Relationship of parameters that characterize the quality of live cocoons

Sh D Burkhanov, R M Mirsaatov, S B Khudoybergenov and B H Kadyrov
Tashkent Institute of design, construction and maintenance of automotive roads, Tashkent, Uzbekistan

E-mail: sarrux@inbox.ru

Abstract. An important parameter for evaluating the technical and economic value of a batch of cocoons, along with silkiness (i.e., the ratio of the mass of shells to the mass of these cocoons as a percentage), is the volume stiffness of cocoons (i.e., the ratio of the external force acting on the cocoon to the amount of deformation of the cocoon shell). We propose to measure the volumetric stiffness using the FTI - 1M device, when an additional load is placed on the lid, which compresses the layer of live cocoons in the measuring container in height. It is obvious that the thinner the shell is, the greater the deformation of the cocoon layer will be. In addition, the volume stiffness was measured in this work by piece with a VC stiffener (i.e., a device for measuring the rigidity of the cocoon shell) separately for each breed with an error of 3%. These additional measurements confirmed the accuracy of the results obtained on the FTI - 1M device for volumetric stiffness. As a result, we obtained correlations between bulk stiffness and silkiness, as well as dependencies between bulk stiffness and shell thickness for various new breeds of silkworm cocoons: Marhamat, Marvarid, Asaka, and Yulduz. Linear dependencies are constructed based on the data presented in the corresponding table. The volume stiffness of various breeds of live cocoons increases both with increasing silkiness and the thickness of their shell. This is quite understandable, since the greater the silkiness, the thicker the shell, and therefore the greater the volume stiffness of the cocoon. Based on the results obtained, it is concluded that the silkiness of the Marvarid breed was lower than that of other breeds. Thus, this paper shows the possibility of determining the prospects of a particular breed by measuring and evaluating cocoons based on the correlation between silkiness and bulk stiffness or silkiness and the thickness of the shell of a cocoon sample.

1. Introduction
The cocoon of the silkworm is called an ellipsoid shell (in the longitudinal section) of the form, most often consisting of two spheres adjacent to each other. Every year, more than twenty-five countries produce at least six hundred thousand tons of cocoons. Uzbekistan is in third place after China and Japan.

Increasing labor productivity while ensuring high yields and improving the technology of production processes, as well as the accuracy of measuring and evaluating the quality characteristics of cocoons without cutting them, remains one of the main tasks of sericulture not only in Uzbekistan, but also in all sericulture countries.
2. **Method for obtaining experimental data**

An important parameter for evaluating the technical and economic value of a batch of cocoons, along with silkiness, is the volume stiffness of the cocoon sample [1]. The FTI-1M device was used as a device for obtaining experimental data on volumetric stiffness (figure 1) [2-6]. To study the dependence of the volume stiffness on the load, the columns of a certain mass (for example - 3 kg) were filled into the measuring container 1, which is installed on the vibro-stand 2 of the FTI-1M device. From above, the cocoons were covered with a lid 3 with a special stand 4 and included a vibration stand for 1 minute in accordance with the technical passport for the FTI-1 device. After stopping the vibro-stand the height of the cocoon layer “H” was fixed and the silkiness (S) of live cocoons was determined using the formula:

\[ S = k \cdot \frac{H}{M} \]  

where \( H \) - is the height of the cocoon layer in the measuring vessel of the device after vibration in standard mode (8 Hz, vibration amplitude 8 mm, duration 1 minute),

\( M \)- mass of the cocoon sample inside the measuring container,

\( k \)- the proportionality coefficient that depends on the breed of live cocoons.

Further, the cocoons were compressed with a load of 5 of a certain mass \( m \) (from 1 to 10 kg). Height sensors 6 transmitted information about changes in the average height of the cocoon layer \( \Delta h \) in computer 7 (figure 1), in which the coefficient of volumetric stiffness of living cocoons was calculated using the empirical formula:

\[ St = \frac{mg}{\Delta h} \]  

where \( m \)- is the weight of the load;

\( g \)-acceleration of free fall;

\[ \Delta h = H - H_1 \]  

\( H \) and \( H_1 \) are the height of the cocoon layer in the measuring capacity of the FTI-1 device before and after compression, respectively.

![Figure 1. Appearance of the device FTI - 1M, which was used to measure the bulk stiffness (St) of live cocoons.](image)

Gradually increasing the weight of the cargo \( m \), it was possible to observe a decrease in the height of the cocoon layer. The volume stiffness was also controlled by a BK-type device for me assuring the stiffness of single cocoons.

