An Investigation on the Progressive Change in Filament Characteristics from Outer to Inner Layers of Mulberry and Tasar Cocoons

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ABSTRACT: The physical properties and residual sericin content of the silk filament were evaluated in relation to its position in different layers of the cocoons corresponding to Daba (*Antheraea mylitta*), oak tasar (*Antheraea proylei*), and bivoltine mulberry (*Bombyx mori*) varieties. A decrease in filament linear density from the outer to the innermost layers was observed in all the varieties. Although the filament tenacity was found to increase in bivoltine mulberry cocoons from the outer to the inner layers, no such specific trend was observed for Daba cocoons. For oak tasar cocoons, it showed a marginal rise. A similar trend was observed for filament initial modulus also. The breaking extension of filament was constant for Daba cocoons, decreased for oak tasar cocoons and showed a rise followed by a fall for bivoltine mulberry cocoons from the first to the last layers. The residual sericin decreased marginally from the outer to the inner layer in the case of tasar cocoons. However, for mulberry cocoons it decreased rapidly initially up to the fourth layer and thereafter showed no change. © 2010 Wiley Periodicals, Inc. J Appl Polym Sci 117: 1319–1324, 2010

Key words: *Antheraea mylitta*; *Antheraea proylei*; *Bombyx mori*; layer; sericin; bivoltine

INTRODUCTION

As nonmulberry tasar silks in India, Daba and oak are two widely used ones which are categorized as tropical and temperate variants, respectively depending on the climate of cultivation. Genetically silkworm of Daba is a pure race under the species of *Antheraea mylitta D.*, whereas oak silkworm (*Antheraea proylei J.*) is an interspecies breed of *Antheraea roylei* and *Antheraea pernyi*. The cultivated bivoltine mulberry silkworm is a species of well known *Bombyx mori L.* In a natural product like silk, inherent variations manifest layerwise in cocoon and any definite mode of variation in property down the cocoon layers may show up objectionable fabric patterns either from visual or textural standpoint. Physical properties of *A. mylitta D.*,[1] *A. proylei J.*,[2] *A. yamamai*,[3] and *B. mori L.*[4] of Japanese, Chinese, and Thai local varieties were studied with respect to the thread size, position of layers, spinning period, etc. and even taking into account the gender of the silkworm. However, the reported literatures show evidence of very limited information on the silk filament characteristics that exists in different cocoon layers.

The aim of the present investigation is to study the layerwise progressive change in the filament characteristics in Daba, oak tasar, and bivoltine mulberry cocoons available from various regions of India.

MATERIALS AND METHODS

Sufficient quantities of daba, oak tasar, and bivoltine mulberry cocoons were collected from different places of India like Bihar, Uttar Pradesh, and Karnataka.

The stifled daba and oak tasar cocoons were cooked in a solution of an organic amine for 50 min and 30 min, respectively, at 80°C.[5] The bivoltine mulberry cocoons were cooked as per the method described elsewhere.[6] The cocoons were reeled slowly with utmost care. While reeling, successive reeled lengths of 120 yards were cut and numbered sequentially so as to identify the location of small hanks in the cocoon during subsequent testing. The numbers given were termed as layers. At least 30 samples corresponding to each layer were collected from different cocoons for each variety.

Each layer representing 120 yards of filament was weighed on an electronic balance to measure the

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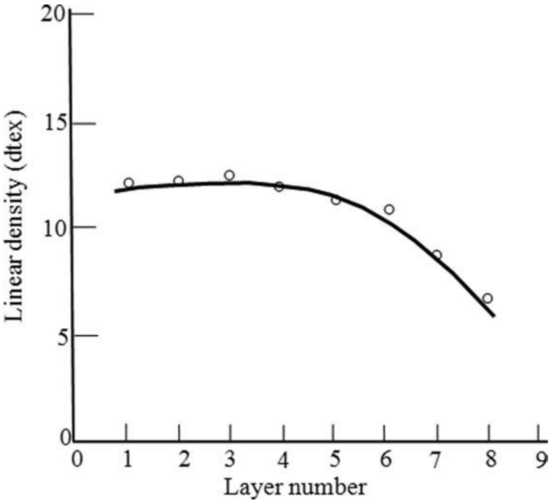

Figure 1 Change in filament size with layers for daba cocoons.

filament fineness. To determine the average value of filament fineness and its variation, 30 readings were taken from each specimen.

