(REFEREED RESEARCH)

THE EFFECTS OF SPINNING SYSTEM AND BLENDING RATIO ON QUALITY OF SILK/COTTON BLENDED YARNS

EĞİRME SİSTEMİ VE KARIŞIM ORANININ İPEK/PAMUK KARIŞIM İPLİKLERİNİN KALİTESİNE ETKİSİ

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ABSTRACT

Mulberry silk can be deemed as the most important silk fiber due to its cultivability. In addition to this, its fiber properties make it one of the most important natural fibers and textile raw materials. Silk fibers which can not be reeled continuously are counted as silk waste and they are used as short staples in industry. Moreover, filament silk can be converted to staple silk fibers, in order to use in blended yarn productions. In this study, we blended mulberry silk and combed cotton fibers in draw-frame and used them to produce silk/cotton blended yarns with three different silk/cotton blending ratios and with three different twist coefficients in ring and siro spinning systems. We performed tests such as unevenness, strength and hairiness to determine physical properties of these yarns. In conclusion, we have found siro spinning system more efficient than ring spinning system due to physical properties of spun yarns and it was clear with our results that tensile strength, unevenness and hairiness values have increased with silk content increment in silk/cotton blended yarns.

Keywords: Mulberry silk, combed cotton, ring spinning system, siro spinning system

ÖZET

Mulberry ipeği, yetiştiriciliğinin yapılabilmesi nedeniyle en önemli sayılabilecek ipek türüdür. Bunun yanında sahip olduğu lif özellikleri onu önemli bir doğal lif ve tekstil hammaddesi yapmaktadır. Filament olarak çekilemeyen ipek, telef ipek olarak adlandırılır ve kesikli lif olarak kısa elyaf iplikçiliğinde değerlendirilirler. Bunun yanı sıra karışımlarda kullanılmak üzere ipek kesikli life de dönüştürülebilmektedir. Bu çalışmada ştapel mulberry ipeğ ile penye pamuk lifleri cerde karıştırılmış ve bu karışımdan iki farklı sistemde, üç farklı ipek/pamuk karışım oranıyla ve üç farklı büküm katsayısıyla iplikler üretilmişlerdir. İpliklerin fiziksel kalite özelliklerini belirlemek için mukavemet, düzgünsüzlük tüylülük gibi değerleri ölçülmüştür. Sonuç olarak siro sistemiyle çalışmanın ipliğin kalite özellikleri açısından daha verimli olduğu ve ipek oranının artmasıyla ipliğin mukavemetinin arttığı ancak düzgünsüzlük ve tüylülüğünde de aynı zamanda artış olduğu gözlemlenmiştir.

Anahtar Kelimeler: Mulberry ipeği, penye pamuk, ring eğirme sistemi, siro eğirme sistemi

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1. INTRODUCTION

Silk is a well-known natural protein fiber which can be mainly classified into two groups: Mulberry and wild silk fibers. Wild silk fibers are Tussah, Muga and Eri silk fibers (1). However, mulberry silk can be deemed as the most important silk fiber due to its cultivability. In addition to this, its fiber properties make it one of the most important natural fibers and textile raw materials. However, reeling process of this fiber which is reeled from cocoons, can be interrupted by both process failures and problems occurring from cocoons themselves. "Silk waste" term comes to sight at this point. These fibers can be used in short fiber spinning systems by converting them into staple fibers.

Mulberry silk has a lustrous aspect, soft to touch handle, superior tensile properties and trilobal fine structure. These properties of the fiber positively affect end-use purposes (2).

New spinning methods have been developed by making some modifications on conventional ring spinning system. Compact spinning system, solo spinning system and siro spinning system can be counted in these new spinning systems (3). In these systems, modifications have been made in the drafting zone. One of these systems, siro spinning system produces two-ply yarns. However, in this system two-ply yarns are not produced from two yarns, they are produced by twisting two non-twisted fiber bundles (4). For this process, two rovings are fed into one drafting system and a roving guide is used to adjust the distance between them. In the end, fiber bundles, which leave drafting zone at the same time, are twisted together and two-ply yarn is produced at one step (5).

