KINETICS OF LOW TEMPERATURE BEET PULP DRYING

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Abstract: Drying of sugar beet pulp is a nonstationary mass transfer process, the rate of which varies throughout the process. When studying the material were constructed the curves of the moisture content depending on drying time, for different initial moisture content, temperature of drying agent and velocity.

Keywords: sugar beet, pulp, low temperature, drying

In figure 1 is presented data regarding drying process of a product with initial moisture content of 750%.

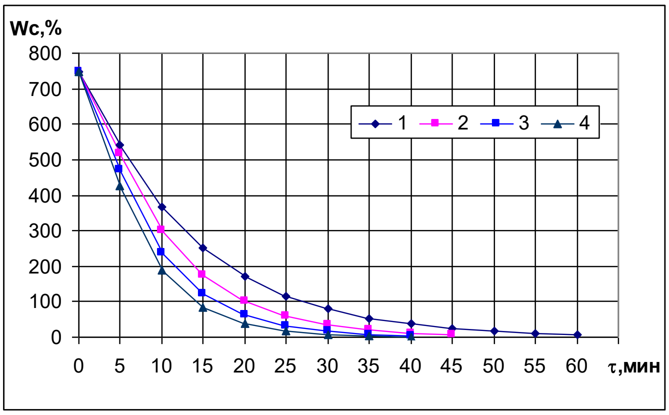

Fig. 1. Sugar beet pulp`s drying curves, air velocity ω = 3 m/s, temperature t: 1 – 60;2 – 80; 3 – 100; 4 – 120 °C.

When constructing the drying curves, material samples, the initial moisture content of which is known, were weighed in well-defined time intervals. Air speed and temperature in the installation didn’t change during one experimental cycle. Studies have shown that materials moisture content reduction at the beginning had a linear character and then passed into a curvilinear one. Thus, the beet pulp drying curves have the same form as for strongly structured food products.

In order to characterize the drying rate, was used an indicator of drying rate, namely the mass of water taken to be removed from a unit of surface of the dried material at a unit of time.

Having the drying kinetic curves, using the differential graphic method, we can find $\frac{dW}{dt}$, using also some simple mathematical relations. The typical drying rate curve is presented in figure 2.The total drying timecan be divided intothree periods: the initial, adequate heating of the material, the period of constant drying rate period and the falling rate of drying.

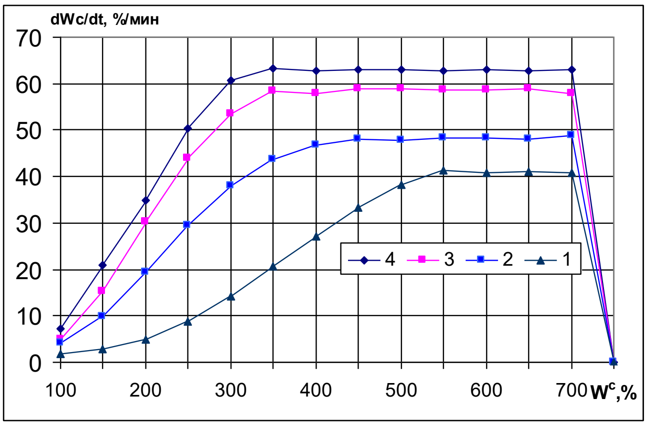

Fig.2. Sugar beet pulp`s drying rate curves, air velocity ω = 3 m/s, temperature t: 1 – 60;2 – 80; 3 – 100; 4 – 120 °C.

Beet pulp at low temperature drying loses moisture throughout the process, and the intensity of the loss of moisture changes during drying. Constant drying rate was observed in cases where the loss of moisture from the surface of the material had time to be compensated by moisture from inner layers of the material. Masstransfer has the main role in this process. For further decrease of the moisture, a decisive role plays mass conductivity.

The amount of moisture removed from the material depends on the interrelated mechanisms of moisture and heat transfer within the material and heat transfer surface of the chip with the environment.