An Instron tensile tester (model 4301) was used to study the tenacity, breaking elongation, and modulus of the filaments corresponding to various layers. The samples were conditioned at 65% RH and 25°C for 24 h before the tensile testing. The filaments were subjected to tensile testing at a gauge length of 5 cm and crosshead speed of 5 cm/min. The test specimen was mounted between the jaws at a pretension level of 0.05 cN/dtex. During testing, the samples which showed jaw breaks (tendency to break close to the jaws) were excluded. For each set of experiment, 50 tests were conducted.

To determine the residual sericin content of different layers, 30 leas of filament from different cocoons representing a particular layer were first weighed on an electronic balance. The leas were subsequently degummed in a solution of 25% Marseilles soap for 90 min at boil keeping the material: liquor ratio of 1 : 50. The residual sericin content of layers was calculated on the basis of the difference in conditioned weight before and after degumming to the initial weight expressed as percentage.

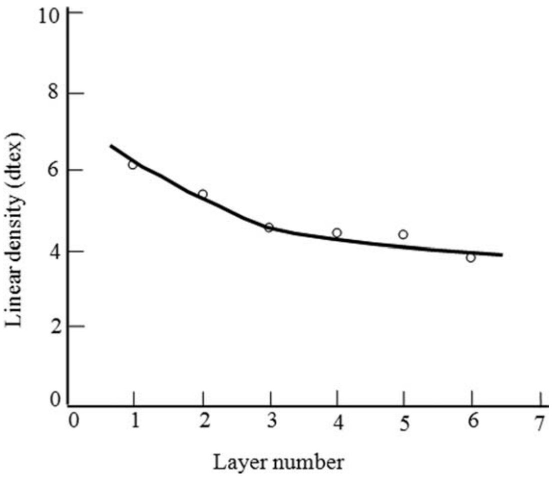

Figure 2 Change in filament size with layers for oak tasar cocoons.

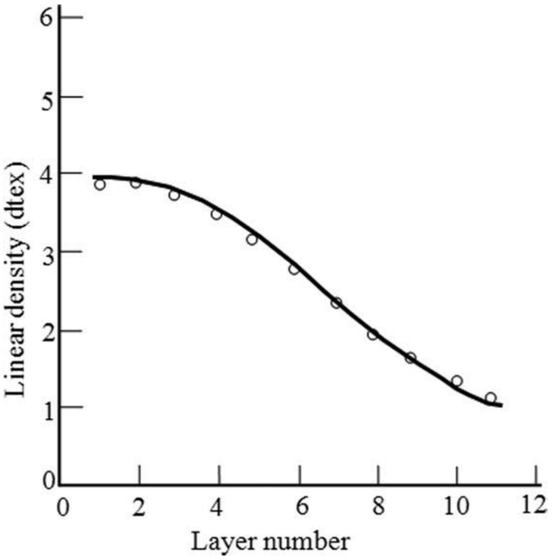

Figure 3 Change in filament size with layers for bivoltine mulberry cocoons.

RESULTS AND DISCUSSION

The progressive change in filament fineness, breaking load, tenacity, breaking extension, modulus and residual sericin with respect to the position of filaments in different cocoons have been depicted in Figures 1–18. It is apparent from Figures 1–3 that the filament becomes continually finer from the outer to

