



MODELING OF MICROBIOLOGICAL AND BIOCHEMICAL PROCESSES UNDER THE CONDITIONS OF STEAM CONTACT STERILIZATION IN CONTAINERS OF TURKEY MEAT PATE

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ABSTRACT

The article proposes modes of sterilization of meat pate from turkey meat, which was determined by the method in which the actual lethality F_f relative to the microflora should be equal to or exceed the required lethality of the sterilization process F_n ($F_f \geq F_n$) canned turkey pate. The results of the study of the dependence of the kinetics of biochemical reactions on the thermal, chemical and mechanical sensitivity of the processed product, on pressure, temperature and chemical potential are presented. One of the effective ways to intensify the heat transfer process is the contact heating of the product by means of steam supply, which has a technological effect on the processed products. When comparing the results of the simulated results with



experimental data, it is established that the solution of the problem of calculating the temperature field of the product on a computer gives quite satisfactory results between the calculated and experimental data. It is established that as a modification for the processed products it is necessary to solve thermohydronechanical equations with the corresponding initial and boundary conditions in addition to the transfer equation for each scalar quantity.

Keywords: Pressure; Temperature; Parameters; Stea; Contact heating; Production; Sterilization; Microflora; Packaging; Diffusion; Physico-chemical Parameters

1. INTRODUCTION

Targeted combination of prescription ingredients provides a food composition with a given chemical composition. This approach forms the basis of the use of raw materials, the main advantage which is the potential for mutual enrichment of ingredients included in the recipe for one or more essential factors with in order to ensure the fullest compliance created compositions of the formula of balanced or adequate nutrition Antipova (2015), Buttriss, (2006) and Tsurkan, Gurich and Polevoda (2014).

An important task of the meat canning industry is to increase production and improve product quality by optimizing technological processes, identifying and using hidden reserves, saving raw materials and energy resources. Meat pate is a source of essential human proteins, calcium, iron and some vitamins, the lack of which leads to a delay in physical development, reduced immunity. Insufficient meat in the human diet slows down the metabolism. Canned meat, namely pâtés, are products made from meat, offal and other raw materials in hermetically sealed containers and pasteurized or sterilized to kill microorganisms and Make Them Stable During Storage (Prylipko, Bukalova & Lyasota, 2019; Yakubchak, 2014).

To date, the range of meat products still lacks scientifically sound recipes for canned meat products in the form of general-purpose pâtés that would meet the standards of healthy eating. The production of combined products, which can include canned pâtés, can be considered as part of the man-made technological sphere (Cherevko & Poperechny, 2014; Vynnykova, 2006; Zhang et al., 2015).

It is known that the nutritional value of meat products depends on the content of biologically important components, the change of which in the process of processing has a decisive influence on the quality of finished products in relation to the enzymes of the gastrointestinal tract, ability to digest and meet certain physiological needs. In a balanced diet,



turkey pate has no substitutes. Their nutritional value is characterized by high caloric content and digestibility (Belk, George & Tatum 2012; Bohirov, Shcherbakov & Bakunova, 2013).

The scientific substantiation of rational modes of sterilization of pâtés should be reduced not only to the study of the possibility of reducing the sterilizing effect in the production of industrial sterile products, but also to establish the dependences of objective criteria of quality and nutritional value. Particular attention should be paid to the study of structural changes in proteins and lipids in canned pâtés depending on the composition and modes of heat treatment (Tsurkan, Gurich & Polevoda, 2014; Kaletnik & Yanovich, 2017).

2. LITERATURE REVIEW

The kinetics of biochemical reactions to varying degrees depends on the thermal, chemical and mechanical sensitivity of the processed product, pressure, temperature and chemical potential. The pressure propagates in the fluid according to the Pascal principle in all directions, passing for small adiabatic changes of pressure with the speed of sound. For this reason, it can be assumed that the pressure occurs almost instantly throughout the chamber.

From this assumption follows the available in the literature not tested enough in real conditions conclusion that the influence of pressure in comparison with thermal processes has the advantage that it can affect rapidly and uniformly the entire processed substance, regardless of shape, size and composition. However, the possibility of physical and thermal inhomogeneity is ignored, which is explained by the fact that in the phase of pressure increase due to the change in volume, the temperature of the treated medium increases (Voronenko, 2008; Prilipko & Kutsyi, 2013; Ibatullin, Zhukorsky & Bashchenko, 2017).

