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RİNG, OPEN-END ROTOR VE VORTEKS EĞİRME SİSTEMLERİ İLE ÜRETİLEN İPLİK VE KUMAŞ ÖZELLİKLERİNİN KARŞILAŞTIRILMASI

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Özet – Bu çalışmanın amacı en eski ve halen en popüler iplik eğirme sistemi olan ring iplik eğirme sistemi ile yüksek üretim hızı ve otomasyon avantajları ile öne çıkan modern eğirme sistemlerinden olan; OE-rotor ve vorteks eğirme sistemlerini karşılaştırmaktır. Bu amaç ile tek tip elyaf cinsi ve tek iplik numarası kullanılarak farklı eğirme sistemlerinde üretilen ipliklerin ve bu iplikler ile üretilen örme kumaşların temel fiziksel özelliklerinin karşılaştırılmalı olarak incelenmiştir. Elyaf olarak viskon lifler, iplik numarası olarak da Ne 28/1 tercih edilmiştir. Çalışmada ipliklerin düzgünsüzlük, ince/kalın yer ve neps özellikleri, üretilen kumaşların ise, kalınlık, gramaj, boncuklanma, patlama mukavemeti, hava geçirgenliği ve tutum özellikleri test edilmiştir. Yapılan testler sonucunda elde edilen değerlerin istatistiksel analiz sonuçlarından yola çıkarak, eğirme yönteminin iplik kalite özellikleri ve kumaş özellikleri üzerindeki etkisi elde edilen veriler ile tespit edilmeye çalışılmıştır. Elde edilen tüm sonuçlar değerlendirildiğinde, vorteks ipliklerin yumuşak tutum, düşük düzgünsüzlük ve yüksek mukavemet gibi özelliklerinin OE-rotor eğirme yönteminde üretilen ipliklere kıyasla avantajlı olduğu saptanmıştır. Diğer taraftan, yüksek iplik mukavemeti, yüksek patlama mukavemeti, daha yumuşak tutum ve yüksek hava geçirgenliği özellikleri açısından değerlendirildiğinde ring ipliklerin vorteks ipliklere kıyasla daha üstün özelliklere sahip olduğunu söylemek mümkündür.

Anahtar Kelimeler: *Ring eğirme, OE-rotor eğirme, Vorteks eğirme, Düzgünsüzlük, Mukavemet, Boncuklanma.*

COMPARISON OF YARNS AND FABRICS PROPERTIES PRODUCED WITH RING, OPEN-END ROTOR AND VORTEX SPINNING SYSTEMS

Abstract – The aim of this study is to compare the oldest and still the most popular ring yarn spinning with new designed modern spinning systems such as; OE-rotor and vortex spinning system which have the high speed production and automation advantages.

For this aim, the basic physical properties of yarns produced in different spinning systems using one type of fiber, a single yarn count and the knitted fabrics produced with these yarns were comparatively examined. Viscose fibers were chosen as raw material and Ne 28/1 as yarn count.

In the study, the evenness, thin/thick places and neps properties were measured with yarn, the thickness, weight per square meter, pilling, bursting strength, air permeability properties of the produced fabrics were tested. According to statistical analysis of the results obtained from the study, the effect of yarn spinning system on yarn and fabric quality parameters were tried to be determined.

When all the test results are evaluated, it has been determined that the properties of vortex yarns with soft handle, low evenness and high strength have advantageous compared to the yarns produced in the OE-rotor spinning system. On the other hand, in terms of high yarn tenacity and fabric bursting strength, softer handle property and higher air permeability, it is possible to say that ring spun yarns had superior properties compared to vortex yarns.

Keywords: *Ring yarn spinning, OE-rotor spinning, Vortex spinning, Evenness, Tenacity, Pilling*

1. Introduction

Each spinning system has its own production restrictions and advantages. Ring spinning method is a traditional and widely used method today. After the yarn leaves the drafting rollers, the spinning yarn gain twist from the traveler and it is wound on the cops placed on the spindle. Ring yarn structure, which is considered the basic structure of continuous spun yarn technology, has had an important place in textile consumption for many years. Twisting of the yarns produced in different spinning systems have very different structures and properties. Each spinning system has its own production limitations and advantages. Due to the uniform distribution of the yarn of fibers in the ring yarn spinning method, this spinning system is still more widely used in fabric production compared to yarns produced in other spinning systems [1,2].

