# Development Testing and Energy Efficiency Assessment of Electrotechnology for Resiving Mulberry Silkworm Sponge

Urolboy Khaliknazarov[a], Bobur Kamilov[b], Abbas Tursunov[c], Ulugbek Ibrokhimov[d] and Bekzod Choriev[e]
*Tashkent State Agrarian University, 100140, University str. 2, Tashkent, Uzbekistan*

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Abstract: Since the cocoon and the dome inside it have different electrical absorption capacity, treatment with an ultrahigh frequency electromagnetic field during degreasing of the silkworm dome of the silkworm makes it possible to achieve higher efficiency compared with other electrical physical influences. Because the ultrahigh frequency electromagnetic field is absorbed only in the dome, almost not being absorbed by the cocoon shell. As a result, the dome inside the cocoon is burned by heating at high temperature for a short period of time.

## 1 INTRODUCTION

Today, new technologies are being applied in the world for growing, storing and processing cocoons. In particular, scientific-research works aimed at developing new scientific and technical solutions of resource-saving technology and techniques of cocoon devitrification are being carried out. In this regard, special attention is paid to the use of energy and resource-saving methods, which ensure complete inanimation of the cocoon without cracking, compared to heat and chemical treatment. Therefore, it is an important task to develop an electrotechnology that ensures the complete death of the cocoon without adversely affecting the quality of the cocoon, as well as to justify its technological parameters and operating modes.

In the cocoon processing enterprises in our country, the silkworm inside the cocoon is killed by hot air treatment to kill the cocoon during the drying process. In this process, the high energy consumption, low productivity and 7-8 hours of re-drying after processing lead to deterioration of the quality index of the obtained silk product. Therefore, comprehensive measures are being implemented to gradually provide the silk industry with modern, energy-efficient technologies (Khaliknazarov et al., 2021; Khaliknazarov & Turdiboyev, 2021; Radjabov et al., 2021; Turdiboyev et al., 2022; Khaliknazarov et al., 2024; Khaliknazarov & Ibrokhimov, 2024; Mirzakhodjaev et al., 2024).

The demand for natural silk and silk fabrics in Jakhan bazaar is increasing day by day. In the world, more than 630,000 tons of cocoons are grown annually by more than 35 countries, and they are primarily processed into raw silk. China, India, Uzbekistan, Thailand, Brazil, Vietnam, North Korea and Iran are among the advanced countries engaged in cocoon preparation and processing (Khaliknazarov & Turdiboyev, 2021; Radjabov et al., 2021; Turdiboyev et al., 2022; Khaliknazarov & Ibrokhimov, 2024).

One of the important issues is the modernization and technical re-equipment of silk industry enterprises, the introduction of modern energy-saving innovative technologies and developments that can ensure the improvement of the quality of natural silk products.

[a] https://orcid.org/0009-0003-8775-5333
[b] https://orcid.org/0000-0003-1430-5029
[c] https://orcid.org/0000-0003-1430-4489
[d] https://orcid.org/0009-0008-6732-9915
[e] https://orcid.org/0009-0005-4806-1982



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## 2 MATERIALS AND METHODS

Requirements for technical and technological indicators of animized and dried cocoons.

According to GOST 8417-57, depending on the quality of the dead and dried cocoons and the yield of raw silk, the cocoons are divided into 1 and 2 grades. (Turdiboyev et al., 2022).

According to the characteristics of the shell surface, each type of cocoon must meet the following requirements:

Table 1: Classification of the cocoon into classes depending on the characteristics of the shell surface.

| Varieties of cocoons | Characteristics of the surface of the cocoon |
|---|---|
| 1 | Clean, unshelled cocoons. A batch with no spots on the surface or spots with a total diameter of no more than 5 mm, each scar no more than 10 mm, and spots with smooth shiny spots no longer than 10 mm in length is allowed. |
| 2 | A cocoon with a spot or a total spot on the surface not exceeding 25% of the shell surface, each spot not exceeding 15 mm in length, a batch of spots with smooth shiny areas not exceeding 15 mm, deformed, thin-walled, forms characteristic of this variety, or hybrid and thin transparent cocoons. |

If there are several scars or smooth shiny areas on the surface of the cocoon, its variety is determined by the largest size of one of the scars or smooth shiny area (Khaliknazarov & Turdiboyev, 2021).

