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MATHEMATICAL DESCRIPTION OF THE VEGETABLE DRYING PROCESS

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Annotation
A mathematical model of IR-convective drying of fruits is constructed. The temperature gradient is expressed by the ratio of the time cyclic effect of infrared heating on the material, experimentally justified by optimizing a given coefficient of air flow and raw materials. The analytical form allows us to investigate the influence and interaction of nonlinear effects.

Keywords: a mathematical model, IR-convective drying, raw materials, analytical form, optimization.

Introduction

Certain results are achieved in the processing of fruits grown in the country, the development of semi-finished and ready-made food products, saving energy resources for products, creating resource-saving drying technologies that ensure the production of high-quality products. The combination of these tasks, including the development of dry food technology with drying methods using electromagnetic waves in the IR ranges of energy transmission, drying according to energy and temperature dependence in order to save energy and shorten the duration of the process, the use of optimal pretreatment Parameters for dried raw materials research aimed at accelerating the drying process by heating and convection, are of great importance.

In order to properly understand and calculate the mechanism of the drying process, it is necessary to know the heat and mass transfer properties of materials and the degree of their impact on the heating time and the set temperature.

In agroengineering, chemical technology, biology and medicine, tubes with filter walls are often found, where the external environment affects the flow of impulses inside the tubes. An example would be medicine, where treatments are carried out using a hemodialysis machine. Examples can also be the tasks of soil irrigation using water filtration pipelines [1-3].

The amount of liquid evaporated from the surface increases with increasing temperature, as well as the flow of liquid from their channels moving also towards the free surface increases with increasing temperature (Fig. 1.).

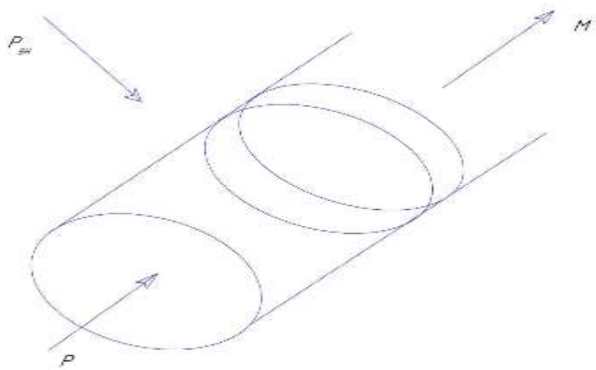

Fig. 1. Elementary microchannel in the form of a thin-walled tube.

M is the power of the juice flow in the microchannel; P is the juice pressure inside the microchannel; RVN is the juice pressure around the tube; γ (t) is the filtration coefficient of the channel wall

depending on the properties of the drying material.

We analyze an experiment to study the dependence of steady-state flow on temperature (Fig. 2).

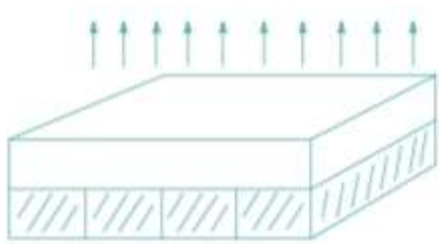

Fig. 2. Diagram of the laboratory experiment

The volume made of heat-resistant plastics is placed inside the microwave oven. There is a flat layer of pumpkin inside the plastic. Its horizontal surface is (20x20) cm2, and the layer thickness is 2.5 cm.

When the microwave is turned on, i.e. the MV furnace, the layer is uniformly heated. In the field of temperature stabilization, for each individual process we have, within 2 hours, evaporation from the surface of the pumpkin [4,5].

The moisture flow from the inner layers is directed upwards. The change in mass Δm is determined from the formula

$$\Delta mg=k(x_2-x_1)$$

where, Δm is the change in the mass of the layer, p is the acceleration of gravity, k is the stiffness coefficient, x_2-x_1 is the change in the equilibrium point (4)
The steady–state regime is determined experimentally.
At 60°C, named M (60°), at 60°C, named M (60°), etc.
got a schedule:
Theoretically, it can be shown using the stationary equation

$$A\begin{cases} P_x = -\varepsilon u^2 \\ u_x = \gamma(1 - \frac{P^{\text{вы}}}{P} \end{cases} \qquad (1)$$

$$M = [M_0 - P^3(\gamma P^{\text{в}} lnP - P)]^{\frac{1}{3}} \qquad (2)$$

If, we enter $P = P_0 + P^{`}$, $\frac{P^{`}}{P_0} \ll 1$ then from (2) we have an arbitrary formula: i.e. the graph and its. The curvature is explained by the nonlinear mechanism of dependence.
Let's write the law of fluid conservation for these tasks

$$p_t + pu_x = f(P^0 - P^{\text{вн}}, t) = f(P - P^{\text{вн}}, t) \qquad (3)$$

where p - is the density of the liquid in the tube; u - is its hydrodynamic velocity; P^o is the pressure of the liquid inside the tube; P^{hn} is the external pressure around the tube.
Now let's write the equations of motion

$$pu_t + \frac{1}{c^2} p_x = -F$$

where F - is a function of hydrodynamic drag forces, in particular:

$$pu_t + p_x = -\varepsilon p \mathrm{U}^2 \qquad (4)$$

Assuming that, the equation of state *P=P(p)*, has the form *P=* $e^2 \cdot p$
were: $e^2 = \frac{dP}{dp}$, we obtain from (3) and (4) by entering φ=ln P/p_0 where, p_o - is the density without motion [3,4]

$$\begin{cases} u_t + c^2\varphi_x = -\varepsilon u^2 \\ \varphi_t + u_x = F \cdot \frac{1}{P} \end{cases} \qquad (5)$$

