The Effect of Persian Silk Waste Blend Ratio on Physical Properties of Rotor-Spun Blended Silk/Cotton Yarns

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ABSTRACT

The aim of this paper is to investigate the effect of Persian silk waste blend ratio on physical properties of rotor-spun blended silk/cotton yarns. The results show that by increasing the silk fiber blend ratio, the yarn elongation and abrasion resistance are significantly increased. However, silk fiber blend ratio has no significant influence on yarn imperfection, frictional and evenness properties. It is also shown that tensile strength of silk waste/cotton blended rotor spun yarn at 50% silk fiber blend ratio is significantly higher than that of 100% cotton as well as two other blended yarns. By applying Hamburger theory, this finding has been confirmed. According to this study, silk waste rotor spun yarn has the highest tensile strength compared with other yarn samples. On the other hand, the results indicate that by increasing the silk blend ratio, slight reduction of yarn linear density and yarn hairiness deterioration observed.

KEYWORDS

silk waste, rotor spinning, cotton fibre, de-gumming, blended yarn, Hamburger theory.

1. INTRODUCTION

In staple fiber yarn processing, blending is carried out for a number of reasons, including uniformity, technical and engineering, functional and aesthetic and economic aspects [1]-[7]. Silk fibre is well-known for its strength, fineness, luster and elasticity [8]. To obtain the desirable characteristics of blended fibre products, silk waste fibres may be blended with cotton fibres in the cotton spinning system to give comfort, strength and elegance in blended yarn.

Several research works studied Throstle-spun-silk/raw-silk-core-spun yarn as well as double-core twin spun silk yarns and fabrics properties [9]-[13]. In recent years, there are some interests on silk waste fibre blends with cotton, wool and polyester fibres [14]-[19]. In particular, Lo and Cheng [16] investigated silk waste/polyester blended DREF-spun yarns. Kumar *et al.* [18] studied the feasibility of spinning pure silk as well as silk waste-polyester on short-staple ring spinning system. In a recent study, Chollakup *et al.* [19] investigated physical properties and fibre arrangement of blended silk waste/cotton yarns in cotton ring micro-spinning system. Concerning the higher speed of rotor spinning compared with ring spinning, the rotor spinning system is more economical than ring spinning [20]. Moreover, there is no comprehensive published work concerning the application of silk waste fibre on rotor spinning system. Therefore, the objective of the current research work is to study the effect of Persian silk waste blend ratio on physical properties of rotor-spun blended silk/cotton yarns.

2. EXPERIMENTAL

A. Materials

Persian silk waste in hank form was prepared. The hanks of Persian silk waste were then cut to an average length of 40 mm staple using a cutting machine designed for cutting the card paper. Degumming was carried out by boiling off in soap solution under the following conditions:

Sodium carbonate	5 g/*l*
Ultravon GPN	10 g/*l*
Silvatol FL	10 g/*l*

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L.R 30:1
Time 90 min.
Temperature 90°C

After degumming, the fibres were washed in soft warm and then in cold water and dried at room temperature for 24 hours. In order to facilitate the processing of silk fibre in spinning, additives agents as softener were also used with following specifications:

SAPAMINE OC 3.0% (in fibre weight)
ACETIC ACID 0.50% (in fibre weight)
L.R 30:1
Temperature 40°C
Time 20 min.

After degumming process, the staple silk fibres appears to get entangled. It was then pre-opened using a special opener (Larosche). The material was allowed to be conditioned for 24 hours. In addition, in order to prevent from static electricity generation in silk fibre, an anti-static solution (ZEROSTAT C) at 20 g/*l* concentration was prepared and then sprayed over fibres at 10% fibre weight.

