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Study of Drying Curves and Temperature with a Pulsation Method of Drying Cocoons

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ABSTRACT: The article shows the curves of drying cocoons at different temperatures of the drying agent (60,70,80,90,100°C) at different cycles (n=1,2,3 cycle/min) for living silk cocoons. By analyzing the drying curves, the periods of the drying stage and the critical point for each option were identified. In the first option, the critical point occurs in 150 minutes, in the second option, the critical point occurs in 120 minutes, and in the third option, it occurs in 90 minutes. The more the cyclist of changes in vacuum and pressure, the more the process of moisture release from the pupa is intensified.

KEYWORDS: raw silk, silk thread, silk yarn, breaking load, elongation at break, density, speed, wettability silk yarn, capillarity, sorption properties.

I. INTRODUCTION

The drying process is to remove moisture from the cocoon. Moisture in a raw cocoon is in a chemically bound, gyrosopic and free state. During the drying process, free moisture is removed, which is mainly in the pupa. The drying process consists of moving moisture inside the cocoon, generating steam and moving it out of the cocoon into the environment. In the process of drying the cocoon, the pupa gives up its moisture to the environment through the air gap and the shell of the cocoon by diffusion.

The intensity of the drying process is determined mainly by the intensity in the mass conductivity through the layer of the cocoon material. The course of the drying process depends on the amount of moisture in the material and the environment, as well as the nature of the connection of moisture with the cocoon. Chemically bound water is involved in the construction of the cocoon shell molecules themselves. Removing it causes irreversible changes, i.e. destruction of matter. For this reason, chemically bound moisture cannot be removed during the drying process of the cocoon.

Hygrosopic moisture depends on the temperature and humidity of the environment. Excessive removal of gyrosopic moisture changes the physicochemical properties of the cocoon, therefore, hygrosopic moisture ranging from 8-12% cannot be removed during drying. Until now, when considering various methods of drying cocoons, we proceeded from the regularities of drying solid colloidal capillary-porous bodies.

Free moisture mechanically retained by the body of the pupa must be removed during the drying process. The cocoon is a complex body, consisting of bodies of different structure, structure and origin - the shell and the pupa. A characteristic feature of a living cocoon is a high moisture content, reaching an average of 160-180%. This moisture is unevenly distributed between the individual components of the cocoon. The moisture content of the cocoon is 12-16%, the moisture content of the pupa reaches 200-280% of the absolutely dry weight. In a frozen cocoon, moisture is contained in the pupa and is the cause of its rotting, therefore, the moisture must be removed.

II. ANALYSIS OF EXISTING FILTERING MATERIALS AND RESEARCH RESULTS

Live silkworm cocoons of medium caliber were used for testing. The experiments were carried out on a developed setup shown in Fig. 1 which consists of a working chamber 1, where the cocoons are placed in a mesh basket, cylinder 2, where the piston is mixed, creating pressure and vacuum in the working chamber by its movement. The piston is connected to the rod, which receives a reciprocating motion using the crank mechanism of the electric motor. A thermometer 12 is connected to the working chamber to change the air temperature, a vacuum gauge 13 is connected to measure the vacuum through valve 15, and an analytical balance is attached to the end of the chamber to measure the decrease in the mass of the test sample. In addition, air ducts 19 are connected to the working chamber, from where hot

air comes from the receiver 11, in which there is an electric heating element, the temperature is regulated by the thermostat 6 using a contact thermometer 10. The receiver is equipped with a pressure gauge 20. At the end of the working chamber there is a cover 17 with a window. The drive of 9 copper-constantan thermocouples is suitable through detachable fittings and the working chamber area: these thermocouples are installed in different sections of the cocoons. To the second end of the drive, through input solders 8, a combined self-cleaning device KSP-4 is connected for measuring and recording temperature 4 through a direct current potentiometer 5 PP-63 and a wafer switch 7.

