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APPROACH TO REALIZATION OF MATHEMATICAL MODELS OF THE PROCESSES OF HEAT EXCHANGE IN VEGETABLE STOREHOUSES

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Currently vegetable storehouses are equipped with ventilation systems and cooling devices for normalizing of technological parameters of microclimate (temperature – humidity condition) in different periods of vegetables' (potato, carrot, onion and others) storage. For the last several years systems with air humidifier have been widely used.

Working efficiency of above mentioned systems is mostly defined by their controlling part development which is considerably dependent on the changes in the parameters of this process, i.e. knowledge of statistical and dynamical characteristics of the storehouse.

It should be noted that current theory of ventilation processes of foods and agricultural products developed by many researchers, for example [1,2], is based on the general theory of energy and material transporting. Solving of system of complex differential equations proposed by this theory for describing stationary process of heat and material exchange makes it possible to obtain temperature and humidity fields in any moment of time for the given initial zero conditions.

But using these results in calculation practice, especially for controlling, is associated with certain level of difficulties (values of heat and material exchange coefficients, their dependence on speed of temperature's change, humidity, i.e.). Considering unimportant details of the process and using of their complex mathematical description are optional, it is enough to consider main features of the process.

Simpler mathematical model for the process of heat and material exchange of stored product is proposed in this work and it is intended for controlling of microclimate of the storehouse.

First of all we consider the physical side of the technological process of ventilation of products (potato, onion).

It is proved that high humidity of air is observed in products ventilation and it is very near to saturated condition. This shows that surface of the products has a good humidity conductance and moisture saturated. Big difference (hundreds thousands times) in the amount of moisture in the material and in the environmental air contributes to that air is saturated by passing though static layer of the product for the long time. From the constructive point of view storehouse is analogues to cooling device. Climatic conditions in the region stipulate the choice of storehouse type.

We write equations for the heat and material balance for the elementary layer ΔZ of the product (potato, onion) (picture1).

$$\left.\begin{aligned} \frac{dQ_1}{dt_x} &= Q_2 - Q_3, \\ \frac{dQ_1^B}{dt_x} &= Q_2' - Q_3', \\ \frac{dM_1}{dt_x} &= M_2 - M_3. \end{aligned}\right\} \qquad (1)$$

The first equation of the system (1) reflects the balance of the elementary volume of the stored product and determines the amount of heat by which air and material are exchanging and it is spent to change the temperature of the material and to evaporate moisture from it. Second and third equations characterize the balances of heat and humidity of air for chosen elementary volume. We write the system of equations (1) by expanding it. For this we determine each of the summands, i.e. $Q_1, Q_2, Q_3, Q_1', Q_2', Q_3', M_1, M_2, M_3$. By using well-known dependencies from the theory of heat and mass exchange [2, 3], we obtain:

$$Q_1 = \int_z^{z+\Delta z} C_M \rho_M \varepsilon T_M(\xi,t)\,d\xi; \qquad Q_2 = \int_z^{z+\Delta z} \alpha S(T_B - T_M)\,d\xi; \quad Q_3 = \int_z^{z+\Delta z} \varepsilon r S\beta(\eta_M - \eta_B)\,d\xi;$$

$$Q_1' = \int_z^{z+\Delta z} C_B \rho_B \varepsilon T_B(\xi,t)\,d\xi;$$

$$Q_2' = \int_z^{z+\Delta z} \alpha S(T_M - T_B)\,d\xi; \quad Q_3' = C_B \rho_B \varepsilon v[T_B(z+\Delta z,t) - T_B(z,t)];$$

$$M_1 = \int_z^{z+\Delta z} \varepsilon \rho_B d_B(\xi,t)\,d\xi;$$

$$M_2 = \int_z^{z+\Delta z} \beta S(\eta_M - \eta_B)\,d\xi; \quad M_3 = \rho_B \varepsilon v[(z+\Delta z,t)\,d_B - d_B(z,t)];$$