The cotton fibres used in this research was a mixture of different Iranian cotton fibres (Ghom-SM, Ghom-GM, Eshtehard-SGM). The physical properties of silk and cotton fibres used in this study are measured as follows: Effective length and short fibre content of cotton and silk fibres were measured using "Comb Sorter" method [21], [22]. Single fibre tensile strength of silk fibre was measured using Fafegraph apparatus. The gauge length and cross-head speed were adjusted at 1 cm and 1000 mm/min values respectively. Cotton fibre bundle strength was measured by Pressley method [21], [22]. Silk fibre fineness was measured using Vibromat method [21], [22]. To evaluate the cotton fibre fineness, Micronaire method was used [21], [22]. Table 1 shows the mean values of cotton and silk fibre specifications.

TABLE 1 SPECIFICATIONS OF FIBRES

Material	Fineness (dtex)	Tensile Strength (cN/tex)	Short fibre content (%)	Effective Length (mm)
Silk-waste	1.42	45.1	13.16	44
Cotton	1.51	27.6*	11.54	29

* Single Fibre Tensile Strength (cN/tex)= 5.26*PI

TABLE 2 SPINNING MACHINE SPECIFICATIONS

Spinning Machine Parameter	Specifications
Rotor type	T40
Take-up nozzle	Steel-4 Grooves
Opener Type	For Synthetic fibre, B171DN
Production Linear Speed	67.8 m/min
Sliver Feed Speed	0.36 m/min
Draft	178.2
Rotor Speed	60000 rpm
Opener Speed	8500 rpm
Yarn Twist	850 TPM

B. Spinning Process

The prepared staple silk fibers were fed into a conventional bale opener. The opened fibres were transported to a Crosrol MK4 Card via a chute-feed system and carded sliver from silk fiber with a linear density of 5 ktex was produced. Cotton fibres were processed on a conventional cotton blow-room line and the opened and cleaned cotton fibres were also transported to a Crosrol MK4 Card via a chute-feed system and 100% carded cotton fiber sliver with a linear density of 5 ktex was produced. In order to produce 35/65, 50/50 and 65/35 silk/cotton sliver, the blended fibers were prepared by layering method (sandwich blending procedure) and then followed the same procedure as for 100% silk fiber and finally silk/cotton carded slivers with a linear density of 5 ktex were produced. The carded slivers were then passed through a drawing process to produce drawn slivers with linear densities of 4.2 ktex (total draft and number of doublings were 7.1 and 6 respectively). The drawn slivers were processed on a rotor spinning machine (Schlafhorst Co.) to produce yarn of 30 Ne. (20 tex) with twist level of 850 TPM. The Rotor spinning machine specifications are listed in Table 3.

C. Yarn tests

The physical properties of produced yarns including linear density, tensile strength, evenness, imperfection, hairiness, frictional and abrasion resistance were investigated.

The yarn linear density was measured using standard test methods [21], [22]. Yarn strength and breaking elongation values were determined on an Instron tensile tester with yarn gauge length of 150 mm and cross-head speed of 200 mm/min. The yarn evenness measurement was obtained on Uster Evenness Tester 3. To measure yarn hairiness, we used a Zweigle G565 hairiness tester. The S3 values (number of hairs with a length greater than or equal to 3 mm) were measured over a length of 100 m of yarn at 60m/min, and 5 tests were conducted for each yarn. Yarn frictional properties were measured using a Shirley yarn frictional tester. The test speed was 60 m/min and 5 tests were conducted for each yarn. The yarn abrasion resistance was measured by using a Shirley yarn abrasion tester. A standard abradant (P2500) was used and 5 tests were conducted for each yarn sample. All tests were conducted under the standard laboratory conditions (22 ± 2°c and 65 ± 2% r.h.). The average test result of yarn properties is shown in Table 4. The experimental results of yarn physical properties were statistically analyzed using ANOVA and Multiple Range Test methods [23].

3. Prediction of Tensile Properties of Silk Waste/Cotton Blended Rotor Spun Yarns

Tensile properties of silk waste /cotton blended rotor spun yarns were predicted using Hamburger theory [4], [24]. In this study, the cotton component is less extensible than silk component. Fig.1 shows a typical tensile strength curve of silk and cotton rotor spun yarns.

