Innovative: International Multi-disciplinary Journal of Applied Technology
(ISSN 2995-486X) VOLUME 04 ISSUE 02, 2026

RESEARCH ON OPTIMAL PARAMETERS FOR THE KILLING OF MULBERRY SILKWORM PUPAE BY A COMBINED METHOD

Safarov Jasur Esirgapovich
Islam Karimov Tashkent State Technical University, Republic of Uzbekistan, Tashkent

Sultanova Shakhnoza Abduvakhitovna
Islam Karimov Tashkent State Technical University, Republic of Uzbekistan, Tashkent

Fu Yaqin
Zhejiang Sci-Tech University, China, Hangzhou

Usenov Azamat Bakir Ugli
Islam Karimov Tashkent State Technical University, Republic of Uzbekistan, Tashkent

Samandarov Doston Ishmukhammat Ugli
Islam Karimov Tashkent State Technical University, Republic of Uzbekistan, Tashkent

Dushanova Dilnoza Davron kizi
Islam Karimov Tashkent State Technical University, Republic of Uzbekistan, Tashkent
E-mail: samandarov7212@gmail.com

Abstract:

The work presented here is the experimental study of a synergistic ultrasonic and infrared treatment of mulberry silkworm pupae. The study investigated pupal mortalities as a function of processing time, temperature and ultrasonic frequency. The range of experimental conditions consisted of processing temperatures from 60–80°C, ultrasonic frequencies from 20–40 kHz, and processing times of 180–480 seconds. The results indicated that mortality rate was always found to be positively associated, with increase in processing time as well as ultrasonic frequencies. It was discovered that high efficiency could be achieved, especially at 40 kHz ultrasonic frequency and significantly lower temperature. According to the experimental results, recommended optimal regime parameters are you to help stifling with a high quality and to minimize its adverse effects on cocoon quality. The findings will be of practical importance in the development of advanced and energy-saving technological solutions for various sectors of sericulture. 5.3×10^{-5} to 1.42×10^{-4}, approaching or exceeding acceptable limits. The findings demonstrate significant contamination of the Aluu River by microplastics with sediment acting as a major sink for these pollutants. The dominance of high-risk polymers, coupled with elevated health risk indices, indicates potential long-term ecological degradation and serious public health concerns for populations dependent on the river. Continuous environmental monitoring, strict regulation of industrial discharges, improved waste management practices, and public awareness initiatives are strongly recommended.

Keywords: Mulberry Silkworm, Cocoon, Silk, Infrared Radiation, Ultrasonic Treatment, Drying Kinetics, Temperature, Stifling

Introduction

The most important post-harvest operation for the preservation of silkworm cocoons (for subsequent processing) is their primary processing (stifling and drying). The traditional hot-air treatment process has disadvantages like long-processing time, uneven heat distribution, and degradation of some beneficial proteins including fibroin and sericin [1]. To address this drawback, hybrid technologies with infrared (IR) radiation and ultrasound (US) have being used in order to enhance heat and mass transfer rates. Electromagnetic energy such as infrared radiation is used to achieve quick surface heating, while ultrasound generates cavitation and micro-streaming in the material [2, 3]. The mulberry silkworm, which feeds on mulberry leaves, is scientifically known as Bombyx mori of the family Bombicidae. The mulberry silkworm is a complete metamorphic insect, and its life cycle consists of four major stages: egg, larva, pupa, and adult (moth); feeding only occurs in the larval stage (Fig. 1). Mulberry silkworm; Its feed is mulberry tree leaves [4].

Figure 1. Lifecycle of the silkworm

Farmers involved in the rearing of mulberry silkworms in our country harvest cocoons and immediately string them out for primary processing. This is essential to smother and desiccated before the pupa become a moth and expands from the cocoon, in which this cycle makes the cocoon ineffective or significantly reduces its value [5, 6].