Let in (3) we have a replacement:

$$\begin{cases} A = u + c\varphi = u + eln\, P/p_0 \\ B = u - c\varphi = u - eln\, P/p_0 \\ \zeta = x - ct \\ \xi = x + ct \\ A_{\text{пр},\ \varepsilon=0,\ F=0} = A_0(\zeta) \\ B_{\text{пр},\ \varepsilon=0,\ F=0} = B_0(\xi) \end{cases} \qquad (6)$$

For A and B we get a rewrite (6)

$$\begin{cases} A_t + cA_x = -\varepsilon u^2 + \frac{F}{p} \\ B_t - cB_x = -\varepsilon u^2 - \frac{F}{p} \end{cases} \qquad (7)$$

In system (7), the linear solution in the absence of filtering is written as:

$$A = A(x - ct)\ u\ B = B(x - ct)$$

For nonlinear and for F≠0, we have, by adding both equations and subtracting the second from the first, after the transition from A=A(ζ,ξ), B=B(ζ,ξ) the following:

$$\begin{cases} \frac{d(A+B)}{dt} = -2\varepsilon U^2 \\ \frac{d(A-B)}{dt} = -\frac{2F}{p} \end{cases} \tag{8}$$

from (6) we have that $A+B=2u$, $A-B=2c\varphi=2c\ln\frac{P}{p_0}$

from system (8) we have

$$\begin{cases} \frac{du}{dt} = -\varepsilon u^2 \\ \frac{dp}{p} = \frac{F}{c} \end{cases} \tag{9}$$

for integration, consider an example

$$F(p,t) = f(p - p^{\mathrm{BH}}) \cdot \gamma(t)$$

We assume that $f = p - p^{\mathrm{BH}} = c^2(p - \frac{p^{\mathrm{BH}}}{c^2})$

By for the second equation, we have

$$\frac{dp}{p} = c\gamma(t) \cdot \left(p - \frac{p^{\mathrm{BH}}}{c^2}\right) \frac{1}{p}$$

or

$$\frac{dp}{p - \frac{p^{\mathrm{BH}}}{c^2}} = \gamma(t)dt$$

or

$$p = \frac{p^{\mathrm{BH}}}{c^2} + (p_{t=0} - \frac{p^{\mathrm{BH}}}{c^2})e^{\int_0^t \gamma dt} \tag{10}$$

for the second equation we have solutions for the hydrodynamic velocity

$$u = \frac{u|_{t=0}}{1+\varepsilon t u|_{t=0}} \tag{11}$$

for pressure we have, multiplying (8) by c²

$$p = p^{\mathrm{BH}} + [p_{t=0} - p^{\mathrm{BH}}]e^{\int_0^t \gamma dt} \tag{12}$$

for the expense, we have

$$M = psu = s\frac{u|_{t=0}}{c^2}\left[p^{\mathrm{BH}} - (p_{t=0} - p^{\mathrm{BH}})e^{\int_0^t \gamma dt}\right]\frac{1}{1+\varepsilon t u|_{t=0}}; \tag{13}$$

We have obtained an exact solution (3) for a specific form if the source function $F = \gamma \cdot f(p - p^{\mathrm{BH}})$ - is given within our constraints (13).

Generally speaking, if $\frac{P-P^{\text{ВН}}}{P^{\text{ВН}}} \ll 1$, then we can decompose (13) into a Taylor series, and get $f = f|_{P=P^{\text{ВН}}} + \alpha \cdot (p - p^{\text{ВН}}$

where $\alpha = \left.\frac{df}{d(P-P_0)}\right|_{P=P_0}$, its solution is similar to (11), (12)

The resulting solution can also be applied to the problems of pulse stimulation of filtration when p=p_0 (t) and p=p_0 (ζ,ξ,0).

Microchannels where there is a low velocity, i.e. $u \ll c$, has a sufficiently large ε, in addition, ε depends inversely on the diameter of the tube.When the juices move with the direction to the surface, cracks or crack-like channels are observed. Sometimes, such cracks are created artificially in order to accelerate drying. And it is called "*scalding*".

Therefore, the problem of neglect with nonlinearity remains open. Solution (10-12) allows us to evaluate its influence of the above-described nonlinearities.

The solution *γ(t)* may have different signs depending on the change in the pressure gradient between the fluid pressure in the tube p, and between the external pressure $p^{\text{ви}}$around the tube.The value of *γ(t)*, still depends on the presence of pores on the walls, i.e. from their area per unit length of the tube.

In conclusion, we note that the analytical form allows us to study the influence and interaction of nonlinear effects.

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