Table 3:
Physical properties of rotor-spun yarns for different silk fibre blend ratio
(The CV% values are indicated in brackets)

Silk fibre Blend Ratio (%)	0	35	50	65	100
Yarn Linear Density (tex)	22.58 (1)	21.95 (1.59)	21.13 (3.92	21.15 (2.08)	19.57 (9.65)
Yarn Tenacity (cN/tex)	10.37 (10.7)	9.95 (12.42)	11.13 (11.23)	10.19 (12.36)	13.19 (9.86)
Elongation (%)	4.72 (9.14)	6.68 (10.71)	7.24 (10.65)	7.46 (7.23)	10.02 (7.54)
Evenness (CV_m%)	11.37 (2.11)	11.73 (1.28)	11.74 (2.89)	10.95 (2.56)	12.02 (6.58)
Neps (280%)	1 (81)	0.5 (116)	0.75 (66.6)	0.75 (126.6)	1 (82)
Thick Places(50%)	0.5 (116)	2 (91)	1 (82)	0.75 (128)	1 (82)
Hairiness (S3 Value/ m)	5.6 (9.28)	8.86 (15.68)	9.2 (8.69)	10.72 (10.35)	9 (2.66)
Yarn Coefficient of Friction	0.06 (0)	0.07 (0)	0.064 (8.55)	0.07 (0)	0.054 (16.56)
Yarn Abrasion Resistance	12.4 (13.47)	19.6 (36.88)	51 (4.39)	52.2 (10.34)	69.2 (13.45)

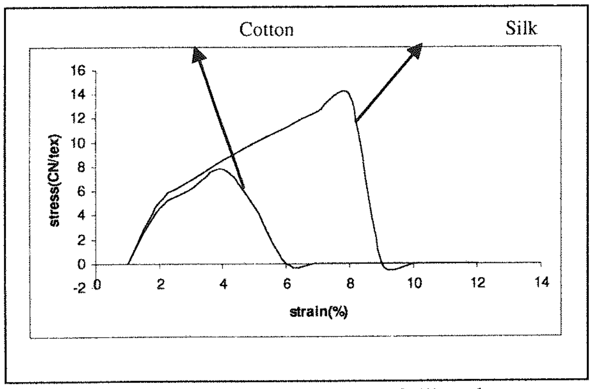

Figure 1 A typical tensile strength curve of silk and cotton rotor spun yarns

To derive the tensile strength equation of blended silk/cotton rotor spun yarns, the following assumptions and calculations were considered:

a = cotton fiber proportion (%)

b = Silk fiber proportion (%)

S_c = Cotton yarn tenacity (cN/tex)

S_s = Silk yarn tenacity (cN/tex)

S_{cs} = Silk component tenacity at the time of cotton component breakage (cN/tex).

P_1 = Blended yarn tenacity at the time of cotton component breakage (cN/tex).

P_2 = Blended yarn tenacity at the time of silk component breakage (cN/tex).

$$p_1 = aS_c + bS_{cs} \quad (1)$$

$$p_2 = bS_s \quad (2)$$

$$a + b = 1 \quad (3)$$

4. Results and Discussion

A. *Tensile Properties*

The effects of silk fibre blend ratio on silk/cotton blended yarn tensile properties are illustrated in Figures 2 and 3. It is shown that tensile strength of silk waste/cotton blended rotor spun yarn at 50% silk fiber blend ratio is significantly higher than those of 100% cotton as well as two other blended yarns (Fig. 2). Thus, silk waste rotor spun yarn has the highest tensile strength compared with other yarn samples. The increase in tenacity of silk rotor-spun yarn is presumably due to higher tensile strength as well as effective length of silk fiber compared with cotton fiber. As also shown in Fig. 2, the predicted yarn strength result according to Humberger's theory is compared with experimental result. It is indicated that by using the Hamburger theory the blended silk/cotton yarn tensile strength behavior is predictable. However, at 50% silk fiber blend ratio, the predicted results is less than experimental values. This result is due to the fact that in the Humberger's theory, the fibre distribution in yarn cross-section is not considered.