The thickness of the shell was determined by a micrometer with an accuracy of 0.01 mm. the Mass of cocoons and shells was measured on a VLR-100 scale with an accuracy of 0.001 g.
3. Dependence of silkiness on the volume stiffness and thickness of the shell of live cocoons

The results of measurements for four live cocoon breeds are presented in table 1.

Table 1. The results of measurements for four live cocoon breeds are presented.

| Cocoon breed | M, g, cocoon weight | V, cm³, the volume of the cocoon | St, N/mm², volume stiffness of the cocoon | M, g, the weight of the shell | S,%, cocoon silkiness | T, mm, shell thickness |
|--------------|---------------------|---------------------------------|-------------------------------------------|-----------------------------|---------------------|---------------------|
| Marhamat     |                     |                                 |                                           |                             |                     |                     |
| 1            | 1.550               | 11                              | 50                                        | 0.3                         | 19.35               | 0.28                |
| 2            | 2.370               | 11                              | 50                                        | 0.475                       | 20.04               | 0.24                |
| 3            | 2.876               | 10                              | 61                                        | 0.502                       | 24.45               | 0.42                |
| 4            | 1.668               | 10                              | 62                                        | 0.46                        | 27.57               | 0.43                |
| 5            | 1.564               | 9                               | 62                                        | 0.4                         | 25.57               | 0.40                |
| 6            | 2.016               | 9                               | 62                                        | 0.525                       | 26.04               | 0.42                |
| 7            | 1.714               | 9                               | 52                                        | 0.305                       | 17.79               | 0.48                |
| 8            | 1.790               | 9                               | 65                                        | 0.525                       | 29.32               | 0.43                |
| 9            | 2.204               | 8.5                             | 60                                        | 0.550                       | 24.95               | 0.44                |
| 10           | 1.402               | 8                               | 59                                        | 0.36                        | 25.67               | 0.34                |
| Marvarid     |                     |                                 |                                           |                             |                     |                     |
| 1            | 1.872               | 10                              | 60                                        | 0.4                         | 21.36               | 0.37                |
| 2            | 2.662               | 12                              | 62                                        | 0.49                        | 23.1                | 0.41                |
| 3            | 1.792               | 11                              | 55                                        | 0.35                        | 19.55               | 0.28                |
| 4            | 1.990               | 9                               | 62                                        | 0.45                        | 19.35               | 0.38                |
| 5            | 1.832               | 13                              | 50                                        | 0.245                       | 13.37               | 0.23                |
| 6            | 2.362               | 10                              | 64                                        | 0.495                       | 20.96               | 0.37                |
| 7            | 2.334               | 9                               | 63                                        | 0.504                       | 21.59               | 0.42                |
| 8            | 2.414               | 9                               | 62                                        | 0.552                       | 22.88               | 0.45                |
| 9            | 1.338               | 8                               | 60                                        | 0.245                       | 18.31               | 0.26                |
| Asaka        |                     |                                 |                                           |                             |                     |                     |
| 1            | 1.524               | 8.0                             | 75                                        | 0.375                       | 24.60               | 0.42                |
| 2            | 1.902               | 8.25                            | 54                                        | 0.315                       | 17.68               | 0.25                |
| 3            | 1.406               | 8.5                             | 69                                        | 0.31                        | 22.04               | 0.36                |
| 4            | 1.216               | 8.4                             | 69                                        | 0.245                       | 20.14               | 0.30                |
| 5            | 1.358               | 8.3                             | 62                                        | 0.29                        | 18.61               | 0.30                |
| 6            | 1.402               | 8.2                             | 71                                        | 0.28                        | 19.97               | 0.32                |
| 7            | 1.542               | 8.2                             | 70                                        | 0.28                        | 18.18               | 0.32                |
| 8            | 1.686               | 8.1                             | 56                                        | 0.29                        | 17.21               | 0.17                |
| 9            | 2.068               | 8.5                             | 63                                        | 0.38                        | 18.38               | 0.28                |
| 10           | 1.690               | 8.6                             | 54                                        | 0.28                        | 16.56               | 0.19                |
| 11           | 1.560               | 8.1                             | 62                                        | 0.29                        | 18.56               | 0.27                |
| Yulduz       |                     |                                 |                                           |                             |                     |                     |
| 1            | 1.618               | 10.6                            | 71                                        | 0.29                        | 17.26               | 0.35                |
| 2            | 2.168               | 10.3                            | 70                                        | 0.5                         | 23.06               | 0.31                |
| 3            | 1.948               | 10.4                            | 69                                        | 0.472                       | 24.25               | 0.33                |
| 4            | 2.380               | 10.4                            | 60                                        | 0.48                        | 20.10               | 0.25                |
| 5            | 2.060               | 10.3                            | 57                                        | 0.352                       | 16.67               | 0.16                |
| 6            | 1.848               | 9.3                             | 56                                        | 0.34                        | 18.38               | 0.18                |
| 7            | 1.680               | 8.7                             | 70                                        | 0.245                       | 24.58               | 0.34                |
| 8            | 2.000               | 10.8                            | 54                                        | 0.325                       | 16.25               | 0.17                |
| 9            | 2.250               | 10.5                            | 49                                        | 0.35                        | 15.55               | 0.17                |
| 10           | 2.030               | 10.3                            | 48                                        | 0.315                       | 15.51               | 0.16                |
Figure 2 shows the results of the correlation between silkiness and bulk stiffness for different breeds obtained by the least squares method are presented.

