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THE USE OF A DIAGRAM OF FUNCTIONS OF STATE FOR A COMPLEX EVALUATION OF PRODUCT STRUCTURAL AND HYGROSCOPIC PROPERTIES IN RELATION TO THE PROCESS OF DRYING

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SUMMARY

To describe heat-moisture transfer in the processes of drying, thermal treatment and storage of dry mixes, the method of thermodynamic analysis has been suggested based on macrophysical quantities, viz., chemical potential, specific enthalpy of bound water, specific enthropy of bound water and differential iso-steric heat of phase transitions. On the diagram of thermodynamic states changes in the properties of products, sausage casings, etc. are reflected. The analysis of the diagram makes it possible to predict the mechanism of heat-moisture transfer, as well as the quality of the product to be expected. An attempt has been made to estimate the porosity of air-dried sausage, sausage casings and films.

INTRODUCTION

Modern sausage technology involves the use of various "additives", this resulting in the altered mechanism of heat-moisture transfer during drying and thermal treatment.

Thermodynamic and mass-exchange characteristics related directly to product hygroscopic and structural properties allow to evaluate the quality of the finished product at the end stage of the technological process and the energy characteristics for their further optimization.

The total mathematical model of convective drying accounts for the external transfer of mass, energy and impulse into the environment, which is described with the equations for the non-stationary hydrodynamic, temperature and diffusion layer, as well as the internal transfer described with differential equations for the non-stationary temperature-humidity field of a sample under respective initial and boundary conditions.

At present analytical and numerical methods do not solve this problem completely. Therefore, simplified methods are practised. Of the latest numerical methods which can be used with computers most suitable are such which describe the occurring phenomena starting from the common equations of mass, energy and impulse balance, or the methods simplified according to the developed physical model and the nature of the process.

MATERIALS AND METHODS

Heat exchange and moisture removal can be described using macroscopic quantities derived from thermodynamic analysis. The interrelation among the components of comminuted saúsage meat, as well as the latter's adhesion to the casing can be expressed through thermodynamic functions of state: chemical potential (μ), specific enthalpy of bound water (H). specific enthropy of bound water (S), iso-steric differential heat of phase transition ($\tilde{q}_{i-st}$).

Using sorption isotherms, the quantities of μ, S, H and $\tilde{q}_{i-st}$ are calculated with the common methods. A diagram is plotted and the above values are laid off on it. Then it is divided into 3 regions according to the physical model selected.

At $\mu = 0$: the product is indefinitely swellable at $U \rightarrow \infty$.

$\mu_{max} = -6\cdot10^3$ J/kg : the product is in equilibrium with the environment (air-dried sausage, T = 285 K, $\varphi = 0.4$).

$\Delta S = 0$: the product contains free water in the liquid phase.

$\Delta S > 0$: the product is hydrophobic.

$\Delta S < 0$: the product contains free water in the solid phase.

$\Delta H = 0$: the ideal mechanical mixture of water with the product.

$H > 2.5\cdot10^3$ J/kg : the product contains mainly adsorbed bound water (pressure and temperature are constant).

$H = 2.5\cdot10^3$ J/kg :water in the liquid phase.

Using this diagram, successive changes in the product state can be followed at a fixed water content.

Hygroscopic and structural properties of a product are found from the graph $\tilde{q}_{i-st} - \ln\varphi$ where the length cut off with the straight line on the Y-axis equals the heat of wetting. For a great number of products, casings and films the equation was derived:

$$\tilde{q}_{i-st} = q_o - B\ln\varphi \quad \text{at } 0.5 \leq \varphi \leq 0.999.$$

On the $\tilde{q}_{i-st} - \ln\varphi$ graph the singular point corresponds to the start of water condensation in capillaries.

By the wetting heat (q_o) and by the known maximal hygroscopic water content of a given product, the total porosity (Π) is estimated which equals the proportion of pore (capillaries) volume to that of a solid object (sample).

As the objects of the study served air-dried raw sausage, natural casings, cutisin, belcosin and cellophane.

RESULTS AND CONCLUSIONS

1. The analysis of the diagram of states makes it possible to predict the mechanism of heat-moisture transfer in the process of drying and thermal treatment, as well as product quality to be expected under respective operating conditions of the environment.
2. For the majority of the test objects the differential iso-steric heat of phase transition depends on the environmental relative humidity as follows:

$$\tilde{q}_{i-st} = q_o - B\ln\varphi \quad \text{at } 0.5 \leq \varphi \leq 0.999.$$

3. The porosity of raw air-dried sausage, natural casings, cutisin, belcosin and cellophane was evaluated ($\Pi = 40\%$ at T = 285 K and $0.78 \leq \varphi \leq 0.95$).
4. The singular point on the $\tilde{q}_{i-st} - \ln\varphi$ plot corresponds to the beginning of moisture condensation in capillaries.