The creation of high-performance heat exchange equipment that meets the current level of development of industry and technology requires significant intensification of heat transfer processes. One of the effective ways, both in terms of intensification of the heat transfer process and energy savings, is the contact heating of the product by means of steam, which has a technological impact on the processed products (Palamarchuk, Polvado & Kutsyi, 2017).

Heat transfer during steam contact heating of products is a complex phenomenon associated with the simultaneous transfer of heat and mass of matter. The amount of transferred mass is determined by the amount of condensed steam, and the transferred heat (provided saturated steam) - the heat of vaporization (Kaletnik & Yanovich, 2017).



When steam-contact heating takes into account a significant number of determinants, with the greatest importance are both thermophysical properties of the heating steam and physico-chemical properties of the product. Taking into account all the factors influencing the heat transfer process during steam contact heating is very difficult not only theoretically but also experimentally (Bogatko, Bukalova & Lyasota, 2019; Terziev, 2012).

The main parameter in the process of thermal sterilization of food products, including by means of steam contact heating, is the temperature of the product, which is the main factor for establishing the sterilization modes of canned food. Therefore, one of the main tasks in the study of the sterilization process with this method of heating is to determine the temperature field of the product or to detect the dynamics of temperature change at different points of the product depending on the parameters of heating steam, its supply conditions and physical properties of processed raw materials (Prylipko, Koval & Kostash, 2020; Lyasota & Bakhur, 2020).

The purpose of the article - calculation of non-stationary temperature field in a container heated from the outer surface from a heat source of a given intensity, taking into account convection in the radial direction.

1. DATA AND METHODOLOGY

In the study and development of new technological solutions for canned meat pate that meets modern market requirements and the principles of healthy eating, the rationale for the optimal sterilization of canned turkey pate was based on analytical, statistical and comparative research methods.

To achieve this goal it was necessary to solve the following tasks:

- to optimize the mode design parameters of the vertical autoclave of periodic action B6-KA2-B-2;
- to carry out mathematical modeling of recipes of meat pate taking into account new types of raw materials and balance of the main components on conformity to requirements of a healthy food and to develop a compounding and the technological scheme of production of pate from turkey meat;
- to carry out rotatable central-compositional planning of multifactorial experiment on the basis of search experiments;

The article proposes modes of sterilization of meat pate from turkey meat, which were determined by the method in which the actual lethality F_f relative to the microflora should be equal to or exceed the required lethality of the sterilization process F_n ($F_f \geq F_n$).

Research methods: biochemical (influence of enzyme preparations on collagen-containing raw materials), physicochemical (changes in the chemical composition of turkey meat under the action of heat loads and during storage), statistical (biometric processing of research materials (Zhuravskaya, Alekhina & Otryashenkova, 2015). Software: MathCad, Microsoft Excel, Compass - 3DV12 were used for theoretical research. To verify the adequacy of the obtained experimental results, we used the method of mathematical statistics using the program Statistics 6.0.

2. RESULTS AND DISCUSSIONS

To formally determine the increase in temperature caused by the increase in pressure, we first used the conservation equation from which we derived equation (1.) relative to the total heat capacity H .

$$\frac{\partial(\rho H)}{\partial \tau} + \nabla \cdot (\rho \vec{v} H) = \frac{\partial p}{\partial \tau} + \nabla \cdot (\lambda \nabla T) + \nabla \cdot (\xi \cdot \vec{v}) + \rho \vec{q} \cdot \vec{v}, \quad (1)$$

\vec{v} - fluid velocity vector,

\vec{q} - weight force vector,

ρ - liquid density, kg / m³;

p - pressure, Pa;

τ - hour, s.;

ξ - tensor of viscous stresses.

He then used the equation for a specific heat capacity h

$$\rho \frac{Dh}{D\tau} - \frac{Dp}{D\tau} = \nabla \cdot (\lambda \nabla T) + \eta \Phi + \rho \vec{q} \cdot \vec{v}, \quad (2)$$

F - dissipation function,

and using the thermodynamic ratio

$$\frac{Dh}{D\tau} = \frac{\partial h}{\partial p} \bigg|_T \frac{Dp}{D\tau} + \frac{\partial h}{\partial T} \bigg|_p \frac{DT}{D\tau} = \frac{1}{\rho} (1 - \alpha T) \frac{Dp}{D\tau} + c_p \frac{DT}{D\tau}, \quad (3)$$

α – coefficient of thermal expansion,

we obtained the equation of thermal energy,

$$\rho c_p \frac{DT}{D\tau} = \alpha T \frac{Dp}{D\tau} + \nabla \cdot (\lambda \nabla T) + \eta \Phi + \rho \vec{q} \cdot \vec{v}. \quad (4)$$

For example, water at room temperature shows an increase in temperature from 2.5 K to 3 K when compressed to 100 MPa. In the case of a similar experiment with edible oils, the temperature rise can reach 10 K and above (Prilipko & Kuts, 2013).

