New Cocoon Sorting Devices That Work On The Basis Of Certain Patterns Of Division Of A Mixture Silkworm Cocoons By Caliber And Mass When Selecting Them For The Tribe.

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Abstract: It is known that the cocoons of the average fraction (caliber and mass) in the breeding party are the most productive part of it. By the method of mathematical statistics, the regularities of division of the mixture of breeding cocoons by caliber and mass are determined. The normalized proportion of the average cocoon fraction of 58-70% and its range of caliber-2 mm determined and the possibility of maximum separation of defective components with small and large fractions from the batch in two stages, when sorting cocoons by caliber and mass was revealed. The article presents the technical characteristics of new devices developed on the basis of the revealed regularities and intended for sorting cocoons by caliber and dividing them by mass (sex) in the process of preparing hybrid silkworm eggs, which differ in increased accuracy of dividing cocoons by caliber and mass, as well as contributing to the replacement of manual labor and a sharp increase in productivity. The results of technological indicators of cocoons and raw silk obtained from them are presented.

Index Terms: cocoon, breed, hybrid eggs of silkworm, caliber, mass, average arithmetic, average quadratic, division of cocoons by sex, cocoon calibration device, automatic division of cocoons by sex.

1. INTRODUCTION

SILK-winding factories are equipped with high-performance cocoon-winding machines. an important requirement that affects the efficiency of this equipment is to provide them with uniform cocoons with a certain range of caliber [1,2]. However, live cocoons obtained from hybrid eggs do not meet the requirements of the standard for a number of indicators such as varietal composition, uniformity in caliber, defectness, etc. As a result, it is difficult to obtain raw silk at silk-winding enterprises, which in its quality meets the requirements of the standard 4-5A [3]. High quality of raw silk is provided mainly due to the uniformity of cocoons in caliber, which should reach up to 95%. This indicator of uniformity of cocoons by caliber is usually 55% on average, against the established norm-80% [4,5]. This situation can be explained by the fact that when preparing industrial hybrid eggs at breeding enterprises, breeding cocoons are sorted organoleptically-visually by appearance. Selection by the main qualitative characteristics-the caliber and mass of cocoons is not regulated due to the lack of appropriate technical means, while for the tribe, cocoons are divided by sex with a significant error. Naturally, this method of sorting cocoons can not increase labor productivity and get a hybrid eggs that gives uniform cocoons with high technological properties.

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To solve this problem, it is necessary to radically change the currently used technology of sorting cocoons by caliber and dividing them by mass and bringing the technology to the level of modern science and technology. The initial breeding material sorted at breeding enterprises is usually a mixture of cocoons of different quality. It consists of normal cocoons that are uniform in size, small and large, as well as various types of defective cocoons (ugly, irregular, thin-walled, etc.) that differ in one way or another from normal cocoons in size and mass. The main part of defective cocoons affects not only the quality of the prepared eggs, but also the quality of raw silk. They are inherited and can be strengthened or weakened in offspring, so they should be carefully culled when sorting. Mass, manual selection on external grounds, only creates an imaginary impression of selection, which does not give effect. When dividing the same mixture of cocoon caliber by sex, less complete groups of light males and large females are allocated for the tribe, while a significant part (35-45%) of the average mass of cocoons of each sex is not allocated. In this case, the average linear density and unevenness of the linear density of the cocoon thread correlate well with the cocoon gauge. Therefore, unwinding cocoons with the same caliber always gives raw silk with less unevenness than unwinding them in mixed form. Therefore, sorting cocoons by caliber, thus it is possible to divide them by valuable quality characteristics and get cocoons in the offspring that give raw silk of class 4-5A when they are unwound.