On the ordinate axis, the silkiness “S” (%) is deposited, and on the abscissa axis, the volume stiffness “St” (N/mm) of live cocoons is set. Volume stiffness is defined as the ratio of the force acting on the cocoon in Newton’s to the size of the shell deformation in mm. It is seen that the silkiness of various breeds of living cocoons increases with increasing their stiffness:

\[ S = 0.46\% \cdot \frac{mm}{N} \cdot St - 10.5\% \text{ (for the Marhamat breed)} \]
\[ S = 0.8\% \cdot \frac{mm}{N} \cdot St - 29.3\% \text{ (for the Marvarid breed)} \]
\[ S = 0.37\% \cdot \frac{mm}{N} \cdot St - 1.09\% \text{ (for the Asaka breed)} \]
\[ S = 0.38\% \cdot \frac{mm}{N} \cdot St - 28.85\% \text{ (for the Yulduz breed).} \]

The standard error in all cases did not exceed 0.4%. The coefficients vary from 0.37 to 0.88 mm/N and show the tangent of the angle of inclination of the straight line in figure 2. The free terms vary from 1.09 to 29.3% and correspond to the segment of the ordinate that cuts off the line from the ordinate axis. The resulting dependencies are easy to explain: the greater the stiffness, the thicker the shell, and therefore the greater the silkiness of the cocoon.

It can be noted that the specified dependence for the Marvarid breed was obtained with a large slope, but the silkiness values on average for this breed are lower than for other breeds.

Figure 2. Dependence of silkiness on the bulk stiffness of cocoons.

Figure 3. Dependence of the volume stiffness “St” (N/mm) on the thickness of the cocoon shell “T” (mm) for the "Marhamat" breed.
Figure 3 shows the dependence of the volume stiffness on the thickness of the cocoon shell, based on the data in table 1 for the "Marhamat" breed.

It can be seen that the volume stiffness increases with the thickness of the cocoon shell, which is to be expected. We give below similar dependencies for other breeds.

\[
St = 43.33 \cdot \frac{N}{mm^2} \cdot T + 41.9 \cdot \frac{N}{mm} \quad \text{(for the Marhamat breed)}
\]

\[
St = 46.78 \cdot \frac{N}{mm^2} \cdot T + 43.30 \cdot \frac{N}{mm} \quad \text{(for the Marwari breed)}
\]

\[
St = 91.68 \cdot \frac{N}{mm^2} \cdot T + 37.58 \cdot \frac{N}{mm} \quad \text{(for the Asaka breed)}
\]

\[
St = 103.36 \cdot \frac{N}{mm^2} \cdot T + 35.39 \cdot \frac{N}{mm} \quad \text{(for the Yulduz breed)}
\]

How much volume stiffness depends on the thickness of the shell is clearly seen in figure 4.

**4. Conclusion**

By examining the volume stiffness, we can judge the thickness of the shell and, consequently, the silkiness of living cocoons. Thus, based on the results of measuring the volume stiffness, it is possible to judge the prospects of new breeds of silkworm without inserting horse raw materials.

![Figure 4](image-url)

**Figure 4.** Depending on the thickness of the shell of cocoons of different breeds on their bulk stiffness.

**Acknowledgements**

The authors express their gratitude to Professor B.U. Nasirillayev for the samples of the breeds of live cocoons.

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