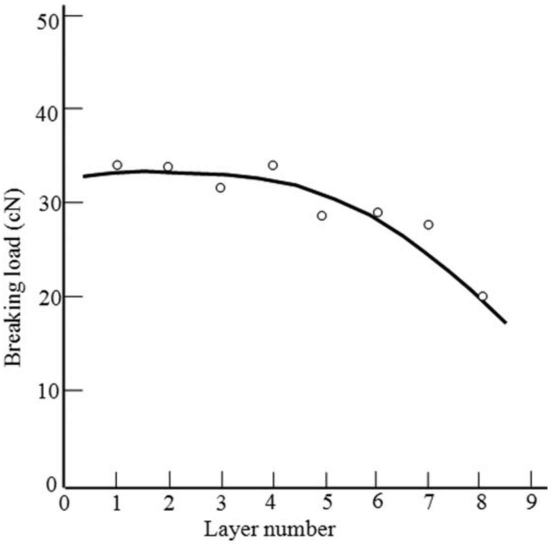

Figure 4 Change in breaking load with layers for daba cocoons.

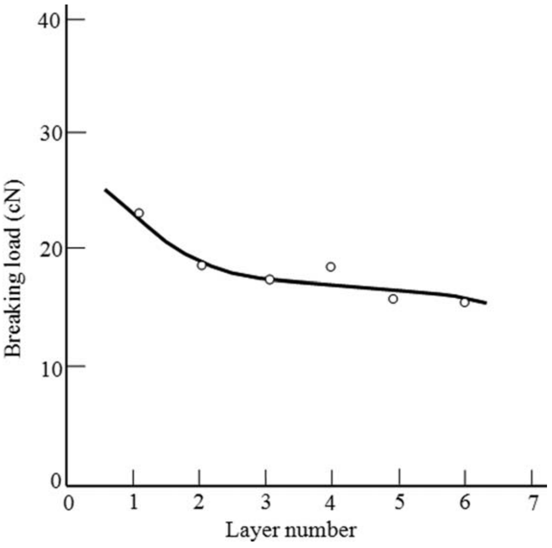

Figure 5 Change in breaking load with layers for oak tasar cocoons.

the inner layer for all varieties of cocoons. This can be ascribed to the gradual decrease in the concentration of aqueous silk as the spinning process progresses from an initial polymer solution of about 30 wt % to about 15 wt %, as observed by Iizuka.[4] As an evidence, the percentage reduction of filament linear density from outer to the innermost layers are 47%, 38%, and 71% for daba, oak tasar, and bivoltine mulberry cocoons, respectively.

The breaking load of filament shows a similar trend as that of filament denier with successive layers. This may be attributed to the reduction in the filament fineness down the layers (Figs. 4–6). Furthermore, the filament tenacity from outer to inner layer shows a rising trend in the case of bivoltine mulberry cocoon and a marginal rise for oak tasar cocoons while no such specific trend was observed

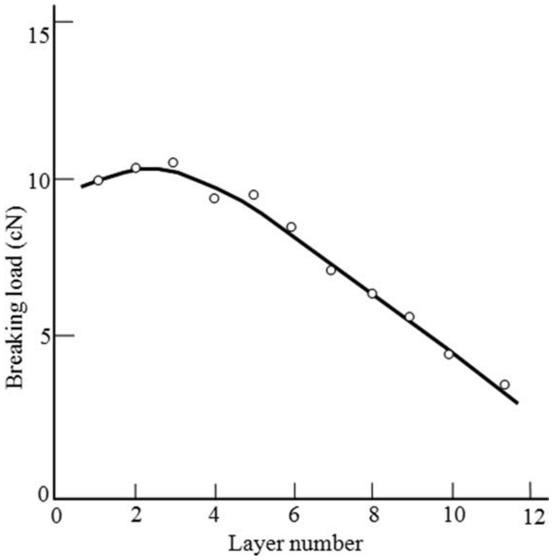

Figure 6 Change in breaking load with layers for bivoltine mulberry cocoons.

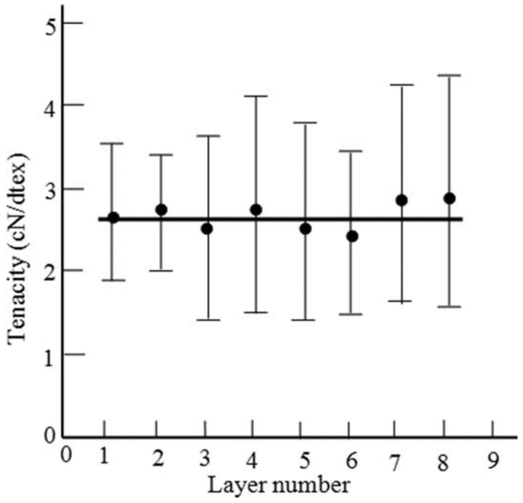

Figure 7 Change in tenacity with layers for daba cocoons.