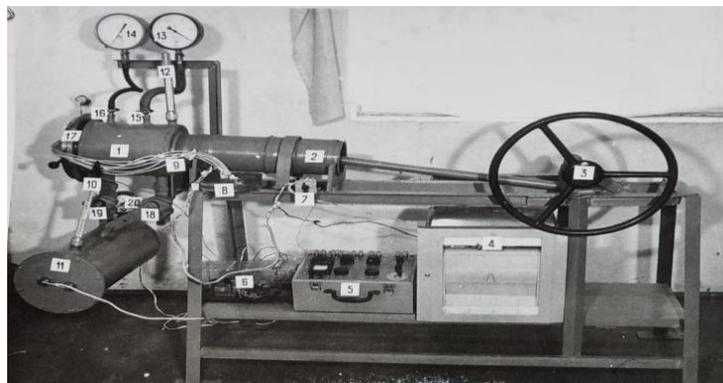


Fig. 1. Experimental setup for studying the thermal parameters of a cocoon in a process with a pulsating pressure change.

The design of the working chamber provides accurate fixation of the mesh basket with the sample of cocoons in the coolant flow, which cyclically changes depending on the work of the piston in the cylinder. The cyclist of the coolant supply can be changed by changing the frequency by moving the piston.

From the side of the chamber, a laboratory analytical balance is mounted on a bracket, intended for weighing a dried sample of a cocoon. Cocoon drying curves are determined from the weighing results.

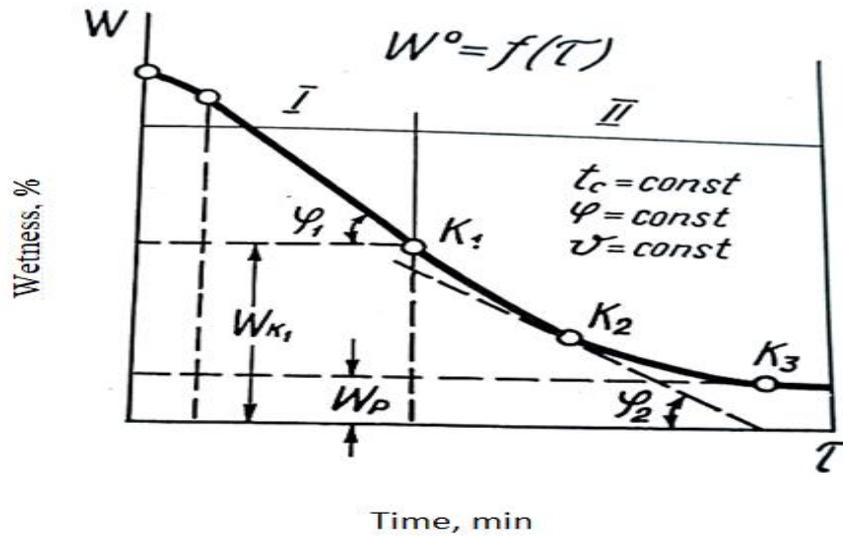
The air temperature in the chamber and in individual sections of the cocoon is measured using copper-constantan thermocouples and is automatically recorded using the KSP-4 device.

III. EXPERIMENTAL RESULTS

As you know, in a living cocoon, moisture is free, hygroscopic and bound. During the drying process, free moisture concentrated in the pupa is subject to removal, which is excessive and causes its decay.

The cocoon is a complex aggregate consisting of bodies of different structure and origin: a shell, an air gap and a pupa. The shell with an inner air gap is a thermal resistance, prevents the supply of heat to the pupa, as well as a barrier that impedes the removal of moisture from the pupa.

In the process of drying the cocoon, the pupa gives up its moisture to the surrounding atmosphere through the air gap in the cocoon and the shell. When the cocoon dries, the change in its moisture content is first described by a decreasing straight line (Fig. 1) (K1-K2), and then, starting from point K2, a decreasing curve, and at the critical point K3, the curve asymptotically approaches the abscissa axis (Fig. 2).



Rice. 2. Cocoon drying curve.

The critical point K2 is often not visible, therefore the point K3 is taken as critical for the land process. The drying period of cocoons can be divided into three periods: warming up, constant and decreasing speed. The experiments carried out on drying living silk cocoons with a pulsating change in the pressure regime also confirm the above pattern for colloidal-capillary-porous bodies, which are silk cocoons.

The experimental results at different temperatures of the drying agent and at different processing cycles are shown in Fig. 3-5.

Option I. Drying of living cocoons at drying agent temperatures of 60-100°C at $n = 1$ cycle /min. The drying curve shows that in 10 min. from the beginning of the experiment, the cocoon loses moisture from 10 to 20% of the initial moisture. This moisture is in a free state in the shell of the cocoon and on the surface of the pupa.

