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High Strength Silk Fiber Obtained from Super Fine Filament of Silkworm Cocoon Treated with Bioactive Substances

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Abstract

High strength silk fiber was investigated for practical use. To obtain a fine filament, silkworms were treated with bioactive substances (anti-JH) and tetramolter silkworms were transformed into trimolter ones. Trimolter silkworm cocoon is smaller than the tetramolter one, filament size of smaller cocoon is finer and the filament strength is higher in general. Using the automatic reeling machine (Nissan CT-2), super fine raw silk aimed at obtaining a size of 9.5 d was produced and evenness (U%) and strength of the raw silk were measured. As a result, cocoon width of 16 mm and above was found to be suitable for the reeling machine. Among the cocoons with a cocoon width of 16 mm and above, trimolter race TC14 × MK treated with anti-JH was found to be suitable. The cocoon filament size was 1.04 denier and the raw silk size deviation was low (U%: 4.59%). The strength of the raw silk was 30% higher in comparison to the raw silk of the authorized and distributed silkworm race Asahi × Tokai.

Discipline: Sericulture
Additional key words: automatic reeling machine

Introduction

The silk filament characterized by a high strength and fine size which has been used for fine fabrics in the industry is being replaced by synthetic fibers. However, silk is a fibrous protein which is particularly suited to living bodies. Today, silk is used to produce textiles and attempts have been made to utilize silk functions in the form of new biomaterials[3,5]. It is considered that if the strength of the raw silk could increase, the demand for silk may also increase. Generally when the cocoon filament size is finer, the raw silk size deviation is lower and the strength of the raw silk is higher[2]. In this paper, the objective was to develop high strength raw silk with a lower size deviation and finer size than the raw silk produced at present. In addition it should also be produced using an automatic reeling machine.

As raw silk consists of a group of cocoon filaments, the cocoon filament size affects the size of raw silk. The unit for the size of the raw silk or cocoon filament is called denier (d). Presently the size of the cocoon filament of the silkworm races used is about 3 d, and raw silk with a size of 27 d is being produced, in addition to 33 d, 21 d and 14 d. When the size of the cocoon filament of the silkworm races used is 3 d, a raw silk size of 27 d is suitable in terms of the deviation in evenness. The size deviation inceases if the raw silk size is 21 d and below. Breeding procedures enable to obtain cocoon filaments with a finer size. A silkworm race with a fine cocoon filament (Akebono, N5·6 × C5·6, cocoon filament size 2.2 d) was developed. On the other hand, application of bioactive substances (anti-JH) to tetramolters transforms them into trimolters (3AJH). A technique for producing finer cocoon filaments using anti-JH has been developed recently[1,4]. Accordingly, if a tetramolter silkworm with a fine cocoon filament becomes a trimolter one with the application of anti-JH, the cocoon filament becomes much finer. However, if the cocoon becomes too small, in the reeling process, 2 cocoons may be fed simultaneously and evenness deviation of raw silk increases. As a result, it is necessary to select races which produce small cocoons in avoiding that 2 cocoons are fed

simultaneously in the feeding end. Therefore, the objective of this study was to obtain fine raw silk with a size of 9.5 d.

Experiment

1) Width of the feeder and feeding rate of 2 cocoon filament feeding ends

The reeling machine Nissan CT-2 model was used in this experiment and reeling was performed by keeping a feeder width of 20 mm. The reeling speed was 130 m per min.

2) 9.5 d raw silk

By using 5 silkworm races (1) Asahi × Tokai, (2) N5·6 × C5·6, (3) N5·6 × C5·6 (3AJH), (4) N2 × TC14 (3AJH) and (5) MK × TC14 (3AJH), 9.5 d raw silk was reeled.

3) U% of raw silk

The evenness of the raw silk was measured based on the U% value using Evenness Tester.

