THERMODYNAMIC AND WATER-EXCHANGE CHARACTERISTICS DETERMINING THE OPTIMAL REGIMES OF SAUSAGE DRYING AND STORAGE OF MEAT PRODUCTS IN CASING(PACKS)

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SUMMARY: Only due to use of the optimal regimes it is possble to decrease sausage drying time and to increase storage time at minimum energy costs and products quality maintenance. The main parameters of the optimal regime for drying-smoking are the following: sausage and casing a_w value, Kirpichev's mass-exchange criterion, Nusselt's mass-exchange number, water penetration depth for evaporation zone, level of a marginal steam-air layer.

There are obtained a functional relation of a_w value to temperature, a law of water redistribution between a product and a package (casing) and a formula describing heat effect of exothermal (endothermal) reactions between the components of complex materials, dry mixtures, meat products and a package.

INTRODUCTION: Drying is a most durable cycle of technological process of ecologically pure raw-dried and raw-smoked sausage production. Product quality depends on it.

Nowdays for sausage drying chambers of limited capacity are used. They operates on independent regimes with programme control. The aim of process optimization is a decrease of drying time and energy costs while maintaing high quality of sausages.

MATERIALS AND METHODS: The following investigations were done: of drying and smoking process, of adsorption phemomena and of analytical methods for criterial relations and water-exchange parameters calculation. Sausages desorption curves were determined by a standard dynamic method of Chuprin.

RESULTS AND DISCUSSION: While developing soft ware packet providing the optimal regimes of meat products drying and storage a mathematical model is being constitued. The latter describes physico-cehmical, biochemical and heat-&-water exchange processes.

Sausage drying time and intensity ar determined by a relationship of external and internal water-exchange I, i.e. by Kirpichev's and Nusselt's water-exchange criterion, thermedynamic parameters (a_w), penetration depth of water evaporation zone(ξ) and level of marginal steam-air layer (ξ_{49}) near sausage chunk surface. All these values are interrelated with regime parameters: humidity and temperature(t) in chambers, rate and direction of sausage air blasting. A mathematical model of drying and storage of meat products in casings includes quantitative regularities of the abovementioned values relationships. It is yet difficult to solve this problem. Based on experiment data analysis and using desorption curves and graphic relationship of water content distribution (W) along the sausage diameter (R) it was obtained that a_w distribution along sausage diameter obeys to a parabolytic law:

$$a_w = a_{w,o} - \left(\frac{X}{R}\right)^2 (a_{w,o} - a_{w,R}) \qquad (1)$$

where $a_{w,o}$; $a_{w,R}$ are a_w values in sausage centre and on its surface, respectively;

X is a running coordinate.

From $a_w = f(R)$ graph it is possible to find the value of penetration depth for water evaporation zone and marginal layer of steam-air media near sausage surface(Fig.1). While regime parameters (φ, t, ϑ) are the same during drying ($\delta\varphi$) increases and causes a decrease of external water-exchange between sausage and surroundings. For water-exchange improvement it is recommended to increase the rate of sausage air blasting or to decrease relative humidity in a chamber (curve 2, Fig.1).