Subsequently, the cocoon is heated until the desired temperature is obtained. This period from K1 to K2 lasts 20-25 minutes depending on the temperature of the drying agent; during this period, the cocoon loses 10-15% of its moisture. Thereafter, a period of constant drying speed begins up to the K3 point. This period (from K2 to K3) is characterized by the fact that the entire amount of free moisture contained in the pupa is removed. With this drying option, the critical point K3 occurs 150 minutes after the start of the experiment. Behind point K3, a period of decreasing drying speed begins. During this period, moisture from the cocoon is removed very slowly to equilibrium moisture.

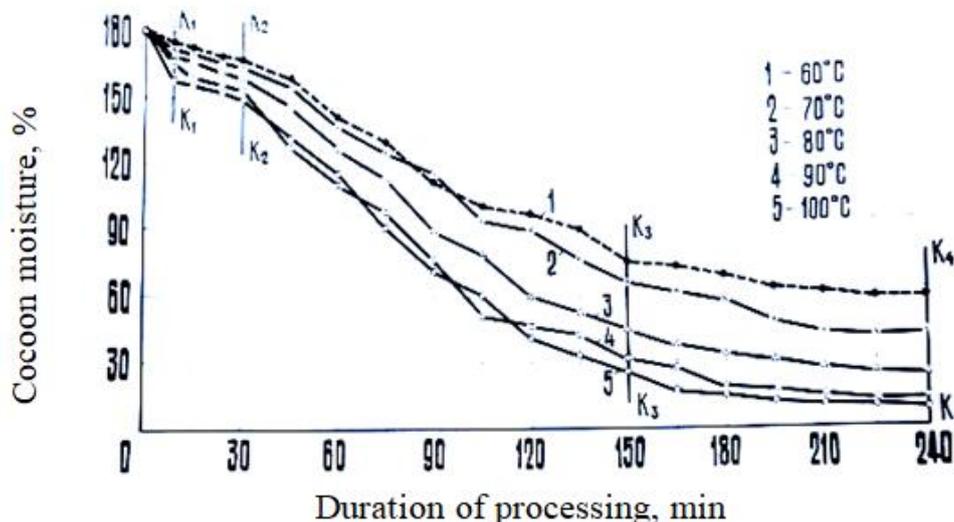


Fig. 3. Drying curves of living silk-cocoons at different temperatures of the drying agent ($n = 1$ cycle / min)

The experiment carried out shows that an increase in the temperature of the drying agent affects the drying process. Analyzing the drying curves in Fig. 3 it can be seen that drying of cocoons takes place in three stages. Up to the point K1, it represents the drying of the shell itself and the surface of the pupa. The cocoon itself is heated up to the point K2. And to the point

Kz in the cocoon is evenly removed with respect to time, and this period is called constant drying rate. Subsequently, after Kz, the cocoons slowly lose moisture, where the curve asymptotically approaches the equilibrium (10%) moisture line.

In this embodiment, until equilibrium moisture is obtained, the period of complete drying is carried out from 4 to 6 hours, respectively, at temperatures of the drying agent from 100 to 60 ° C. This has the effect of extending the drying period.

Option P. Drying of cocoons at a cyclic change in pressure of 2 cycles/min and a temperature of 60-100 °C of the drying agent (Fig. 4). During the heating period, the cocoon loses from 20 to 30% moisture from the initial moisture, instead of 10-15% in the first variant, i.e. moisture removal is faster.

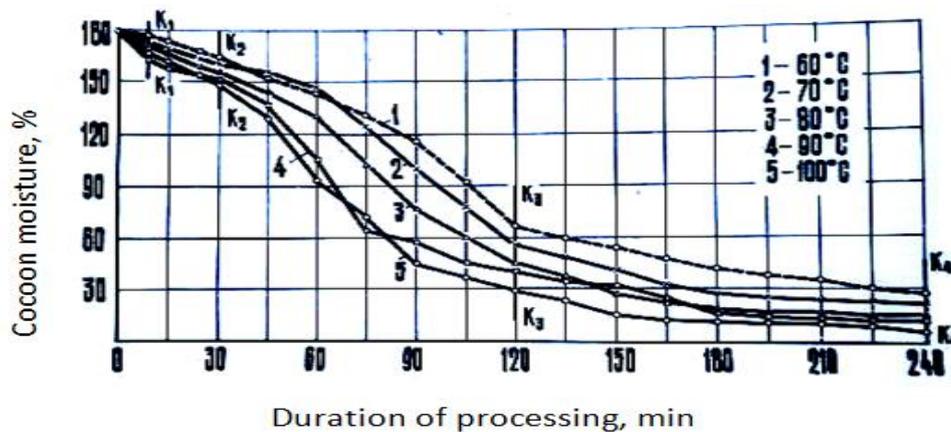


Fig. 4. Drying curves of living silk-flowered cocoons at different temperatures of the drying agent (n = 2 cycles / min)

