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Theoretical And Experimental Study Of The Drowing Process Of The Soft Part Of A Melon

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Abstract: The problems of drying dried plant products, the problem of removing moisture from the soft part of the dried material, are represented by drying curves: such tasks as speed and temperature are covered. The drying rate curve describes the change in melon moisture per unit of time. Drying a wet product is the transfer of moisture from the surface to the surrounding environment and from the inside of the product to its surface.

Keywords: Products, melon, convective drying, hygroscopic moisture, drying rate.

Introduction: It is devoted to such issues as the state of computational and theoretical research of heat and mass transfer processes during the drying process of high-moisture agricultural products; theoretical approach to accounting for the melon drying process during convective heat transfer; heat exchange during the drying of melon slices and the selection of a heat source; electrophysical factors influencing the drying process of melon slices. The problems of drying dried plant products, the problem of removing moisture from the soft part of the dried material, are described by drying curves: such tasks as speed and temperature are highlighted. The drying rate curve describes the change in melon moisture per unit of time. Drying a wet product is the transfer of moisture from the surface to the surrounding environment and from the inside of the product to its surface.

The soft part of the melon is a complex biological system, belonging to colloid-capillary porous bodies with initial and final moisture content, hygroscopicity, heat capacity, heat resistance, as well as thermal, electrophysical, and heat-mass transfer properties. Researchers' experiments have confirmed that the best way to dry melons is to cut them into ring-shaped slices and hang them freely in a stream of warm air.

When drying melon slices and choosing a heat source, it is shown that the main heat source used for drying in a conveyor drying unit with a heat transfer chamber, together with the airflow, is an electric heater, which ensures the formation of a heat carrier with these temperature parameters. Considering the design features of the device and the implementation of the drying chamber in the form of a multi-directional labyrinth with a cooling device, it was decided to install a single fan with an electric heater.

It has been shown that the heating of the drying product occurs according to a certain exponential law. The coefficient characterizing the heating conditions according to physicochemical indicators for each product provided different data on physical and temporal indicators. A specific task has been formulated on the influence on the drying process of melon slices. A theoretical discussion of the laws of electrophysical influence on the melon drying process is presented.

To study the conditions for carrying out convective drying by transforming the balance equation of the process and the general equation of heat convection by modern methods, the equation of the drying process rate was obtained.

$$\frac{dQ_{ВЛ}}{d\tau} = \frac{\alpha F(t_2 - t_1) - (C_{ВЛ} + C_{ВЛ} G_{ВЛ})\frac{dt}{d\tau}}{r + C_{ВЛ} * n(t_2 - t_1)} \qquad (1)$$

The results of the study of the equation made it possible to represent the drying curve in the form of Fig. 1.

Since in the first stage dt/dτ=0, the drying rate practically depends only on the product αF (t2-t1), and its value remains practically constant due to proportional increase in material settling and changes in size.

τ0-heating period; τ1-period of constant drying; τ2-period of drying with decreasing speed; 1-first critical point; 2-second critical point.

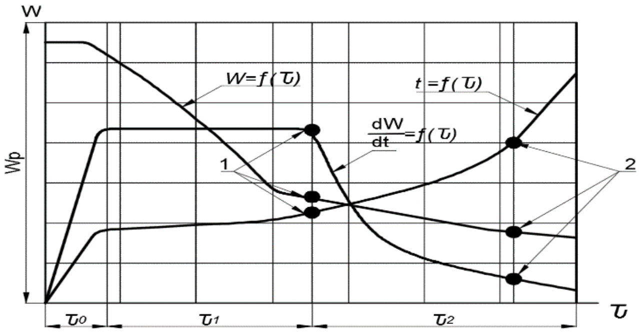

Figure 1. Capillary drying curve of porous material.

With a decrease in hygroscopic moisture on the material surface, a period of decreasing drying rate begins. This leads to an intensification of the deepening of the evaporation zone into the material, increases its temperature, reduces the rate of moisture removal, and decreases α. This is a decrease in the transfer of heat from the carrier to the product. In addition, part of the heat is spent on the deepening of the heating zone and the evaporation of moisture. A characteristic feature of the second period is a decrease in the drying rate. When equilibrium moisture is reached, the temperatures of the heat carrier and the product equalize, and moisture release ceases.

Evaporation of moisture from the surface creates a moisture difference in the product, as a result of which moisture begins to move from the inner layers of the product to its surface. Moisture exchange between the product and the external environment is generally characterized by Nusselt's mass transfer criterion.