As a result of made experiments on the study of beet pulp drying regimes, was established a body of experimental data, taking into account the following parameters: initial moisture content, the temperature of the drying agent, the speed of the drying agent. On its base was made the analysis of the dynamics of the join mass transfer. Since the mass conductivity parameters are not separately identified, the main parameter was adopted the so-called volumetric heat transfer coefficient:

$$\alpha_v = \frac{r \cdot \Delta G}{\Delta\tau\left(t_{ca} - \bar{t}_{ж}\right)V_{нас}} \qquad (1)$$

where ΔG – amount of removed moisture during the time internalΔτ;

r –evaporation heat;

t_{ca} – drying agent temperature;

$\overline{t}_{æ}$ –average temperature of the sample in the intervalΔτ;

$V_{нас}$ – sample volume.

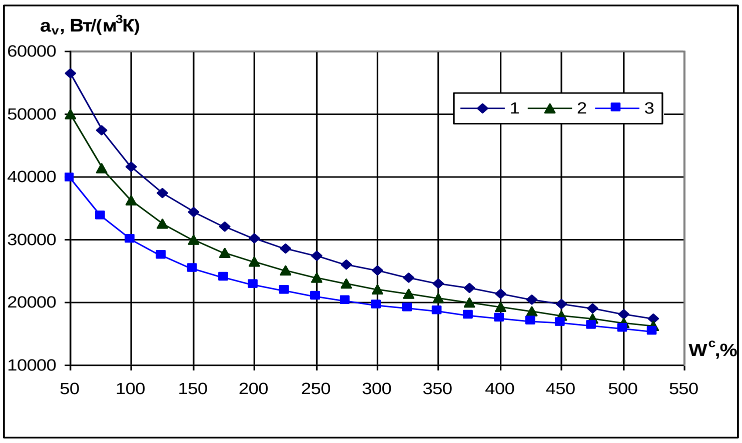

Fig. 3. The dependence of the volume coefficient of heat transfer from the current moisture content at $Woc = 525\%$, speed of drying agent $v = 3\frac{m}{s}$ and temperatures 1 – 70 ; 2 – 80 ; 3 – 90 °C

Figures 3-5 shows the functional dependence of the bulk heat transfer coefficient. They can be used to trace the existence of aclear dependence of this ratio on the parameters of the drying process.

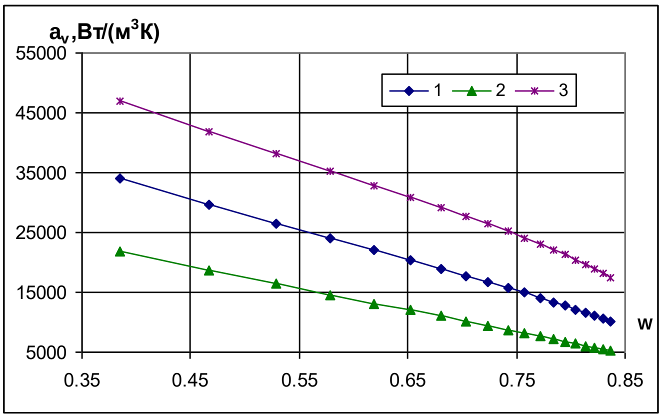

Fig. 4. The dependence of the volumetric coefficient of heat transfer on moisture content (for nominal moisture content of $Woc = 525\%$), temperature t=70 °C and drying agent speeds: 1 – 1 ; 2 – 3 ; 3 – 4,5 m/s