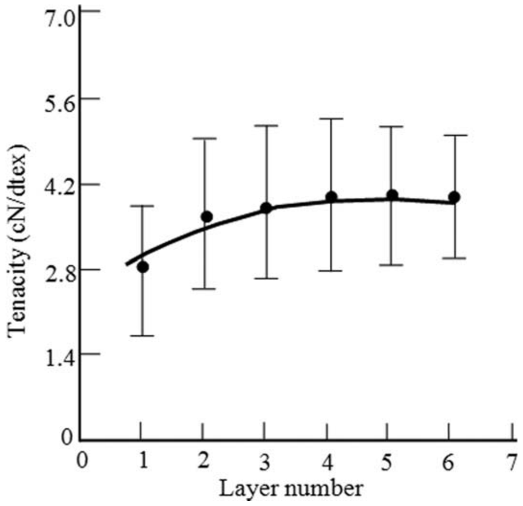

Figure 8 Change in tenacity with layers for oak tasar cocoons.

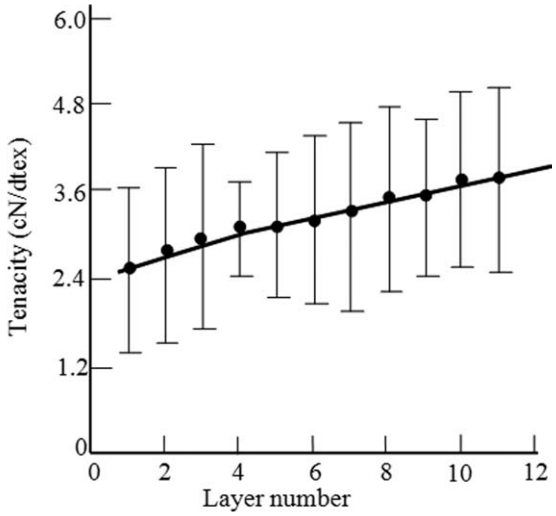

Figure 9 Change in tenacity with layers for bivoltine mulberry cocoons.

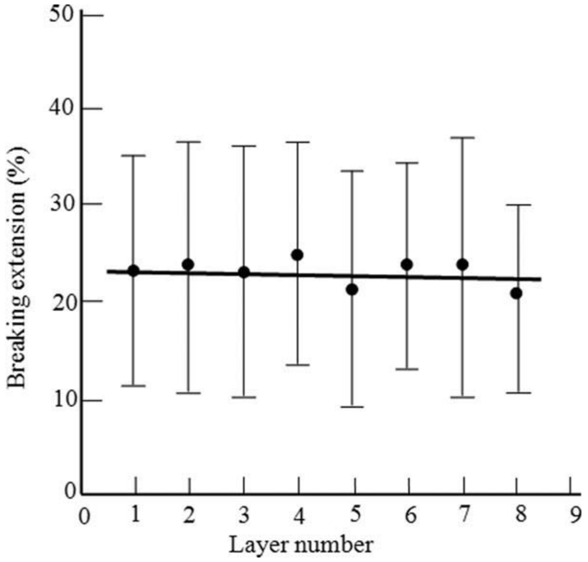

Figure 10 Change in breaking extension with layers for daba cocoons.

for daba cocoons (Figs. 7–9). The increasing trend of filament tenacity for bivoltine mulberry cocoon in the direction of inner layers can be ascribed to the slow drop in breaking load compared to the drop in fineness, which is associated with lower concentration of aqueous silk during spinning. In the case of daba and oak tasar varieties, the influence of low spinning speed as postulated by Tsubouchi et al.[3] may be compensating the effect of reduction in filament linear density as postulated by Iizuka et al.,[1,2] showing no or a marginal change in tenacity.