Literature about siro spinning system tells us that siro-spun yarns have higher migration parameters in comparison with RoCoS compact and conventional ring spun yarns (3).In the second part of Soltani and Johari's study, they have found out that siro-spun yarns had higher tensile strength than RoCoS compact and ring-spun yarns (6). These results corroborates with Basal and Oxenham's findings which indicates that tensile strength and migration parameters of yarns are directly proportional (6,7). Sun and Cheng have stated that siro-spun yarns have less hairiness, higher tensile strength and abrasion resistance than ring-spun yarns (8). Üte and Kadoğlu, also stated that sirospun yarns had higher tensile strength, lower unevenness and hairiness compared to ring-spun yarns in their study in which they produced 100% PET yarns with both systems (9).

Chollakup et al has several studies about silk/cotton blended yarns. They have used three different thai hybrit silk waste types for blending with cotton and they concluded that "pierced cocoon" waste is the most suitable among them (10). They have blended "pierced cocoon" silk waste which are 35mm in length and cotton fibers and have spun 30 tex yarns by using microspinning method. Their analyzes shows that IPI faults and unevenness increases with increasing silk content in blended yarns (11). They have investigated Eri silk and cotton blended yarns. They have indicated that silk fiber content in the yarn positively effects tensile strength and breaking elongation, whereas it increases unevenness values (12). Kumar et al indicated in their study that increasing silk fiber ratio in the silk/cotton blended yarns causes higher yarn faults (13).

These foretold studies gave us insight about the differences about siro and ring spinning systems as well as silk fiber's contribution to silk/cotton blended yarns in different spinning systems and using wild silk fibers, generally. In this study, we produced mulberry silk/cotton yarns with different yarn counts and twist coefficients. We used two different spinning systems which were conventional ring spinning system and siro spinning system. We have investigated yarn properties in order to evaluate the effects of spinning system, twist coefficient and blending ratio on staple silk/cotton blended yarn properties.

2. MATERIAL AND METHODS

This study deals with the effects of blending ratio, as well as the effects of spinning system on silk/cotton blended yarns. Therefore, we blended staple mulberry silk fibers and combed cotton fibers, initially in this study. Properties of fibers are given on Table 1. Blending process was carried out in RIETER RSB-D 35 drawframe in pilot spinning mill of Ege University, Department of Textile Engineering. Silk/cotton blended drawframe slivers were produced with three different blending ratios (Table 2).

Table 1. Properties of Silk and Cotton Fibers (HVI and Favigraph Results)

Cotton Fiber Properties	Results	Silk Fiber Properties	Results
Mic (Mic)	4,7	**Tensile Strength(cN/tex)**	47
Str (g/tex)	31,7	**Tensile Strength %CV**	20,9
El (%)	4,1	**Breaking Elongation (%)**	13,85
ML (mm)	28,6	**Breaking Elongation %CV**	29,34
Unf (%)	84,2	**Fiber Fineness (dtex)**	0,93
SCI	144	**Fiber Fineness %CV**	22,66
SFI	5,4	**Fiber Length (mm)**	52
Rd	74,1	**Fiber Length %CV**	50,2
+b	9,8		
Cnt	9,8		

Table 2. Blending ratios of produced yarns

Type	Blending Ratio
1	15% Silk-85% Cotton
2	30% Silk-70% Cotton
3	45% Silk-55% Cotton

After sliver production, Ingolstadt roving frame was utilized for producing Ne 1.5 rovings and RIETER G30 spinning frame for spinning. Three different yarn counts (Ne 20, Ne 30 and Ne 40) and three different twist coefficients (α_e 3.4, α_e 4.0 and α_e 4.6) were used for ring-spun yarn production. Siro-spun yarns were also produced with same three twist coefficients. However, we only used Ne 30 yarn count for these yarns. Siro-spun yarns were produced by using the same machine parameters (except drafting ratio) as ring-spun yarns. Distance between the rovings was 4 mm in siro-spun yarn production. Information about the yarn production is given on Table 3.

Table 3. Yarn production parameters

Machine Type	RIETER G 30 Ring Frame	
Spindle Speed (rpm)	10000	
Ring Type and Diameter (mm)	Orbit / 42	
Traveller (ISO)	**Ne 20**	90
	Ne 30	45
	Ne 40	31,5
Clips (mm)	5,5	
Distance between the rovings for siro-spun yarns (mm)	4	

Following the yarn production, yarn samples were conditioned at 20±2 °C temperature and %65±3 RH according to the standard.

Incipiently, roving unevenness tests were carried out using Uster Tester 5. After then, tensile strength and breaking elongation tests were done with the help of Lloyd tensile tester according to the standards. Finally, unevenness and hairiness results were obtained with Uster Tester 5. These results were statistically analyzed by using SPSS 20 software later on.