2 MATERIAL AND METHODS

Using a statistical method by studying the law of distribution of cocoons of the initial mixture, the normalized fraction of the average fraction was determined, with the selected value of the span of its caliber. Experiments were performed on breeding cocoons of B1, B2 breeds and hybrids with C8 x B1, C9 x B2. The resulting digital material for each breed and hybrid was divided into classes, selecting the appropriate class interval. Using variation series, we calculated the indicators of variation statistics M, σ, and Cv. then we constructed actual and theoretical curves for each breed and hybrid. Figure 1 illustrate the most typical cocoon distribution curves for all breeds and hybrids. The sizes of cocoons of the considered breeds and hybrids differ greatly and their limits, showing the maximum and minimum, are: lim = 14,5 ÷ 23,0 mm. The limits of the cocoon caliber vary, depending on the breed and hybrid of silkworm in a wide range in the direction of increasing or decreasing, but the span (the difference between the max and min values of the caliber) varies slightly and is 4.2-5.4 mm. The average arithmetic, average quadratic indicators and coefficients of variation of the groups compared also differ within small limits, i.e. M = 16,9 ÷ 20,2 mm; σ = 0,96 ÷ 1,25 mm: Cv = 4,9 ÷ 6,87 %.X_1 and X_2 are segments equal to -1 and +1mm, respectively, of the cocoon caliber; M-the arithmetic mean caliber; φ_{av}-the normalized fraction of the average fraction.

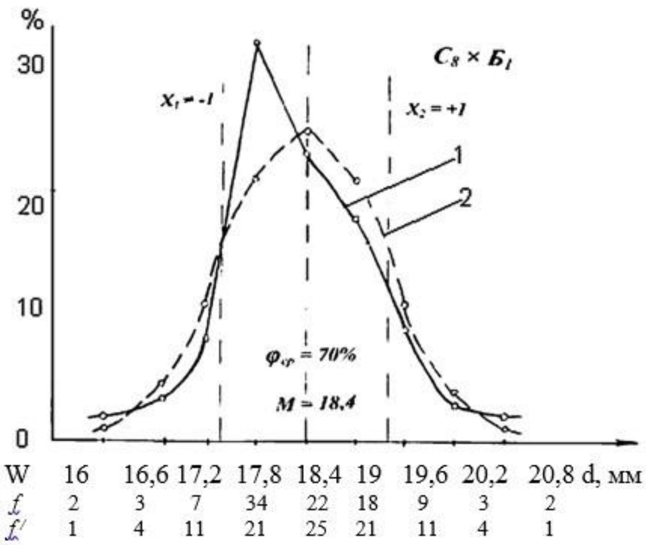

Figure 1. Comparison of factual 1 and normal 2 distributions on variational curves and calculation of the normed fraction of the average and extreme fractions of cocoons hybrid C8 × B1.

To determine the standard fraction of the average, as well as small and large fractions of cocoons, taking into account the requirements of automatic cocoon winding for the alignment of cocoons by caliber and biological properties, the average size of cocoons, the range of the caliber of the device is equal to 2 mm. To do this, in both sides of the center of the theoretical curves (figure 1), which coincides with the arithmetic mean M, one segment was laid on the X axis equal to 1mm of the cocoon caliber, i.e. X_1 = + 1,0 mm and X_2 = - 1,0The zone between these two bounding lines indicates the percentage of cocoons that is between the arithmetic mean and the specified attribute value and is equal to the average fraction. The left part of the line is considered a small fraction, and the right part is considered a large fraction. Using the working formula [6], we calculated the percentage of cocoons that make up their average, small and large fractions, which are respectively equal: φ_{av} = 57,6 ÷ 70%; φ_{small} = 14,2 ÷ 20,9%; φ_{large} = 14,2 ÷ 20,9. It should be noted that by displacing the dividing lines X_1 and X_2 in one direction or another, you can increase or decrease the percentage of cocoons of the average fraction. This is most effectively done by reducing the amount of large fraction and increasing the small fraction of cocoons. Since there are more female cocoons in a large fraction. However, it can be assumed that after the selection of small and large fractions of cocoons from the batch, the average fraction selected for produce of silkworm eggs may also contain certain amount of the defective cocoons with the same average calibers, which will negatively affect the quality of reproductive silkworm eggs. To identify this issue, let's consider the division of the cocoon mixture into components based on two characteristics - caliber and mass. For experiments, we used batches of breeding cocoons of the hybrid C8 x B1, consisting of normal and defective components. The results of measuring the caliber and mass of cocoons were divided into groups, taking the appropriate class interval. Placed these classes in the form of a variational curves. Figure 2 shows the characteristics of the caliber of the mixture of C8 x B1 hybrid cocoons and its components as an illustration of the statistical method, and figure 3 shows the characteristics of their mass. To identify the question of the possibility of net separation of defective cocoons from the batch, according to the above method, in both sides of the center of curves 1 (figure 2.), which coincides with the arithmetic mean M, one segment X_1 = - 1 and X_2 = + 1, equal to 1 mm of the cocoon caliber, was deposited on the X axis. 1 - cocoons of the mixture; 2- cocoons with a dead pupa; 3 - thin-walled; 4-irregular and ugly forms X1 and X2-segments, respectively, equal to -1 and +1mm caliber cocoons; M-the average diameter; K-class gap.