Despite these advantages, the ring spinning method has disadvantages such as low production speed and high cost. For this reason, with the modern spinning methods developed, economical methods that provide twisting with air are being studied as an alternative to mechanical methods, especially in adding twist to yarns. In addition, by winding large bobbins, the power consumption per meter required for yarn production is reduced [3].

Among modern spinning methods, the most developed and today the most preferred spinning system after the traditional ring spinning system is the OE-rotor spinning method [4,5]. In the OE-rotor spinning system, the processes of opening the fibers, parallelizing them, conveying the fibers into the rotor and gathering them together at the open yarn end, and turning the fibers gathered at the open yarn end into yarn are carried out. OE-rotor yarn production is widely used in workwear, especially in denim fabric production. The most important disadvantage of the system is that it is not suitable for fine count yarn production [6].

Vortex spinning method is another modern spinning system. The preference of this spinning method is high because 100% combed cotton fiber can be spun at high speeds (400 m/min) and the yarn structure produced resembles the ring yarn structure. In this system, there is no need for a roving preparation step, and it is fed to the machine in fiber strip form. However, easy machine maintenance is another advantage of this method. Vortex yarn structure differs from the air-jet system in that it contains more winding fibers and resembles a two-layer yarn. Thanks to this structure, some edge fibers can be caught and bent towards the center. In this way, the number of winding fibers, winding length and thus the strength of vortex yarns are higher than air-jet yarns. However, as the cotton ratio in blended yarns increases, the difference in strength becomes more evident [5].

The effect of the count and spinning system on the dyeing properties of the yarns in bobbin form was investigated in the yarns produced in OE-rotor and vortex spinning systems. As a result of the study, it was determined that vortex yarn had lower evenness, defect and hairiness values compared to OE-rotor yarn. However, it has been stated that vortex yarn is dyed brighter due to its smoother and lower hairiness [7]. In a study in which the properties of yarns produced by ring, rotor and air-jet spinning systems were comparatively examined, yarns of the same count were produced from Ne 20 count 100% viscose fibers in three different spinning systems. Properties of the produced yarns such as strength, elongation at break, thin places/thick places, irregularity, number of neps and hairiness were comparatively examined. According to the results, it was determined that ring yarns had better values in terms of strength and breaking elongation, while rotor and air-jet yarns provided better values in terms of thin/thick place, evenness, number of neps and hairiness [8].

In another study, the properties of ring, rotor and vortex yarns produced in different counts from cotton, viscose and 50% cotton/50% modal blended fibers were examined. Then, single jersey fabric was produced from the yarns and dyed with reactive dyestuff, and its physical performance in knitted form was evaluated. As a result of the tests, it was determined that vortex yarns have lower pilling, and the fabric knitted from this yarn has better pilling resistance. Additionally, it has been stated that higher strength results are obtained in vortex yarns produced from viscose fibers, especially in thick yarn counts [9].

The physical properties of ring, compact and vortex yarns produced from PTT/wool/modal blends and the clothing comfort properties of fabrics knitted from these yarns were examined in another study. As a result of the study, it was determined that fabrics produced from vortex yarns tend to have less pilling than fabrics produced from ring yarns [10].

In an article examining the yarn and knitted fabric properties produced from viscose fibers by ring, compact, OE-rotor and vortex spinning methods, it was found that compact yarns have higher strength, higher breaking elongation and lower hairiness values than ring yarns, while vortex yarns have low strength and elongation values. It has been determined that fabrics produced from vortex yarns show lower pilling performance compared to fabrics produced from OE-rotor yarns [11].