Varieties include undifferentiated cocoons, cocoons with spots on the cocoon surface more than 25% of the total cocoon shell surface, scar more than 15 mm, smooth shiny area more than 15 mm. The entire length of the shell is strongly deformed and the bark is sticky, the surface of the shell is covered with spots, twining, leaking, moldy, hardened, underdeveloped, and the shape is sharply distorted (Khaliknazarov & Turdiboyev, 2021; Radjabov et al., 2021; Turdiboyev et al., 2022; Khaliknazarov & Ibrokhimov, 2024; Mirzakhodjaev et al., 2024).

A whole cocoon that is of high quality in terms of shell surface characteristics and meets the requirements of Level 2 cocoons, but has a raw silk yield of less than 23%, is classified as substandard.

The productivity of cocoons of grade 1 should be -35.7%, the productivity of cocoons of grade 2 - 28.8% (Turdiboyev et al., 2022).

Moisture content for all types of cocoons is set at 10.0%.

No more than 10.0% of the cocoon content of black pods and live specimen pods, separated into varieties, is allowed.

Moisture content of raw silk is allowed up to 11.0%.

The moisture content of cocoons supplied to sericulture factories should be less than 4% (Khaliknazarov & Ibrokhimov, 2024).

## 3 RESULTS AND DISCUSSION

An ultra-high frequency electromagnetic field treatment device in killing mulberry silkworm cocoons.

On the basis of the above results obtained in laboratory conditions, a technical assignment was developed for the design of an electrical technological device for the death of the mulberry silkworm cocoon.

Figure 4.1 shows an overview of the ultra-high-frequency electro-magnetic field treatment device used to kill the mulberry silkworm cocoon. The first processed cocoons are placed in a hopper with a distributing iron box. From the hopper, the cocoons are transferred to the processing chamber by means of a moving belt conveyor. The belt conveyor is driven by a 1.1 kW asynchronous electric motor and a reduction gear. The drive of the belt conveyor through the reducer is carried out with the help of pulleys and a belt.

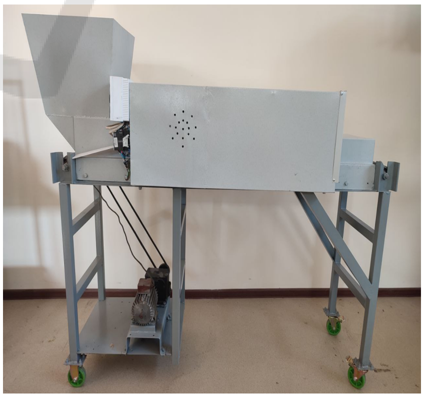
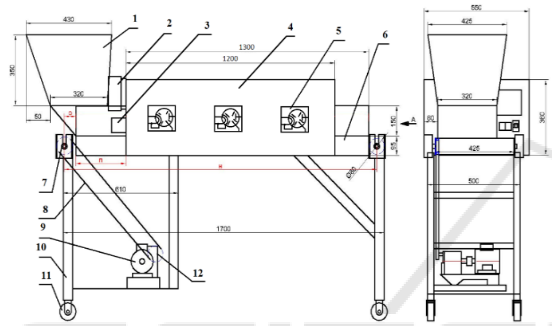


Figure 1: An overview of the first ultra-high-frequency electric magnetic field treatment device for cocoons.

The device consists of three working cameras. Three 1000 W magnetrons are installed on the side walls of the working chamber. (Figure 2). The cocoons are placed in a hopper with a distributing iron box. Device start-up electrical control box 2 and 3 (shchiti). From the hopper, the cocoons are transferred to the processing chamber 4 by means of a moving belt conveyor. On the sides of the working chambers, 5 magnetrons with 1000 W of power for primary processing of the cocoon are installed. The dead cocoons are introduced into the working chamber through a conveyor belt 6. The conveyor with a moving belt is driven by the drive shaft 7, the electric motor 9 with a power of 1.1 kW.

The principle circuit diagram of the cocoon pretreatment device with an ultra-high frequency electric magnetic field is shown in Figure 2. The device is protected by a circuit breaker (QF) to protect it from short circuit and overload currents.



a) Main view b) Side view

Figure 2: Scheme of arrangement of the elements of the pretreatment device with an ultra-high frequency electric magnetic field in the cocoon. 1. Iron cell bunker 2. Electric control box that starts the device 3. Programmable time relay 4. Working camera 5. Ultra high frequency electromagnetic wave scattering magnetron 6. A cocoon conveyor with a moving belt 7. Belt conveyor drive shaft 8. Belt drive belt conveyor 9. Electric motor 10. Device support 11. Wheels of the device.

