**Development of a Solar Installation for Primary Processing of Silkworm**

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**Abstract.** This article explores a promising direction for reducing energy consumption during the primary processing of mulberry silkworm cocoons. Existing methods and equipment are analyzed, and their advantages and limitations are discussed. The technical characteristics of a specially developed and improved solar-powered device for cocoon processing and complete drying are presented.

**Keywords:** sericulture, energy resources, solar energy, device, cocoon production, cocoon shell, humidity, complete drying.

**INTRODUCTION**

One of the most important tasks at present is to solve problems associated with the processes of growing cocoons and producing silk to obtain high-quality raw material that meets international standards. In order to increase production volumes, improve the quality of cocoons and reduce fuel and energy consumption at the stage of preliminary processing (searing and drying) of silkworm cocoons, it is necessary to introduce modern energy-saving technologies. In solving this problem, it is necessary to pay special attention to the organization of a complex of scientific, practical and organizational work based on modern scientific and technical innovations [1, 2, 3].

The quantity and quality of silk that can be obtained from a cocoon largely depends on the methods of primary processing. The method must preserve the natural properties of the cocoon and ensure important physical and mechanical characteristics of the resulting silk thread [4, 5, 6].

Studies have been conducted on the use of infrared radiation for cocoon stifling. The essence of the method lies in the ability of the rays to penetrate the cocoon shell, reach the live pupae, and induce heating, thereby initiating the stifling process. It has been established that using emitters with a wavelength of no more than 1 µm and operating at high temperatures yields effective results. To preserve cocoon quality, the optimal radiation temperature should be maintained at 70°C [7, 8, 9, 10].

In recent years, research on this method has continued. Scientists have also succeeded in developing experimental prototypes of devices for cocoon stifling using infrared radiation. However, these devices are limited to the stifling stage of mulberry silkworm cocoons, while the subsequent drying process is still carried out using traditional shaded drying sheds. Moreover, the productivity of these devices remains low, and they have not yet been adopted in practical applications [11, 12, 13, 14].

There are units for drying cocoons that operate on the principle of convective heat and mass transfer One such unit is the conveyor-type СК-150К, which is currently used at primary cocoon processing facilities. To process one ton of live cocoons, this unit consumes approximately 85–90 kg of diesel fuel and 70–75 kWh of electricity. During the complete drying process, both energy consumption and processing time increase, which negatively affects the quality of the silk. The СК-150К unit is both morally and technically outdated, and its production has been discontinued [15, 16, 17, 18].

One of the promising areas for reducing energy consumption is the use of solar energy, which will reduce fuel and electricity costs and improve the environmental friendliness of the process. For this purpose, there are solar panels that convert solar energy into electrical energy [19].

The primary processing of mulberry silkworm cocoons coincides with the sunniest months of the year (May–June), which creates favorable conditions for the widespread use of solar energy for this purpose. Taking this into account, research was conducted to develop efficient devices for the primary processing of cocoons using solar energy.

**OBJECT OF RESEARCH**

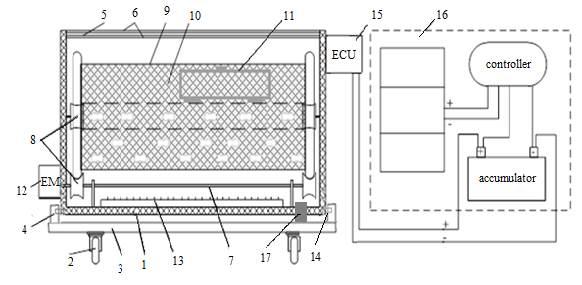
A general view of the solar device for the primary processing of mulberry silkworm cocoons is shown in Figure 1. The system consists of a thermally insulated chamber (1). The front lower part of the chamber is connected via a hinge (4) to the upper platform (3) of a cart mounted on four wheels (2), which allows for 360-degree rotation in the horizontal plane. The upper surface of the chamber, which functions as a light-receiving surface, is covered with glass panels composed of two layers of transparent glass (6) with an air gap (5) between them.