Materials and Methods

Raw Materials

In this study fresh samples of Bombyx mori cocoons have been used, which were grown in the conditions of Uzbekistan. Cocoons of similar size and high quality but without shell damage were chosen for the experiment. Following collection, all samples were maintained refrigerated for 24 h prior to the beginning of experiment. The weight of 100 fresh cocoons used in each drying group ranged from 240 to 250 g and the distance between the material and the infrared emitter was kept at a constant value of 10 cm.

Process Parameters. It was studied on work of the combined ultrasonic-infrared unit for the high-quality anesthesia (stifling) mulberry silkworm pupae. The following 9 combinations were tested:

- Processing time (s): 180, 240, 300, 360, 420, 480;
- IR wavelength (μm): 3.0;
- Ultrasonic frequency (kHz): 20, 30, 40;
- Temperature (°C): 60, 70, 80;
- Infrared radiation power: 220, 260, and 300 W.

Experimental Setup. The research was carried out on a combined ultrasonic-infrared drying unit in the laboratory of "Processes and Apparatuses for Agricultural and Food Products Processing" carousel at Tashkent state technical university. This device is illustrated schematically in Fig. 2.

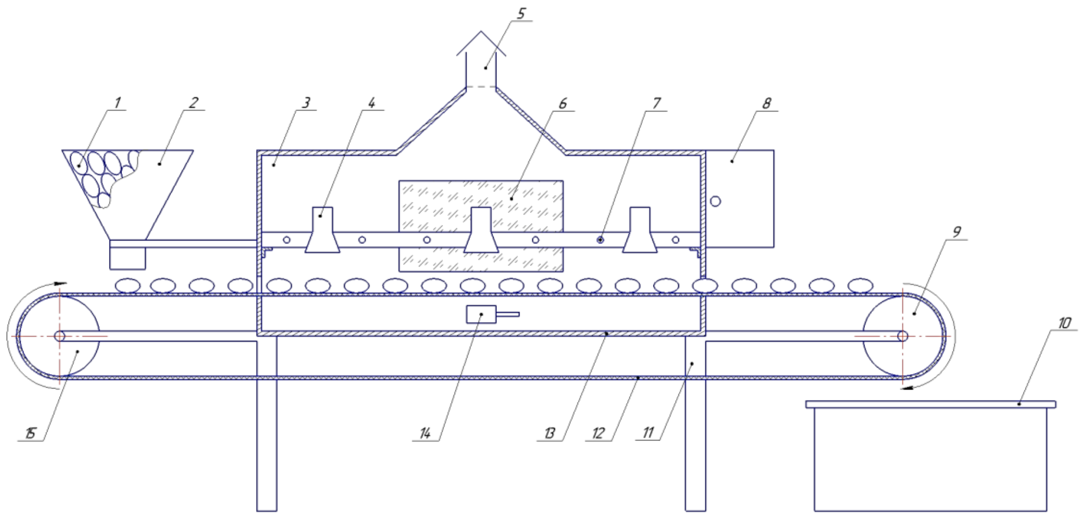

Figure 2. Schematic diagram of the unit: 1 - fresh cocoon harvest; 2 - cocoon loading hopper; 3 - working chamber; 4 - ultrasonic emitters; 5 - ventilation system with a fan for moisture removal; 6 - process observation window; 7 - ceramic infrared emitters; 8 - control unit; 9 - driven shaft of the belt conveyor; 10 - cocoon collection container; 11 - device legs; 12 - belt conveyor; 13 - infrared reflectors; 14 - thermocouple; 15 - drive shaft of the belt conveyor

Processing Method

The raw cocoon harvest (1) is placed in the stowage bin (2). The control unit (8) is used to turn on the infrared emitters of the unit, and then the alimentary cocoons are placed on the belt conveyor (12) and heated to a predetermined temperature. Upon reaching the drying temperature, the conveyor commences, and cocoon feeding is performed for pretreatment in the working chamber (3). (applied via control unit (8)) for launching the ultrasonic generator. The belt conveyor is also controlled through the control unit (8) which regulates its movement speed.

