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Application of the Least Square Method for Determining the Quality of Living Cocoons

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Abstract

A non-destructive method and a mathematical model are proposed using the least squares method to determine the silkiness of cocoons in a handed over batch, which is the most important in terms of determining the quality indicators of raw silk. The developed method provides higher accuracy in determining the silk content in the handed over batch of cocoons. The results of determining the silkiness of living silk cocoons are also given. The root-mean-square error of the silkiness, determined by the proposed method, relative to the cutting is 0.456%.

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The development and implementation of new effective methods for determining and monitoring the quality indicators of silk cocoons is extremely important, which is a great reserve for increasing the profitability of sericulture. Quality control of silk raw materials, at all stages of its production, is necessary and mandatory, especially at the stage of primary processing of cocoons.

Mathematical methods for determining the quality indicators of cocoons are based on the laws of mathematical statistics. They, in turn, can be divided into elucidation of correlation dependencies between:

a) the silkiness of the cut cocoon samples of different sizes and the actual silkiness of a batch of cocoons;

b) the geometric dimensions of cocoons and their silkiness.

With the existing method of accepting living cocoons from silkworm breeders by their total mass and determining the quality of cocoon raw materials by the organoleptic method according to the characteristics of the shell, it is difficult to fight against the collection and delivery of immature and low-quality cocoons [1].

When determining the silkiness of living cocoons using the FTI-1M device, the correction factor K_0 is of great importance. K_0 is the correction factor, which depends on the breed, conditions of brooding, etc., and was established by a special commission before the mass arrival of live cocoons at the receiving points [2].

Experience shows that the correction factor K_0 is inversely proportional to the average cocoon volume, which can be determined quickly in 3 minutes by the express method, according to the method developed by us, and efficiency is the most important thing in the season of harvesting with a massive supply of cocoons. We determine the average volume of cocoons by the "water" method [3]. The error due to water adsorption has a systematic error in one direction and does not exceed 3 percent. It is easy to pass from the average volume of the cocoon to the value of the correction factor K_0 along the calibration line (Figure 1).

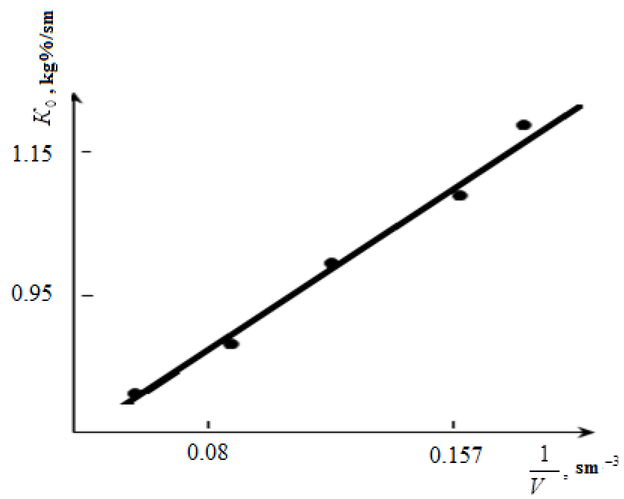

Figure 1: Graduated straight line for definition correction factor K_0.

According to the results of experiments in 2021, a correction factor K_0=0.96 was set at the Yangiyul head cocoon dryer in the Tashkent region, which falls into the range of correction factors from 0.95 to 1.15 obtained earlier in [4]. The results of the experiment to determine the silkiness of living cocoons by cutting and using the FTI-1M device are shown in Table 1.

Table 1: The results of the experiment to determine the silkiness of living cocoons by cutting and using the FTI-1M device.

№	$\gamma = \frac{H}{m}$	$K = \frac{S_{bycutting}}{\gamma}$	$S_{by\ cutting}$, %, Cocoon Silkiness	S_{FTI-1M} (%), Cocoon Silkiness	$\Delta S = S_{bycutting} - S_{FTI-1M}$
1	22.31	0.906	20.23	20.42	0.19
2	21.38	0.963	20.61	20.52	0.09
3	21.33	0.944	20.14	20.45	0.31
4	20.87	0.968	20.21	20.03	0.18
5	21.63	0.953	20.62	20.76	0.14
6	21.81	1.031	22.50	21.94	0.56
7	20.50	1.046	21.45	20.68	0.77
8	21.89	0.935	20.47	21.01	0.54
9	24.33	0.883	21.49	21.35	0.14
10	21.14	1.011	21.39	21.29	0.1
11	20.70	1.038	21.49	20.87	0.62
12	21.84	0.948	20.71	20.97	0.26
13	22.66	0.925	20.96	21.75	0.79
14	22.80	0.927	21.15	21.89	0.74
15	24.30	0.946	23.0	23.33	0.33
16	22.30	0.912	20.33	20.40	0.07
17	20.10	0.991	19.92	19.30	0.62
Average	21.87	0.960	20.98	20.997	0.38

Root-mean-square error of silk-bearing living cocoons, determined with respect to cutting with the FTI-1M device:

$$\delta = \sqrt{\frac{\sum \Delta Ø^{2}_{FTI-1M}}{n}} = 0.456\%$$

Thus, in order to reduce the percentage of immature cocoons that cause serious economic damage to sericulture, a simple version of the modernized FTI-1M device with a constant weight of a sample of live cocoons (3kg) and automatic removal of the height of the cocoon layer, designed to determine the silkiness of live cocoons without cutting them, is proposed. The root-mean-square error of silk-bearing living cocoons, determined with respect to cutting with the FTI-1M device, is 0.456%.

