

# Effects of Silkworm Rearing and Mounting Conditions on Cocoon Reelability

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Four silkworm races were reared under different conditions of 6 sericultural farms to examine effects of races and of rearing conditions on measurable characters of cocoons. The effects are shown in terms of contribution ratio in Table 1.<sup>4)</sup> It shows that the rearing condition is far more influential than the race on 4 characteristics of cocoons except neatness defect. The largest variation observed among the farmers was cocoon yield per single egg case. As the cocoon yield depends on cocoon weight and percentage of missing larvae, the difference between the contribution ratio of the rearing condition to the cocoon yield and that to the cocoon weight (Table 1) may be regarded as a rough estimate of percentage of missing larvae. This relationship implies that the pre-requisite for improving cocoon quality is healthiness of silkworms, and hence protection against epidemics is inevitable. The second characteristic of cocoons liable to be influenced by rearing conditions of farmers was reelability percentage. The influence of rearing conditions was as great as about 3.5 times that of races.

## Causes of poor reelability

Causes of dropping end of cocoon filaments have not been made clear yet, but several facts are pointed out phenomenally.

1) About a half of the total number of dropping end of cocoon filaments occurs by the tension lower than the usual reeling tension of thread. This fact suggests that the filament is already torn or nearly torn prior to the reeling in this case.<sup>6)</sup>

2) Microscopic observations of the dropping end portion revealed that 75–85% of the total number of dropping end showed abnormal shape such as flatness, etc., and that the filaments were already broken or nearly broken before reeling.<sup>8)</sup>

3) Distribution of dropping end in a mass of cocoons shows the general Poisson distribution or its analogues which are observed in general. Namely it was made clear that even though how poor is the reelability percentage of a cocoon baggage, the cocoons approximately corresponding to the reelability percentage can be reeled without dropping end.

Table 1. Extent of influence of silkworm races and rearing conditions on cocoon qualities, as expressed in terms of contribution ratio<sup>4)</sup>

Cocoon qualities	Contribution ratio (%) of			
	Silkworm race	Rearing condition	Other factors	Total
Cocoon yield per single egg case	24.4	71.0	4.6	100.0
Cocoon weight	23.5	43.6	32.9	100.0
Percentage of cocoon shell weight	31.8	43.2	25.0	100.0
Reelability	19.1	68.4	12.5	100.0
Neatness defect	46.5	3.5	50.0	100.0

4) In the cocoons produced under adverse environmental conditions for cocooning, the drying velocity of bave becomes slow, the sericin crystallization proceeds, making a dense molecular cohesion structure with lowered swelling and solubility to hot water, and as a result poor reelability.<sup>3)</sup> It was also observed that the micro-structure of the baves differing in reelability showed different characteristics in physical properties of sericin.<sup>2)</sup>

From the phenomena described above, it is inferred that the occurrence of the dropping end is related not only to the process of solidification of liquid silk but also to the spinning behavior, and hence to the physiological activity of silkworms.

### Reelability percentage and raw silk percentage of cocoons

Reelability percentage strongly influences reeling efficiency,<sup>9)</sup> and directly determines raw silk percentage. For example, when the reelability is improved to 80% from 50%, with the cocoons showing 50% of reelability and 19% of raw silk percentage, the raw silk percentage is increased to  $19.0 + 1.05 = 20.05\%$ , resulting in 5.5% increase of raw silk yield,<sup>7)</sup> as shown in Table 2.

Table 2. Increase of raw silk percentage caused by improvement of reelability of cocoon<sup>7)</sup>

Original reelability (%)	Increase of raw silk percent					
	Improved reelability (%)					
	100	90	80	70	60	50
40	2.11	1.95	1.76	1.50	1.17	0.70
50	1.41	1.25	1.05	0.80	0.47	—
60	0.94	0.78	0.58	0.34	—	—
70	0.60	0.45	0.25	—	—	—
80	0.35	0.20	—	—	—	—
90	0.15	—	—	—	—	—

### Treatments of egg-larval period and reelability

When the eggs raised in the preceding year are stored for a long term until the next year,

hatching percentage decreases in some cases. It was recognized that the cocoons produced by silkworms derived from such eggs showed a slight decrease of reelability.<sup>11)</sup> Lowering of reelability is also expected when silkworms are reared under the conditions of extremely high temperature and humidity, or rapid temperature changes. Proper protection of eggs is important.

Poor cocoon crops due to damage by agricultural chemicals or silkworm diseases are known to cause decreased reelability percentage. Although experimental results directly dealing with the relation between nutritional conditions of silkworms and reelability are not available, it is inferred that reelability may not be influenced by nutritional variations which may possibly occur among sericultural farmers, because no definite relationship was found between cocoon shell weight and reelability percentage, when the same race was reared during the same season.

