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Determination of the Speed of Convective Drying of Products at the Adjustment Power of the Heater Source in the Cradle-Conveyor Drying Equipment

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Abstract

Drying is not only the most complicated non-stationary process of heat and mass transfer, but also a very energy-intensive technological process. In connection with the foregoing, it is of great practical interest to establish the character of the drying rate distribution along the height of the drying chamber of the drying method in question and on this basis to determine the average drying of the products in it. In convection dryers with a dense layer of dried products at a constant drying rate, in any (for example, h) section, all the inflow of useful heat supplied by the drying agent to the products to be dried is expended on evaporation of moisture, i.e. Due to the fact that at a constant drying rate, the temperature at the surface of the dried products (t_{pr}, T_{pr}) is equal to the temperature of the drying agent by a wet bulb (t_m, T_m), and the value of the partial pressure of water vapor on the surface of the dried products (P_{pr}) is equal to the partial pressure a saturated drying agent.

Keywords: Heat source; Convective drying; Temperature; Cradle-pipeline drying equipment; Drying agent

Introduction

One of the features of convective drying of high-moisture agricultural products in a dense layer with the adherence of the product layer by the drying agent stream is the uneven drying process along the height of the drying chamber. The drying agent entering the drying chamber having the maximum drying potential first interacts with the primary (i.e., initial) elementary layer of products, where the heating and then the drying process proceeds at the maximum rate. Pouring through the primary elemental layer of the dried products, the drying agent partially loses its drying potential. By the next elementary layer of products, the drying agent on its way interacts already as spent in the primary elementary layer, i.e. with a weakened (compared to the primary) drying potential. At the same time, the elementary layers of products located in the zone of a dense layer close to the outlet of the drying agent from the drying chamber practically still “do not feel” the heating and drying effect of the drying agent, t. In this zone the latter comes with a “zero” or close to it drying potential.

Materials and Methods

In connection with the foregoing, it is of great practical interest to establish the nature of the distribution of the drying rate along the height of the drying chamber of the drying method in question and on this basis to determine the average drying of the products in it.

In convective dryers with a dense layer of dried products at a constant drying rate, in any (for example, h) section, the entire inflow of useful heat supplied by the drying agent to the products to be dried is expended on evaporation of moisture, i.e.

$$\alpha_k(t_h - t_{pr}) = g_{mois_h} r \ , \qquad (1)$$

where t_h *and* g_{mois_h} - respectively, the temperature of the drying agent and the drying speed in the section of the drying chamber, located at a distance h from its initial section (i.e., inlet).

For the initial section of the drying chamber, which is taken as the primary, i.e. h=1, the analytic expression (1) has the form

$$\alpha_k(t_1 - t_{pr}) = g_{mois_1} r \ , \qquad (2)$$

Where t_1 *and* g_{mois_1} - the temperature of the drying agent and the drying rate in the drying chamber in question (i.e., in the initial section).

From the joint consideration of (1) and (2) we have

$$\frac{g_{mois_h}}{g_{mois_1}} = \frac{t_h - t_{pr}}{t_1 - t_{pr}} \ . \qquad (3)$$

Substituting the value of the relation $\frac{t_h - t_{pr}}{t_1 - t_{pr}}$ from

$$t_{\eth} = t_{pr} + \left(t_1 - t_{pr}\right)e^{-\frac{\alpha_k a + kbc}{\upsilon\rho c_p}h} . \qquad (4)$$

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$$g_{pr_h} = g_{pr_1}e^{-\frac{a_v\alpha_k + kbc}{\vartheta\rho c_p}h} \text{, kg/(m}^2\text{·c)} \qquad (5)$$

The drying speed average of the drying chamber can be determined by integrating (5), i.e.

$$\overline{g}_{pr} = \frac{1}{L}\int_0^L g_{pr_h}\,dh \text{, kg/(m}^2\text{.c)} \qquad (6)$$

Substituting (5) in (6) and after integration we have

$$\overline{g}_{pr} = -\frac{\vartheta\rho c_p}{a_v\alpha_k + kbc}\cdot\frac{g_{pr_1}}{L}\left(e^{-\frac{a_v\alpha_k + kbc}{\vartheta\rho c_p}L} - 1\right) . \qquad (7)$$

As the results of calculations show, under real operating conditions of convective drying chambers with a dense layer of dried products avαk>>kbc и and in connection with this, for practical calculations the solution of (7) with allowance for

〖dF〗_δ/F_dl =c·dh (8)