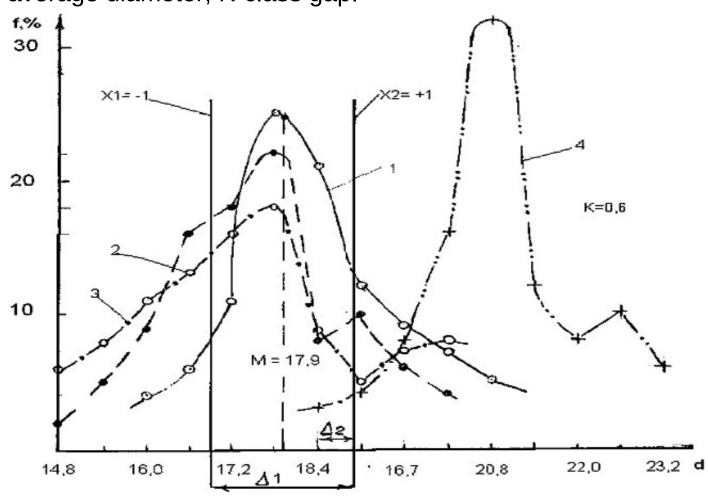

Figure 2. Variation curves for the caliber of cocoons of the mixture and its hybrid components C 8×B 1.

1 - cocoons of the mixture; 2- cocoons with a dead pupa; 3- thin-walled; 4-cocoons of the average fraction; X1 and X2- segments, respectively, equal to ± 0.1 g of the mass of cocoons; X3-a segment dividing the defective cocoons into 2 parts; M-the average mass; K-the class gap.

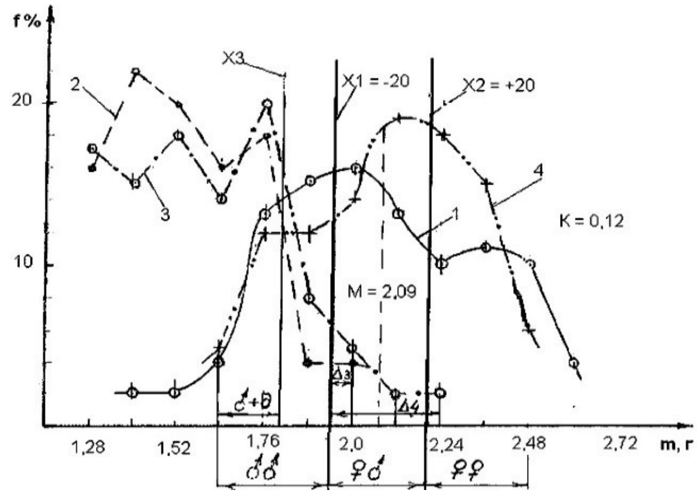

Figure 3. Variation curves for the mass of cocoons of the mixture and its components of the hybrid C8 × B1