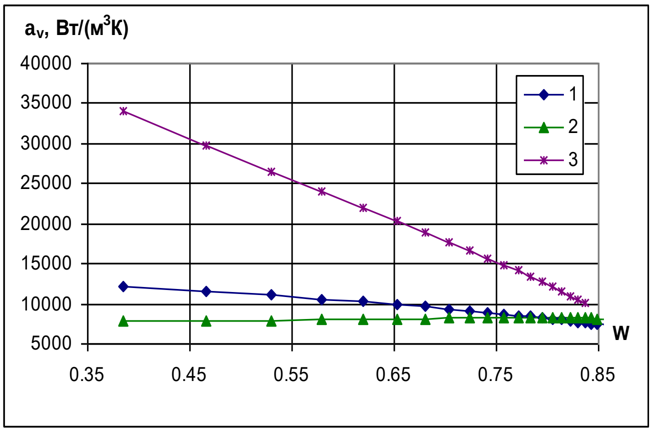

Fig. 5. The dependence of the volumetric coefficient of heat transfer on moisture content, drying agent speed ω= 3m/s, temperature t=70 °C and nominal moisture content: 1 – 1565; 2 – 745; 3 – 525 %

In order to generalize the results, based on the similarity theory was considered the dependence of the form:

$$\alpha^{\dagger} * = f((^{\dagger} *; W) \qquad (2)$$

$$\alpha^{*} = \frac{\alpha_{v}\delta_{жс}}{\lambda_{жс}}\ ; \quad \omega^{*} = \frac{v_{ca}^{3}}{g\nu_{ca}} \qquad (3)$$

where:

$\delta_{Ж}$–beet pulp layers height;
$\lambda_{Ж}$–beet pulp thermal conductivity coefficient;
ω* –dimensionless velocity of the drying agent;
ω_{CA}–dryingagentvelocity;
ν_{CA}–kinematic viscosity of the drying agent.

When approximating function α*=f(ω*;W) reliable results are obtained when using the relation of the following form: $\alpha^{*} = A_1\left(\omega^{*}\right)^{A_2} W^{A_3}$ and $\alpha^{*} = B_1\left(\omega^{*}\right)^{B_2}$, where auxiliary coefficients A_1, A_2, A3 and B_1, B_2 take into account the dependence of the results of the current product moisture. However, there are a number of restrictions on the use of these approximations, especially in the initial period of drying.

The correlation of the experimental data and calculated results is dependent as follows:

$$\alpha^{*} = A_1 + A_2 \exp(Le)^{A_3} \qquad (4)$$

whereA_1 ,A_2 ,A3 are auxiliarycoefficients;

$$Le = \frac{t_{жс}}{t_{ca}}$$ – dimensionless temperature dependence.

Figure 6 shows comparative curves of the calculated and experimental values.The graphic shows that the functions are in good agreement.

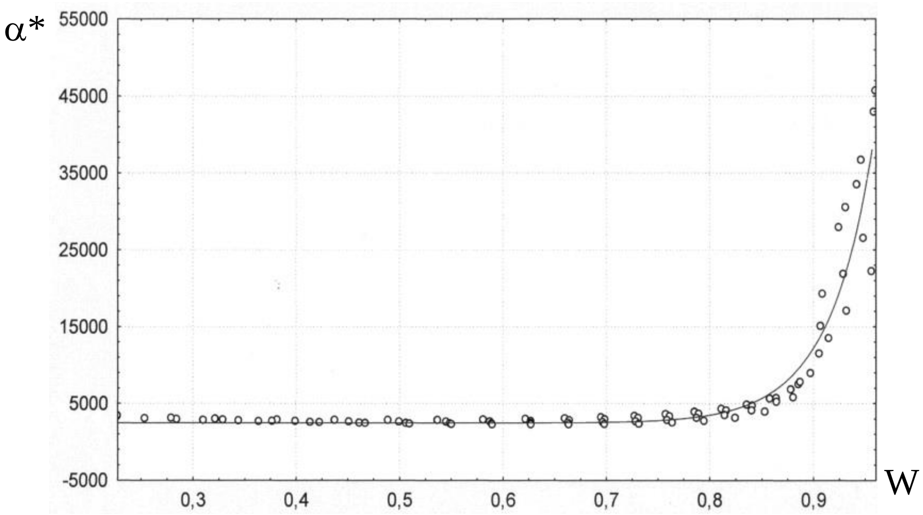

Fig. 6.Thedependenceofthegeneralized volumetricheat transfer coefficient on moisture content, drying agent speed ω = 1 … 4,5 m/s, temperaturet = 60 … 120°C

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