The continuous drying period lasts approximately 90 minutes, after which the cocoon begins to dry at a decreasing rate. In fig. 4 it can be seen that with an increase in the cyclist of pressure changes, the drying process is accelerated and the period of complete drying of the cocoon is shortened. It is especially necessary to note the quality of the cocoons: at temperatures of the drying agent of 70-80°C, there are no spotty cocoons inside.

Option III. In this case, the drying of living cocoons is carried out with a piston cycle of n = 3 cycles / min and the same temperature as the first two options (from 60 to 100°C) (Fig. 5).

In this embodiment, the first heating period occurs in 5-6 minutes, the continuous drying period lasts 70-75 minutes. Subsequently, a slow moisture extraction from the cocoon is carried out for 2.5 hours.

The intensity of the cyclic change in pressure accelerates the drying process of cocoons, but introspect cocoons begin to appear, which negatively affects the quality of unwinding and the yield of raw silk.

Considering the results of all three options, we chose the mode of drying living silk cocoons with a piston cycle of n = 2 cycles / min and a drying agent temperature of 70-80°C, which ensures the preservation of the natural qualitative properties of the cocoon and its components - sericin and fibroin.

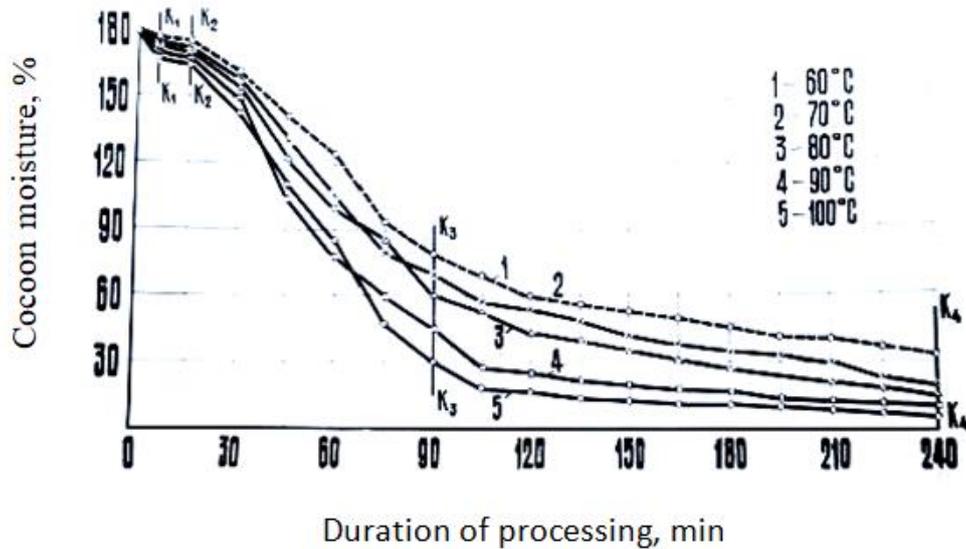


Fig. 5. Curves of drying of living silkworm cocoons at different temperatures of the drying agent (n = 3 cycles / min)

IV. CONCLUSION AND FUTURE WORK

On the basis of an experimental study, the obtained curves of drying of cocoons at different temperatures of the drying agent (60,70,80,90,100°C) at different cycles (n = 1,2,3 cycle / min) for living silk cocoons.

By analyzing the drying curves, the periods of the drying stage and the critical point for each option were identified. In the first option, the critical point occurs in 150 minutes, in the second option, the critical point occurs in 120 minutes, and in the third option, it occurs in 90 minutes.

These data show that the greater the cyclic change in vacuum and pressure, the more the process of moisture release from the pupa is intensified, but it should be taken into account that too much increase in the cyclicity of work increases the number of defective cocoons inside, which leads to a decrease in the quality of raw materials.

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