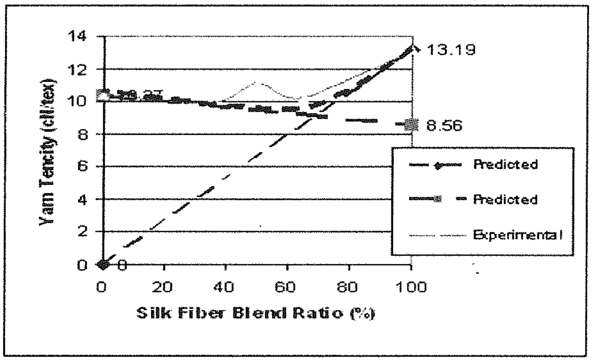

Figure 2 Yarn tenacity of silk/cotton blended rotor-spun yarns (Predicted and Experimental Results).

The results of experiment showed that by increasing the silk fiber blend ratio, the yarn elongation (Fig. 4) significantly increased. This result is attributed to the higher tensile elongation of silk fiber compared with cotton fiber.

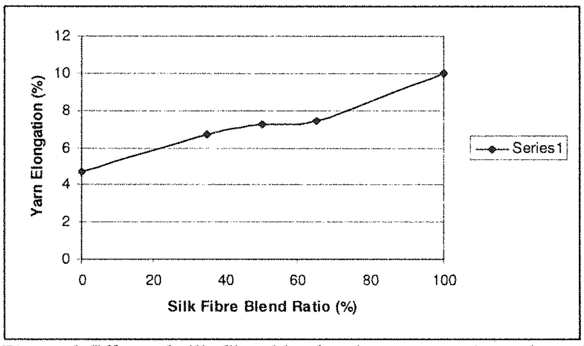

Figure 3 Effect of silk fibre blend ratio on yarn elongation of silk/cotton blended rotor-spun yarns.

B. *Yarn Abrasion Resistance*

The effect of silk fibre blend ratio on yarn abrasion resistance is represented in Fig.4. It is shown that by increasing the silk fibre blend ratio, the yarn abrasion resistance is significantly increased particularly at 50% and higher values. It is deduced that due to longer length and higher fineness of silk fibre compared with cotton component, the silk component is migrated towards the interior section of blended yarn [3] and hence leads to increase of yarn abrasion. The higher tensile strength of silk fibres compared with cotton fibres (Table 1) may be responsible for increase of yarn abrasion resistance.

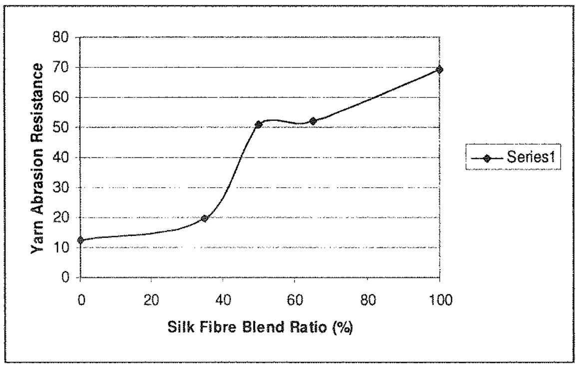

Figure 4 Effect of silk fibre blend ratio on yarn abrasion resistance of silk/cotton blended rotor-spun yarns.

C. *Yarn Hairiness*

The effect of silk fibre blend ratio on silk/cotton blended rotor-spun yarn hairiness is shown in Fig. 5. It is represented that with increase of silk fibre blend ratio up to 65%, the blended yarn hairiness is significantly increased. This result is attributed to the higher short fibre content of silk fibre compared with cotton fibre. Furthermore, the nature of yarn formation in rotor spinning system is also responsible for increasing of yarn hairiness. However, 100% silk rotor-spun yarn exhibited lower hairiness value compared with 65/35 silk waste/cotton rotor-spun yarn. It is represented that cotton rotor spun yarn exhibited a lower yarn hairiness value compared with 100% silk and blended silk/cotton rotor spun yarns. This result is attributed to the lower value of short fibre content of cotton fibre component. In addition, it is expected that longer and finer silk fibres are more subjected to fibre breakage in rotor spinning process than cotton fibre component and subsequently leads to increase of yarn hairiness.

