values of the cotton-blended yarns also were not found statistically significant.

### 3.2.2. Imperfections (Thin, thick places and neps)

Yarn imperfection test results were given in Figure 5-7 and statistical evaluation of these values according to the yarn type was given in Table 6-8.

Table 6 shows that the bamboo yarns have the highest values for thin places. The micromodal yarn has the lowest thin place value together with the lowest CVm value. The difference between micromodal, modal, promodal, lyocell and viscose was not statistically significant. Thin places results of the blended yarns were found similar to the CVm values.

As the thick places results were examined, similar to the thin places values, the micomodal yarn gave the lowest and cotton yarn gave the highest values.

It was observed 50% cotton -50% lyocell yarns highest thick places among the blended yarns. There is no statistically significant difference between yarns composed of viscose, bamboo, micromodal and modal in cotton blends.

**Table 6.** Student–Newman–Keuls test results related with thin places (-40% /1000m)

| Type | N | Subset | | | | | Subset | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | | N | 1 | 2 | 3 |
| Micromodal | 10 | 7,6000 | | | 50%Cotton-50% Micromodal | 10 | 14,7000 | | |
| Modal | 10 | 11,8000 | | | 50% Cotton-50% Viscose | 10 | 19,3000 | 19,3000 | |
| Promodal | 10 | 12,9000 | | | 50% Cotton -50% Promodal | 10 | 26,9000 | 26,9000 | |
| Lyocell | 10 | 15,9000 | | | 50% Cotton -50% Bamboo | 10 | 32,2000 | 32,2000 | |
| Viscose | 10 | 19,7000 | | | 50% Cotton -50% Modal | 10 | | 41,0000 | 41,0000 |
| Cotton | 10 | | 33,9000 | | 50% Cotton -50% Lyocell | 10 | | | 58,5000 |
| Bamboo | 10 | | | 55,5000 | | | | | |
| Sig. | | ,287 | 1,000 | 1,000 | Sig. | | ,201 | ,075 | ,051 |