The zone between these two limiting, straight lines X_1 and X_2 is equal to the average fraction, the left of the straight X_1 is a small fraction, and the right of the line X_2 is a large fraction. Of the curve of the cocoons with a dead pupa 2 and thin-walled 3 located on the left side X_1 and the straight part is superimposed on curve 1, direct limited X_1 and X_2, and a small part of them is located on the right side direct X_2 and is superimposed on curve 1. Therefore, about half of the curves of these defective cocoons are located in the area of the area of light and large fractions of cocoons and they can be separated from the general mixture with these fractions. And the rest cocoons is located in the area bounded by straight lines X_1 and X_2 on the area of the average fraction with an interval $_\Delta 1$. In this case, it is impossible to separate them from the average fraction of cocoons only by caliber. Curve 4 of the ugly and irregular shape of the cocoons is located on the right side of the X_2 straight line. Some part is superimposed on a curve bounded by the cocoon curve of a large fraction. Obviously, these cocoons can theoretically be completely distinguished by this feature with cocoons of a large fraction. Let's analyze the variation curves of cocoon mix components based on their mass (figure 3). According to the well-known method of dividing cocoons by mass into female and male individuals, they are divided into approximately three groups in the following proportions:

- light mass (males)-30 %;
- average mass (indefinite group) -40 %;
- heavy by mass (females) -30 %.

The middle part consists of the sum of the two second functions of the normalized deviation, i.e. $2\varphi_{(x)} = 0,4 = 40$ %. Half of the central part of the second function $\varphi_{(x)} = 0,2$ corresponds to X = 0,53 (table VII. [6]). Taking into account these indicators, one segment of X_1= -0,53 and X_2 = +0,53, equal to ± 0,1 g of the cocoon mass, was laid on both sides of the center of the cocoon curves of the average fraction 4, on the X axis, and the limiting lines dividing the curve into three zones were passed through them. The area between these two lines is the average weight group (40%), the right of the line X_2 is considered part of the heavy, and the left by X_1-light group. Curves cocoons with a dead pupa 2 and thin-walled 3 is located the maximum imposed from left to right on the left part of the curve 1, i.e. with the left side straight and X_1 are in the area of the space light mass cocoons. A small part of the area bounded by straight lines X_1 and X_2 and curves 2 and 3 is covered by areas at intervals of $_\Delta 3$ and $_\Delta 4$. With this division of cocoons into three groups by mass, to completely clean them from defective cocoons, it will be necessary to cull the entire light (male) group. Although produce enterprises of silkworm eggs use males 1,5-2 times, but males of an indefinite groups will not be enough for mating butterflies. Therefore, some of the most healthy part of the males must be preserved. To effectively solve this problem, a third dividing line X_3 was drawn from the intersection of curves 2 and 3 with curve 4, which divides the light mass cocoon group into approximately two groups. The right of the line X_3 is part of the largest, healthiest males and a small part of cocoons with a dead pupa and thin-walled, and the second is the left side - of the lungs, a weakened males and the main part of the cocoons with a dead pupa and thin-walled, which are not used for the tribeSelection of small, large fractions and defective components from a mixture of cocoons can be carried out in two stages when sorting them by caliber and mass. The obtained materials were used to create cocoon sorting devices based on the size and mass characteristics of cocoons.

3 The technical characteristics of new devices developed on the basis of the revealed regularities and intended for sorting cocoons by caliber and dividing them by mass (sex)

The cocoon calibration deviceSorting cocoons by caliber is one of the most important operations when selecting them for the tribe. To select more viable and productive individuals of medium-sized cocoons for the tribe, a cocoon calibration device was created, which is shown in Fig. 4 [7].