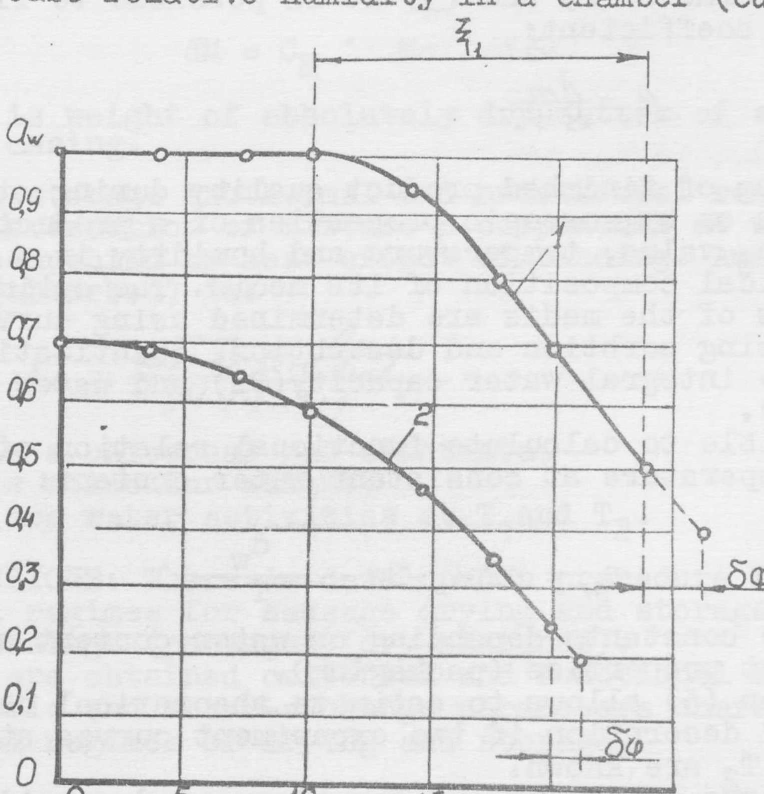

Fig.1. Water activity distribution in dried sausage dry-curing process

Nusselt's criterion is being determined according to the formula

$$Nu_m = \frac{R}{\delta\varphi} \qquad (2)$$

Zone of water evaporation in sausage reaches the centre after the second critical water content that iss determined by the curve of drying rate. From this moment sausage water move as vapour.

The Kirpichev's water-exchange criterion characterizes water-exchange intensity as compared to intensity of water-productivity in a chunk. The more is the K_{im} value the more intensive is the external water-exchange. The maximum K_{im} value may testify to appearing of "hardening" on sausage surface.

According to heat-&-water exchange theory (Lykova A.V., 1981) Nusselt's water-exchange criterion is:

$$Nu_m = \frac{\beta \cdot \ell}{\lambda m}, \qquad (3)$$

where λm is a coefficient of marginal layer water-conductivity (determined from tables).

Using the formula (2) and (3) it is possible to find out water-exchange coefficient:

$$\beta = \frac{\lambda m}{\delta\varphi} \qquad (4)$$

Maintaining of finished product quality during storage, mainly, depends on hygroscopic properties of a product and casing, their a_w value, temperature and humidity in a storehouse and chemical composition of its media. The optimal regime parameters of the medis are determined using curves of product and casing sorbtion and desorbtion, quantitative values of average integral water capacity(Cm) and water transfer potentials (Θ).

It is possible to calculate functional relation of water activity to temperature at consistent water content:

$$a_w = \exp(-Bw - \frac{d_w}{T}) \qquad (5)$$

where B_w, d_w are constants depending on water content and product properties (packaging).

The equation (5) allows to estimate theoretical curves of sorption and desorption if two experiment curves at temperatures T_1 and T_2 are known.

Having a curve of drying and sorption and desorption curves time is possible to determine at the optimal conditions of product storage.

During storage a product and a casing (package) tend to thermodynamic balance(their water transfer potentials are equal).

At this time redistribution of water takes place at condition of:

$$\frac{W_p}{W_c} = \frac{C_m'}{C_m''} \qquad (6)$$

where C_m', C_m'' are average integral water capacities of a product and casing, respectively;

W_p, W_c are water contents for a product and a casing.

For complex products and dry mixtures water transfer potential(mixture) is equal to:

$$\Theta_{cm} = \frac{\Theta_1 \cdot C_{m,1} + \Theta_2 C_{m,2}}{C_{m,1} + C_{m,2}} \qquad (7)$$

where Θ_1 and Θ_2 are potentials of water transfer for components of complex products, mixtures;

$C_{m,1}$ and $C_{m,2}$ are average integral water capacities of components.

Amount of water dM migrating from casing to product and vice versa is calculated by the formula:

$$dM = C_M \cdot Mo \cdot d\Theta \qquad (8)$$

where Mo is weight of abbolutely dry matter of a product or casing.

During storage exothermal and endothermal reactions taking place at interaction of mixture's components at water-exchange are accompanied by heat effect of binding. Amount of heat extracted(absorbed) is:

$$\Delta L = \frac{R T_1 T_2 \ln \frac{a_{w2}}{a_{w1}}}{M (T_2 - T_1)} \qquad (9)$$

where R is a universal gas constanta;

is molecular weight;

a_{w1}, a_{w2} are water activities at T_1 and T_2.

CONCLUSIONS: There is developed a procedure for selection of optimal regimes for sausage drying and storage of meat products in casings (packages)(dry mixtures).

There are obtained criterial and functional relations of thermodynamic and water-exchange parameters characterizing the optimal regimes of drying and storage.

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