It is noted from Figures 10–12 that the breaking extension shows practically no change for daba tasar filament with the layers, however, it diminishes in the inner layers for oak tasar. In case of mulberry cocoons, it shows an initial rise followed by a fall in the more interior layers. The decreasing trend of filament breaking extension at the interior layers can be ascribed to the more ordered filament structure at this region than that of outer layers, as suggested by Iizuka et al.[7]

It is evident from Figures 13–15 that the filament modulus follows the trend as same as filament tenacity and therefore the result may be advocated to the similar lines as discussed in the preceding paragraph.

A high variation of filament tenacity, breaking extension, and modulus is observed for all cocoons. For instance, the CV% of filament tenacity, breaking extension, and modulus are ranging from 10% to 23%, 20% to 44.5%, and 15% to 41%, respectively.

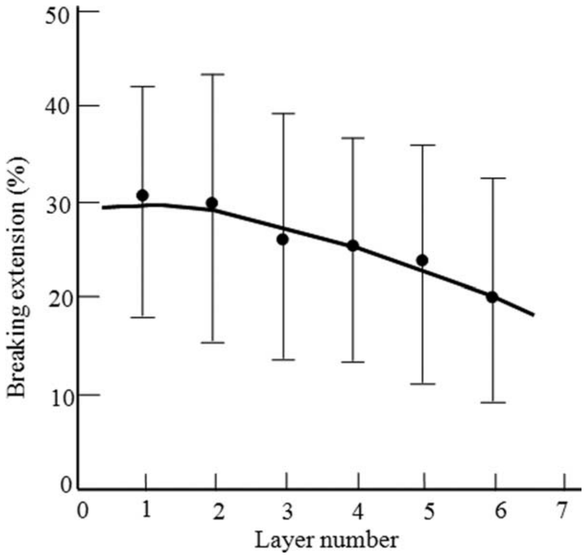

Figure 11 Change in breaking extension with layers for oak tasar cocoons.

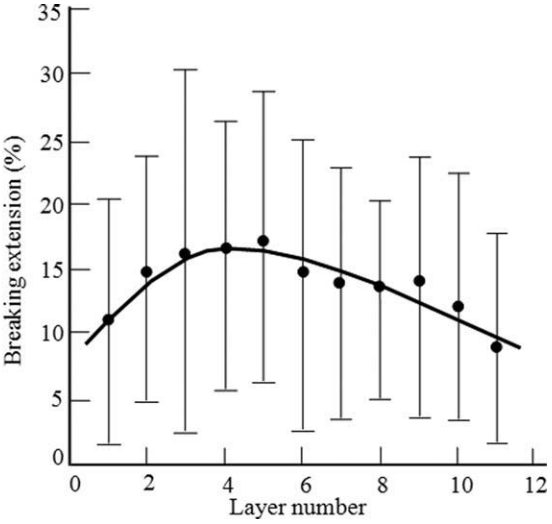

Figure 12 Change in breaking extension with layers for bivoltine mulberry cocoons.

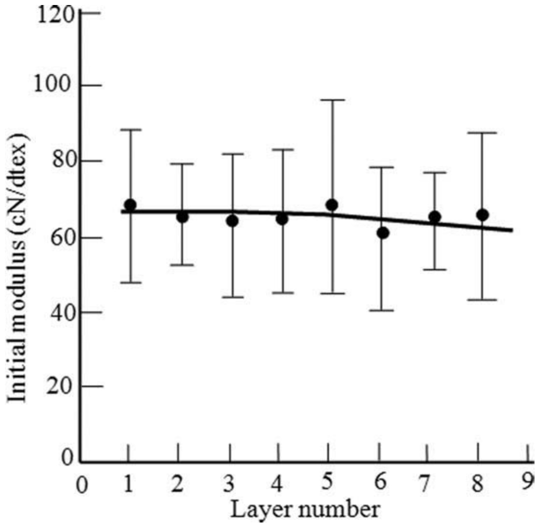

Figure 13 Change in initial modulus with layers for daba cocoons.