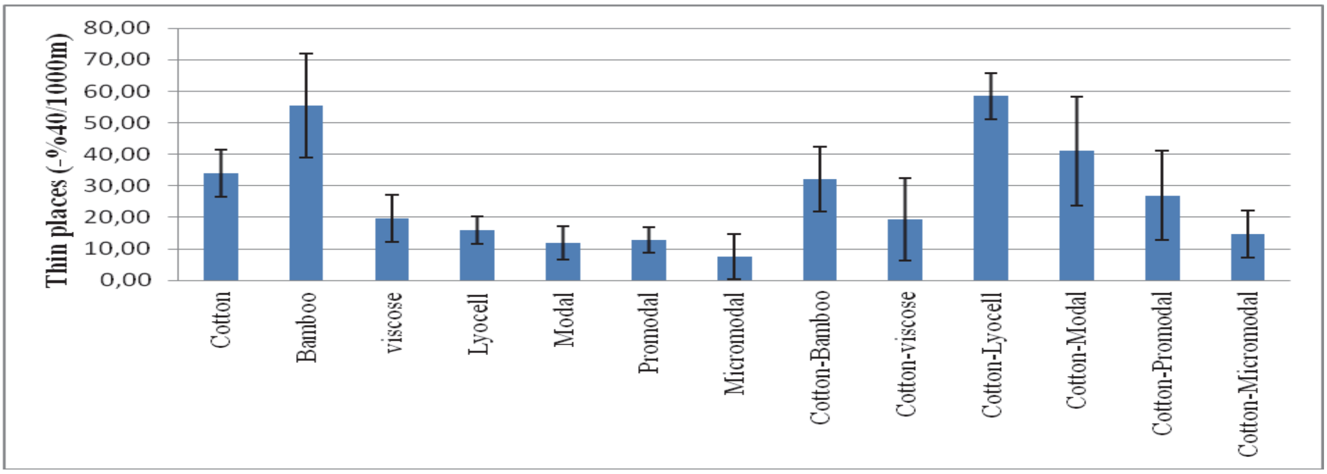


**Figure 5.** Thin places (-%40 /1000m) values of the yarns

**Table 7.** Student–Newman–Keuls test results related with thick places (+35% /1000m)

| Type | N | Subset | | | | | N | Subset | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | | | 1 | 2 | 3 |
| Micromodal | 10 | 39,7000 | | | | 50% Cotton-50% viscose | 10 | 134,4000 | | |
| Modal | 10 | 57,1000 | 57,1000 | | | 50% Cotton -50% bamboo | 10 | 174,3000 | | |
| Viscose | 10 | | 80,9000 | | | 50% Cotton -50% micromodal | 10 | 186,8000 | 186,8000 | |
| Promodal | 10 | | 97,3000 | | | 50% Cotton -50% modal | 10 | 209,0000 | 209,0000 | |
| Bamboo | 10 | | | 146,7000 | | 50% Cotton -50% promodal | 10 | | 262,2000 | 262,2000 |
| Lyocell | 10 | | | 167,0000 | | 50% Cotton -50% lyocell | 10 | | | 313,6000 |
| Cotton | 10 | | | | 251,3000 | | | | | |
| Sig. | | ,304 | ,051 | ,232 | 1,000 | Sig. | | ,097 | ,053 | ,109 |

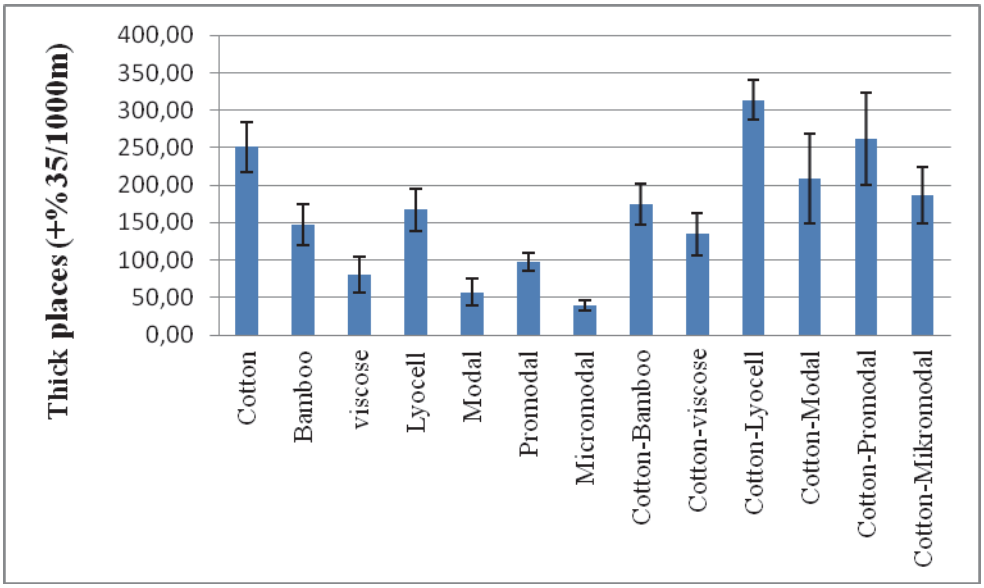


Figure 6. Thick places (+ %35 /1000m) values of the yarns

When the neps results of yarns were examined, cotton, lyocell and promodal yarns have the highest values and 50% Cotton-50% Lyocell yarn has highest neps value as similar to the result of thick places. High fibrillation characteristic of the lyocell fibers can be considered as the reason of the highest amount of neps.

**Table 8.** Student–Newman–Keuls test results related with neps (+200% /1000m)

| Type | N | Subset | | | | N | Subset | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | | | | | |
| Modal | 10 | 22,0000 | | | 50% Cotton-50% Modal | 10 | 42,3000 | | |
| Viscose | 10 | 22,1000 | | | 50% Cotton-50% Micromodal | 10 | 51,0000 | | |
| Micromodal | 10 | 28,0000 | | | 50% Cotton-50% Bamboo | 10 | 52,3000 | | |
| Bamboo | 10 | | 46,8000 | | 50% Cotton-50% Viscose | 10 | 84,7000 | | |
| Cotton | 10 | | | 59,4000 | 50%Cotton-50% Promodal | 10 | | 160,5000 | |
| Lyocell | 10 | | | 62,5000 | 50% Cotton-50% Lyocell | 10 | | | 271,2000 |
| Promodal | 10 | | | 64,2000 | | | | | |
| Sig. | | ,459 | 1,000 | ,606 | Sig. | | ,646 | 1,000 | 1,000 |