An M1 electric motor is used to rotate the conveyor belt.

The main technical indicators of the device are presented in Table 2.

Table 2: Technical indicators of the device.

| № | Productivity | Value |
|---|---|---|
| 1 | During the death of the cocoon, kg·h | 60 |
| 2 | During semi-drying, kg·h | 12 |
| | Device parameters | |
| 1 | Number of working chamber, piece | 3 |
| 2 | Width of the working chamber, mm | 320 |
| 3 | The thickness of the processed cocoon layer, mm | 30 |
| 4 | Movement speed of conveyors, m/min | 0,68 |
| 5 | Installed electric motor capacity, kW | 1,1 |
| 6 | Power of magnetrons, kW | 3·1=3 |
| 7 | Fan power for cooling, kW | 0,075 |
| 8 | Total energy consumption, kWh | 2.1 |
| 9 | Service worker | 1 person |

The structural indicators of the cocoon obtained for the experiment are presented in Table 3.

Results of an experiment conducted under production conditions of a mulberry silkworm cocoon deactivation device.

The following were taken as the main factors representing the effect of an extremely high frequency electric magnetic field: Power of processing device (R), Processing time (t), and thickness of the processed product layer (h). In order to evaluate the effectiveness of the ultra-high frequency electromagnetic field and to characterize the processed product, the degree of inactivation of the sponge inside the cocoon (W) was adopted.

The following parameters were adopted in order to achieve the maximum level of inanimation during treatment with an extremely high frequency electric magnetic field before inanimation of the mulberry silkworm cocoon: R=950-1000 W; t = 29-30 minutes; h = 30mm.

In killing the silkworm cocoon: the cocoon is treated with an extremely high frequency electric magnetic field.

Table 3: Structural indicators of the cocoon taken for the experiment.

| № | Cocoon Class | Class | The size of the cocoon, % | | | Average weight of the cocoon, g | The average weight of the cocoon, g | Average silkiness of cocoons,% | Average flatness of silk | Metric number of cocoon fiber, m/g |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Small (14-15 мм) | Medium (16-19 мм) | Large (20-22 мм) | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1. | China | I | 4,50 | 78,26 | 17,24 | 2,.23 | 0,417 | 41,78 | 0,274 | 3650 |
| | | II | 4,10 | 77,15 | 16,33 | 1,94 | 0,389 | 40,28 | 0,238 | 3592 |
| 2. | Ipakchi-1 | I | 4.48 | 77.33 | 16.67 | 2.22 | 0.497 | 50.90 | 0.272 | 3676 |
| | | II | 4,36 | 76,83 | 16,12 | 1,99 | 0,415 | 50,56 | 0,242 | 3601 |
| 3. | Ipakchi -2 | I | 4.31 | 78.21 | 16.85 | 2.21 | 0.424 | 42.25 | 0.269 | 3595 |
| | | II | 4,25 | 76,28 | 16,61 | 2,18 | 0,422 | 41,85 | 0,253 | 3498 |

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By first treating the cocoon with an ultra-high frequency electromagnetic field, the degree of inactivation of the cocoon bubble was increased to 96-100%. The duration of electrical treatment, the thickness of the cocoon layer, the amount of slime on the surface of the cocoon, the type of cocoon, and the intensity of the electric field affect the death of the mulberry silkworm cocoon. The duration of electrical treatment, the thickness of the cocoon layer, the amount of slime on the surface of the cocoon, the type of cocoon, and the intensity of the electric field affect the death of the mulberry silkworm cocoon.

The following varieties of cocoons were taken for research.

"China" - I, II class
"Ipakchi 1" - I, II class
"Ipakchi 2" - I, II class

As a result of the tests conducted under production conditions, it was determined that the cocoon processing device with an ultra-high frequency electric magnetic field is suitable for providing the parameters and modes of the technological process under the production conditions of the laboratory copy.

A study was conducted to check the technological mode and parameters of mulberry silkworm cocoons in the production line of the cocoon primary processing enterprise belonging to "TST Agrocluster" LLC, Kuyichirchik district, Tashkent region.

In order to conduct experiments under production conditions, the structural indicators of cocoons were analyzed in the laboratory of the primary cocoon processing enterprise belonging to "TST Agroklaster" LLC.