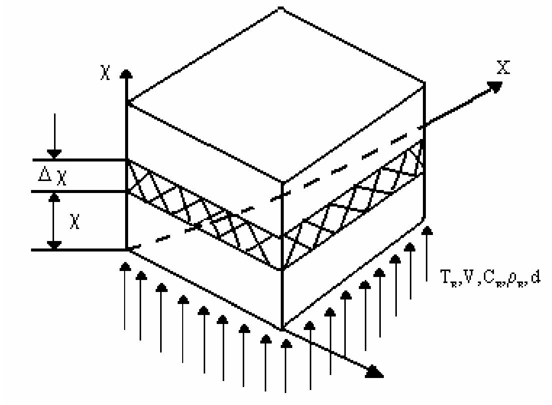
Then the system (1) could be written as follows by substituting $Q_1, Q_2, Q_3, Q_1', Q_2', Q_3', M_1, M_2, M_3$ s with their values:

$$\begin{cases} \dfrac{d}{dt}\displaystyle\int_z^{z+\Delta z} C_M \rho_M \varepsilon T_M(\xi,t)\,d\xi = \int_z^{z+\Delta z} \alpha S(T_M - T_B)\,d\xi - \int_z^{z+\Delta z} \varepsilon r\beta S(\eta_M - \eta_B)\,d\xi, \\ \dfrac{d}{dt}\displaystyle\int_z^{z+\Delta z} C_B \rho_B \varepsilon T_B(\xi,t)\,d\xi = \int_z^{z+\Delta z} \alpha S(T_B - T_M)\,d\xi - C_B \rho_B \varepsilon v[T_B(z+\Delta z,t) - T_B(z,t)], \\ \dfrac{d}{dt}\displaystyle\int_z^{z+\Delta z} \rho_M \varepsilon d_B(\xi,t)\,d\xi = \int_z^{z+\Delta z} \beta S(\eta_M - \eta_B)\,d\xi - \rho_B \varepsilon v[d_B(z+\Delta z,t) - d_B(z,t)]. \end{cases} \quad (2)$$

We'll obtain the following by applying the theorem on mean value to the integral system (2),

$$\begin{cases} C_M \rho_M \varepsilon \dfrac{\partial T_M(z,t)}{\partial t}\Delta z = \alpha S(T_M - T_B)\Delta z - \varepsilon r S\beta(\eta_M - \eta_B)\Delta z; \\ C_B \rho_B \varepsilon \dfrac{\partial T_B(z,t)}{\partial t}\Delta z = \alpha S(T_B - T_M)\Delta z - C_B \rho_B \varepsilon v[T_B(z+\Delta z,t) - T_B(z,t)]; \\ \rho_B \varepsilon \dfrac{\partial T_B(z,t)}{\partial t}\Delta z = \beta S(\eta_M - \eta_B)\Delta z - \rho_B \varepsilon v[d_B(z+\Delta z,t) - d_B(z,t). \end{cases} \quad (3)$$

Or by dividing them to ΔZ



Picture1.

$$\begin{cases} C_M \rho_M \varepsilon \dfrac{\partial T_M(z,t)}{\partial t} = \alpha S(T_M - T_B)\Delta z - \varepsilon r S \beta(\eta_M - \eta_B), \\ C_B \rho_B \varepsilon \dfrac{\partial T_B(z,t)}{\partial t} = \alpha S(T_B - T_M) - C_B \rho_B \varepsilon v \left\{ \dfrac{[T_B(z+\Delta z,t) - T_B(z,t)]}{\Delta z} \right\}, \\ \rho_B \varepsilon \dfrac{\partial T_B(z,t)}{\partial t} = \beta S(\eta_M - \eta_B) - \rho_B \varepsilon v \left\{ \dfrac{[d_B(z+\Delta z,t) - d_B(z,t)]}{\Delta z} \right\}. \end{cases} \tag{4}$$

Leading ΔZ to zero we obtain the system of differential equations defining the process of heat and mass exchange in the embankment of the product (potato, onion):

$$\begin{cases} \dfrac{\partial T_M}{\partial t} = \dfrac{\alpha S}{C_M \rho_M \varepsilon}(T_B - T_M) - \dfrac{r \beta S}{C_M \rho_M}(\eta_M - \eta_B), \\ \dfrac{\partial T_B}{\partial t} = \dfrac{\alpha S}{C_B \rho_B \varepsilon}(T_M - T_B) - v \dfrac{\partial T_B}{\partial z}, \\ \dfrac{\partial d_B}{\partial t} = \dfrac{\beta S}{\rho_B \varepsilon}(\eta_M - \eta_B) - v \dfrac{\partial T_B}{\partial z}. \end{cases} \tag{5}$$

System of differential equations in first-order quotient derivatives fully defines the process of heat and mass exchange in stored products within the above assumed conditions.

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