(REFEREED RESEARCH)

THE PERFORMANCE PROPERTIES OF THE FABRICS PRODUCED FROM CUPRO AND SOME OTHER REGENERATED CELLULOSE FIBERS

CUPRO VE DİĞER BAZI REJENERE SELÜLOZ LİFLERİNDEN ÜRETİLEN KUMAŞLARIN PERFORMANS ÖZELLİKLERİ

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ABSTRACT

In this study, performance properties of single jersey knitted fabrics made from viscose, modal, lyocell and cupro yarns are investigated. Performance properties of the fabrics such as fabric weight per unit area, thickness, bursting strength, abrasion resistance, fabric stretch, porosity, air permeability and pilling were evaluated statistically and the importance levels of the relationship between the measured parameters were determined. The highest air permeability value is obtained from cupro fabrics. The highest bursting strength is obtained from lyocell fabrics whereas modal fabrics showed highest abrasion resistance. The results revealed that fiber type is an effective parameter with regard to physical properties of the fabrics.

Keywords: Cupro, viscose, modal, lyocell, regenerated cellulose fiber, bursting strength, air permeability, abrasion resistance

ÖZET

Bu çalışmada, viskon, modal, liyosel ve cupro ipliklerden yapılmış süprem örme kumaşların performans özellikleri incelenmiştir. Kumaşların, gramaj, kalınlık, patlama mukavemeti, aşınma direnci, esneme, gözeneklilik, hava geçirgenliği ve boncuklanma özelliği gibi özellikleri istatistiksel olarak değerlendirilmiştir ve ölçülen parametreler arasındaki ilişkinin önem düzeyleri belirlenmiştir. En yüksek hava geçirgenliği cupro kumaşlardan elde edilmiştir. En yüksek patlama mukavemeti lyocel kumaşlardan elde edilirken modal kumaşlar en yüksek aşınma direnci göstermiştir. Sonuçlar, lif tipinin kumaşların fiziksel özellikleri açısından etkin bir parametre olduğunu göstermiştir.

Anahtar Kelimeler: Cupro, viskon, modal, lyocel, rejenere selüloz lifi, patlama mukavemeti, hava geçirgenliği, aşınma dayanımı.

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1. INTRODUCTION

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 fibers were derived from the natural polymers by special chemical treatments [1]. They are classified as regenerated cellulosic fibers and regenerated protein fibers.

The global fiber production in 2014 was counted about 89.4 million tons [2]. Whereat, the proportion of regenerated cellulose fiber was around 6.7 %, of cotton around 29.4 %, of wool around 1.3 % and of synthetic fibers around 62.6 % .

Cellulose is a raw material with a wide variety of uses in the chemical industry for producing man-made textile fibers [3]. The development of man-made cellulosics began about 100 years ago and has significantly determined that textile world of today [4].

One of the most important of the regenerated cellulosic fibers is viscose. Viscose fiber is the first commercial regenerated fiber that is made from modified cellulose/ wood pulp [5]. Viscose fabric has a luxurious appeal, almost like silk. Due to the natural (cellulosic) source, it has many similarities to other natural cellulosic fibers. It is absorbing, comfortable and breathable. Although viscose is the most produced and consumed regenerated cellulose fiber today, its low wet strength property has led to the development of modal fiber.

Modal fiber is produced from the wood of the beech-tree. The dry and wet strength of this fiber is high. Either woven or knitted modal fabrics have smooth handle with high resistance to wear and they transfer humidity well [6]. Then, lyocell has been developed by reducing the cost of viscose and searching for renewable raw materials.

Lyocell is a cellulosic fiber regenerated from eucalyptus wood and it is soft as silk. It is strong as polyester, cool as linen, warm as wool and as absorbent as cotton. Lyocell combines good water absorbency with a smooth fiber surface which makes it a fiber which is very gentle to the skin [7]. It is fully biodegradable as well as highly durable too [8].

Cupro is a regenerated cellulosic fiber made from wood pulp or cotton linters. Cellulose is dissolved in a mixed solution of copper salts and ammonia, then the solution is pressed into a coagulation bath using a spinneret had where the cellulose is subjected to regeneration, giving a multifilament yarn [4]. So it is also called Cuprammonium Rayon [7].