Infrared reflectors (13) are used to redirect the rays onto the raw material in the entire interior of the chamber. Thermocouples (14) are used to monitor the temperature within the chamber. The ultrasonic emitters in the unit are briefly applied to raw material through periods of 10 seconds. Infrared rays transfer the heat directly inside the material and accelerate moisture evaporation, while ultrasonic waves help in uniformly distributing the heat inside and increase the rate of moisture evaporation. By using the combination of these two strategies, both stifling and drying process can be implemented properly with enormous reduction in energy use.

The unit is specially designed for drying and stiffing of mulberry silk worm pupae. The main advantage of osmosedseny unit is the ability to combine infrared radiation with ultrasonic waves and to choose parameters of processing regimes within necessary rages. Able to apply IR and US waves in a concurrent fashion on the introduced object allows it, which combined with thermo-radiative effect brings good prospects for simultaneous thermo-radiative and mechano-acoustic impact.

Results and Discussion

Experimental studies were performed on the stifling of mulberry silkworm pupae and are shown in detail below (Figures 3–5). According to Fig. 3, the pupal mortality rate significantly increased as the processing time was prolonged at a temperature (60°C) and ultrasonic frequency (20 kHz) [7]. The mortality rate at 180 seconds was 85.1%, compared to 92.9% ($P < .000\ 01$) after 300 seconds. The mortality was about 95–97% in the range of 360–420 seconds, and near-total mortality (99.7%) was achieved at 480 seconds. This means that the efficiency of this process at low temperatures and relatively low frequencies is fundamentally limited by the length of time exposed to these stimuli [8, 9].

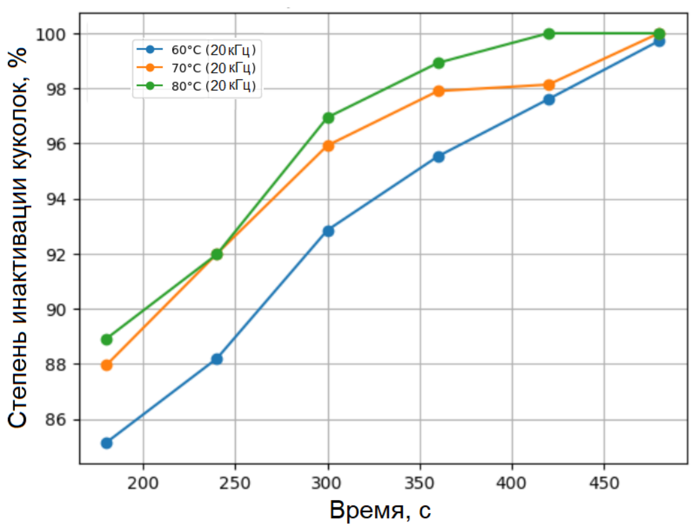

Figure 3. Results of experiments on the stifling of mulberry silkworm pupae using 20 kHz ultrasound under the influence of 220 W infrared radiation at temperatures of 60, 70, and 80 °C

At the ultrasonic frequency of 20kHz and operating temperature (70 °C), mortality was faster than at 60 °C; after only 240 seconds, mortality exceeded 92% and after another 60 seconds reached the level of 95.9% [10]. Full (100%) anesthesia was performed in 480 seconds. Therefore, the temperature increase caused the thermal and acoustic stress on pupal tissues to increase, which in turn decreased processing time [11]. Further necrosis was achieved more intensively at ultrasonic frequency of 20 kHz and temperature of 80 °C. The mortality rate was at 96.9% within 300 seconds and total mortality was achieved at 420 seconds. Yet, high temperatures may lead to adverse effects in the cocoon shell and silk quality. So, although being technologically efficient, there is a threshold on quality conservation [12, 13].

It was found that raising the ultrasonic frequency to 30 kHz greatly increased the general anesthesia efficiency. After 300 seconds, the stifling coefficient was at 97.5%, and after 420 seconds a practically complete result was registered. This indicates that as the ultrasonic frequency increases, the cavitation effect and mechanical vibrations are also raised up to a greater extent, causing pupal viability to decrease rapidly (Fig. 4).