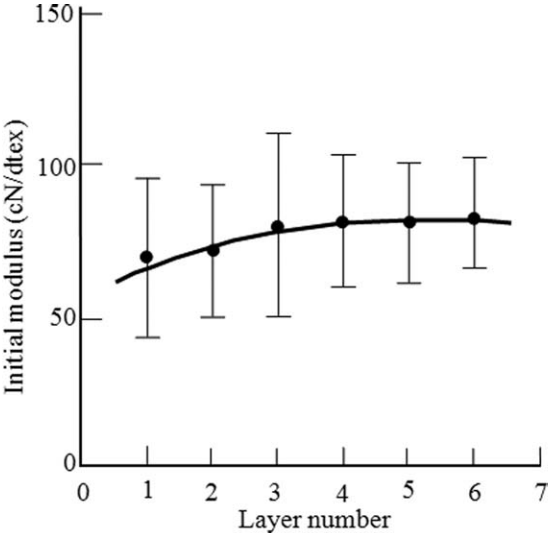

Figure 14 Change in initial modulus with layers for oak tasar cocoons.

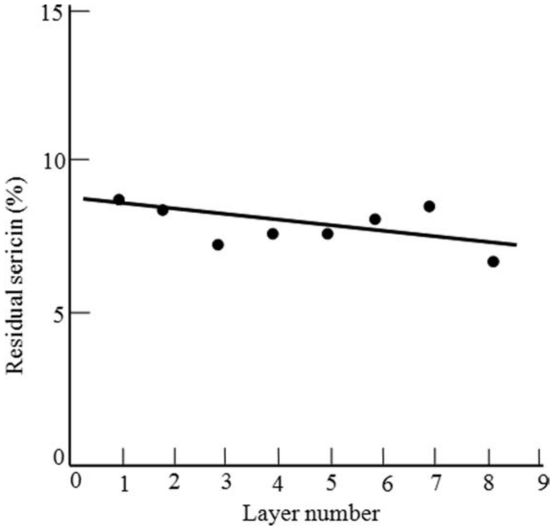

Figure 16 Change in residual sericin with layers for daba cocoons.

Silk being a natural product shows obvious inherent variation in its mechanical properties.

The residual sericin content decreases marginally for daba and oak tasar cocoons, however, for mulberry cocoons it rapidly decreases up to the fourth layer starting from the outer layer and afterward remains unchanged (Figs. 16–18). This can be elucidated by the following lines. To protect itself from the unfavorable environmental conditions, the insect may deliver more protein to make the outer layer of the cocoon shell tough. In case of bivoltine mulberry cocoons, the present cooking method[6] does not remove an appreciable quantity of sericin. So, a progressive reduction in the residual sericin content from the outer to the fourth layer is a natural characteristic of sericin distribution in the case of bivoltine mulberry cocoons. Perhaps, Daba, and oak tasar insects also behave in a similar fashion. However, the treatment used for daba and oak tasar cocoons with organic amine for cooking is vigorous in nature. As a result, the outer part of the cocoon shell gets more affected than the inner part. Hence the removal of sericin becomes disproportionate for different layers. More sericin is removed from the outer layers than the interiors, showing a marginal reduction in residual sericin from outer to inner layers.

CONCLUSIONS

The change in characteristics from outer to the inner layer has been investigated for different varieties of silk cocoons. The filament linear densities for all varieties of cocoons decrease from the outer to the

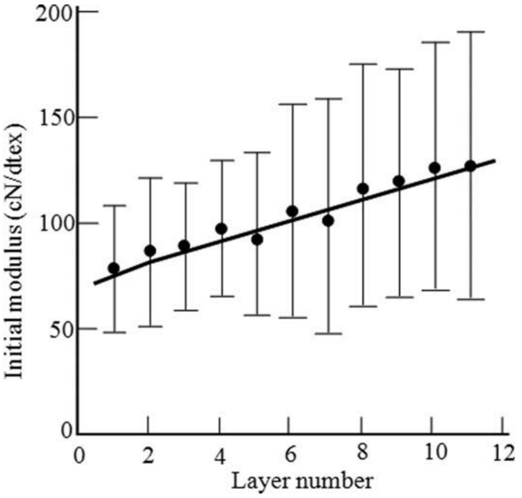

Figure 15 Change in initial modulus with layers for bivoltine mulberry cocoons.