Cupro is considered as an eco-textile because by definition it uses what would have been a waste product and transforms it into something usable and fabulous through little energy and emissions. Also, cupro is soluble in the soil in a short time without damaging to the the environment. So it is biodegradable. Cuprammonium rayon is also a specialised yarn used in lightweight summer dresses and blouses, sometimes in combination with cotton to make textured fabrics with slubbed, uneven surfaces [8].

The properties of knitted fabrics produced from regenerated cellulosic yarns were investigated by various researchers.

Ozcelık et al. [3] studied on the structural properties of viscose, modal and lyocell fibers and yarns. Besides, they determined 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. The results show 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.

Röder et al. [9] compared man-made cellulose fibers viscose, modal and tencel with other regenerated. They studied systematically the properties like crystallinity, orientation and cross section dependend on the fiber processing parameters.

Sakthivel and Anbumani [10] investigated the influence of different fiber types such as viscose, modal and lyocell fibers on the dimensional properties of single jersey knitted fabric. The results obtained indicate that the fabrics made from lyocell shows maximum bursting strength and lower spirality and better dimensional properties as compared with viscose and modal fabrics due to the structural characteristics of lyocell fibers.

Bredereck and Hermanutz [11] studied the classical processes and new alternative routes for the production of man-made cellulosics. They presented the relationships between fiber production, fiber structure and fiber properties.

Kreeze and Malej [12] investigated of the new lyocell and conventional viscose and modal fibers attempt to explain the reasons for differences in molecular and fine structure of these fibers. Their research is a systematic analysis of structural characteristics and their influence on fiber properties.

In this research, knitted fabrics made from viscose, modal, lyocell and cupro fibers are used. No study has been done on performance characteristics of knitted fabrics produced from cupro. For this reason, in this study, the performance properties of the cupro knitted fabrics were compared with those produced from some other regenerated cellulose fibers.

2. MATERIAL AND METHOD

This study was carried out in two stages. In the first stage, 4 different yarns (100% viscose, 100 % modal, 100% lyocell, %100 cupro) were selected.

All of the yarns were Ne 30/1 (ring). Yarn unevenness (CVm), imperfections (IPI fault) values [thin places (-40%), thick places (+50%) and neps (+140%)], hairiness values and breaking elongation were determined.

Yarn evenness, hairiness and imperfections (IPI fault) values were measured by USTER Tester 5 according to ISO 16549. 10 tests were done each type of yarn and the average value was taken.

Breaking elongation of the yarns were carried out according to TS 245 EN ISO 2062. 250 mm measuring range were used and testing speed were 250 mm/minute.

In the second stage of the work, these yarns were used to produce plain singe jersey fabrics. All single jersey fabrics were manufactured at the Mesdan Lab knitting machine by using the same production settings in order to eliminate the production effects.

Then these fabrics were analyzed to determine weight per square meter, thickness, porosity, resistance to abrasion, resistance to pilling, bursting strength, air permeability and fabric stretch.

Before testing, all yarn and fabric samples were conditioned for 24 hours under the standard atmospheric conditions (20 ± 2°C °C temperatures, 65% ± 5 % relative humidity).

Thickness and weight of the fabrics were measured according to the relevant standards [13-14].

Bursting strengths of the fabrics were tested according to ISO 13938-2 with 5 repetitions using JH Truburst.

The pilling tendencies of the grey fabrics were tested according to ISO 12945-2 standard on Martindale pilling & abrasion tester.

The test samples for the pilling 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.

Abrasion resistance of the fabrics were also tested according to ISO 12947-2 [15] and ISO 12947-3 standard [16] on Martindale abrasion tester. Three specimens were tested for each fabric sample.

Air permeability tests of the samples were carried out by using a Textest FX3000 testing machine in accordance with ISO 9237 standard specifications [17]. The number of measurements is ten for Textest FX3000 (pressure was 100 Pa, measured area was 20 cm²) and their average values were calculated.

Fabric stretch were tested according to TS 10985 [18]. Three specimens were tested for each fabric sample.