In another study, the effect of yarns produced in ring, compact, siro yarn, OE-rotor and vortex spinning methods on denim fabric performance was examined. For this purpose, threads were produced from 100% cotton fiber with five different spinning methods and these threads were used as weft threads in denim fabric. As a result of the tests performed on the yarns within the scope of the study, the highest evenness, thin places, thick places and neps values were obtained in OE-rotor yarns. It has been observed that the performance properties of denim fabrics woven from yarns produced with different spinning technologies vary significantly. It has been determined that denim fabrics produced with compact spinning technology have better performance properties compared to denim fabrics produced with other spinning technologies. [12].

Soe et al. investigated the structure, properties and observed differences in the yarn structure of 100% carded cotton vortex spun yarn, ring yarn and OE-rotor yarn. As a result of the research, they observed that ring and OE-rotor yarns consist of core fibers and therefore have a parallel structure, while vortex yarns consist of core and sheath fibers. They stated that in vortex yarns, the sheath fibers cover the surface of the yarn and receive less twist. For this reason, it has been stated that vortex yarns have a medium level of breaking strength compared to ring and OE-rotor yarns, and on the other hand, they have less hair and a bulkier structure [13].

The aim of this study is to comparatively examine the basic physical properties of yarns produced using a single type of viscose fiber in a single yarn count with ring, OE-rotor and vortex spinning systems and the knitted fabrics produced with these yarns. The difference of this study from other studies is the selected fiber type, yarn count and examined fabric properties. Unlike the closest similar study to this study, the air permeability and handle properties of the fabrics produced were comparatively examined within the scope of this study [11]. Based on the statistical analysis results of the values obtained because of the study, the effect of the spinning method on the yarn quality characteristics and fabric properties was tried to be determined with the obtained data.

2. MATERIAL AND METHOD

The study is about comparing the basic properties of yarn produced by different spinning methods and knitted fabrics produced from these yarns. Yarns were produced in three different spinning systems using the same raw material and yarn count.
Ne 28/1 yarn count and 100% viscose fibers, which are frequently used in ready-made clothing production, were preferred as raw materials in the study. The length of the viscose fibers used in the study is 35.4 mm and the fineness is 1.58 dtex. Twist coefficient values for three different spinning systems were determined to be suitable for knitted fabric production, and production parameters were determined for three different spinning systems, with this coefficient value being $\sigma e = 3.2$, which is suitable for knitted fabric production.

In ring yarn production, the spindle speed was 19.000 turn/min, the rotor speed was 125.000 turn/min on the OE-rotor spinning machine, and the output speed was 480 m/min on the vortex spinning machine, at Ucak Textile Company. Uniform single jersey fabrics were produced from the produced yarns on the Mesdan Laboratory type knitting machine located at Ege University Textile Engineering. The physical properties of the produced yarns and fabrics were measured three times in a laboratory with standard atmospheric conditions (20°C, 65% relative humidity) after conditioning for 24 hours before the test. The irregularity, thin/thick places, neps, hairiness, strength and breaking elongation properties of the yarns were tested. The thickness, weight, pilling, bursting strength, air permeability and handle properties of the produced fabrics were tested.

Evenness, irregularity and hairiness values of the yarns were measured in the Uster Evenness 4 test device according to ISO 16549 standard. The strength properties of the yarns were tested in the Uster Tensorapid 3 Strength tester according to TS EN ISO 2062 standard (Table 1). In the evenness test, the test speed was determined as 400 m/min. In the strength test, the test length was set to 50 cm, and the yarn pre-tension was set to 0.5 cN/tex. Knitted fabrics main properties such as thickness and weight were measured. Then, to compare the quality and comfort features of the fabrics; pilling, bursting strength, air permeability and handle properties were examined respectively.

The SDL Atlas Digital Thickness Gauge M034A Tester was used for thickness and was measured in accordance with ASTM 1777 Standard. The pilling properties of the fabrics were determined using the Martindale Abrasion and Pilling Tester according to BS EN ISO 12945-1 standard. Pilling test evaluation was carried out in the observation cabin by comparing the test fabrics according to reference pilling photographs and grading them from 1 to 5. The strength properties of the fabrics were tested using the Truburst Burst Strength Tester. Burst strength and burst height were measured in the test device operating based on the hydraulic method, in accordance with TS 393 En ISO 13938-1 Standard. Air Permeability Test was determined with FX 3300 air permeability tester according to TS 391 En ISO 9237.