As to the effect of larval density in rearing, it was reported that reelability was lowered by very high density which apparently delayed silkworm growth.<sup>1)</sup>

### Mounting methods and reelability

The mounting operation in "the rearing with mulberry shoots" is done mainly by the "Jobarai method" (larvae are dropped by shaking shoots). When mature larvae are dropped on a wooden bed from the height of more than 1 m, they vomit, and cocoon shell weight and reelability are reduced (Table 3).

Table 3. Reelability of cocoons of the silkworms fallen from different height at their mature-larval stage<sup>11)</sup>

Falling height	Sex	Reelability		
		Autumn 1976	Spring 1977	Average
0 cm	female	97.1 %	95.7 %	96.4 } 96.3
	male	96.7	95.7	
90	female	93.9	96.2	95.0 } 95.4
	male	97.1	94.4	
180	female	95.3	94.8	95.0 } 94.0
	male	91.4	94.8	

Table 4. Relationship between larval maturity and cocoon qualities<sup>5)</sup>

Silkworm race	Larval maturity	Cocoon weight	Cocoon shell weight	Reelability
N 115 × C 108	premature	1.53 <sup>g</sup>	27.1 <sup>cg</sup>	73 <sup>%</sup>
	mature	1.66	29.9	81
	overmature	1.45	25.7	65
N 112 × C 110	premature	1.46	27.0	62
	mature	1.66	31.5	65
	overmature	1.63	30.0	62

Table 5. Effect of the suspending position of rotatory cocooning frames in the mounting room on the cocoon reelability<sup>2)</sup>

Room	Reelabilities (%) as influenced by different suspending positions									Coefficient of variation
	1	2	3	4	5	6	7	8	Average	
A	60.1	65.5	73.3	72.0	61.4	76.6	78.1	—	69.6	12.08
B	89.2	91.2	90.5	91.2	91.3	94.6	93.8	91.0	91.5	2.93
C	82.0	85.3	81.9	79.0	77.0	80.2	88.3	—	82.0	7.85
D	84.5	81.5	80.9	89.7	78.2	82.4	84.8	—	83.4	6.44
E	83.5	83.7	82.4	83.2	91.7	87.1	91.7	—	86.2	5.70

Drop-distance should be less than 90 cm, and the use of buffering materials on the bed is desirable.

The Jobarai method aims at the simultaneous mounting of mature larvae, but it is natural that premature larvae are included. As shown in Table 4, the premature larvae gave less cocoon weight, less cocoon shell weight, and lower reelability than mature larvae mounted at the proper stage. Overmatured larvae also gave poor cocoon quality.<sup>5)</sup> However, in usual practice of sericulture, the mounting earlier or later by 12 hr than the proper time of mounting as shown in Table 4 is not made. With a mass of silkworms, the mounting practiced after 10% of the total number of larvae reached maturity gives no difference in cocoon yield and reelability as compared with the proper time mounting. Picking up individual larvae for mounting is extremely inefficient, so that the simultaneous mounting method will have to be employed by permitting the inclusion of a few premature larvae. Even with the mature larvae,

their cocoon quality is lowered when they are exposed to a condition which induces vomiting of many of them, being piled up for a long time after dropped by Jobarai. The safety range is within 60 min under the pile of 10 cm in height of mature larvae at 25°C.

### Cares during mounting and reelability

The most influential factor to reelability percentage is conditions during spinning.<sup>1,13)</sup> The result of a survey on the relationship between suspending position of rotatory cocooning frames in farmer's mounting room and reelability is given in Table 5. It shows that the average reelability percentage was lower in the mounting room which shows larger variation of reelability depending on the suspending position of the rotatory cocooning frames.<sup>2)</sup> However, it can be seen that there is a position which gives high reelability even in a mounting room showing low average reelability.

Table 6. Effect of the interaction among temperature, humidity and air current at the spinning stage on the reelability<sup>14)</sup>

Temperature	Humidity	Air current	Reelability
23°C	65%	cm/sec 0	92.3
		50	96.2
	90	0	53.5
		50	90.6
30°C	65	0	85.2
		50	93.9
	90	0	28.4
		50	83.0

In relation to the management during mounting, relations of three factors, temperature, humidity, and air current, to reelability are given in Table 6.<sup>14)</sup> Combination of three adverse factors remarkably reduces reelability, but it rapidly recovers when even one of the factors is improved. Particularly, humidity and air current exert a great effect on reelability. The optimum temperature during mounting is regarded to be 21–25°C from the viewpoint of health and spinning amount. Temperatures higher or lower than the optimum temperature increase the amount of silk remained in the larval body. However, from standpoint of reelability percentage, the range of optimum temperature is wide. When humidity is low or there is air current, temperature around 30°C is not too high.<sup>12,14)</sup>

The silkworm evolves a large amount of moisture such as 22–25 l per 10,000 silkworms during a period of about 50 hr from the beginning to the end of spinning. About 30% of it comes from urine and feces, while the balance, 70%, is the moisture released during the solidification of liquid silk by spinning. Being in the form of gas, the latter is apt to be neglected and it causes very high humidity inside the mounting room.