$Nu_r=ARe^n_r(Pr_r)^{0,33}Gu^{0,135}$, (2)

where Nur = βl/D - Nusselt's criterion; Re=w/γ - Reynolds criterion; Pr=γ/D - Prandtl criterion; Gu= (Tc-Tm) Tc - parametric Guchmann criterion; γ - kinematic viscosity, m2/s; Ts, Tm - temperatures in wet and dry thermometers, K.

The values of the quantities A and n in equation (2) depend on the Rer criterion and are calculated according to the modes of motion.

The drying rate N in the first period is determined experimentally or using the mass transfer coefficient.

Since the amount of evaporated moisture Gu is equal to$G_u=F\Delta X_{cp}$ (3)

$$N=\frac{Gu}{Gc}=\frac{\beta F\Delta X_{CP}}{\beta F\Delta X_{CP}}$$

(4)

where β is the mass transfer coefficient in the gas phase; F-evaporation surface area, m2; ΔX - average driving force, kg of steam /dry air; F - unit area per 1 kg of dry matter, m2/s. The mass transfer coefficient β can be found from the criterion equation of A.A. Nesterenko.

The intensity of moisture release during the drying rate decrease depends on the moisture concentration on the product surface and in the heat carrier.

$Q_m = \beta\gamma (w_t-w_n)$. (5)

Calculation of temperature and thermal gradients presents some difficulties due to the multifactorial relationship. Therefore, the duration of the product drying process is determined in the form of drying curves and drying rate curves.

The duration of the food drying process is calculated using the drying coefficient K and the method of G.K. Filonenko according to the method of A.V. Likov.

Taking a single ring-shaped piece of melon, the heat and mass transfer processes occurring in it were considered to be free evaporation of moisture from both sides of the ring.

If the diameter of the piece is assumed to be 180-200 mm, the thickness of the flesh is 50-55 mm, and the thickness of the piece is 20 mm, then the problem to be solved can be considered one-dimensional, and moisture inside the piece passes according to Fick's law, expressed by the following equation.

$$\frac{dU}{d\tau}=D_M\frac{d^2U}{dx^2}; \qquad -\delta\le x+\delta;\ \tau>0,$$

(6)

where - moisture content in the slice, kg; τ - drying time, hours; - slice thickness, m; - coordinate, m; Dm - diffusion coefficient, m2/s.

After mathematical processing, we get

$$W_{(\tau)}=W_{CP}\exp-[d_M(\tau+\tau_1)],$$

(7)

where v is the duration of the first drying period, hours. This functional relationship expresses the regularity of the change in humidity over time, since the critical humidity and time in equation (7) are constant for a given drying regime, and the coefficient dm, characterizing the drying temperature, shows the change in the logarithm of humidity over a certain time interval, i.e.

$$d_M=\frac{l_nW_{KP}-l_nW_\tau}{\tau+\tau_{(T)}}$$

(8)

This expression describes the drying rate of melon pieces per unit of time. When, this regularity is clearly expressed in mathematical form, and equation (8) works only for the local operating range of humidity.

The desired dm is always positive because the critical humidity is always higher than the final humidity. Therefore, equation (8) has the ability to express any regularity of humidity change in the particle, since there are no functional divisions of the main characteristic and it works within the investigated range.

In the chamber-chain design of the drying unit proposed by us, the main source of heat consumed for drying is a heater, which, together with the airflow, forms a heat carrier with parameters equal to the given temperature and flow rate.

From the heat balance equation of the drying process, the equation for the temperature of the heat carrier entering the drying chamber is obtained.

$$t_2=\frac{P_k K_{\Pi}\eta * 3600 = L_B \rho_B C_B t_1}{L_B \rho_B C_B}$$

(9)

To determine the state of change in the temperature of the heat carrier, a time interval Δτ is allocated from the electric heater to the outlet of the chamber, in which the rings of melon hanging on the ground are washed and heated by the heat carrier air, the temperature of which decreases by Δt (Fig. 2).

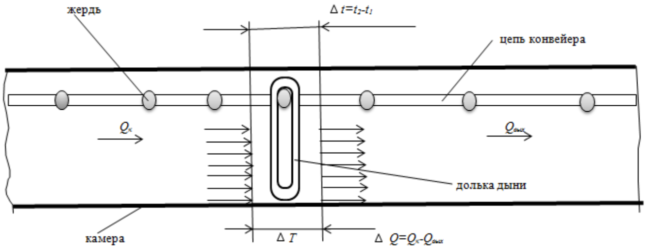

Figure 2. Elementary section of the drying chamber, in which heat loss and temperature of the heat carrier decrease in time Δτ are shown.