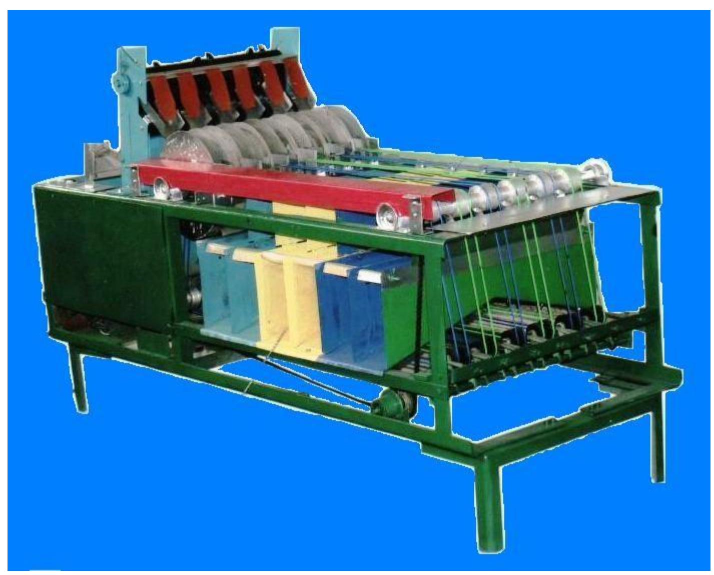

***Figure 4**. The cocoon calibration device*

The device allows you to divide breeding cocoons by caliber into six groups with an interval of 1 mm. The average fraction of cocoons with a span of 2 mm in the range of 60-70% is selected for the tribe, according to the above studies. To do this, the device provides a number of fan-shaped infinite calibration strap and a multi-section chamber equipped with gates (flaps) that allow you to adjust the selected share of cocoons.

Technical and operational indicators:
a) productivity, kg / hour-60-65;
b) the range of the selected cocoon fraction caliber, mm-2-2,5;
c) fraction ratio:
- small – 18-22%
- average – 60-70%
- large – 12-18%;
d) number of calibration sections, ps-6;
e) number of rows in the ladle conveyor, PCs-6;
f) power consumption, kW-0.4;
Upgraded automatic cocoon division by sex (ACD)

When producing high-quality hybrid silkworm eggs, it is very important to divide breeding cocoons by sex with high accuracy, for further crossing of females of one breed with males of another and vice versa.

One of the most effective methods is the division of cocoons using an upgraded ACD division (Fig. 5). The weight mechanism, which is made in the form of variation weights of the carousel type. The automaton, depending on the mass of cocoons, divides them into three groups: light (males), medium (indefinite group) and heavy (females). At the same time, by changing the position of the tabs of the machine, it is possible to distinguish the lightest by mass cocoons of males and defective components within 18-21%, while preserving the higher-quality, divided into indefinite and female groups of cocoons for the tribe.

***Figure 5**. Upgraded automatic for dividing cocoons by the sex.*

Technical and operational indicators:
a) productivity, kg / hour-11÷13;
b) sex division ratio:
- males-18÷21%;
- undefined group-49-54;
- females-28-30% (the error is not more than 5%);
c) the tribe uses cocoons of an indeterminate group and females.

To implement the tasks set, the range of adjustment of the dividing head tabs has been increased by making some design improvements, i.e. the zone (channel) of passage of light cocoons (males) has been reduced to the maximum permissible value, and the zone of passage of heavy cocoons (females) has also been reduced. At the same time, up to 15-20% of cocoons from the total mass of the party can fall into the light mass group, and up to 30% of pure cocoons of females can fall into the heavy weight group, while the remaining 50-55% of cocoons will fall into an indefinite group. The results of sorting cocoons using devices are shown in the table 1.