3. RESULTS AND DISCUSSION

In this part, results of foretold yarn and roving tests are given in separate titles. Moreover, results of variance analysis which was carried out to reveal the effects of silk fiber content to yarn properties and paired sample t test which was carried out to show the effects of spinning system are given on Tables 4 and 5, respectively.

As it is shown on table 4, changes in silk fiber content resulted with statistically significant differences in yarn properties; tensile strength, breaking elongation, unevenness and hairiness ($p<0,05$). These results are given thereinafter.

Paired sample t test was carried out to understand how much spinning systems affect properties of yarns, produced in these systems which are siro and ring systems. This test was repeated for each twist coefficient and silk fiber content of blended yarn. Test results are given on Table 5.

According to the tests; differences between tensile strength, unevenness and hairiness properties of the sirospun and ring spun yarns are statistically significant ($p<0,05$). Yarn types which have significant difference of breaking elongation are fewer compared to other yarn properties.

Table 4. Variance Analysis of silk content effect on yarn properties

Factor	Yarn Properties	Significance
Silk Content	Tensile Strength (cN/tex)	,000*
	Breaking Elongation (%)	,000*
	Uster CV%	,000*
	Tüylülük	,000*

*Significant for α=0,05

3.1 Roving Unevenness

As mentioned before in this paper, three different blending ratios were used while producing the slivers. Rovings with different blending ratios were tested to investigate their unevenness values. These tests were carried out with Uster Tester 5 for five rovings of each blending ratio. Results were given on Table 6.

Results indicate that with increasing silk fiber content, unevenness values of the rovings also increase. This characteristic will help us to explain yarn unevenness results, later in this study

Table 5 Paired Sample T Test results of ring-spun and siro-spun Ne 30 yarns

Yarn Properties	15%			30%			45%		
	α_e 3,4	α_e 4,0	α_e 4,6	α_e 3,4	α_e 4,0	α_e 4,6	α_e 3,4	α_e 4,0	α_e 4,6
Tensile Strength (cN/tex)	0,009*	0,043*	0,009*	0,198	0,024*	0,000*	0,007*	0,000*	0,503
Breaking Elongation (%)	0,234	0,649	0,780	0,003*	0,170	0,116	0,284	0,338	0,041*
Uster % CV	0,025*	0,015*	0,094	0,197	0,004*	0,039*	0,105	0,007*	0,041*
Hairiness (H)	0,012*	0,045*	0,005*	0,004*	0,026*	0,730	0,174	0,340	0,043*

*Significant for α=0,05

Table 6. Unevenness values of rovings

Silk Content (%)	Uster CV %
15	10,09
30	10,92
45	11,34

3.2 Yarn Properties

Yarn properties are given on Table 7. These properties are also evaluated separately in sub titles.

Table 7. Properties of produced yarns with different silk fiber contents (15%, 30%, 45%) and different twist coefficients(3.4, 4.0, 4.6)

Yarn Properties	Spinning System*	Yarn Count (Ne)	15%			30%			45%		
			αe 3,4	αe 4,0	αe 4,6	αe 3,4	αe 4,0	αe 4,6	αe 3,4	αe 4,0	αe 4,6
Tensile Strength (cN/tex)	R	20	15,76	17,16	18,29	16,54	17,21	18,34	17,09	17,61	18,61
	R	30	14,08	15,2	16,17	15,52	16,06	16,26	15,65	16,12	17,68
	S	30	15,43	17,28	17,7	15,77	17,38	17,78	16,86	17,57	18,05
	R	40	13,68	13,75	15,66	15,47	15,51	16,66	16,1	16,59	17,06
Breaking Elongation (%)	R	20	11,35	12,08	12,69	11,56	12,29	13,76	11,95	12,46	14,55
	R	30	9,82	10,89	10,72	11,46	11,97	12,57	11,32	11,95	13,26
	S	30	10,23	10,97	10,84	10	11,35	11,95	11,08	11,63	12,38
	R	40	9,82	10,89	10,72	11,46	11,97	12,57	11,32	11,95	13,26
Uster % CV	R	20	14,34	13,84	14,78	14,61	15,7	14,62	16,59	15,62	15,45
	R	30	16,88	16,35	16,05	16,52	16,7	17,96	18,46	18,62	17,77
	S	30	15,27	14,92	15,09	14,82	15	15,2	16,06	16,15	15,54
	R	40	16,36	17,44	16,84	17,03	17,97	17,22	17,43	18,08	19,02
Hairiness (H)	R	20	5,6	4,99	4,65	5,74	5,17	4,41	5,82	5,57	4,6
	R	30	4,62	4,42	4,03	4,92	4,45	4,22	5,01	4,68	4,24
	S	30	4,29	3,97	3,84	4,36	4,13	4,16	4,84	4,48	4,49
	R	40	4,15	3,7	3,48	4,18	3,86	3,6	4,42	3,92	3,65