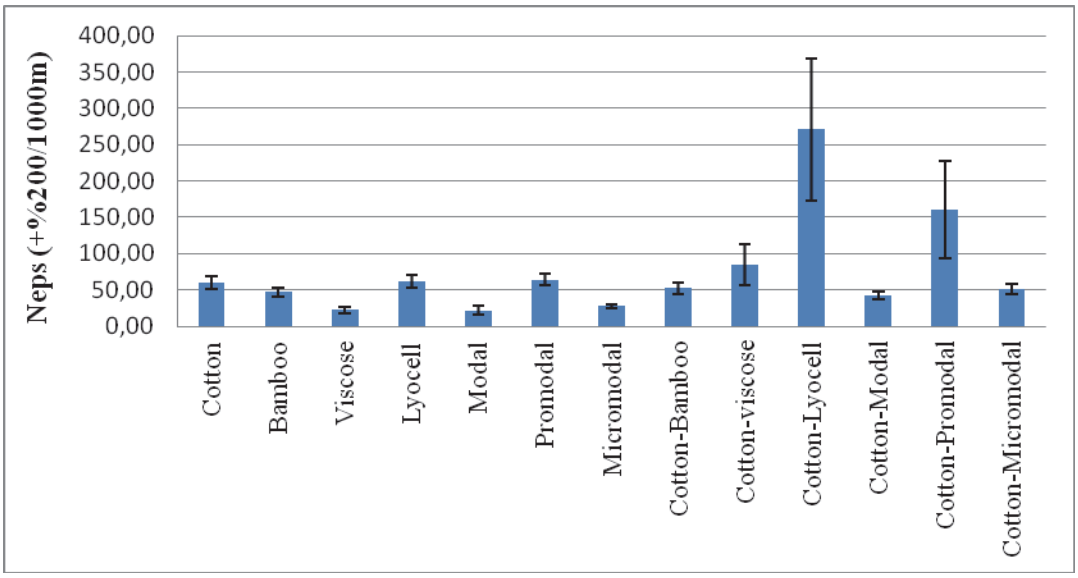


**Figure 7.** Neps (+%200 /1000m) values of the yarns

The difference between cotton-modal, cotton-micromodal, cotton-bamboo and cotton-viscose were not found statistically significant.

### 3.2.3. Yarn diameter

Yarn diameter test results were given in Figure 8 and statistical evaluation values according to the yarn type was given in Table 9.

As the Figure 8 was examined, it was found that promodal and lyocell have the lowest diameter values, while cotton yarns have the highest. The ticker structure of cotton fiber rather than the others is an effective factor in this result. According to Table 9, it was found that all the diameter values of the blended yarns are higher than % 100 regenerated yarns and the difference between the diameters of them was not statistically significant.

**Table 9.** Student–Newman–Keuls test results related with yarn diameter

| Type | N | Subset | | | | | N | Subset |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | | | |
| Promodal | 10 | ,1923 | | | | 50% Cotton-50% Lyocell | 10 | ,2089 |
| Lyocell | 10 | ,1943 | | | | 50% Cotton -50% Promodal | 10 | ,2110 |
| Modal | 10 | | ,1987 | | | 50% Cotton -50% Micromodal | 10 | ,2141 |
| Micromodal | 10 | | ,2010 | ,2010 | | 50% Cotton -50% Bamboo | 10 | ,2145 |
| Bamboo | 10 | | | ,2027 | | 50% Cotton -50% Viscose | 10 | ,2154 |
| Viscose | 10 | | | ,2032 | | 50% Cotton -50% Modal | 10 | ,2157 |
| Cotton | 10 | | | | ,2235 | | | |
| Sig. | | ,221 | ,160 | ,368 | 1,000 | Sig. | | ,110 |