Since the front lower part of the chamber is attached via a hinge to the cart's upper platform, raising the rear of the chamber allows the incoming sunlight to strike the device’s upper surface perpendicularly. Inside the chamber (1) is a mesh drum (9) mounted on pulleys (8), which rotate on shafts (7) fixed to the bottom and sidewalls of the chamber via bearings. The mesh drum includes a tightly sealed window (11) for loading cocoons (10). Rotation of the shaft (7) is driven by an electric motor (12), which in turn rotates the mesh drum containing the cocoons.

Below the mesh drum (9), U-shaped tubular electric heaters (13) are installed in parallel along the lower section of the chamber. To ensure perpendicular incidence of sunlight on the upper surface of the device, a screw-type lifting mechanism (14) is mounted on the rear wall of the chamber, allowing vertical adjustment. An electronic control unit (15) is installed on the external side wall of the chamber [20, 21, 22].

The electronic control unit includes an ESP32 microcontroller, which performs all tasks in accordance with the device’s operational algorithm. It processes data from DS18B20 temperature sensors and controls the actuators located inside the chamber. The unit makes decisions based on signals received from the computer and sensors, thereby regulating the operating modes of the device’s components.

The device for the primary processing of mulberry silkworm cocoons receives electrical power from a photovoltaic solar unit (16). Using this system, the cocoons placed in the mesh drum undergo complete drying through the combined effect of both direct solar exposure (where sunlight directly impacts the cocoons) and indirect exposure (where electric heaters are powered by electricity generated from the photovoltaic system). During the primary processing of cocoons, the temperature inside the chamber, as well as the speed of rotation of the mesh drum and the humidity of the cocoons are monitored. These parameters are monitored via a computer connected to the electronic control unit [23, 24]. Excess moisture released during the stifling process accumulates as water condensate at the bottom of the device and is drained through an S-shaped siphon (17).



**FIGURE 1.** Solar device for the primary processing of mulberry silkworm cocoons:   
1 – thermally insulated chamber; 2 – cart with four wheels; 3 – upper platform of the cart; 4 – hinge; 5 – air gap;   
6 – glass panel consisting of two layers of light-transmitting glass; 7 – shaft; 8 – pulley; 9 – mesh drum; 10 – cocoons;  
11 – tightly sealed window; 12 – electric motor; 13 – U-shaped tubular electric heaters; 14 – screw-type lifting mechanism;   
15 – electronic control unit; 16 – photovoltaic solar unit; 17 – S-shaped siphon

**METHOD FOR OBTAINING EXPERIMENTAL DATA**

In the solar device for the primary processing of silkworm cocoons, three methods of applying solar energy for stifling and complete drying were used:

- stifling and complete drying of live cocoons through direct exposure to solar energy;

- stifling and complete drying of live cocoons through indirect exposure to solar energy, using a photovoltaic solar unit to power the electric heaters;

- stifling and complete drying of live cocoons using a combination of both direct and indirect solar energy.

To study the technical capabilities of the device, experiments were conducted in the following order: the mesh drum was removed from the device through the rear section. A total of 150–160 kg of live cocoons were placed into the mesh drum through the tightly sealed window located on the drum. The drum was then reinserted into the chamber of the device.

The upper part of the chamber was adjusted to a vertical position relative to the sunlight using the screw-type lifting mechanism, allowing the sun’s rays to strike the cocoons perpendicularly. Then, through the electronic control unit, the U-shaped tubular electric heaters were activated, and the drum was set in motion by the electric motor at a rotation speed of 0.33 rpm. The air temperature inside the chamber was automatically maintained within the range of 90°C to 95°C via the electronic control unit. This unit made decisions based on signals received from the computer and sensors placed among the cocoons inside the drum, regulating the operating modes of the device’s components. To maintain a stable temperature inside the chamber, the microcontroller supplied voltage to the electric heaters from the power source until the value received from the temperature sensor matched the setpoint. During the experiments, it was also ensured that the hot air temperature did not exceed 95°C (the recommended limit).