The investigated pattern has the form of an exponent.

$Q_\tau = Q_k\,(1 - e^{-\delta\tau})$ (10)

With increasing time τ, the second term of the difference e-δτ decreases and becomes zero at τ→∞. All of the heat supplied to this camera

Qτ=Qout or Qout-Qτ=0, that is, it can be concluded that the change in the amount of heat remaining in the chamber per unit of time leads to a decrease in the amount of heat involved in the melon drying process with an increase in time. Such a reasoning, carried out taking into account the physical essence, allows one to characterize heat loss.

As can be seen from Fig. 3, when treating melon pieces at a distance of 100 mm from the source of IR radiation for 30 s, the temperature gradients are from 35 to 60°C, when the source of IR radiation is 125 mm from the pieces, the temperature gradient varies from 33 to 500°C, and at a distance of 150 mm - from 31 to 400°C. This means that the thicker the melon pieces, the slower the heat penetrates the flesh of the melon. Regression equations of the process were obtained.

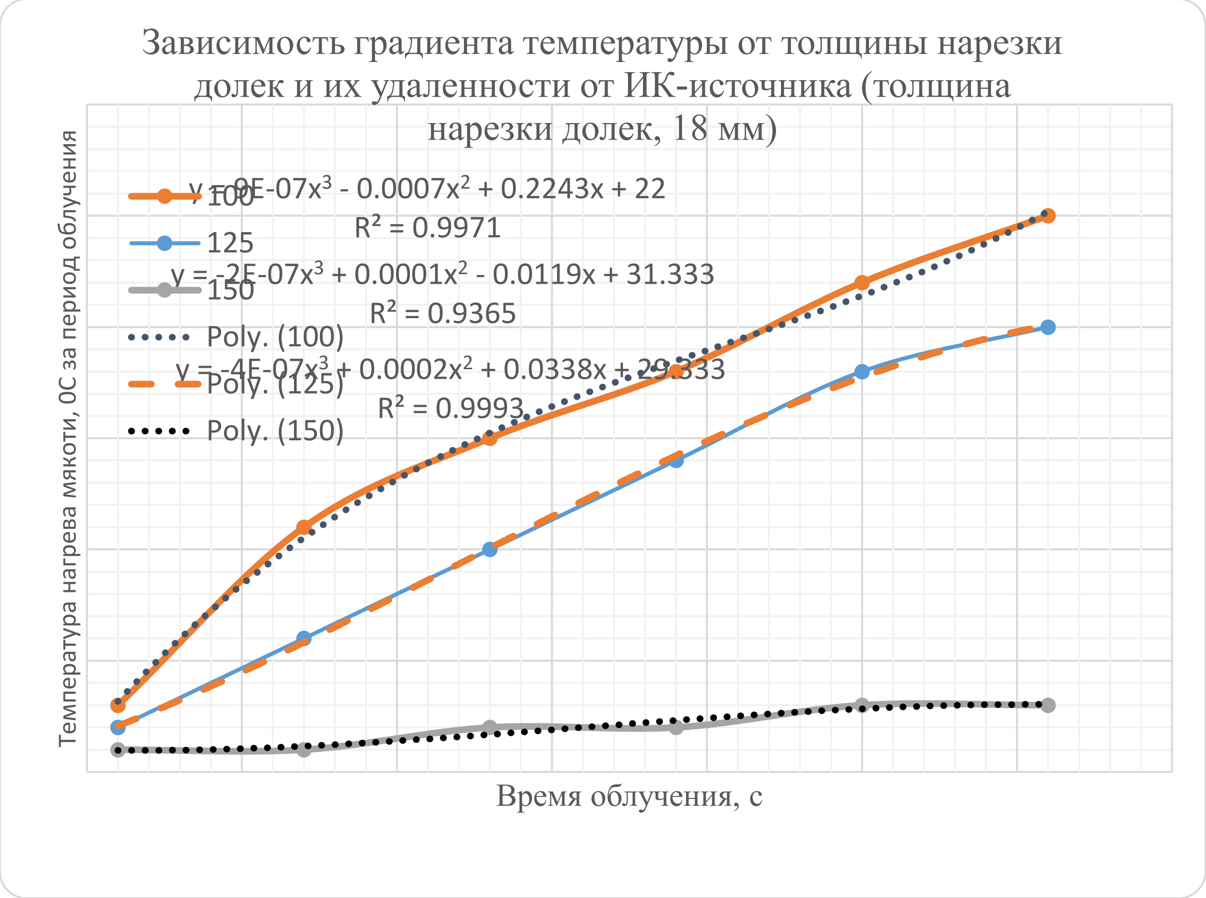

Figure 3. Dependence of temperature gradients on the thickness of melon pieces and the distance from the source of IR radiation (δ=15 mm).