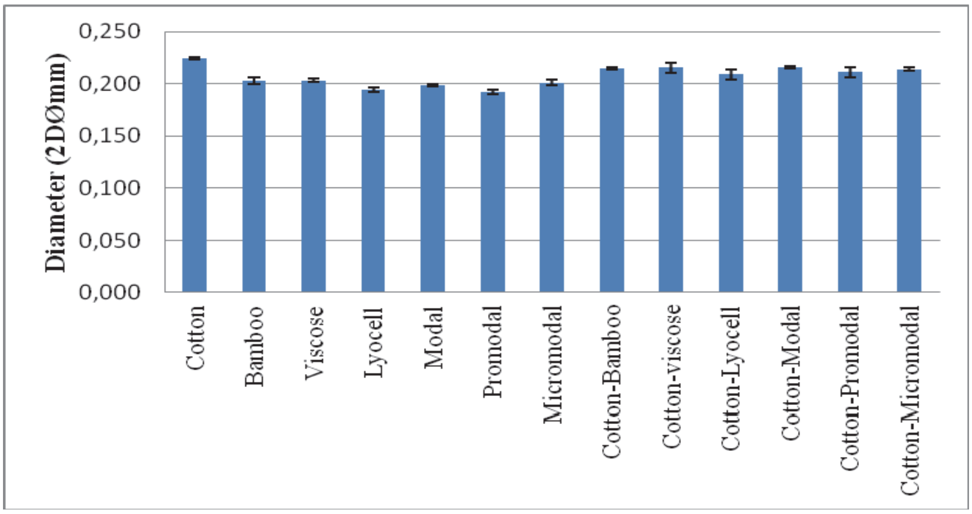


**Figure 8.** Diameter values of the yarns

### 3.2.4. Yarn hairiness

Yarn hairiness test results were given in Figure 9 and statistical evaluation values according to the yarn type was given in Table 10.

When the results of yarn hairiness values are examined; viscose, bamboo and cotton yarns are not statistically different from each other, it is observed that viscose has the lowest hairiness values. Lyocell and promodal yarns have the highest hairiness values.

**Table 10.** Student–Newman–Keuls test results related with yarn hairiness

| Type | N | Subset | | | | | N | Subset | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | | | 1 | 2 | 3 |
| Viscose | 10 | 4,5610 | | | | 50% Cotton-50% Bamboo | 10 | 4,5820 | | |
| Bamboo | 10 | 4,6250 | | | | 50% Cotton-50% Viscose | 10 | 4,6170 | | |
| Cotton | 10 | 4,7278 | 4,7278 | | | 50% Cotton-50%Micromodal | 10 | 4,6570 | | |
| Modal | 10 | | 4,9950 | 4,9950 | | 50% Cotton-50% Modal | 10 | 4,7760 | 4,7760 | |
| Micromodal | 10 | | | 5,1010 | 5,1010 | 50% Cotton-50% Lyocell | 10 | | 4,9310 | |
| Lyocell | 10 | | | | 5,3750 | 50% Cotton-50% Promodal | 10 | | | 5,1460 |
| Promodal | 10 | | | | 5,4040 | | | | | |
| Sig. | | ,470 | ,063 | ,456 | ,090 | Sig. | | ,194 | ,113 | 1,00 |