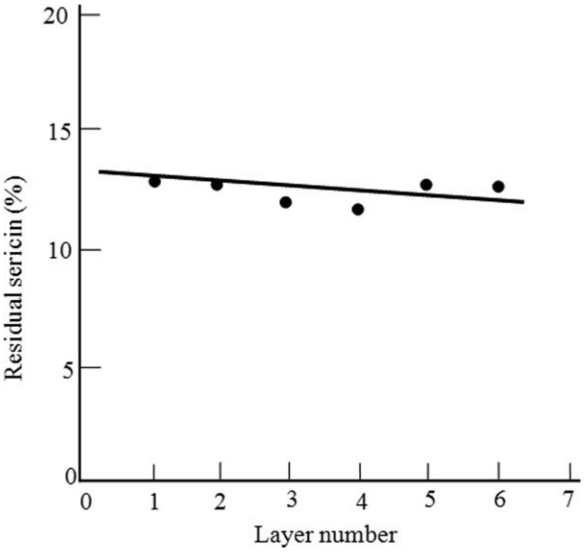

Figure 17 Change in residual sericin with layers for oak tasar cocoons.

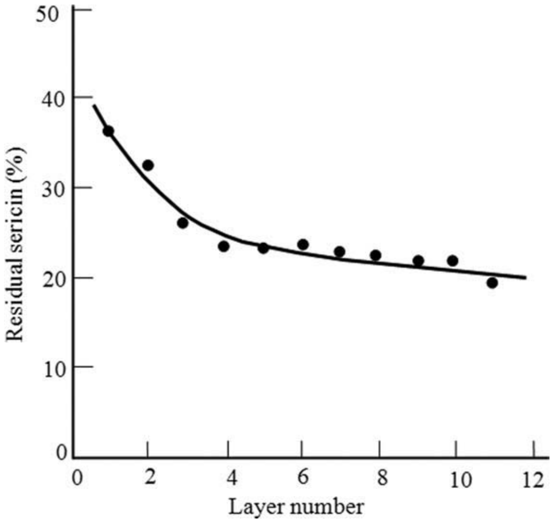

Figure 18 Change in residual sericin with layers for bivoltine mulberry cocoons.

inner layer. The tenacity and initial modulus remain constant for daba and rises marginally for oak tasar but shows a definite increasing trend for bivoltine mulberry cocoons. The breaking extension remains constant for daba, decreases for oak tasar, but shows an initial rise followed by a fall for mulberry cocoons. Residual sericin shows a tendency to decrease up to the fourth layer from the outermost layer for bivoltine mulberry cocoons and thereafter it remains unchanged. Daba and oak tasar cocoons show a marginal decrease from the outer to the inner layer.

References

1. Iizuka, E.; Okachi, Y.; Shimizu, M.; Fukuda, A.; Hashizume, M. Indian J Sericult 1993, 32, 175.
2. Iizuka, E.; Kawano, R.; Kitani, Y.; Shimizu, M.; Fukuda, A. Indian J Sericult 1993, 32, 1.
3. Tsubouchi, K. K.; Imai, T.; Sudo, M. Proceedings of the XVIII International Congress of Entomology, Vancouver, Canada, 1988, pp 119.
4. Iizuka, E. Chemical Processing of Silk; Gulrajani, M. L., Ed.; Department of Textile Technology, Indian Institute of Technology: India, 1993, p 27.
5. Das, S.; Ghosh, A. J Nat Fibers 2007, 4, 1.
6. Sonwalkar, T. N. Sericologia 1985, 25, 183.
7. Iizuka, E.; Okachi, Y.; Ohbayashi, S.; Fukuda, A.; Shimizu, M. Indian J Sericult 1993, 32, 27.