The handle properties of the fabrics were evaluated subjectively. For this purpose, two frequently used in behavior tests of fabrics were used; (a) four-finger attitude test and (b) two or more finger pinch methods were used [14]. In the first method, the grip of the fabric was tested with four fingers and features such as the surface structure of the fabric and the feeling of warmth were evaluated by making back and forth movements on the fabric surface. In the second method, the fabric is squeezed between the thumb and index fingers; Properties such as texture, toughness, weight, warmth, friction and stretching amount were evaluated for both sides of the fabric. Fabric attitude, which is generally evaluated by two different methods, was scored

by 10 different people, consisting of textile technicians and textile engineers who are experts in the field of physical textile inspections, using an indicator chart applied between 1 and 5 values (1: hardest, 5: softest), and the average data obtained was used.

3. RESULTS

3.1 Yarn Test Results

The results of the irregularity properties of the yarns are given in Table 1. When the yarns produced in three different spinning systems were examined, the lowest evenness value was observed in ring yarns. Vortex yarns have better smoothness and less hairiness than rotor yarns. The highest number of thin and thick places is in OE-rotor yarn. In other spinning methods, the number of thin places is either non-existent or almost non-existent. The number of neps is lowest in OE-rotor yarn, then in vortex and highest in ring yarn. Similar results have been found in previous studies on this subject [7,8,11].

Table 1. Yarn evenness, thin/thick place, neps and hairiness properties

Yarn Type	Ring	OE-rotor	Vortex
CVm(%)	10.88	13.63	11.76
Thin place (-50%)	0.5	8.0	0.0
Thick place (+50%)	17.0	31.0	13.8
Neps (+200%)	21.0	7.5	15.0
Hairiness	4.59	4.56	4.28

The strength properties of the yarns are given in Table 2. The highest strength and breaking elongation value is in ring yarn. The lowest strength and breaking elongation values were also observed in OE- rotor yarns. Similar results have been found in previous studies on this subject. When yarns were produced from cotton fibers using OE-rotor, ring and air jet/vortex spinning methods, the highest strength and breaking elongation values were observed in ring yarns. The lowest evenness value was observed in OE-rotor yarns [8,11]. In this study, the highest evenness value is in OE- rotor yarns. While the irregularity in the OE-rotor spinning system is less in cotton fibers, it may be slightly higher in artificial fibers [15].

It is thought that the high value of vortex yarns, which have the highest strength value after ring yarn, is due to the higher number of winding fibers in the structure of vortex yarns [5].

Table 2. Yarn tenacity and elongation ratio properties

Yarn Type	Tenacity (RKm)	Elongation Ratio (%)
Ring	17.31	14.23
OE-rotor	12.29	8.68
Vortex	16.16	10.80

100% cotton yarns were produced using five different spinning methods (ring, compact, sirospun, OE-rotor and vortex) by Kaynak et al., and then denim fabrics were produced from these yarns and the properties of the fabrics were comparatively examined. When the results were examined, the highest evenness, thin place and thick place values were measured in OE-rotor yarns. It has been observed that ring spinning systems provide better yarn strength as well as better breaking and tear strength properties [12].

The results obtained within the scope of the study were analyzed by analysis of variance method using the SPSS program with a 95% confidence interval. The analyzes were carried out in two stages; in the first stage, the yarn results were evaluated, and in the second stage, the test results of the fabrics were evaluated.

Yarn quality parameters of the spinning method in yarns with unique yarn count and twist value; Its effects on irregularity, thin places, thick places, neps, strength and elongation at break properties were first examined. As a result of the analysis, the F, significance and R^2 values found for the effect of the spinning method on the examined yarn quality characteristics are given in Table 3.

