**Solar Device for Thermal Processing of Silkwheat Cocoons**

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**Abstract.** One of the promising directions for reducing energy resources during primary heat treatment of silkworm cocoons is the topic discussed in this article. Existing methods and equipment were analyzed, and their advantages and disadvantages were assessed. The technical characteristics of the device for heat treatment of silkworm cocoons, as well as the equipment for their complete drying using solar energy, are presented.

**Keywords:** energy resources, solar energy, sericulture, cocoon, device, humidity, cocoon death, complete drying

**INTRODUCTION**

The production of silk cocoons, primarily silkworms, forms the basis of sericulture-one of the branches of agriculture. Today, improving the cultivation of cocoons and silk production to obtain high-quality raw materials that meet world standards is an important task. The introduction of modern energy-saving technologies, including the use of solar energy, is necessary to reduce energy costs, improve the quality, and increase the volume of primary cocoon processing. To solve this problem, it is important to effectively organize scientific and practical work using modern technologies.

For the primary processing of silkworm cocoons, research was conducted using infrared rays [1]. An experimental sample of an infrared morgue device was created. The method is based on the penetration of rays through the cocoon shell and the heating of the pupae for their death. Radiators with a wavelength of up to 1 μm at a temperature of about 70°C give good results. However, these devices only perform morgue, and the complete drying of cocoons is carried out traditionally in shaded dryers [2, 3, 4, 5, 6]. The performance of this device is still low, and they haven't been implemented in production yet.

In addition, devices operating on the principle of convective heat and mass transfer and using the hot air method are often used for silkworm cocoon killing. Among the devices is the SK-150K conveyor unit, used in primary processing bases [7, 8, 9, 10, 11, 12, 13]. For 1 ton of live cocoons, it consumes 85-90 kg of diesel fuel and 70-75 kW of electricity. When the cocoons are completely dried, energy consumption and processing time increase, which deteriorates the quality of the silk. The unit is outdated and its production has been stopped.

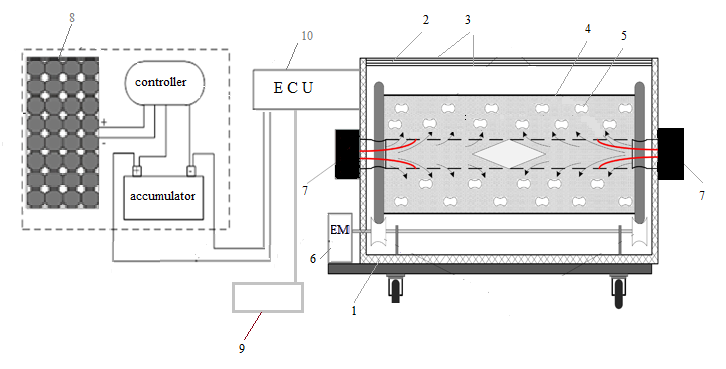
To increase production volumes, improve quality, and reduce energy consumption during the heat treatment of silkworm cocoons, it is necessary to implement modern energy-saving technologies.

A promising direction is the use of solar energy, which will reduce fuel and electricity costs, as well as reduce the harmful impact on the environment. The heat treatment of silkworm cocoons occurs during the most sunny months of the year - May and June, which allows for the widespread use of solar energy for this purpose. In this regard, research has been conducted on the creation of effective devices for primary heat treatment of silkworm cocoons using solar energy [14, 15, 16].

**OBJECT OF RESEARCH**

The general view of the solar device for heat treatment of silkworm cocoons is presented in Figure 1. The device's design includes chamber 1, equipped with thermal insulation. The air layer 2 is located between two glass plates 3 consisting of two layers of light-transmitting glass and covering the upper part of the chamber. Inside the chamber, there is a mesh drum 4. The mesh drum consists of two inserted cylinders. Cocoons 5 are placed in the outer cylinder of the drum. The cocoon drum is rotated by a shaft driven by an electric motor 6. With the help of thermoventilators 7, installed on both sides of the small cylinder, hot air under pressure is supplied into the channel. Hot air under high pressure passing through the central channel moves between the cocoons to the outer part, ensuring their uniform and complete drying [17, 18, 19, 20].

The device for heat treatment of silkworm cocoons is powered by a solar photovoltaic device 8. For complete drying of silkworm cocoons, the temperature of the hot air, the rotation speed of the mesh drum, and the moisture content of the cocoons are monitored. These parameters are monitored through the computer 9 connected to the electronic control unit 10.



**FIGURE 1.** Solar device for thermal processing of silkworm cocoons.   
1-thermally insulated chamber; 2- air layer; 3- glass plates consisting of two layers of light-transmitting glass; 4- mesh drum;   
5- cocoons; 6- electric motor; 7- thermal fans; 8- solar photovoltaic device; 9- computer; 10- electronic control unit

**RESEARCH METHODS**

Various methods were used in the research process, including the random number method (based on test and observation data), as well as analytical and experimental approaches. In addition, measurement errors and uncertainties were taken into account, statistical methods were applied, and a comparative analysis was conducted.

**METHOD FOR OBTAINING EXPERIMENTAL DATA**

In the solar installation, the primary heat treatment of silkworm cocoons is carried out simultaneously using both direct and indirect methods of solar energy exposure. In the direct method, the heat treatment process, i.e., morrowing and complete drying of live cocoons, is carried out under the direct influence of solar energy. In the indirect method, heat treatment is carried out using two thermal fans powered by solar photovoltaic devices.