Following equation was used to calculate the porosity values of the fabrics [19].

$$P(\%) = (1 - m / \rho \, . \, h) \, 100$$

In this equation;

P(%) = Porosity, m = Fabric weight (g/cm²), ρ = Fiber density (g/cm³) and h = Fabric thickness (cm)

Results were evaluated by SPSS statistical program. All test results were assessed at a confidence level of at least 95% (at most 5% significance level).

3. RESULTS AND DISCUSSIONS

In this study, yarn samples were tested for the following important quality characteristics to help the research and the results are given below (Table 1).

Thickness and weight values of fabrics used in the study are given in Table 2.

The results on the fabric porosity, air permeability, pilling, bursting strength, fabric stretch and abrasion resistance are given in Table 3.

The results of Anova Test “p- significance level” are given in Table 4. According to statistical evaluation, the differences between air permeability, bursting strength, fabric stretch and abrasion resistance values of the fabrics knitted with viscose, modal, lyocell and cupro yarns were statistically significant.

Table 1. Properties of the Yarn Samples

YARN PROPERTIES				
	Viscose	Modal	Lyocell	Cupro
Yarn count (Ne)	30/1	30/1	30/1	30/1
Unevenness (CVm %)	12.53	11.58	13.75	11.72
Thin places (-40%)	67.28	17.78	48.28	18.54
Thick places (+50%)	9.78	15.28	108.26	14.02
Yarn twist (T/m)	729.86	675.82	745.75	806.66
Hairiness (H)	5.48	5.65	7.90	6.34
Force (N)	2.22	3.07	3.20	2.51
Elongation at break,%	10.81	8.43	7.60	8.41

Table 2. Thickness and weight results of the fabrics

Material	VISCOSE	MODAL	LYOCELL	CUPRO
Fabric thickness, (mm)	0.517	0.554	0.668	0.629
Fabric weight, (g/m²)	133.5	105	105.6	102.5

Table 3. Physical Properties of the Fabrics

PHYSICAL PROPERTIES OF THE DIFFERENT FABRICS					
Material	Porosity (%)	Air permeability (l /m²/s)	Bursting strength (kPa)	Fabric Stretch (%)	Abrasion resistance weight loss in 10.000 cycles (%)
100%Viscose	82.78	2041	390.0	37.60	4.88
100% Modal	87.61	2944	444.1	19.33	3.23
100% Lyocell	89.46	2855	540.5	28.00	24.43
100% Cupro	89.34	3458	379.4	33.60	25.10

Table 4. Statistical Significance Values of the Samples

STATISTICAL SIGNIFICANCE VALUES				
p	Air permeability	Bursting strength	Fabric stretch	Abrasion resistance weight loss
p	0.000*	0.000*	0.003*	0.000*

*p < 0.05 it is significant

As it can be seen from Figure 1, the fabrics made of lyocell fibers have the highest bursting strength. The bursting strength values of the modal fabrics is also higher compared to cupro and viscose fabrics. Lyocell fibers have high fiber and yarn strength compared to viscose and modal fibers because of their high crystallinity. This high strength is also reflected in the fabric properties.

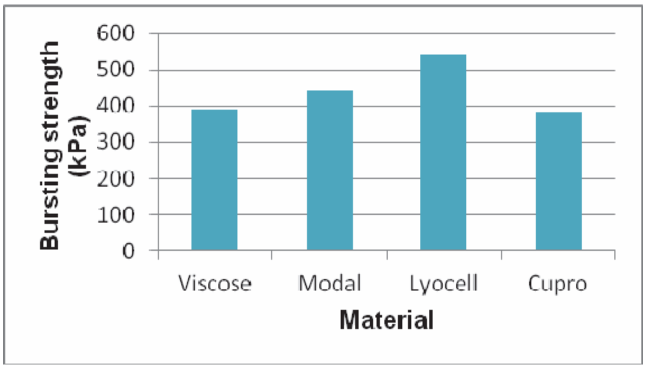

Figure 1. Bursting Strength Values of the Fabrics

The average pilling degrees of the test samples are given in Table 5. As all the fabric production parameters are same, the differences of the pilling tendencies of the fabrics are due to the yarn and fiber characteristics. It can be stated that fabrics made of cupro yarns have the most pilling tendency due to the high yarn hairiness value. The viscose fabric has the lowest pilling value since it has the lowest yarn hairiness.