Table 3. Statistical analysis results of yarns

Spinning Method	The Effect of Spinning Method		
	F	Sig.	R^2
Evenness	83.29	0.000*	0.94
Thin place	6.94	0.015*	0.60
Thick place	5.09	0.033*	0.53
Neps	6.19	0.020*	0.57
Hairiness	2.24	0.158	0.14
Tenacity	31.04	0.000*	0.87
Elongation ratio	64.88	0.000*	0.93

**Statistically significant at %95 level*

As a result of the analysis, it was determined that the spinning method had a statistically significant effect on all yarn properties examined. R^2 values obtained because of the analysis explain how effective the independent variable is on the dependent variable. High values indicate how well a statistical model fits the data. When the R^2 values obtained in the analyzes are examined, it is understood that especially the evenness, strength and breaking elongation values vary significantly depending on the spinning method. When evaluated in terms of these features, it is possible to say that the most ideal spinning method is the ring spinning system due to its high strength, high elongation at break and low evenness. On the other hand, the lowest thin, thick place and hairiness values were obtained in the vortex spinning method. In terms of neps property, the lowest value was determined in the OE-rotor spinning method.

3.2 Fabric Test Results

Knitted fabrics two main properties such as thickness and weight were measured. Then, to compare the quality and comfort features of the fabrics; pilling, bursting strength, air permeability and handle properties were examined respectively. The basic properties of the fabrics are given in Table 4 below.

Table 4. The main properties of fabrics

Spinning Method	Ring	OE-Rotor	Vortex
Thickness (mm)	0.47	0.50	0.51
Weight (g/m^2)	95	110	109
The density of wale (number/cm)	10	10	12
The density of courses (number/cm)	10	12	8

The pilling test of the produced knitted fabrics was evaluated in the observation cabin by comparing them with the reference pilling photographs. Standard pilling photographs contain five grades from 1 to 5, with grade 1 indicating very high and intense pilling or pilling and 5 indicating very low or no pilling [16]. The strength properties of the fabrics were tested using the Truburst Burst Strength Tester. The pilling and bursting resistance properties of the fabrics are given in Table 5.

Table 5. Pilling and bursting resistance properties of fabrics

Spinning Method	Pilling	Bursting strength (kPa)	Bursting height (mm)
Ring	3	319.7	10.4
OE-rotor	4	266.5	10.3
Vortex	3-4	270.8	10.7

The results obtained showed that the lowest pilling, bursting strength and bursting height values were obtained in fabrics produced from OE-rotor yarns. The highest pilling, bursting strength and bursting height were observed in fabrics produced from ring yarns. Fabrics produced from vortex yarns have been found to have lower pilling properties compared to fabrics produced from ring yarns, and similar results have been obtained in previous studies on this subject [10]. The strength values of vortex yarns are higher than those of OE-rotor yarns, on the other hand, the bursting strength of knitted fabrics produced from vortex yarns is similar to knitted fabrics produced from OE-rotor yarns. Air permeability is an important parameter that provides the comfort properties of clothing. Air permeability in the fabric is affected by many parameters such as the type of fiber used, spinning method and yarn count [17].

In the study, the handle properties of the fabrics were evaluated subjectively. Fabric handling, which was generally evaluated by two different methods, was determined using an indicator chart applied between 1 and 5 values (1: hardest, 5: softest). Air permeability and handling properties of fabrics are given in Table 6.

Table 6. Fabric air permeability and handle properties

Spinning Method	Air Permeability ($cm^3/s/cm^2$)	Handle
Ring	3526	5
OE-rotor	3574	2
Vortex	2970	3

When the air permeability results of the fabrics are examined; The highest air permeability was obtained in fabrics produced from OE-rotor yarns, and the lowest air permeability was obtained in fabrics produced from vortex yarns. Although the weights of fabrics produced from OE-rotor and vortex yarns are very close to each other, the difference between the hairiness values is not significant. The air permeability values of fabrics produced from ring and OE-rotor yarns are similar, and the air permeability was measured to be lowest in knitted fabrics produced from vortex yarns. Similar results were found in a previous study on this subject. Since vortex yarns have two different fiber structures, namely sheath and core, it is thought that the protruding structure of the mantle fibers in the yarn reduces the air permeability in fabrics produced from these yarns [18].