***Table 1.** Sorting results*

№	Indicators of operation	The Existing technology	Propose technology
1	2	3	4
I. Sorting cocoons by caliber			
1	Operation execution method	Manually divided into two fractions: tribal and non-tribal	A device for calibrating cocoons into three fractions: small, medium and large
2	Productivity in 7 hours, kg	30	300
3	Percentage of cocoons selected from the batch, %	Breedings (mixed kalibre), 47 - 50	Average fraction (kalibre), 65,3 - 69,2
4	Mass of selected cocoons, kg	2,35 - 2,50	3,26 - 3,46
5	Presence of defective cocoons in the selected batches, %	15-16	7-8
6	Average mass of silk cocoon shell, mg	425-432	445-450
II. Separation of cocoons by sex			
1	Operation execution method	Automatic cocoon division by sex	Upgraded automatic cocoon division by sex
2	Division of cocoons by sex into three groups,%: males undefined group females	34 - 30 31 - 38 35 - 32	18 - 20 54 - 50 28 - 30
3	Presence of cocoons of the opposite sex in groups,%: males females	16 - 18 15 - 20	~ 10 - 12 ~ 4 - 6
4	The mass s elected for papilonage groups of cocoons, kg.	Males, undefined group, females 2,35 - 2,50	Undefined group females 2,67 - 2,77

4 DISCUSSION OF RESEARCH RESULTS

The results shown in this table indicate the effectiveness of mechanized selection of cocoons of the average fraction per tribe. Where the number of cocoons selected for the tribe by the cocoon calibration device increased by 1.3 – 1.4 times, labor productivity increased by 8-10 times and defective components decreased by half in comparison with manual sorting. In the future, the cocoons of the selected medium fraction of breeds C8 and B1 were divided by mass (sex) on a modernized cocoon division machine (ACD) into three groups – males, an indefinite group and females. Division by weight (sex) of cocoons only of the average fraction makes it possible to reduce the division error. The results of the division of cocoons by sex of breed B1 are shown in the table, section II. The division by sex of only the average fraction of cocoons with the automatic adjustment allowed to reduce the error of division of cocoons of males and 3,5 times of females on average, with a slight increase (by 15-18%) in the number of cocoons in an undefined group. At the same time, the male group, which is mostly composed of the lightest and most defective cocoons, was rejected within 18-20%.The decrease in the error of experimental cocoons is explained by the fact that when calibrating cocoons by caliber, the average fraction of cocoons is aligned not only by caliber, but also by mass, since small female and large male cocoons, which under the usual method of division can fall into the opposite sex group, forming an error, are excluded from the measurement. The large error in the division of uncalibrated cocoons is explained by a wide variation in the mass of individual cocoons [8]. The selection of cocoons used in China and India for a tribe by dividing by sex at the pupa stage does not make it possible to obtain medium-sized cocoons in the progeny, as in our case [9.10]. The productivity of experimental and control grains C8×B1 and B1×C8 prepared from cocoons selected by the proposed and currently used technologies was studied based on the results of production feedings. The results of feeding are shown in table 2.

Table 2. Average technological indicators of cocoons obtained from the results of feeding

Hybrid	The average mass of cocoon, g	Average shell weight, mg.	The average span of the cocoon caliber, mm.	The number of uniform cocoons, with a 2-2,5 mm caliber span %.	The total number of high-quality cocoons, %
Experience					
C8×B1	2,22	0,48	3,0	85	95
B1×C8	2,10	0,45	3,5	82	93
Control					
C8×B1	1,93	0,41	4,5	62	85
B1×C8	1,87	0,39	5,0	60	82

The results feeding found that the main quality indicators experienced in relation to control is much higher: the average weight of cocoon and weight of the silk shell, respectively, at 12 and 15%; the varietal composition of cocoons 10 and 11%, indicator of the scope of the caliber decreased approximately 2 times the ratio of the starting material and 1.5 times relative to the control, and the share of uniform cocoons with an average span caliber 2-2. 5 mm increased by 22% and 23% against the control and amounted to 82 and 85%, which is within the requirements of cocoons unwinding. The results of production feedings clearly show that mechanized selected cocoons, aligned by caliber and mass, in the progeny increase productivity, uniformity, and other quality indicators of cocoons. The technological properties of experimental and control samples of cocoons were studied based on the results of single unwinding, the obtained values of which are shown in table.3.