Table 5. Pilling Values of the Fabrics

Fiber type	Pilling degrees
Viscose	2-3
Modal	2
Lyocell	2
Cupro	1-2

Air permeability results were given in Figure 2. Statistical evaluation show that differences between air permeability values of fabrics were statistically significant. As the air permeability results were analyzed, it was observed that, 100% cupro fabric has the highest air permeability value. This is due to low fabric weight and high porosity. It is seen that viscose had the lowest air permeability value all of them. Because it had lowest porosity.

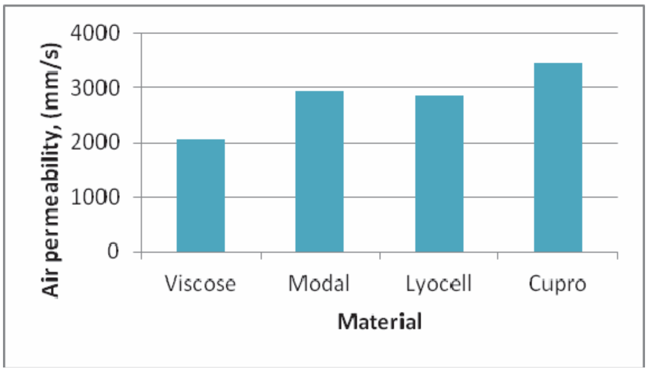

Figure 2. Air Permeability Values of the Fabrics

According to statistical evaluation, the differences between abrasion resistance values of the fabrics knitted with viscose, modal, lyocell and cupro yarns were statistically significant. In order to evaluate the resistance of the samples to abrasion, percentage of the weight loss is calculated and also the number of abrasion cycles at which fabric breakage occurred is registered. The weight loss values (%) of the fabrics for the 10000 cycles are given in Figure 3 and the number of abrasion cycles at which fabric breakage occurred in the Martindale abrasion resistance tester are given in Figure 4. According to the results obtained, there is a certain difference between the fabric samples in terms of weight loss. Value of weight loss after 10000 cycles of lyocell and cupro fabrics have much higher than viscose and modal fabrics. The reason for this is that the hairiness values of these yarns are high.

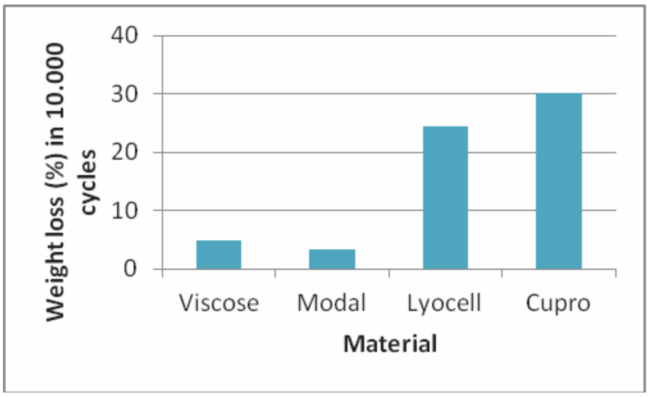

Figure 3. Weight Loss Rates of Fabrics After the Abrasion Test

At the end of the test, the fabrics were examined for the presence of a hole. Modal fabrics had the highest resistance to abrasion. As it can be seen from Figure 4, the number of abrasion cycles at which fabric breakage occurred in the fabrics made from viscose, modal, lyocell and cupro yarns are 31500, 32000,12000 and 10000 respectively. The weight loss in the lyocell fabric was found to be too much, although the yarn strength was high. The reason for this is thought to be due to the fact that the yarn hairiness is too high. The high weight loss in the cupro fabric is an expected condition due to being made of cotton linters.