The fabrics with the softest handle were the fabrics produced from ring yarns, and the hardest handle was observed in fabrics produced from OE-rotor yarns. Similarly, in another study examining the properties of viscose yarns and knitted fabrics produced using different spinning technologies, it was stated that fabrics knitted from ring, vortex and compact yarns had lower density and more porous structure than fabrics knitted from vortex yarns [11]. In the second stage of the study, the effect of the spinning method on the fabric properties of the yarns produced with three different spinning methods was examined. For this purpose, the fabrics of the spinning method were tested; Its effect on pilling, bursting strength, bursting height, air permeability and handling properties were analyzed. F, significance and R^2 values found as a result of the analysis regarding the effect of the spinning method on the examined fabric properties are given in Table 7.

Table 7. Statical analysis test results of fabric pilling and tenacity

Spinning Method	Spinning Method Effect		
	F	Sig.	R^2
Pilling	9.0	0.000*	0.66
Bursting strength	1.22	0.350	0.29
Bursting height	0.52	0.610	0.15
Air permeability	20.43	0.000*	0.60
Handle	21.00	0.002*	0.87

**Statistically significant at %95 level*

When the statistical analyzes obtained from the tests performed on the fabrics were examined, it was observed that the effect of the spinning method on fabric pilling, air permeability and handle properties was statistically significant. On the other hand, the spinning method does not have a significant effect on the bursting strength and bursting height properties. Due to the high R^2 value obtained, it is understood that the handle properties vary significantly depending on the type of spinning method. It has been determined that ring yarns are more advantageous than other spinning methods due to their low pilling and soft handle properties.

4. RESULTS AND DISCUSSION

This study provides important information about the basic properties of yarns and fabrics produced from viscose fiber with different spinning systems. Single jersey fabrics were produced from viscose fibers using ring, OE-rotor and vortex spinning methods, with knitted twist value of Ne 28/1, under the same production conditions. Then, the properties of yarns and fabrics were tested and the properties of yarns and fabrics produced in different spinning systems were comparatively examined. The resulting test was analyzed statistically.

As a result of the analyses, the difference between the evenness, thin/thick places, neps, strength and elongation at break properties of the yarns produced in different spinning systems was found to be statistically significant. While the lowest evenness is observed in ring yarns, the highest evenness is in OE-rotor yarns. OE-rotor yarn has the highest number of thin and thick places. In other spinning methods, the number of thin places is either non-exist or almost non-exist. The lowest nep count is in OE-rotor yarn, followed by vortex and the highest in ring yarn.

When examined in terms of strength and breaking elongation properties, the highest strength and breaking elongation values are obtained with ring yarn. The lowest strength and breaking elongation values were also observed in OE-rotor yarns. In vortex yarns, both strength and breaking elongation values are between the two types of yarns.

When the analysis results of the fabrics were examined, although the effect of the spinning method on the yarn strength and breaking elongation values was found to be statistically significant, this effect was not observed on the fabric strength properties. The strength value obtained in knitted fabrics produced from ring yarns is the highest and the lowest is in fabrics produced from OE-rotor yarns, but this difference was not found to be statistically significant.

On the other hand, the difference between pilling, air permeability and handle properties of the fabrics is statistically significant. While the lowest pilling was observed in fabrics produced from OE-rotor yarns, the highest pilling occurred in fabrics produced from ring yarns. When evaluated in terms of air permeability, fabrics produced from ring and OE-rotor yarns have close permeability, and the lowest air permeability was found in fabrics knitted from vortex yarns. The softest handle was observed in fabrics knitted from ring yarns, and the hardest handle was observed in OE-rotor yarns.

When all the results were examined, it was observed that vortex yarns were advantageous compared to OE-rotor yarns due to their features such as soft handle, low evenness and high strength. On the other hand, ring yarns stand out with their lower evenness, higher strength and softer handle compared to vortex yarns.

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Conflict of Interest
No conflict of interest is declared by the authors.

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