и

$$\text{Fdl}=\pi\left(\frac{\text{Đ}_\delta}{\varphi_{\hat{\imath}}\cdot 4.579\cdot 10^{\frac{7.45t_{\hat{\imath}}}{235+t_{\hat{\imath}}}}} - 1\right)^{-1}/4, \qquad (9)$$

for products having a spherical shape can be represented in the form

$$\overline{g}_{mois} = g_{mois_1}\frac{\vartheta\rho c_{\eth}}{\alpha_{\hat{e}}\grave{a}_v L} = \frac{g_{mois_1}\vartheta\rho c_p d_{av}}{6\alpha_k(1-\varepsilon_{la})L} . \qquad (10)$$

As follows from (10), under the condition $\frac{a_v\alpha_k + kbc}{\vartheta\rho c_p}L > 3\div 4$ the average height of the drying chamber, the value of drying speed in a dense layer, all other things being equal, depends on the drying speed in the current elementary layer, which is taken as the primary (g_{mois_1})

Value g_{mois_1} in (10) is in turn determined from formula

$$g_{mois_1} = \beta(\chi_{pr} - \chi_1) \text{, kg/(m}^2\text{.c)} \qquad (11)$$

where β- moisture exchange coefficient for convective drying in a dense layer, m/c; χpr и χ1 - respectively, the absolute humidity of the drying agent on the surface of the dried products and at the inlet to the drying chamber (kg/m^3).

In accordance with

P_s=0.289P_s/T, kg/m^3 (12)

and

$$\text{Рн}\ \frac{E_{\acute{y}\hat{a}} + \sum E^{\tilde{n}}_{\text{ïðåîáð}} + E^{\tilde{n}}_{\hat{\imath}\tilde{n}} + T_o\Delta S_{\tilde{n}\hat{e}} + E^{\tilde{n}\hat{e}}_{\hat{\imath}\tilde{n}} + E^{\tilde{n}\hat{e}}_{\tilde{n}\acute{a}}}{E^{\tilde{n}}_{\text{ïàä}} + E_{\acute{y}\hat{a}}} \text{, kg/m}^3. \qquad (13)$$

For values χpr and χ1 in (11) we can write the corresponding expressions

$$\chi_{pr} = 0.289\frac{P_{pr}}{T_{pr}} \text{, kg/m}^3 \qquad (14)$$

$$\chi_1 = 0.289\frac{P_1}{T_1} \text{, kg/m}^3 \qquad (15)$$

Due to the fact that at a constant drying rate, the temperature at the surface of the dried products (tpr, Tpr) is equal to the temperature of the drying agent by a wet bulb (tm, Tm), and the value of the partial pressure of water vapor on the surface of the dried products (Ppr) is equal to the partial pressure Saturated drying agent at the same temperature (т.е. tm) - Рн, for the difference χpr and χ1 in (11), on the basis of the previously obtained solution [1-4].

T_m-P_s1=1.323(〖10〗^((7.45t_m)/(235+t_m))/T_m -φ_1 〖10〗^((7.45t_1)/(235+t_1))/T_1) (16)

have

$$\chi_{pr} - \chi_1 = 1.323\left(\frac{10^{\frac{7.45t_m}{235+t_m}}}{\grave{O}_m} - \phi_1\frac{10^{\frac{7.45t_1}{235+t_1}}}{T_1}\right), \text{ kg/m}^3 \qquad (17)$$

Substituting (17) into (11), and then obtaining the result in (10), we have

$$\overline{g}_{mois} = 0.2205\frac{\beta}{\alpha_{\hat{e}}}\frac{\vartheta\rho\tilde{n}_{\eth}d_{av}}{(1-\varepsilon_{la})\grave{O}_{la}}\left(\frac{10^{\frac{7.45t_m}{235+t_m}}}{_m} \overline{T} \phi_1\frac{10^{\frac{7.45t_1}{235+t_1}}}{m_1} \tilde{n}\right), \frac{kg}{^2\,.} \qquad (18)$$

Conclusion

As follows from the solution (18), the value of the drying rate average for the drying chamber at a constant drying rate, with other things being equal, is directly proportional to the drying agent speed in the section of the drying chamber that is free from the layer of dried products - υ and the ratio of the diameter of the elements of the dried products in the dense layer (d_{av}) and inversely proportional to the height of the layer of the dried products in the drying chamber (L_{la}).

It also follows from the solution of (18) that for constant υ, t_m, t_1, d_{av} and H_{la} the value $\overline{g}_{mois}$ depends on the ratio β/α_k and the depravity of the layer of dried products (ε_{la}).

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