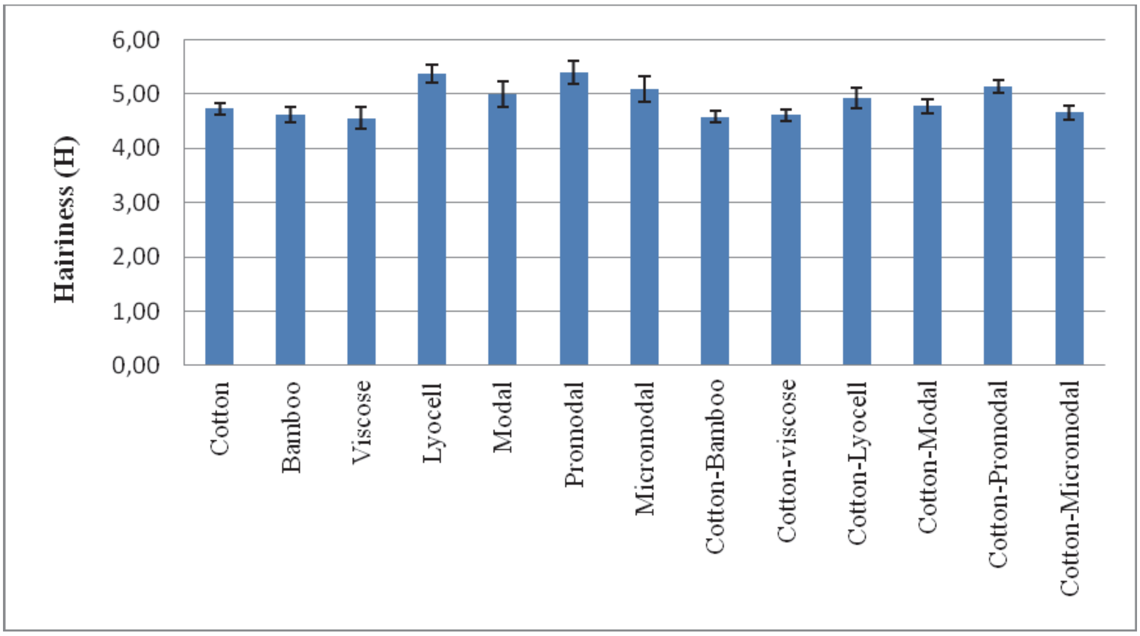


**Figure 9.** Hairiness values of the yarns

Lyocell fibers have a very smooth surface compared to other fibers, while viscose and modal fibers have a rough surface. This shape difference in the fibers significantly affects the crystallization grade, orientation and surface morphology. Lyocell fiber has a compact fiber core, a nanoporous intermediate layer and a semipermeable multi-porous amorphous fiber shell. The pores in modal and viscose fibers can vary in diameter from nanometer to micrometer. This also significantly affects the cross-sectional appearance of the fibers. For example; viscose and modal fibers have a multi lobular cross-section and lyocell fibers have a round / oval cross-section (6, 7, 14, 26). Although lyocell has higher breaking strenght, it easily fibrillates as compared to other cellulosic fibers. Due to high fibrillation and round cross-sectional structure, lyocell fibers to have higher hairiness. The lobular structure of viscose fibers causes higher fiber interfriction and that sturucture provides low hairiness. Cotton-bamboo blend yarns have the lowest value and the cotton-promodal blend has the highest value.

### 3.2.5. Yarn friction coefficient

Yarn friction coefficient test results were given in Figure 10 and statistical evaluation values according to the yarn type was given in Table 11.

When the values of friction coefficient are examined, it is seen that lyocell yarn has the lowest value and micromodal has the highest value. The difference between promodal and cotton, the difference between bamboo and viscose is statistically insignificant.

As stated in hairiness, the circular cross-section structure of lyocell fibers causes decrease in yarn-metal friction. Promodal fibers contains lyocell fibers also have a low coefficient of friction. Micromodal fiber that is the thinnest fiber, give a high coefficient of friction because of its higher amount of fiber content in cross section and its lobular cross-section characteristics.

**Table 11.** Student–Newman–Keuls test results related with yarn friction coefficient

| Type | N | Subset | | | | | N | Subset | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | | | | 1 | 2 | 3 |
| Lyocell | 10 | ,3333 | | | | 50% Cotton-50% Micromodal | 10 | ,3600 | | |
| Promodal | 10 | | ,3500 | | | 50% Cotton-50% Lyocell | 10 | ,3633 | ,3633 | |
| Cotton | 10 | | ,3567 | | | 50% Cotton-50% Modal | 10 | ,3700 | ,3700 | ,3700 |
| Bamboo | 10 | | | ,3900 | | 50% Cotton-50% Promodal | 10 | | ,3733 | ,3733 |
| Viscose | 10 | | | ,3900 | | 50% Cotton-50% Viscose | 10 | | ,3733 | ,3733 |
| Modal | 10 | | | | ,4100 | 50% Cotton-50% Bamboo | 10 | | | ,3767 |
| Micromodal | 10 | | | | ,4167 | | | | | |
| Sig. | | 1,000 | ,149 | 1,000 | ,149 | Sig. | | ,057 | ,094 | ,350 |