**RESULT AND DISCUSSION**

During the current cocoon production season, experiments were conducted to determine the technical performance indicators of the device for stifling and complete drying of cocoons under production conditions at “TST Agrocluster” in the KuyiChirchik district of Tashkent region.

The reliability of a solar device for the primary processing of cocoons was also investigated.

According to the results, it was found that the reliability of the solar device for the primary processing of silkworm cocoons is most influenced by the stability and uniform distribution of heat inside the chamber where the cocoons are placed, as well as the quality of the device elements. It was found that the reliability of the elements of the developed device for 5000 hours of operation is as follows (1):

(1)

As is known, the preservation of the quality of the produced cocoons largely depends on the methods of their preparation and primary processing. In this regard, during the research, comparative experiments were conducted on the quality of cocoons processed by the new solar method and cocoons processed in the conveyor unit СК-150К.

Fully processed cocoon samples that reached the conditioned humidity level (12%) were tested in a certified special laboratory for cocoon unwinding at the Research Institute of Sericulture on an unwinding machine, where their main technological (quality) indicators were determined. The technological indicators of cocoons processed in two types of devices are given in Table 1. The average values of the indicators for each experimental variant, obtained in three repetitions, are given.

**TABLE 1.** Technological indicators of cocoons processed using the existing and new technologies

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Processing method | Variants | Mass of one dry cocoon, g | Raw silk yield, % | Silk product yield, % | Continuous reeling length, m | Total length of silk filament, m | Filament metric count, m/g |
| Solar energy | 1 | 0,735 | 42,70 | 50,32 | 1076 | 1093 | 3439 |
| 2 | 0,715 | 43,92 | 53,81 | 1177 | 1178 | 3208 |
| 3 | 0,722 | 43,96 | 52,22 | 1093 | 1156 | 3467 |
| Average value | 0,724 | 43,53 | 52,11 | 1115 | 1142 | 3371 |
| СК-150К  (control) | 1 | 0,632 | 48,17 | 50,62 | 1178 | 1216 | 4177 |
| 2 | 0,760 | 41,33 | 49,46 | 1007 | 1068 | 3277 |
| 3 | 0,567 | 33,49 | 49,32 | 1101 | 1111 | 5170 |
| Average value | 0,653 | 40,99 | 49,80 | 1095,3 | 1131,6 | 4208 |

According to the analysis of the above indicators, the continuous and total lengths of the silk filament from cocoons processed by both methods are nearly identical: 1115 m and 1142 m, respectively, for the new technology, and 1095.3 m and 1131.6 m for the СК-150К. However, the main quality indicators—such as raw silk yield and silk product yield—are higher for cocoons processed using the new technology. The new method achieved yields of 43.53% and 52.11%, respectively, compared to 40.99% and 49.80% for the СК-150К. Overall, even with similar length characteristics, it can be concluded that the new cocoon processing method is more efficient [25].

**CONCLUSIONS**

1. Existing methods and equipment for the primary processing of mulberry silkworm cocoons were analyzed, and their advantages and disadvantages were assessed. As a result, the use of solar energy for primary cocoon processing was identified as the most optimal solution to address the challenges in this area.
2. It was established that the reliability of the components of the developed device over 5000 hours of operation is 0.91.
3. Based on the test results of the cocoon stifling device, it was found that the device can hold 145–150 kg of live cocoons. When using either direct or indirect solar energy, the stifling process takes 90 minutes. If both methods are applied simultaneously, the processing time is reduced to 60 minutes.
4. Complete drying of 150–160 kg of mulberry silkworm cocoons takes 2.5 hours.
5. The developed device for stifling and drying mulberry silkworm cocoons, which uses solar energy, is aimed at optimizing energy consumption and addressing practical challenges related to accelerating the complete drying process, thereby ensuring the long-term preservation of the quality of the processed cocoons.

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