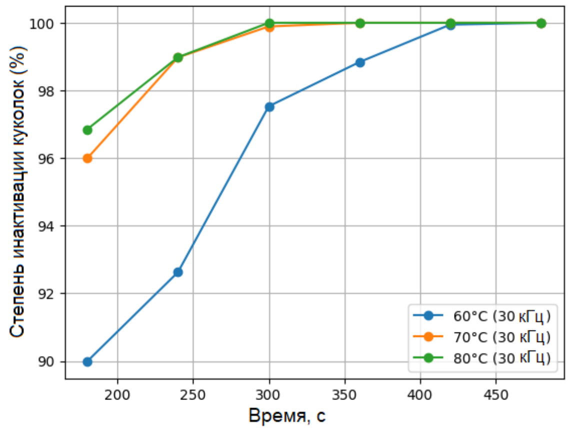

Figure 4. Results of experiments on the stifling of mulberry silkworm pupae using 30 kHz ultrasound under the influence of 260 W infrared radiation at temperatures of 60, 70, and 80 °C

A regime that stood out as highly effective was the combination of 70 °C and 30 kHz. At 180 seconds the mortality rate was around 93%, it took less than 300 seconds to achieve complete mortality. The beauty of this regime is that it saves a lot of precious time and is very efficient. Destruction happened so quickly by heating temperature of 30 kHz and at the temperature of 80 °C. The mortality rate climbed to 99 percent at 240 seconds and reached 100 percent after 300 seconds. However, as high-temperature may affect the negative in industrial practice, this regime needs to be carefully adapted. At 40 kHz ultrasonic frequency, the necrosis process had shown great efficacy even at 60 °C, achieving 98.9% mortality after 300 seconds and complete mortality in under 420 seconds [14]. This is especially true because it permits high results to be obtained low (Fig. 5).

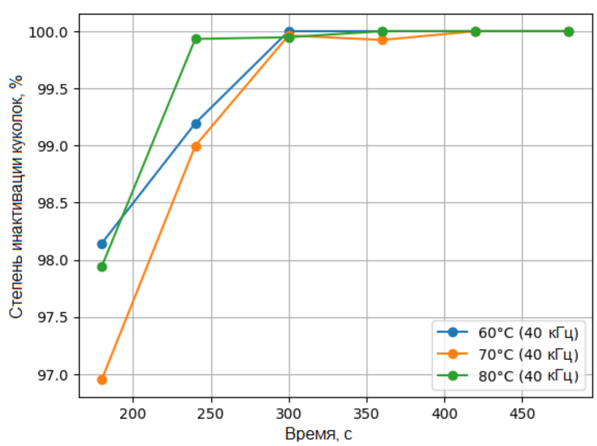

Figure 5. Results of experiments on the stifling of mulberry silkworm pupae using 40 kHz ultrasound under the influence of 300 W infrared radiation at temperatures of 60, 70, and 80 °C

At 70 °C and 40 kHz, you would achieve a death rate of over 99.9% within just 300 seconds. Total anesthetic was reached in 420 seconds. This regime works quickly, relatively fast and it is also has good quality retention. In the highest temperature and frequency, the destruction process is at the fastest speed. Mortality was >99.9% in the 240–300-s range. Nevertheless, because high temperatures decrease cocoon quality, this regime is appropriate only for short-term processing [15].
The test results proved that ultrasonic frequency and temperature are the main factors affecting the process of silkworm pupae stifling. As the frequency increased, the necrotic degree significantly rises, while the processing time is greatly reduced. But an extreme rise in temperature can also decrease the

quality of cocoons [5, 6].

Conclusion

The combination giving the best results was found based on the experiment: a duration of 300 seconds, IR wavelength of 3.0 μm, ultrasonic frequency of 40 kHz, power of 300 W and temperature of 60 °C. This regime ensures high necrosis but at the same time retains the maximum chemical quality indicators for cocoons and raw silk. We performed a series of experiments on the pretreatment of silkworm pupae using a combined ultrasonic-infrared apparatus. According to the combined results of these experiments, a combination of parameters that yielded the best performance in terms of handling time – 300 s; IR range: 3.0 μm; ultrasonic frequency – 40 kHz and ultrasonic power – 300 W was determined not only able to achieve amelioration stifle quality optimum involving silkworm pupa but also maximum cocoon quality.