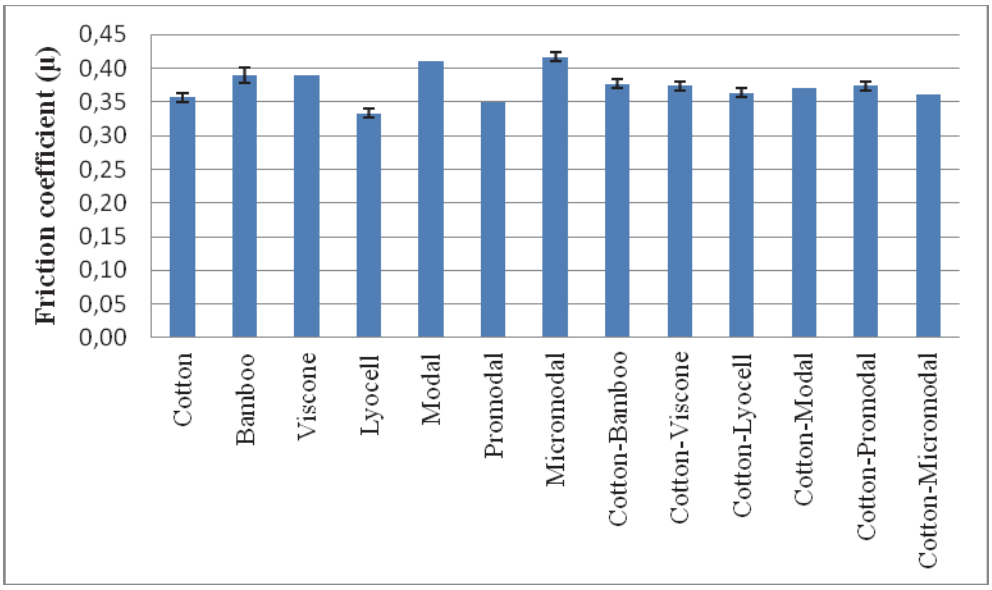


**Figure 10.** Friction coefficient values of the yarns

As the blended yarns examined, it was found that the cotton-bamboo blend had the highest value, while the cotton-micromodal blend was found to have the lowest value. The difference between cotton-lyocell, cotton-modal, cotton-viscose and cotton-promodal were not statistically significant.

## 4. CONCLUSION

In this study, the properties of the yarns produced from regenerated cellulosic fibers, which are frequently used in 100% and blended with %50 of cotton, were examined.

Similar to fiber properties, strength value of the fibers except viscose and bamboo were found higher than cotton. Lyocell yarn has the highest strength value. The yarns produced from the regenerated cellulose fibers have been found to have higher values than the cotton yarn in terms of the breaking extension. Yarns made from regenerated cellulose fibers are suitable for use in textile materials where flexibility is preferably important due to these properties. It has been evaluated that these yarns are suitable for many functional uses, with their strength and breaking extension values. In cotton blends of these yarns, lower values were obtained in terms of breaking load and breaking extension when compared to 100% values.

As the irregularity, thin and thick places values examined, bamboo and cotton yarns showed the highest values, while micromodal yarns the lowest. Higher irregularity values were observed for cotton blended yarns rather than 100%

regenerated yarns and the differences of the results were not statistically significant between different blended yarns. It also found that lyocell and promodal yarns, which exhibit high fibrillation characteristics, have higher neps values.

When the yarn diameter values are taken into consideration, cotton and viscose yarns which are made of thicker fibers have high yarn diameter values. Yarns produced from viscose fibers have the lowest hairiness, whereas lyocell and promodal yarns produced from lyocell fibers have high hairiness due to rounded cross-section and fibrillation characteristics. It has been found that the yarns spun from cotton blends of these fibers have lower hairiness. The lyocell yarns exhibited low values due to the smooth surface structure in terms of friction coefficient, while the fibers with the lobular cross section showed high friction.


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