It is believed that the movement of the liquid is necessarily present during the treatment of the liquid substance by pressure. To show this mathematically, we assumed that the density increases with increasing pressure and decreases with increasing temperature, which is justified for most foods and similar substances in the environment. The appearance of the running field in a fluid that is initially at rest, during compression, we showed using the equation of mass balance.

$$\frac{\partial \rho}{\partial \tau} + \nabla \cdot (\rho \vec{v}) = 0. \quad (6)$$

During the compression phase, the density increases with increasing pressure. Therefore, the first term of equation (6) becomes nonzero. Since the left side must be zero, the fluid velocity \vec{v} must take non-zero values. Therefore, increasing the pressure enhances the movement of the fluid. Temperature gradients play an important role in the deviation of flow behavior from the hydrostatic state. We traced this conclusion using the basic equations of hydrostatics:

$$\frac{\partial p}{\partial x} = 0, \quad (7)$$

$$\frac{\partial p}{\partial y} = 0, \quad (8)$$

$$\frac{\partial p}{\partial z} = -\rho \vec{q}. \quad (9)$$

In equations (7-9) x, y and z are Cartesian coordinates. Without losing sight of the general idea, we assumed that the vector of gravity points in a negative direction. Further transformation of equation (8) in relation and equation (9) in relation gave the following result:

$$\frac{\partial^2 p}{\partial y \partial z} = \frac{\partial^2 p}{\partial z \partial y} = -\frac{\partial \rho}{\partial y} \bar{q}. \quad (10)$$

Therefore, the right-hand side of equation (10) and the density derivative with respect to the relation must be constant and equal to zero (Tsurkan, Gurich & Polevoda, 2014)

$$\frac{\partial^2 p}{\partial y \partial z} = \frac{\partial^2 p}{\partial z \partial y} = -\frac{\partial \rho}{\partial y} \bar{q}. \quad (11)$$

However, this condition, as follows from hydrostatics, cannot be maintained. While the density is a function of temperature, and the latter is transmitted in a direction different from the direction of the vector of gravity, equation (11) is violated. As a result, the flow of steam at a rate other than zero must occur, which leads to convective transfer of high temperature and suspended solids.

The presence of thermal inhomogeneity in the product and the subsequent inhomogeneity of the process make it necessary to predict thermal inhomogeneity, including for the application of countermeasures.

The results of a numerical experiment to calculate the temperature field along the radius of a cylindrical container depending on the parameters of the heating steam and the product are presented in Figure 1.

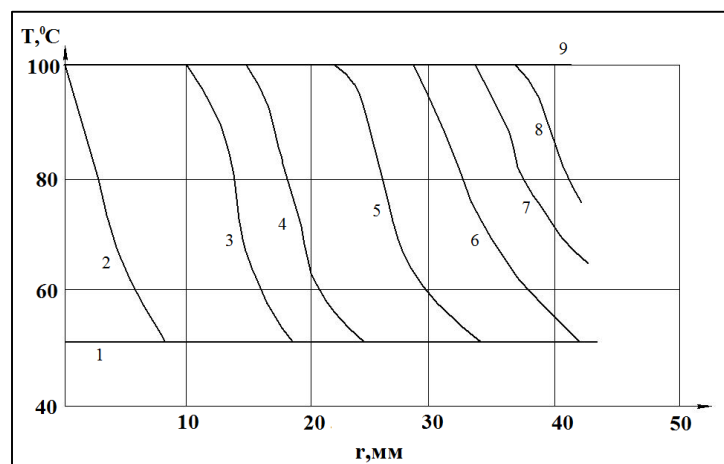


Figure 1: Curves of temperature field changes in the process of steam contact heating of the product in a cylindrical container with external heat supply at the temperature of the heating steam $T_{\text{H}} = 100 \text{ }^{\circ}\text{C}$: 1 – t = 0; 2 – t = 1; 3 – t = 20; 4 – t = 40; 5 – t = 80; 6 – t = 120; 7 – t = 160; 8 – t = 180; 9 – t = 200

In Figure 1 curves of changes in the temperature field of the product during steam heating of the product from the initial temperature $T_n = 50^\circ\text{C}$ to the final temperature $T_k = 100^\circ\text{C}$ condensing steam with a temperature $T_p = 100^\circ\text{C}$, with a steam flow rate of 0.001 kg/s . The ambient temperature is taken $T_s = 20^\circ\text{C}$, and the heat transfer coefficient on the outer surface of the cylinder $= 10\text{ W/(m K)}$. As can be seen from Fig. 1 at the initial time (1.5-3 s) the temperature in the Central layer almost instantly increases to the condensation temperature of the vapor. The temperature in the peripheral layers of the product does not change.