4) Strength of raw silk

The strength-elongation curves of the raw silk samples were determined using Tensilon UTM-II-20. The measurement was performed for both knotted and

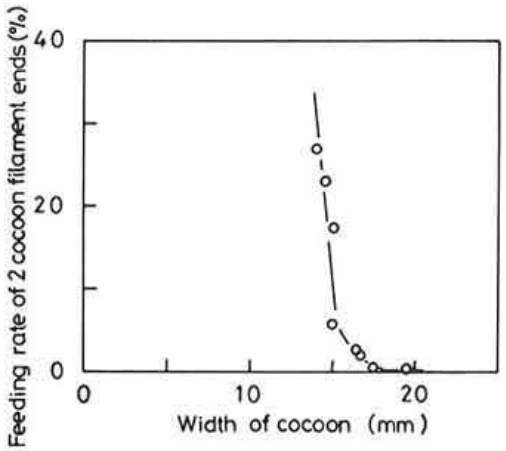

Fig. 1. Width of cocoon and feeding rate of 2 cocoon filament ends during reeling

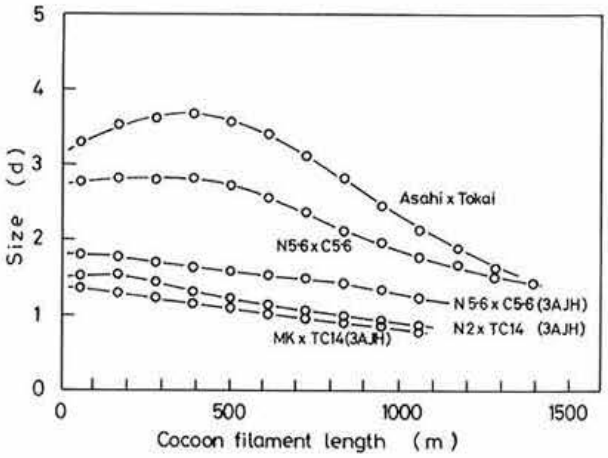

Fig. 2. Cocoon filament size curves
Average size of the cocoon filament is shown in Table 1.

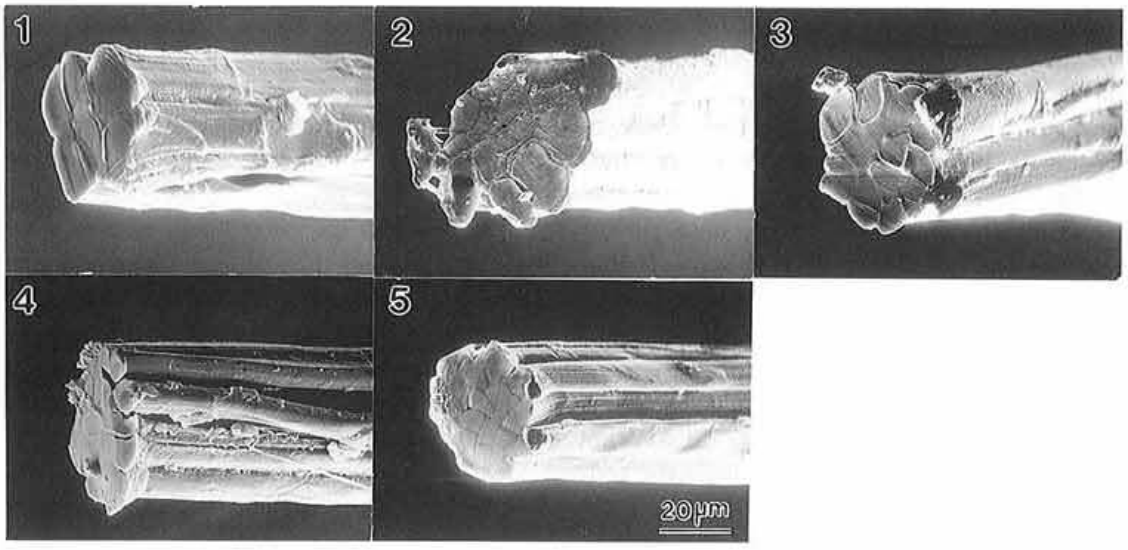

Plate 1. Microscopic photographs of raw silk samples from cocoon filaments with different sizes
1: Asahi × Tokai, 2: N5·6 × C5·6, 3: N5·6 × C5·6 (3AJH), 4: N2 × TC14 (3AJH), 5: MK × TC14 (3AJH).

unknotted raw silk samples. The strength and elongation were measured at 20°C and 65% RH, the holding grip distance was 10 cm and the elongation speed was 100% per min.