*Spinning System: R: Ring, S: Siro

3.2.1 Tensile Strength

The results indicate that higher silk fiber content in yarn body enables higher tensile strength for silk/cotton blended yarns (Figure 1). In terms of fiber tensile strength, silk fibers we used in this study had higher strength than cotton fibers. In addition to this, silk fibers were also finer than cotton fibers which led to more fiber amount with higher tensile strength in the cross-section of the yarn when we increased silk content in the yarn (Table 1). Hence, higher silk fiber amount in the cross-section of the yarn caused higher yarn tensile strength. It is also clear that increasing twist coefficient allows producing yarns with higher tensile strength. These results also show that even using α_e 4.6 twist coefficient, critical twist coefficient limit has not been passed for mulberry silk/cotton blended ring-spun and siro-spun yarns at the yarn counts of Ne20, Ne 30 and Ne40.

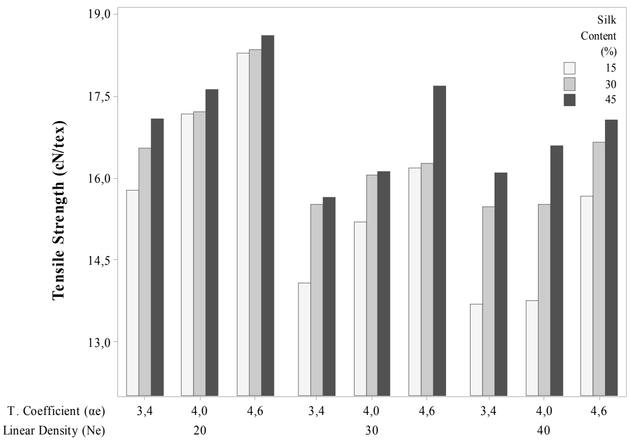

Figure 1. Tensile strength results ring-spun yarns

Siro-spun yarns have better tensile strength properties then ring-spun yarns. The difference between the tensile strengths of these two systems is statistically significant ($p<0,05$). This was an expected result due to the previous studies about siro-spun yarns (6,9). This result also confirms that increasing silk fiber content and twist coefficient also allows higher tensile strength for siro-spun silk/cotton blended yarns.

3.2.2. Elongation at Break (%)

The results of tests show us that the highest elongation at break result comes with increasing silk fiber content and twist coefficient. Effect of silk fiber ratio is found significant, statistically ($p=0,000$). Investigation of siro-spun yarns which were produced with Ne 30 yarn count clarified that this yarn type has more elongation than ring-spun yarns when low silk fiber content was used (for only %15 silk fiber content). In case of using more silk fibers in the blend, like 30% and 45% silk fiber content in yarn body, ring-spun yarns have higher breaking elongation than siro-spun yarns. However, the differences between elongation at break results of ring and siro-spun yarns were mostly not significant, statistically (Table 5). Results also indicate that, higher twist coefficient has caused higher breaking elongation for both ring-spun and siro-spun yarns, generally.

3.2.3 Yarn unevennness (%CV)

In general terms, when silk fiber amount in blending ratio increased, CV% of the yarns also increased. Roving unevenness results can also ease to understand why high silk fiber content resulted in high Uster %CV values. Table 3 contains unevenness results of rovings with three different silk fiber ratio used on them. According to the results given there, higher silk fiber amount in rovings caused higher irregularity. Thus, using these rovings resulted similar also in yarns, in terms of yarn unevenness.

Siro spinning system is more reasonable compared to conventional ring spinning system in view of yarn unevenness. For all blended yarn types which were produced in this study, siro system allowed us to produce yarns with better unevenness results. Nevertheless, yarns produced with higher silk blending ratio generally were more uneven compared to those with lower silk fiber content.

3.2.4 Yarn hairiness (H)

One of the most important properties which tell us about yarn quality is hairiness which can also be investigated using Uster Tester 5. It is a well-known fact that increasing twist of the yarn results in lower hairiness in yarn. Our test results for Ne 20 and Ne 40 ring-spun yarns also confirmed that. Moreover, we have found that blending more silk fiber in cotton fibers increased Uster yarn hairiness values of the yarns in our study with the exception of the Ne 20 silk/cotton blended yarn with %15 silk fiber content and αe 4,6 twist coefficient (Figure 2). Statistical analysis showed that the effect of silk fiber ratio was significant ($p=0,000$).

