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Effect of Blending Factors on Eri Silk and Cotton Blended Yarn and Fabric Characteristics

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Summary: Eri cocoons were prepared into short fibers and subsequently blended with cotton fiber in order to develop the new fiber blended yarn in the short spinning system. The Eri and cotton fibers were blended using the drawframe blending with varying blending factors, viz. blending composition (0–100%) and yarn counts (30 and 50 tex). The results showed that Eri fiber which was longer and stronger than cotton fiber, affected the fiber distribution in the yarn cross-section. The mechanical properties of the blended fibers and yarns increased with increasing silk content. Longer fibers of Eri silk tended to move towards the yarn core, especially at silk content higher than 50%. Moreover, stronger and more extensible Eri silk fiber gave an advantage to the improvement of mechanical properties of those blended yarns with silk content higher than 50%. However, with increasing silk content, the blended yarns were more irregular as shown in %CV. Concerning the yarn count effect, the higher yarn count of 50 tex resulted in a more regular yarn with higher yarn strength than that of 30 tex. The plain-woven fabrics were prepared using the blended yarns as a weft yarn and the cotton yarn or silk yarn as a warp yarn. The mechanical properties of those woven fabrics were characterized in order to study the influence of silk contents. The results showed that tensile strength, %elongation and tear strength of woven fabrics using the blended yarn were increased with an increase in silk content. This is an advantage of Eri silk in the aspect of rendering the strength to the blended yarns and fabrics.

Keywords: blending factor; characteristics; cotton; Eri silk

Introduction

Eri silk (*Philosamia ricini*) is a wild silk which cannot be reeled out using the normal reeling process due to its open-mouthed cocoon. Hence, it can only be used for raw material to blend with other fibers such as wool, cotton, polyester[1–3] in the cotton-like spinning. In Thailand, Eri silk culture has been carried out only in research using feeds such as castor and cassava leaf. Compared to a mulberry silk, Eri silk had the higher elasticity, stronger durability against diseases and insects and more abundant sources of cassava leaves, which were side products from cassava export. As mentioned above, Eri silk was used as a staple fiber, which needed to blend with other fibers to obtain special yarns with different functional properties. In the case of fiber blending, the yarn, fiber arrangement in yarn cross-section was recognized to be an important parameter affecting the yarn and fabric characteristics.[4–5] Also, the distribution of the different component fibers in the yarn cross-section was affected by the blending and spinning processes, fiber properties, blend proportions, and yarn counts affecting this way the yarn and fabric characterization.[5–6]

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For the previous study of the Eri silk and cotton blending at the ratio of 50/50 in cotton spinning, it was found that the intimate blending and the drawframe blending resulted in no significant difference in the physical properties of their blends.[1] So in this study, the drawframe blending was chosen due to easy control of the weight ratios of silk and cotton fibers. The two factors of silk contents (0–100%, factor A) and yarn counts (30 and 50 tex, factor B) were studied their influence on yarn and fabric characteristics. Also, the fiber distribution in yarn cross-sections at different ratios of silk and cotton fibers were analysed to explain the blending factors on theirs characteristics.

Experimental Part

Silk and Cotton Blended Yarn

The Eri silk fibers were prepared from Eri cocoon (*Philosamia ricini*) to be the staple fibers as described previously with the cut length of 30 mm.[7] The raw material characteristics of the Eri silk and cotton fibers used in this study are shown in Table 1 with the same analysis method. Eri silk fibers were longer compared to cotton fibers due to cutting effect and similarity in fiber fineness. These properties were used for parameters in machine setting during yarn process. The drawframe blending and spinning processes of 30 and 50 yarn tex were carried out in the cotton spinning. Following preliminary laboratory scale processing,[1] it became apparent that the pure 100% Eri silk would require some kind of additive before satisfactory mechanical processing performances (especially in carding and drawing) could be obtained. Due to different humidity level from opening to drawing stages in the cotton spinning process (~50–55%) compared to that in the spun silk process (~65–80%)[8], it needed to add some softeners (~10–15%) in order to eliminate static electricity of Eri silk and to increase interfiber cohesion during processing. The Eri and cotton blended slivers were pre-drawn to obtain an equilibrium silver count before blending at different ratios of the two components. Pre-drawn slivers of silk and cotton at different proportions were doubled for 8 slivers and drawn twice. Roving was prepared and then was spun with twist multiplier (tex) of 3,500 for yarn count of 30 and 50 tex.