Results and discussion

1) Width of the cocoon feeder and feeding rate of 2 cocoon filament feeding ends

In the reeling machine, the width of the cocoon feeder which is about 30 mm can be adjusted up to 20 mm. The feeding rate of 2 cocoon filament ends was examined in relation to the width of the cocoon. The results are shown in Fig. 1. The feeding rate of 2 cocoon filament ends increased rapidly when the width of the cocoon ranged from 15 to 17 mm. Fig. 1 shows that the width of the cocoon should be 16 mm and above.

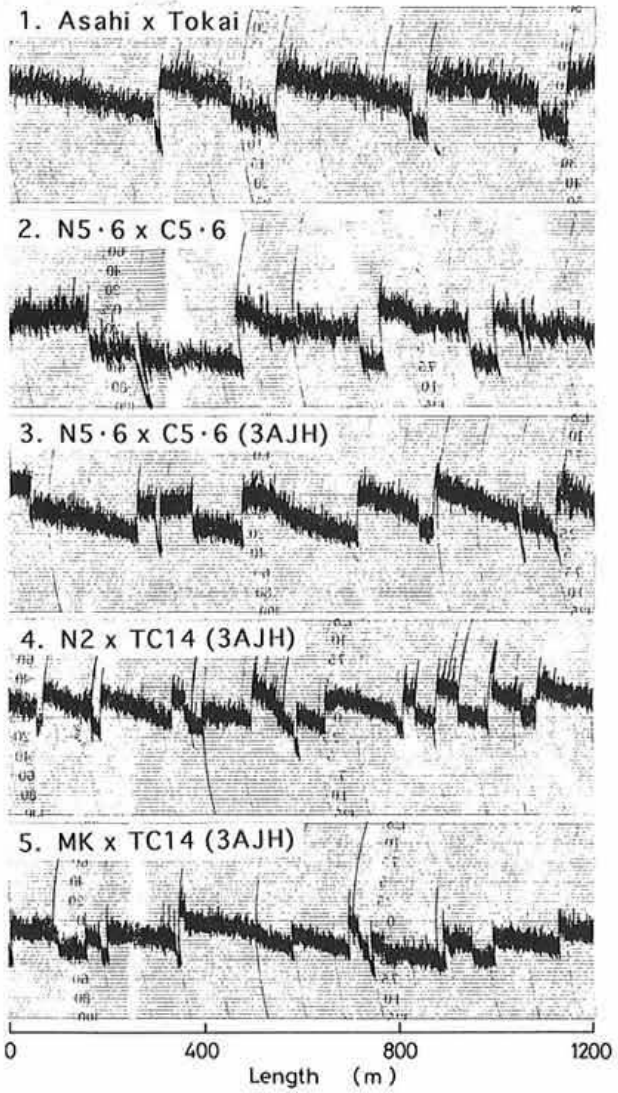

Plate 2. Size curves of raw silk from cocoon filaments with different sizes determined by Evenness Tester

2) U% of raw silk

Raw silk with a size of 9.5 d was produced from cocoon filaments with different sizes and U% of the raw silk was investigated. First, the cocoon filament size curves were analyzed for the Asahi × Tokai, N5·6 × C5·6, N5·6 × C5·6 (3AJH), N2 × TC14 (3AJH) and MK × TC14 (3AJH) races. The results are shown in Fig. 2. Then after fixing the minimum limit value at 9.0 d in the denier indicator device, raw silk was reeled from cocoon filaments with different sizes (Fig. 2). The microscopic photographs of raw silk are shown in Plate 1 which indicates that when the cocoon filament size is larger, the number of reeling cocoons decreases and the same relation applies to the evenness of the raw silk. The U% values obtained with the Evenness Tester are depicted in Plate 2. The U% values of the raw silk depended upon the cocoon filament size and that of MK × TC14 (3AJH) was 4.59%. The average cocoon filament size and raw silk size, reeling cocoon number and U% value of the raw silk for a 9.5 d size are listed in Table 1.