The later the exposure to such adverse factors during a cocooning period, the more remarkable their effect.

## Cares after the end of spinning and reelability

Environmental conditions after the end of spinning hardly affect reelability. However, strong impact such as dropping down of cocoon from a high place cuts silk filaments physically and reduces reelability.

## Conclusion

Factors which exert adverse effects on reelability of cocoons are classified into two groups, the one related to spinning behavior, and the other to physical properties of cocoon filaments. However, as to the physical properties of cocoon filaments, it is also considered that there are two different cases, i.e., (1) solidification and drying of liquid silk as affected by adverse environment, and (2) physiology of silkworms as affected by adverse environment during the rearing and mounting period causes irregular spinning performance, which induces some changes in physical properties of cocoon filaments.

Cocoons with poor reelability are often inferior in other quality of the filaments.

## References

- 1) Inoue, R.: Effect of the mounting condition of the silkworm on the cocoon reelability is greater than that of the rearing condition. *Sanshi-Shinpo*, 29(334), 4–10 (1921) [In Japanese].
- 2) Kimura, R. et al.: Effects of the rearing and mounting conditions of the silkworm on the cocoon reelability. I. Relationship between suspending position of rotatory frame in the mounting room and cocoon reelability. *Tech. Bull. Sericul. Exp. Sta.*, 103, 19–28 (1976) [In Japanese].
- 3) Komatsu, K.: Recent advances in sericin research (Review). *J. Sericult. Sci. Jpn.*, 49, 457–465 (1980) [In Japanese].
- 4) Kowada, K.: The silkworm race from the standpoint of raw silk production. Report of 16th meeting of technical training for silkworm egg production, 55–78 (1971) [In Japanese].
- 5) Matsumura, S.: Relationship between mounting condition of silkworm and cocoon reel-

- ability. *Preliminary report of chemico-physiological studies for qualitative improvement of silk fiber*, 2, 309-319 (1949) [In Japanese].
- 6) Mizuide, M. et al.: The reelability of silkworm cocoon—The relationship between reeling tentation of cocoon filament at the time of dropping end and molecular arrangement of silk. *Compilation of studies of silk reeling and silk*, 17, 64-68 (1967) [In Japanese].
  - 7) Mizuide, M.: Relationship between cocoon quality and productivity of raw silk. *Sanshi-kagaku-to-Gijutsu*, 21(6), 17-21 (1982) [In Japanese].
  - 8) Ogawara, T. & Murayama, J.: Studies on the dropping end of the silkworm cocoon. (1) Relationship between abnormality of cocoon filament and dropping end. *Tech. Bull. Sericult. Exp. Sta.*, 72, 1-29 (1957) [In Japanese].
  - 9) Ohno, T.: Relationship between qualitative characters of cocoon and automatic reeling method (Review). *J. Sericul. Sci. Jpn.*, 24, 420-425 (1955) [In Japanese].
  - 10) Shimazaki, A.: On the distribution properties of the dropping ends of cocoon filaments. II. On the relation between the number of dropping ends of cocoon filaments and compound Poisson or Polya-Eggenberger distribution function. *J. Sericul. Sci. Jpn.*, 24, 280-286 (1955) [In Japanese].
  - 11) Suzuki, K. & Ueda, S.: Effects of the rearing and mounting conditions of the silkworm on the cocoon reelability. II. Effects of two-step refrigeration eggs and high rearing temperature in 4th and 5th larval instar on the cocoon reelability. *Tech. Bull. Sericul. Exp. Sta.*, 103, 29-35 (1976) [In Japanese].
  - 12) Suzuki, K.: Relationship among reelability, degumming loss and filament ultrastructure of the cocoon, under influence of the different diet in silkworm rearing. *Sanshi-Kenkyu*, 110, 132-139 (1979) [In Japanese].
  - 13) Ueda, S.: Effects of the air current in the spinning stage of the silkworm surrounded with high temperature and high humidity upon the reelability of cocoon. *J. Sericult. Sci. Jpn.*, 42, 129-134 (1973) [In Japanese with English summary].
  - 14) Ueda, S. et al.: Effects of the rearing and mounting conditions of the silkworm on the cocoon reelability. III. Effect of the interaction among temperature, humidity and air current in the spinning stage of the silkworm on the form and reelability of cocoon. *Tech. Bull. Sericul. Exp. Sta.*, 103, 37-43 (1976) [In Japanese].

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