All types of bundle fibers were sampled after the last drawing frame in order to characterize the physical properties (fiber length, evenness, tenacity and elongation) using HVI (High Volume Instrument). Also, the evenness and imperfections of all yarns were evaluated following the standard method of ASTM D-1425 with UT3 device. The mechanical properties of all yarns were analyzed using Tensorapid device (ISO 2062, 1993). Furthermore, the blended yarns were dyed with two different types of dye, one for each component; cut and their cross-sections were photographed to evaluate the fiber distribution. The data were statistically analyzed at a 95% confidence level by One-Way ANOVA, and also by Multifactor ANOVA design to study the influence of blending factors.

Silk and Cotton Blended Fabric

The silk and cotton blended yarns were used for weft yarns in weaving two sets of plain woven fabrics. One was the woven fabric which composed of cotton as warp yarn and the blended yarns of 50 tex at different blending ratios as weft yarn. The other was the woven fabrics comprised silk as warp yarn and the blended yarns at

Table 1.
Physical properties of cotton and Eri silk fibers.

Fiber properties	Upper Half Mean Length (UHML)	Fiber fineness	Tenacity	%Elongation
Cotton fiber	28.50 mm	142 mtex	28.59 cN/tex	6.62
Eri silk fiber	36.31 mm	144 mtex	48.86 cN/tex	12.69

different blending ratios of 30 tex as weft yarn. The fabric structures were determined following the ISO methods. The mechanical properties of these two fabrics were evaluated for tensile strength and elongation (ISO 13934-1, 1999) and for tear strength (ISO 13937-2, 2000) using tensile tester. The data were statistically analyzed at 95% confidence level by One-Way ANOVA. The Pearson-correlation of physical properties between blended fibers, yarns and fabrics were also analyzed.

Results and Discussion

Silk and Cotton Blended Yarns

The physical properties of the drawframe slivers are summarized in Table 2. Fiber length and strength in the blends, except for %uniformity in length tended to increase as the silk content increased. It is due to the performance of Eri silk fibers which improves some characteristics of the blended bundle fibers. Compared to uniformity of the cotton fibers, silk fibers which were cut to be staple fibers from carded slivers, have a broaden distribution of length. It resulted in an irregular length uniformity.

In order to evaluate the general effects of the two factors–silk content and yarn count, a multi-factorial ANOVA was applied for analysis of the physical properties of the blends (Table 3). Concerning the silk content effect, the %CV of unevenness and the mechanical properties of the blends increase with increasing silk content. However, the imperfections of the blends tended to provide irregular yarns compared to the pure component. This may be due to difference in fiber migration of Eri silk and cotton in yarn cross-section. Concerning the yarn count effect, the higher yarn count of 50 tex resulted in a more regular yarn with higher yarn strength than that of 30 tex (Table 3). Figure 1 shows that the Eri silk yarn was less uniform as compared with the cotton yarn but the strength was higher. The blended yarns with 50% upward of Eri silk content attributed to an increase in CV% values. The mechanical properties were enhanced when the silk content in the blended yarn was 50% upward. The coarser yarn serves distinctive results in the

Table 2.
Physical properties of the blended bundle fibers at the last drawframe.

	0		25		50		75		100	
UHML (mm)	28.96	d	30.94	c	33.07	b	33.46	b	35.75	a
ML (mm)	24.79	c	25.85	bc	27.17	ab	27.29	ab	28.70	a
%Uniformity	85.60	a	83.54	b	82.16	bc	81.50	bc	80.28	c
Tenacity (cN/tex)	30.11	d	30.65	d	36.85	c	42.40	b	50.84	a
%Elongation	6.68	c	6.94	c	11.80	b	13.63	ab	13.30	a

The letter a signifies the best quality in terms of the bundle fiber physical properties compared to b and c respectively at $p < 0.05$ at the same properties.