Table 3. Technological parameters of the cocoon shell.

Hybrid	The mass of one of the dry cocoon, g	Linear density of the cocoon thread, Tex	Length of continuous unwinding cocoon thread	Total length, m	Total of raw silk, %
Experience					
C8×B1	0,85	0,31	792	1205	42,10
B1×C8	0,80	0,30	750	1140	41,55
Control					
C8×B1	0,74	0,29	615	1004	38,31
B1×C8	0,72	0,26	590	906	38,04

The results of cocoon unwinding show that the main technological indicators - raw silk output, linear density, total length and length of continuously unwound cocoon thread-are higher in experienced cocoons. This is due to the fact that the experimental cocoons have a higher mass of silk shell and they are more uniform in caliber.

5 CONCLUSION

Experimental studies conducted in production conditions found that the amount of the average fraction of cocoons selected from the batch by the cocoon calibration device, depending on the breed and hybrid, was from 56 to 64%, and the span of their caliber was 2-2,5 mm. The content of ugly and irregular cocoons in it is minimal – 2,25±0,32%, and the number of cocoons with dead pupae and thin – walled cocoons, respectively, is 3,9±0,21 and 3,27±0,23%, which is about half of the total number of them in the batch. Calibration was able to identify the main part of the ugly and irregular cocoons with small and large fractions, and part of the cocoons with dead pupae and thin-walled failed. Cocoons of the average fraction have higher indicators for the average mass of the cocoon and the mass of the silk shell in relation to half of the total values of the other two fractions, as well as to the control group of cocoons selected manually. With the manual method, only a certain selection of cocoons by type of defects is carried out, but the selection of cocoons by the main characteristics of the caliber and average mass of the cocoon does not occur. When dividing the cocoons of the average fraction by mass into 3 groups on the improved machine, the average error of division was significantly reduced (by 2 times), and the main part (up to 70%) of cocoons with dead pupae and thin-walled cocoons were in the easiest, rejected group. The effectiveness of cocoon division can be explained by the fact that the cocoons of the average fraction are aligned not only by caliber, but also by mass, which reduces the probability of getting heavy cocoons of males and light cocoons of females in opposite groups, which has a positive effect on reducing the error and the number of undefined cocoons. According to the results of experimental studies, as well as laboratory and production feedings of silkworm caterpillars, it was found that mechanized selection of cocoons per tribe by average caliber and weight in general gives a significant increase in labor productivity (4-5 times) and the number of cocoons selected from the batch (1.2-1.3 times), and the resulting eggs has a higher viability, gives more varietal and uniform cocoons. These data confirm that using aligned according to the size and weight of the cocoons in the offspring is a more productive and uniform cocoon raw materials. Created cocoon sorting devices in the process of preparing hybrid silkworm eggs led to an increase in the accuracy of dividing cocoons by caliber and mass, and also contributed to a sharp increase in labor productivity. According to the results of production feedings, it was revealed that from hybrid silkworm eggs prepared from cocoons aligned by caliber and mass, more cocoons were obtained, on average by 10 kg, uniform cocoons by 22% and varietal cocoons by 13% more than in the control. Based on the study of the results of uncoiling cocoons obtained from hybrid eggs prepared by the proposed and currently used technologies, it is revealed that the main technological parameters of the cocoon shell are such as the yield of raw silk, linear density, total and continuously unwinding length of the cocoon thread in experimental (uniform in caliber and mass) cocoons, respectively, are 20 and 27% more than the control ones (less uniform), and the coefficient of variation in the linear density of raw silk in the experimental samples is significantly lower than in the control ones.

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