References

[1] D. Huang et al., "Application of ultrasound technology in the drying of food products," Ultrasonics Sonochemistry, vol. 63, p. 104950, 2020.

[2] J. Gao et al., "A combination of contact ultrasound and infrared radiation for improving the quality and flavor of air-dried beef during hot air drying," Ultrasonics Sonochemistry, vol. 110, p. 107047, 2024.

[3] Uzbekipaksanoat Association, "Official website of Uzbekipaksanoat Association." [Online]. Available: https://uzbekipaksanoat.uz/uz/index.php

[4] J. E. Safarov, Sh. A. Sultanova, Y. Fu, A. B. Usenov, D. I. Samandarov, and D. D. Dushanova, "Experimental study of mulberry silkworm cocoon drying using infrared and ultrasonic impact," Universum: Technical Sciences, no. 1(142), pp. 6–11, 2026. (In Russ.).

[5] C. Guo, C. Li, X. Mu, and D. L. Kaplan, "Engineering silk materials: from natural spinning to artificial processing," Applied Physics Reviews, vol. 7, p. 011313, 2020.

[6] J. E. Safarov, Sh. A. Sultanova, Y. Fu, D. I. Samandarov, and A. B. Usenov, "Preliminary results of a theoretical study of the silkworm cocoon drying process by a combined (IR+US) method," Journal of Food Science, vol. 3, no. 9, pp. 52–61, 2025.

[7] Y. Zhang, F. Wang, H. Liu, X. Chen, and Z. Shao, "Relationship between cocoon structure and heat-mass transfer behavior during silkworm cocoon drying," Journal of Materials Research and Technology, vol. 15, pp. 4123–4134, 2021.

[8] T. Supavititpatana and P. Sa-adchom, "Experimental investigation and mathematical modeling of silkworm pupae drying using far-infrared radiation combined with hot air," Asia-Pacific Journal of Science and Technology, vol. 29, no. 6, Art. no. APST-29-06-01.

[9] D. I. Samandarov, "Experimental studies of infrared-ultrasonic drying of mulberry silkworm cocoons," Universum: Technical Sciences, no. 5(122), pp. 56–58, 2024. (In Russ.).

[10] A. Puig, I. Pérez-Munuera, J. A. Cárcel, I. Hernando, and J. V. García-Pérez, "Moisture loss kinetics and microstructural changes in eggplant dried by combined ultrasound and hot air drying," Food and Bioproducts Processing, vol. 90, no. 3, pp. 463–471, 2012.

[11] D. I. Samandarov, Sh. A. Sultanova, and J. E. Safarov, "Research on combined drying of mulberry silkworm cocoons," Universum: Technical Sciences, no. 1(118), pt. 3, pp. 10–14, 2024. (In Russ.).

[12] D. I. Samandarov, J. E. Safarov, Sh. A. Sultanova, and A. B. Usenov, "Study of the chemistry and biological activity of Bombyx mori cocoons," American Journal of Technology Advancement, vol. 2, no. 12, pp. 91–96, 2025.

[13] J. A. Cárcel, J. García-Pérez, A. Riera, and C. Mulet, "Influence of high-intensity ultrasound on drying kinetics of persimmon," Drying Technology, vol. 25, no. 1, pp. 185–193, 2007.

[14] Z. Erbay and F. Icier, "A review of thin layer drying of foods: theory, modeling, and experimental results," Critical Reviews in Food Science and Nutrition, vol. 50, no. 5, pp. 441–464, 2010.

[15] B. K. Bala and M. A. Mondol, "Experimental investigation on solar drying of fish using solar tunnel dryer," Drying Technology, vol. 19, no. 2, pp. 427–436, 2001.