Table 3.
Analysis factorial ANOVA of two blending factors on the yarn characteristics.

Yarn characteristics	Effect of silk content, % (A)					Effect of yarn count, tex (B)		AxB
	0	25	50	75	100	30	50	
%CV	a	b	b	c	b	b	a	S
Neps/km	a	b	a	ab	a	b	a	S
Hairiness	ns	ns	ns	ns	ns	a	b	S
Tenacity, cN/tex	c	c	c	b	a	b	a	S
%Elongation	c	c	c	b	a	b	a	S

The letter a signifies the best quality in terms of the yarn characteristics compared to b and c respectively at $p < 0.05$ at each factor. ns means no significant difference and s means significant difference.

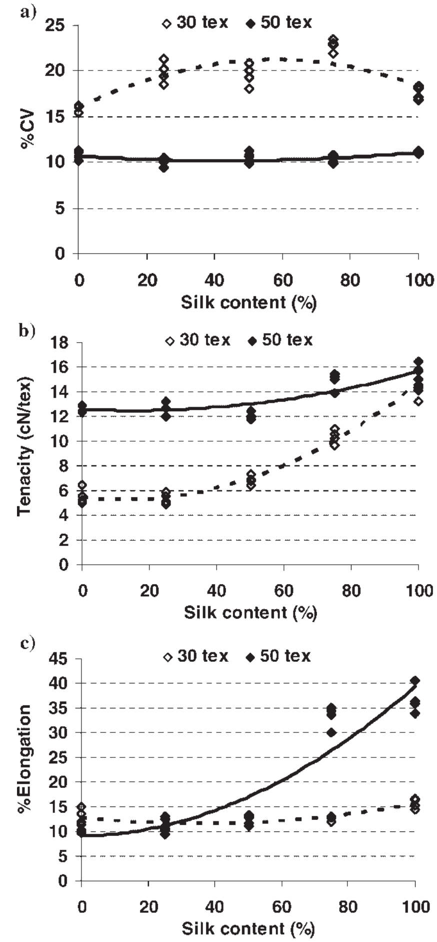

Figure 1.
Yarn physical properties at different silk contents and yarn counts. a) %CV b) Tenacity c) %Elongation.

mechanical properties of the blends as compared with thinner yarn. These results yielded the 50 tex blended yarns with 50% upward of Eri silk content having sharply higher elongation (Figure 1c).

As previous study[9] suggested that the fiber cross section distribution and migratory behaviour affected yarn characteristics. Photographs of yarn cross-section were captured in order to realize fiber distributions (Figure 2). The results of blending these two fibers were followed blending law and being able to be confirmed using fiber distribution principles. The Eri silk fiber was longer and stronger than cotton thereby tending to migrate to the core of the yarns with silk content higher than 50%. As shown in Figure 2, Eri silk fibers with triangle cross-section appeared densely in the yarn core at silk content of 50–75%. Moreover, stronger and more extensible Eri silk fiber gave an advantage to the improvement of mechanical properties of those blended yarns. For the difference between of thinner and coarser yarns, the coarser yarn exhibited more fiber migration than that the thinner yarn. This provided more regular and strengthen in the blended yarns with 50 tex compared to ones with 30 tex.

Silk and Cotton Blended Fabrics

Two types of woven fabrics were prepared using the blended yarns as weft yarns. One

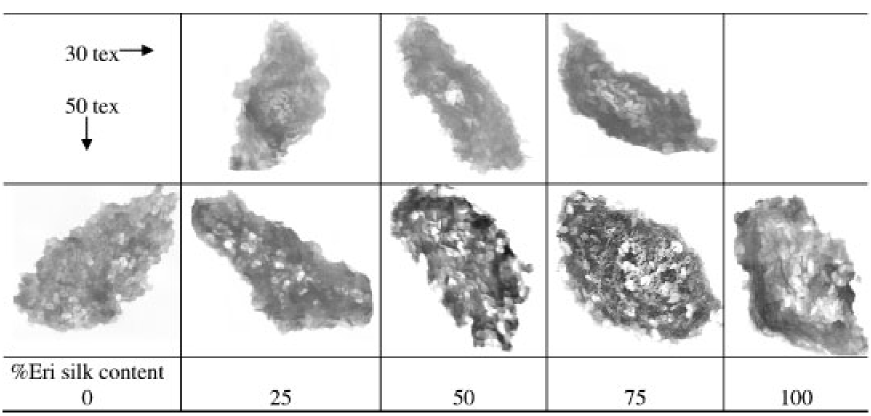

Figure 2.
Yarn cross-section of the blended yarns of 30 and 50 tex.

