



Development of an Energy-Efficient Electrotechnology for the Inactivation of White Grub (*Polyphylla Olivieri*) through Electrophysical Treatment.

Urolboy Khaliknazarov*¹, Abduaziz Abduvasikov¹, Iroda Tadjibekova¹,
Maoruf Djiyanov¹, Nodira Nuralieva²

¹Tashkent State Agrarian University, Tashkent, 100140, Uzbekistan

²"TIAME" National Research University, Tashkent, 100000, Uzbekistan

u.xaliknazarov@mail.ru

Abstract. In primary silk cocoon processing facilities, only the hot air (convective) method is currently used for the inactivation and drying of silkworm pupae. However, most of the equipment operating with this method is physically and morally outdated, constructed from bulky and heavy metal materials, which leads to excessive fuel and energy consumption during processing. Experimental research has shown that the use of ultra-high frequency electromagnetic field treatment in the initial processing of cocoons ensures complete inactivation of the silkworm pupae while preserving the quality of the silk and significantly improving energy efficiency. This makes it one of the most optimal electrotechnological methods for cocoon processing.

Keywords: cocoon, cocoon processing, pupa, pupa inactivation, ultra-high frequency, energy-efficient technology

1 Introduction

In silk processing enterprises of the Republic of Uzbekistan, the current method used for inactivating and drying the silkworm pupae inside the cocoon involves hot air treatment. However, this method results in high energy consumption, low operational efficiency, extended processing time due to the need for additional drying after treatment, and a deterioration in the quality indicators of the obtained silk. As a result, comprehensive measures are being implemented to gradually introduce modern, energy-efficient technologies into the silk industry [2].

Among the key priorities are the modernization and technical re-equipment of silk industry enterprises, as well as the introduction of energy-efficient innovative technologies and developments that meet contemporary standards and ensure improved quality of natural silk products [1,2].

Previous studies have achieved certain positive results in developing new methods for the inactivation of silkworm pupae and drying of cocoons, as well as in improving the quality indicators of silk through the application of primary electrophysical treatments

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and the optimization of their operating modes and parameters. However, these studies did not take into account the electrical resistance of the cocoon to various physical quantities (such as electric current, electromagnetic fields, optical radiation, etc.), and the issue of achieving energy efficiency by directly affecting the pupa inside the cocoon has not been adequately investigated.

2 Materials and methods

In the initial processing of cocoons, it is essential to preserve the physicochemical properties of fibroin and sericin components within the cocoon shell, as well as the natural technological characteristics of the silk fiber [3].

The proteins present in the cocoon are primarily composed of fibroin and sericin. The fibroin molecule consists of a long chain formed by a high number of amino acid residues. The longer these molecular chains are, the greater the elasticity and flexibility of the silk fiber. Fibroin enzymes enhance the fiber's resistance to external influences and ensure its insolubility in alcohol, ether, and other solvents. Fibroin is also resistant to weak acids; it swells in water but retains its structural integrity [3–4].

Since sericin—the substance that binds multiple fibroin filaments together—is a protein-based compound, its physical, mechanical, chemical, and technological properties are highly dependent on the drying and storage conditions applied during the initial processing of the cocoon. Accordingly, the processes of inactivating and drying the silkworm pupa can be classified into two main groups, depending on whether these stages are performed separately or simultaneously.

The first group includes methods in which the silkworm pupa is only inactivated. After inactivation, the cocoons are dried on racks placed in shaded areas. This method of pupa inactivation involves treatment using hot steam, chemical agents, hermetic sealing, gamma radiation, or storage in a cold environment.

The second group includes methods in which the processes of silkworm pupa inactivation and drying are carried out simultaneously. This approach involves treatments using sunlight, vacuum-assisted working chambers, electromagnetic fields of various frequencies, high-temperature hot air (convective method), and exposure to optical radiation.

Most ongoing scientific research is focused on methods for inactivating silkworm pupae and drying moist cocoons, as well as on improving the overall technology of silk production from cocoons. Among these, one of the most widely used methods—both in Uzbekistan and abroad—is the thermal inactivation and drying of live pupae using hot air. This method is currently employed with equipment such as the "Simplex," conveyor-based KSK-4.5 and SK-150K units, and Japan's modern "Yamato-Sanko" systems, all of which are still in use at silk-processing enterprises. In this method, live pupae inside the cocoon are inactivated within 60–90 minutes under hot air at temperatures ranging from 75°C to 90°C [4].

Nevertheless, the currently used hot air treatment method leads to chemical alterations in the structure of sericin within the silk thread, which prevents the complete preservation of the natural technological properties of the cocoon shell. As a result, the reelability of the silk fiber decreases, and the quality of the raw silk deteriorates. Therefore, developing and implementing new, improved methods for the simultaneous

inactivation and drying of live silkworm pupae using conveyor-type drying systems is considered one of the most urgent tasks today [5–6].

Although various methods have been explored in the above-mentioned studies, the theoretical and practical aspects of a single optimal method for the initial processing of cocoons have not yet been widely implemented in industrial practice. Therefore, addressing this issue remains one of the most pressing challenges in the field.