Let's build a graph based on these data: $S = K_0 \gamma$. On the y-axis (Y) we plot the value of silkiness «*S*" (%), on the abscissa (X) the value $\gamma = \frac{H}{m}$ (Figure 2). The coefficient K_0 is found by the least squares method according to the formula:

$$K_0 = \frac{\sum x_i y_i}{\sum x_i^2} = \frac{7809.87676}{8154.880889} = 0.9577$$

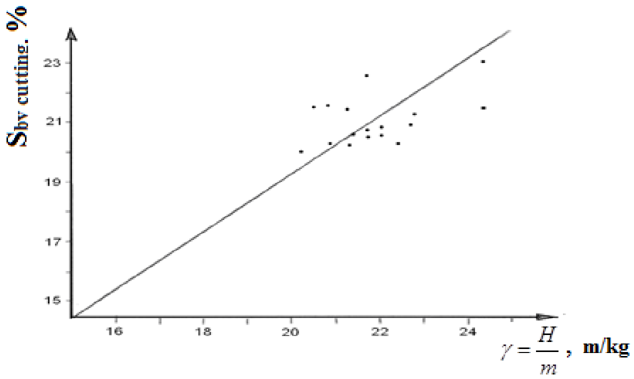

Figure 2: Determination of the correction factor by the mean square method.

In this way $K_0 \approx 0.96$.

It is noted that the smaller the cocoons of any breed or hybrid, the more tightly the cocoons are packed in the measuring container of the FTI-1 device, and therefore the value of the correction factor «K» increases. Therefore, having measured the average volume of the cocoon by the express method, it is possible according to Figure 1 quickly set the correction factor "K" for any breed or hybrid right at the very receiving point of cocoon raw materials.

From Figure 3 it can be seen that the coefficient K_1 as a function of the reciprocal value of the volume of cocoons has a linear dependence [5-7]:

$$K_1 = f\left(\frac{1}{V_0}\right), K_1 = \bar{K} \cdot \frac{1}{V_0} + b$$

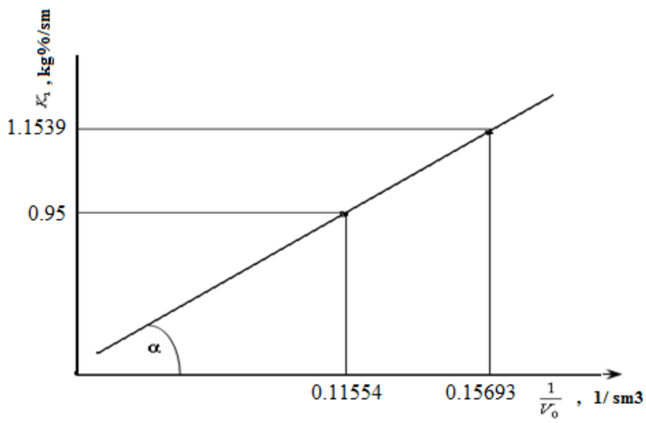

Figure 3: Dependence of the correction factor on the average volume of cocoons.

where is the tangent of the slope ($tg\alpha = \bar{K}$), b is a member showing what part of the ordinate the line cuts off from the y-axis.

With the help of the results shown in Figure 3 we can find the value $\bar{K}$ and b.

$$\frac{K_1 - 0.95}{1.1539 - 0.95} = \frac{\frac{1}{V_0} - 0.11554}{0.15693 - 0.11554}$$

Hence, we have $K_1 = 4.926 kg \cdot sm^2 \% \cdot \frac{1}{V_0} + 0.381 \frac{kg}{sm} \%$

Here it turns out that $\bar{K} = 4.926 kg \cdot sm^2, b = 0.381 kg / sm$

Then, to calculate the silkiness of a sample of living cocoons using the FTI-1M device, we have the formula

$$\O = (4.926 \frac{1}{V_0} + 0.381) \frac{kg}{sm} \% \cdot \frac{H(sm)}{m(kg)}$$

With the help of a specially developed computer program [8] and this formula, it is possible to determine the silkiness of living cocoons without cutting them.

Thus, to determine the qualitative parameters of silk cocoons, the use of non-destructive statistical methods is proposed. As a result, signals are obtained, analyzing and processing them using mathematical methods and computer software, it is possible to determine such qualitative parameters as the volumetric rigidity of the cocoon sample, the silkiness of the cocoons, the degree of maturity of the cocoons, the thickness and density of the cocoon shell.

And also proposed and experimentally proved a mathematical model for calculating the correction factor for the volume of live cocoons, which is proposed to be used in determining the silkiness in a handed-over batch of live cocoons.

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