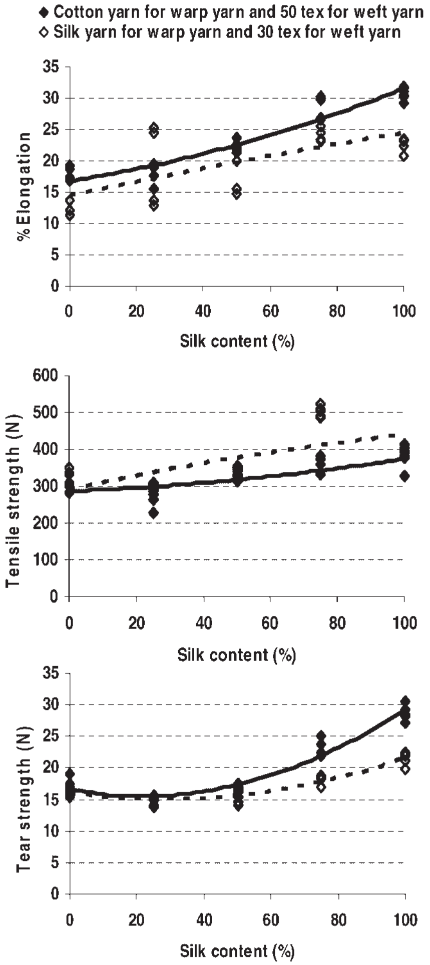

Figure 3.
Fabric mechanical properties in weft direction at different silk contents of the blended yarn as weft yarn and different warp yarns.

was the woven fabrics comprised silk as warp yarn and the blended yarns at different blending ratios of 30 tex as weft yarn. The other was the woven fabrics which composed of cotton as warp yarn and the blended yarns of 50 tex at different blending ratios as weft yarn. The fabric weights of two woven fabric types were 105.4–112.8 g/m^2 for the fabrics using silk as warp yarn and 143.7–149.7 g/m^2 for the fabrics using cotton as warp yarn. The fabric weights were not significantly different between different silk contents. No significant differences on the fabric structure are found between the different silk contents of weft yarns at each fabric type. The mechanical properties of these two fabrics are shown in Figure 3. The tensile strength, %elongation and tear strength in weft direction increased with increasing Eri silk content for both sets of woven fabrics. These results were in accordance with the blended fiber and yarn characteristics,[10] being confirmed by the correlation coefficient as shown only for elongation in Table 4. These results are in agreement with the scientific literature and indicate that the blending factors affect the mechanical properties as discussed above. It indicated the distinctive properties of silk which gives the blended yarn and fabric a higher strength and elongation at a certain silk contents.[11]

Conclusions

In this study, Eri silk provided the blended yarn with additional function of each fiber. The Eri silk and cotton blending with the two blending factors in the cotton spinning system affected the fiber, yarn, and woven fabric characteristics. With increase the silk content at higher than 50%, Eri silk fibers with longer and stronger than cotton fibers migrate into core yarn and resulted in increasing the mechanical properties of the blended yarns. In case of the yarn count factor, fiber distribution in coarser yarn provides distinctive arrangement than in thinner yarn, which results in more

Table 4.
Pearson correlation coefficients of elongation of the blended fibers, yarns and fabrics.

Elongation	Blended fiber	Blended yarn	Blended fabric
Blended fiber	1.0000	0.8052	0.8034
Blended yarn	0.8052	1.0000	0.8886
Blended fabric	0.8034	0.8886	1.0000

strengthen yarns. Blended fabrics form these blended yarns provide the same effect with increasing silk content. The physical properties of blended fiber, yarn and fabric are in good agreement to get an advantage of high strength and extensible fiber of Eri silk.

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