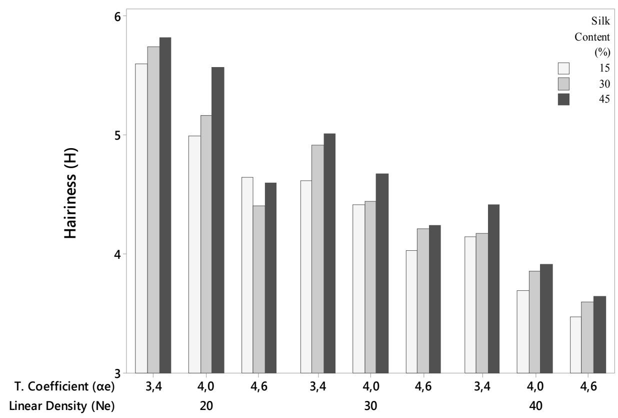

Figure 2. Hairiness (H) results ring-spun yarns

Using siro spinning system to produce Ne 30 yarns with the three twist values used in this study resulted with lower yarn hairiness than ring-spun yarns (Figure 9). This is due to the system's effect of causing lower yarn hairiness than ring spinning system. Differences between the hairiness values of ring-spun and siro-spun yarns were generally significant (Table 5). Moreover, the effect of twist which has been seen on Ne 20 and Ne 40 ring-spun yarns was also obtained for Ne 30 ring and siro-spun yarns. Increasing twist coefficient caused lower hairiness in both ring and siro spinning systems (Figure 2 and Figure 3).

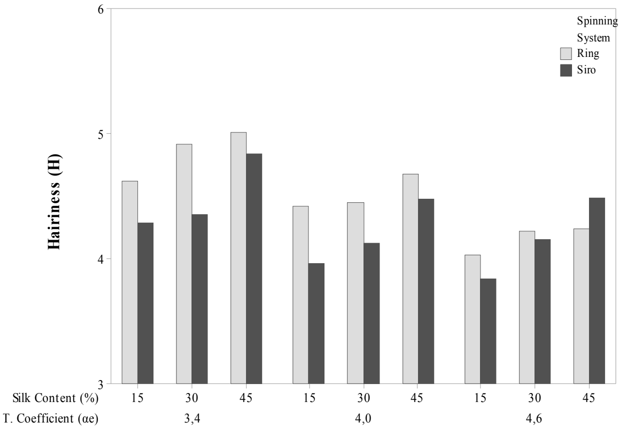

Figure 3. Hairiness (H) results of Ne 30 ring-spun and siro-spun yarns

4. CONCLUSION

The aim of this study was to present the effects of silk fiber when staple mulberry silk fiber is used to build yarns with cotton and to find out the differences of these yarns' quality when they are produced with ring and siro systems. For this reason Ne 20 and Ne 40 yarns were produced with ring spinning system and Ne 30 yarns were produced with both siro and ring spinning systems and then, results of various tests were gathered and investigated.

Tensile strength results exhibit that the more silk fiber in cotton/silk blend the more strength yarn has. This is a reasonable result, because of the silk fibers' higher strength in comparison to most of the cotton fiber types (2). Nevertheless, producing yarns with siro system allowed us to get yarns with higher tensile strength than ring system which is not a surprise with respect to the previous studies about these both systems (6,8,9).

Breaking elongation (%) has the same tendency in this study as tensile strength for silk content in Ne 20 and Ne 40 ring-spun yarns. Higher silk content in yarn resulted in higher breaking elongation of the yarn. However, siro-spun yarns had more breaking elongation than ring-spun yarns for only with %15 silk and %85 cotton fiber blended yarns.

Unevenness results shows that adding silk to cotton had increased Uster CV% values of ring-spun yarns. This condition was also presented in siro-spun yarns. The important relationship in unevenness values is siro-spun yarns had lower unevennes than ring-spun yarns.

Hairiness increased with higher silk content in yarn for all yarn counts and both systems. However, siro spinning system can be related to lower Uster hairiness values (H) than ring spinning system.

Consequently, throughout this study, it can be stated that if staple mulberry silk fiber is wanted to be used in silk/cotton blended yarn production, siro spinning system is more available to produce yarns with better quality.

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