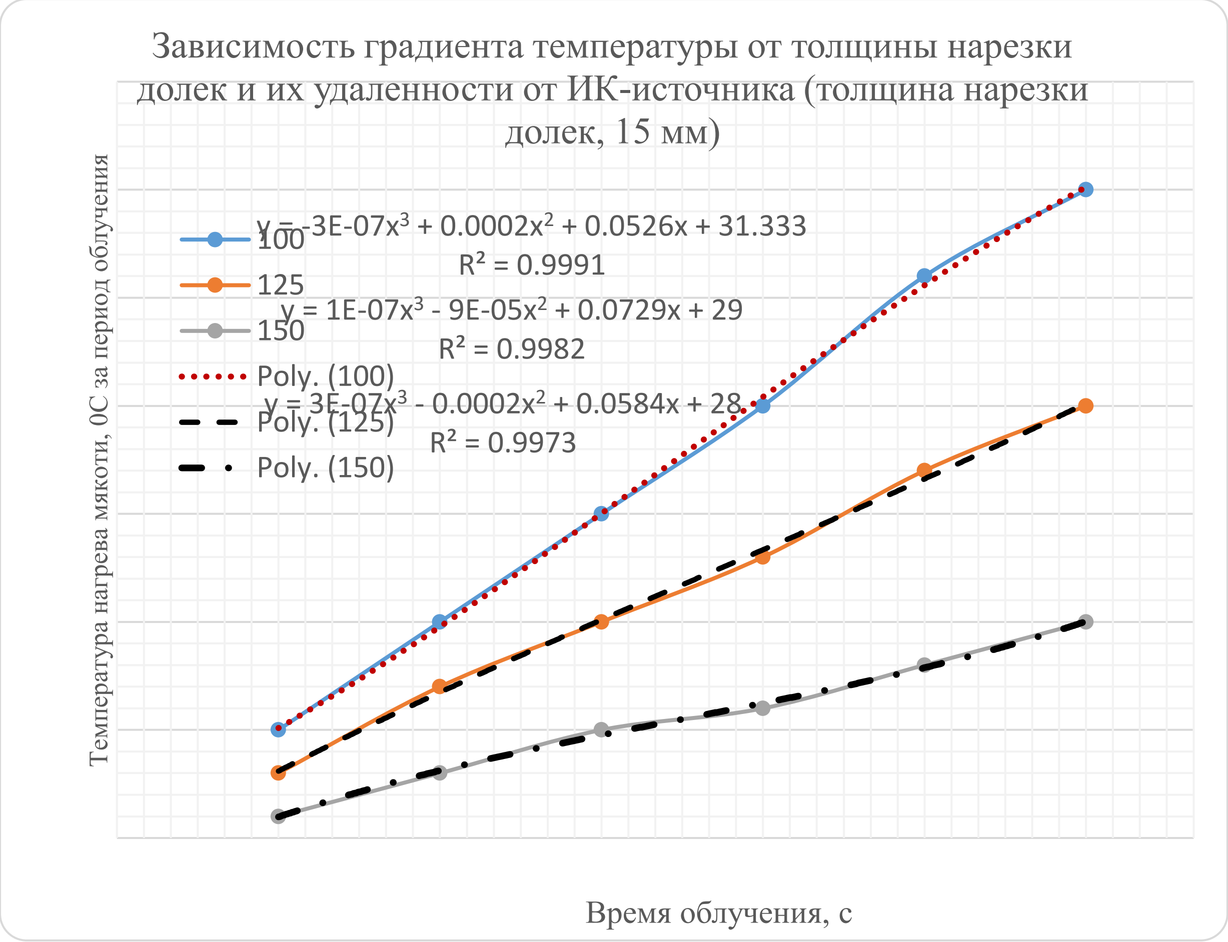

Figure 4. Dependence of temperature gradients on the thickness of melon pieces and the distance from the source of IR radiation (δ=18 mm).

In Figures 3 and 4, when processing melon pulp, at a distance of 100 mm from the melon pieces to the IR source, the temperature gradient ranges from 33 to 55°C for 300 s of processing, at a distance of 125 mm, the temperature gradient is 32-50°C, and at a distance of 150 mm, the temperature gradient is 31-340°C. Analysis along with the curve on the graph shows that the thicker the melon slice, the slower the temperature penetrates the fleshy part of the melon. Regression equations of the process were obtained.

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