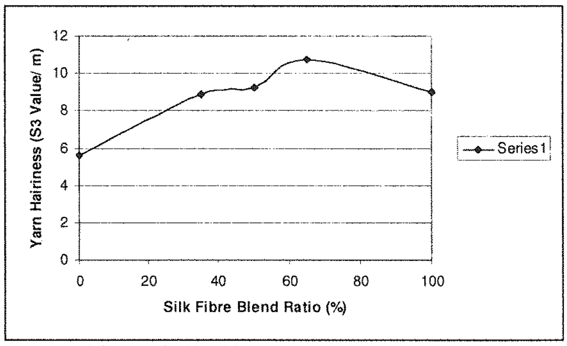

Figure 5 Effect of silk fibre blend ratio on yarn hairiness of silk/cotton blended rotor-spun yarns.

The reduction of yarn hairiness may be explained in terms of slightly lower yarn linear density as shown in Table 4. It is reasonable to state that due to the higher centrifugal force inside of the rotor wall, the silk gum will be separated from silk fibre resulting to slightly reduction of yarn linear density [14]. It also implicated that opener roller of rotor spinning machine has some effects on silk fiber length which in turn results to a decrease of yarn linear density.

D. *Yarn evenness and imperfections*

The effect of silk fibre blend ratio on rotor-spun yarn evenness is shown in Fig. 6. The statistical analysis results have shown that silk fibre blend ratio has no significant influence on yarn evenness and imperfections [23].

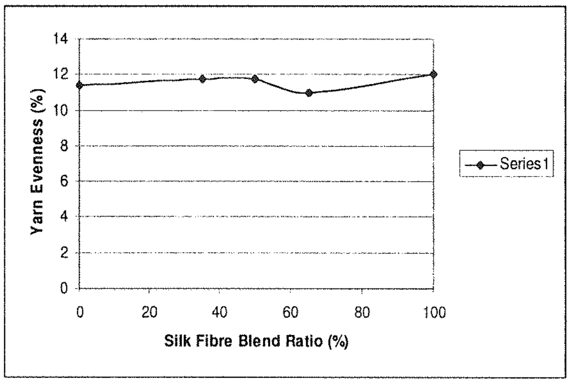

Figure 6 Effect of silk fibre blend ratio on yarn evenness of silk/cotton blended rotor-spun yarns.

5. CONCLUSION

In this work, processes of cutting, de-gumming of silk-fibre waste samples and silk waste sliver preparation were explained. Silk waste and cotton slivers were blended at three different blend ratios (65/35, 50/50 and 35/65) and silk waste/cotton blended as well as cotton and silk rotor spun yarns were produced. The physical and mechanical properties of the produced yarns including linear density, tensile strength, evenness, imperfection, hairiness, frictional and abrasion resistance were measured.

The results indicate that by increasing the silk fiber blend ratio, the yarn elongation and abrasion resistance significantly are increased. However, silk fiber blend ratio has no significant influence on yarn imperfection, frictional and evenness properties. It was also shown that tensile strength of silk waste/cotton blended rotor spun yarn at 50% silk fiber blend ratio are significantly higher than those of 100% cotton as well as two other blended yarns. Thus, silk waste rotor spun yarn has the highest tensile strength compared with other yarn samples. The result of this research suggests that the tensile strength of silk waste/cotton blended rotor-spun yarns is predictable by applying Hamburger theory. It is also found that with increase of silk fiber content, the linear density of produced yarns is slightly decreased, whereas, the yarn hairiness is partially deteriorated.. Further studies are needed to investigate the structural properties of silk/cotton rotor-spun yarns and the physical and mechanical properties of fabrics made from these yarns.

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