The results of the experiment on killing the mulberry silkworm cocoon with an extremely high frequency electric magnetic field are presented in Table 4.

From the experimental tests carried out under production conditions, we can say that the yield of defective cocoons when killing the mulberry silkworm cocoon according to the proposed technology is up to 4-5%, while in the current technology it is 10-11%. Compared to the current technology, the output of defective cocoons is reduced to 5-6%. As a result, it is possible to improve the quality indicators of the silk obtained from the cocoon.

**Evaluating the efficiency of electrotechnology for killing the mulberry silkworm cocoon.**

The ultra-high frequency (UHF) electric magnetic field treatment device for killing the mulberry silkworm cocoon was tested at the cocoon processing enterprise of "TST Agrocluster" LLC, Lower Chirchik district. Economic efficiency was calculated on the basis of the current technology used in killing the mulberry silkworm and the results obtained with ultra-high frequency (UHF) electromagnetic field treatment. Table 5 lists the names of the equipment used in the death of mulberry silkworm cocoons and the amount of electricity and heat energy used to process 1 ton of the product.

Based on the table given above, we determine the relative amount of electricity and fuel used for the processing of 1 ton of the product and the amount of processed product of the equipment used in the process of killing the mulberry silkworm through the following expression.

$$W_i = \frac{P_i}{A_i}, \frac{\text{kW} \cdot \text{hour}}{\text{tons}} \quad (1)$$

Here $P_i$ – power of the equipment; $A_i$ – Product processing efficiency of the equipment in 1 hour;

We calculate the relative electricity and diesel fuel consumption for killing 1 tons of mulberry silkworm cocoon in the SK-150K device.

$$W_{\text{electricity}} = \frac{34{,}8}{0{,}3625} = 96 \frac{\kappa W \cdot hour}{\text{tons}}$$

$$W_{\text{diesel}} = \frac{36{,}5}{0{,}3625} = 100 \frac{\text{liter}}{\text{tons}}$$

Table 4: The technological process of killing the mulberry silkworm cocoon and the amounts of energy used for it.

| № | Technological process | Device name | Productivity | Electricity consumption in 1 hour for cocoon processing; kWh | Diesel fuel consumption in 1 hour for cocoon processing; l. |
|---|---|---|---|---|---|
| 1 | Killing the mulberry silkworm cocoon | SK-150K | 8,7 tons/day | 34,8 | 36,5 |
| 2 | Killing the mulberry silkworm cocoon | Very high frequency electric field | 0,288 tons/day | 2,1 | - |

We calculate the relative electricity consumption for killing 1 tons of mulberry silkworm cocoons in the proposed ultra-high frequency electric magnetic field treatment device.

$$W_{\text{electricity}} = \frac{2{,}1}{0{,}012} = 175\,\frac{\kappa W \cdot hour}{\text{tons}}$$

Considering that the price of 1 kW·s of electricity for production enterprises today is 450 soums, 43200 soums for processing 1 ton of live cocoons in the SK-150K device;

Considering the price of diesel fuel is 5800 soums, 580000 soums will be spent.

78750 soums will be spent if the proposed ultra-high-frequency electric magnetic field is treated.

We determine the difference in comparative costs for killing 1 ton of mulberry silkworms according to the current and proposed technology.

$$\Delta Э = 43200 + 580000 - 78750$$
$$= 544450 \quad \frac{\text{soum}}{tons}$$

If an average capacity cocoon processing plant processes 60 tons of cocoons in one season;

$$\Delta Э_{\text{season}} = A_{\text{season}} \cdot \Delta Э = 60 \cdot 544450$$
$$= 32667000 \ \text{soum}$$

38925000 soums are saved in one season.

If we subtract 5825000 soums from this profit, the expected economic efficiency per season is 26842000 soum.

## 4 CONCLUSIONS

According to the results of experimental tests carried out in production conditions, the level of deactivation of the sponge increases up to 96% with the initial treatment of the cocoon with an extremely high frequency electric magnetic field. The duration of treatment with electric physical action in killing the sponge inside the cocoon affects the type of cocoon, its physical-mechanical properties and processing power, and allows up to 41% energy saving compared to the current technology. As a result, the cost of the silk obtained from the cocoon is reduced. Because the high-frequency electric magnetic field is almost not absorbed in the cocoon, but only in the mushroom. As a result, the fungus inside the cocoon becomes dead due to heating at high temperature in a short period of time.

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