3) Strength of the raw silk

The strength-elongation curves of the raw silk produced from cocoon filaments with different sizes

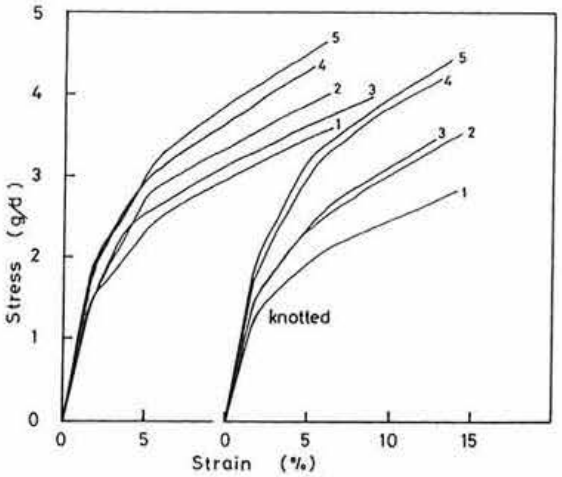

Fig. 3. Strength-elongation curves of raw silk from cocoon filaments with different sizes
1: Asahi × Tokai,
2: N5·6 × C5·6,
3: N5·6 × C5·6 (3AJH),
4: N2 × TC14 (3AJH),
5: MK × TC14 (3AJH).

Tbale 1. Average cocoon filament size shown in Fig. 2 and reeling cocoon number, raw silk size and U% of raw silk samples with 9.5 d using the cocoons

Silkworm race	Cocoon filament size (d)	Reeling cocoon number	Raw silk size (d)	U%
1. Asahi × Tokai	3.01	3.41	10.98	6.81
2. N5·6 × C5·6	2.12	4.71	10.75	6.15
3. N5·6 × C5·6 (3AJH)	1.45	6.27	10.54	5.96
4. N2 × TC14 (3AJH)	1.18	7.98	9.97	4.75
5. MK × TC14 (3AJH)	1.04	8.68	9.71	4.59

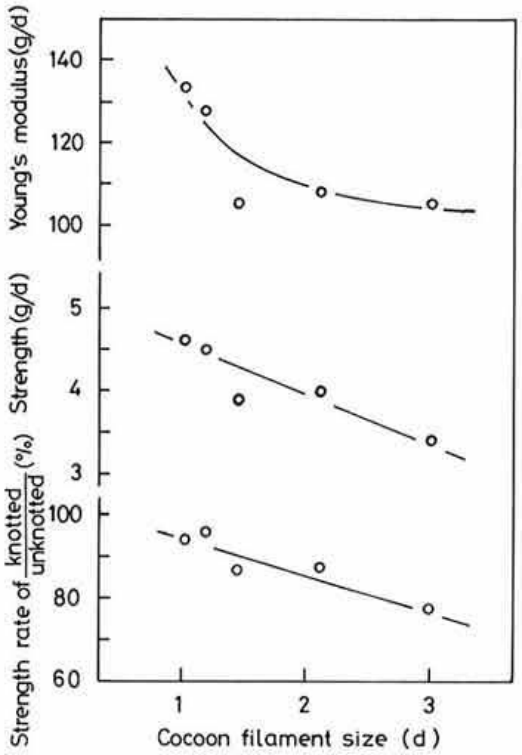

Fig. 4 Young's modulus and strength of knotted raw silk samples and strength rate of knotted/unknotted raw silk samples from cocoon filament with different sizes

were analyzed. These curves are shown in Fig 3. The strength of raw silk using MK × TC14 (3AJH) cocoon was about 30% higher than when the Asahi × Tokai cocoons were used. The Young's modulus, strength and strength rate of knotted/unknotted raw silk samples are shown in Fig. 4. When the raw silk was derived from finer cocoon filaments, regardless of whether the raw silk samples were knotted, the Young's modulus and the strength values were larger. When finer filaments were used, the strength difference between knotted and unknotted raw silk samples became smaller as shown in Fig. 4, suggesting that when the cocoon filament size is finer, knotted raw silk strength increases. Knotted raw silk with a high strength is important because knotted yarn is frequently used. It is thus possible to produce raw silk with a size of 10 d from cocoon filaments 1 d in size using an automatic reeling machine.

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