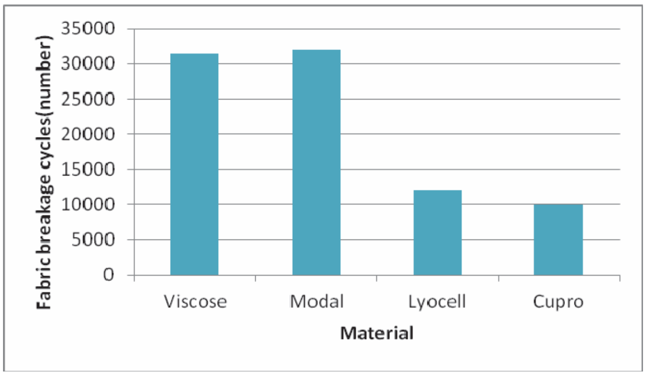

Figure 4. The Number of Abrasion Cycles at Which Fabric Breakage Occurred

Stretchability of the fabrics can be seen in Figure 5. By the results in terms of fabric fabric stretch, differences in fabric stretch values were statistically significant. Viscose fabrics had the highest stretchability. The fabrics produced from cupro yarns have higher stretchability than modal and lyocell fabrics. The viscose has high fiber elongation due to high amorphous region of the and also high yarn elongation values.

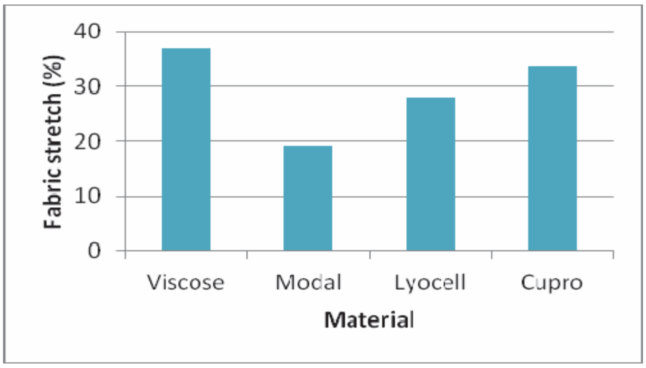

Figure 5. Fabric Stretch Values of the Fabrics

4. CONCLUSIONS

In this paper, physical properties of single jersey knitted fabrics produced from viscose, modal, lyocell and cupro yarns were investigated. Since all the yarn and fabric production conditions are same, the results revealed that fiber type has an effect on the performance properties of the fabrics. The following conclusions can be drawn on the basis of the study:

Permeability and porosity are strongly related to each other. If a fabric has very high porosity, it can be assumed that it is permeable. Therefore, the air permeability of the fabrics produced from lyocell, modal and cupro are higher than viscose. This is because the viscose fabric has the lowest porosity value. It is also seen that the cupro fabric with the highest porosity and the lowest weight has the highest air permeability. But fabric made from lyocell is thicker and heavier than the fabrics made of cupro, so its air permeability is lower.

Among the other pyhsical properties, bursting strength is extremely important. The fabric should have sufficient strength against forces acting upon it during dying, finishing, and usage. Comparison of the bursting strength of the fabrics show that the lyocell fabric has the highest bursting strength. The reason of this result is that the fiber and yarn strength are high compared to viscose and modal fibers because of their high crystallinity. This is followed by modal, viscon, cupro respectively.

In terms of the abrasion resistance, the modal fabric had the lowest value of weight loss after 10000 cycles. The weight loss values of cupro and lyocell fabrics after 10,000 cycles have much higher than viscose and modal fabrics depending on the high hairiness values of the these yarns. The weight loss in the lyocell fabric was found to be too much, although the yarn strength was high. The reason for this is thought to be due to the fact that the yarn hairiness is too high. The high weight loss in the cupro fabric is an expected result due to being made of cotton linters.

When the elastic properties of the fabrics are compared, it is seen that the stretch value of the viscose fabric is the highest. Because the viscose fiber has high elongation due to high amorphous region of the fiber and also high yarn elongation values. Cupro fabric also has higher stretchability than modal and lyocell fabrics.

Cupro fabric has the highest air permeability and the highest strechability, besides having the lowest bursting strength and abrasion resistance. Due to too much flexibility, this fabric is likely to be used in garment production.

It can be stated that cupro fabrics that have high porosity and high air permeability, therefore for summer cloths it can be preferred much more compared to other regenerated cellulosic fabrics. Although the cupro fiber is made entirely from waste fibers, it is seen that a yarn having a high strength is obtained by giving high twist. It has been found that the bursting strength of the fabric knitted with this yarn is close to the bursting strength of the viscose fabric. The use of cupro fiber can be used in terms of less cost. But the selection of fabric should be taken into account the place where the clothes will be used, rather than the cost.

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