3 Results

Based on the above, a scientific hypothesis was proposed that high efficiency can be achieved in the inactivation of silkworm pupae through treatment with an ultra-high frequency electromagnetic field. A series of experiments were conducted to test this hypothesis.

One of the recommended electrotechnological methods is the inactivation of cocoons using an ultra-high frequency (UHF) electromagnetic field. In this method, the death of the pupa occurs as a result of internal heat exchange generated within the UHF electromagnetic field. The internal heat exchange process in the pupa depends on selecting frequency parameters that do not alter the properties of the cocoon shell, as well as on the intensity of the electric field. The heat inside the cocoon is dissipated to the outside by convective means. Initial experimental results showed that when treated with an electromagnetic field at a frequency of 2450 MHz for 30 seconds, the pupa inside the cocoon is completely inactivated without heating the cocoon shell [7]. During this time interval, the cocoon loses 13–15% of its total weight, and the drying period in shaded conditions is reduced to 15–20 days. The results of the conducted research are presented in Table 1 [8].

Table 1. Effect of Ultra-High Frequency (UHF) Electromagnetic Field Current on the Inactivation of Cocoons by Time and Temperature.

No	Type of cocoon	Number of cocoons (pieces)	Power (W)	Processing time, seconds (t)	Temperature change, degrees (°C)	Cocoon mortality rate (%)
1	Ipakchi-1 x ipakchi-2 hybrid	100 pieces	1000 Watts	Initial temperature	29 °C	Live pupa
2				5 seconds	33 °C	3%
3				10 seconds	37 °C	24%
4				15 seconds	41 °C	45%
5				20 seconds	50 °C	71 %
6				25 seconds	60 °C	87%
7				30 seconds	70 °C	100 %
8				35 seconds	75 °C	100% of pupae are inactivated, but

						some pupae crack, leading to deterioration in silk quality.
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Based on the preliminary experiments, it can be concluded that the use of an ultra-high frequency electromagnetic field in the inactivation of silkworm pupae yields high efficiency. However, when the cocoon temperature reaches 70°C and the treatment duration exceeds 30 seconds under the influence of the ultra-high frequency electromagnetic field, cracking of the pupa was observed. This leads to a deterioration in silk quality. Therefore, it is necessary to conduct systematic studies to theoretically determine the dependence of the ultra-high frequency electromagnetic field parameters on the quantity of cocoons treated and the exposure time, as well as to justify the optimal conditions [9].

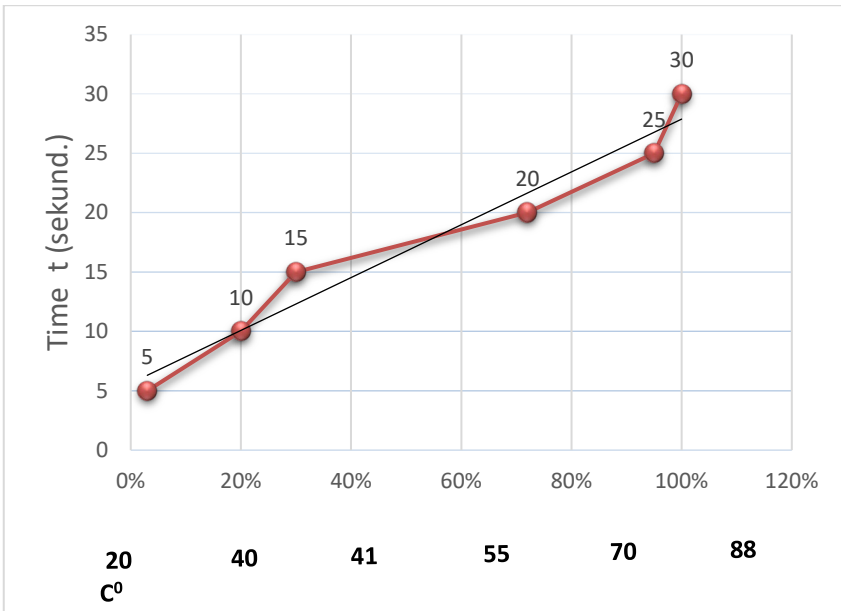


Fig. 1. Graph of the effect of time and temperature of ultra-high frequency electromagnetic field treatment on cocoon inactivation.

Therefore, the objective of this research was defined as the development of an energy-efficient electrotechnology for the inactivation of silkworm pupae through electrophysical treatment. The process involves treating live cocoons with an ultra-high frequency electromagnetic field to achieve complete inactivation of the pupae inside, thereby preserving the quality characteristics of the silk obtained from the cocoon and reducing electricity consumption (Fig. 1).

4 Conclusion

Currently, in cocoon processing enterprises, the inactivation and drying of silkworm pupae are carried out exclusively using the hot air (convective) method. However, most of the equipment operating under this method is physically and morally outdated and consists of large volumes of heavy metal, resulting in excessive fuel and energy consumption during the process. Experimental research results have shown that the use of ultra-high frequency electromagnetic field treatment in the initial processing of cocoons allows for complete inactivation of the pupae, preserves the quality of silk obtained from the cocoon, and achieves energy efficiency, making it the most optimal electrotechnological method.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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