**RESULT AND DISCUSSION**

During the current silkworm cocoon harvesting season, experiments were conducted at the "TST Agroklaster" LLC's main silkworm breeding facility (Kuyichirchik district, Tashkent region) to determine the technical characteristics of the silkworm cocoon harvesting and complete drying device under production conditions.

The main technical indicators of the device include:

* productivity - the number of cocoons processed per unit of time, kg/hour;
* energy consumption - the consumption of electricity or fuel during device operation.
* temperature regime - the range and stability of the maintained temperature during the heat treatment process, °C;
* processing time - duration of one complete heat treatment cycle, min;
* Efficiency (efficiency) - the ratio of energy expended to the achieved result.
* uniformity of drying - the degree of uniformity of drying of all cocoons (in terms of moisture content).
* raw material losses - percentage of spoiled or poorly processed cocoons.
* process automation - the presence of control systems, sensors, and automatic modes.
* reliability and service life - failure resistance, average service life.

The following factors influence the heat treatment of silkworm cocoons in the device: heating temperature, uniform distribution of hot air, and cocoon heat treatment time.

During the experimental studies, the effectiveness of the simultaneous application of direct and indirect methods of solar energy utilization was assessed, and the technical characteristics of the developed device were analyzed.

When applying the direct method, solar radiation, upon reaching the glass surface of the device, passes through the double glass and is converted into thermal energy, ensuring the thermal processing of the cocoons.

In the indirect method, thermoventilators powered by photoelectric panels supply heated air under pressure from both sides of the small cylinder. The fans provide circulation, and the built-in heater heats the air flow. The air flow under high pressure, passing through the central channel, is evenly distributed among the cocoons and directed to the outer part, contributing to the efficient and uniform distribution of heat in the drum. Thus, a full-fledged technological process of primary heat treatment of silkworm cocoons takes place.

To study the technical capabilities of the device, the experiments were conducted in the following order. Cocoons weighing 150-160 kg of live raw material, which were processed in the puppy killing device, were removed and placed in the drum of the unit for complete drying. From the total mass of underdeveloped (non-viable) cocoons, 250 g of aggregate (representative) samples were selected from various areas. The selected samples were placed in bags made of air-permeable material and placed in a drum of a fully drying unit. Thermal treatment was carried out using both direct and indirect solar energy exposure. During the device's operation, the mesh drum was rotated by an electric motor at a speed of 0.33 revolutions per minute. A thermal sensor for measuring the temperature of hot air was installed in the center of the air distribution channel. The air temperature was automatically maintained in the range of 90-95°C using an electronic control unit. This unit is built on the basis of the ESP32 microcontroller, which, interacting with DS18B20 thermal sensors located inside the camera, as well as with actuators, performs all functions according to the device's operating algorithm. The experiments were continued until the cocoons were completely dried, that is, until their conditional moisture content (12%), and all the time spent was recorded. The obtained results are presented in Table 1. According to the results, it was established that if the temperature of the hot air is maintained at 95°C, then the complete death of live silkworm cocoons at a conditional humidity of 12% occurs in 2.5 hours.

**TABLE 1**. Results of complete drying of heat-treated cocoons

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Experiment date (day, month, year) | Number of repetitions | Start time of the drying process (hours, minutes) | Temperature inside the device, 0C | Cocoon sample weight, g. | Cocoon moisture content, % |
| 17.06.2024 | 1 | 1000  1100  1200  1230 | 92  93  93  95 | 250  220  110  65 | 190  135  57  12 |
| 18.06.2024 | 2 | 1000  1100  1200  1230 | 88  90  94  95 | 250  222  100  69 | 192  145  59  12 |
| 19.06.2024 | 3 | 1000  1100  1200  1230 | 89  90  93  95 | 250  227  120  70 | 194  139  58  12 |

Fully dried cocoon samples that reached the conditional moisture content of 12% were tested in a certified special cocoon reeling laboratory at the Silk Research Institute on a KMS-10 model reeling machine, where their main technological (quality) indicators were determined.

According to the analysis of the above indicators, the length of continuous and total silk fiber in cocoons processed by both methods is practically the same: according to the new technology - respectively 1118 m and 1138 m, and on SK-150K - 1136 m and 1139 m. The main quality indicators of cocoons, such as the yield of raw silk and silk products, are higher in cocoons processed using the new technology. According to the new technology, they constitute 43.52% and 52.11%, respectively, while for SK-150K - 41.03% and 49.80%. In general, even with equal indicators, it can be said that the method of processing cocoons using the new technology is more effective.

**CONCLUSIONS**

1. Existing methods and equipment for primary processing of silkworm cocoons were analyzed, and their advantages and disadvantages were assessed. As a result, it was recognized that the most optimal solution to eliminate problems in this direction is the use of solar energy for primary processing of cocoons.

2. Complete drying of 155-160 silkworm cocoons in a drying device takes 2.5 hours.

3. The developed device for heat treatment of silkworm cocoons using solar energy is aimed at optimizing energy consumption and solving practical problems for accelerating the complete drying process, which ensures long-term preservation of the quality of the processed cocoons.

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