Upon further heating, mainly due to the emerging radial convective flows, as well as thermal conductivity, the heat flux gradually reaches the peripheral layers over time $t = 260\text{ s}$. As a result, a uniform temperature field is established over the entire radius. To determine the influence of the parameters of the heating steam on the distribution of the temperature field of the product, we performed calculations at different temperatures of the heating steam. (Palamarchuk, Polyevoda & Kutsyi, 2017)

In fig. In Figure 2 shows the curves of changes in the temperature field at the temperature of the heating steam $T_p = 110^\circ\text{C}$. As can be seen, the increase in temperature contributes to the intensification of the heat transfer process. However, this leads to a sharp temperature difference between the central and peripheral regions.

Comparison of the results of the simulated results with experimental data allows us to conclude that the solution of the problem of calculating the temperature field of the product on a computer gives quite satisfactory results between the calculated and experimental data.

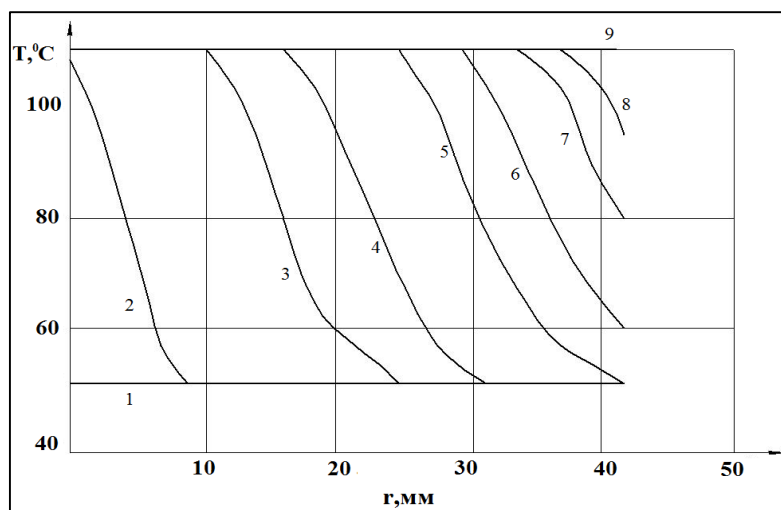


Figure 2: Curves of temperature field changes in the process of steam contact heating of the product in a cylindrical container with external heat supply at the temperature of the heating steam $T_p = 110^\circ\text{C}$: 1 - $t = 0$; 2 - $t = 1$; 3 - $t = 20$; 4 - $t = 40$; 5 - $t = 80$; 6 - $t = 120$; 7 - $t = 160$; 8 - $t = 180$; 9 - $t = 200$

The transfer of molecular (index m) and cellular (index z) systems occurs by means of mechanisms induced by forced and natural convection. Based on small length ranges ($l_m^* \approx 10^{-9}$ m for proteins and $l_z^* \approx 10^{-6}$ m for microorganisms) they are in mechanical and thermal equilibrium. Characteristic internal time scales of pulse transfer into water as a dispersion medium $\tau_{i,m}^{\text{гнуп}^*} = \frac{l_m^{*2}}{\nu^*} \approx 10^{-12}$ s and $\tau_{i,z}^{\text{гнуп}^*} = \frac{l_z^{*2}}{\nu^*} \approx 10^{-6}$ s give instructions on mechanical equilibrium.

Similarly characterize the internal time scales $\tau_{i,m}^{\text{БНУТ}^*} = \frac{l_m^{*2}}{a} \approx 10^{-11}$ s and $\tau_{e,z}^{\text{гнуп}^*} = \frac{l_z^{*2}}{a} \approx 10^{-5}$ s energy transfer to water. These estimates require further consideration near the phase transition boundaries. There is a significant change in the state of "reaction time to thermohydrodynamic effects", because they create velocity fields, fields induced by friction of normal stresses and tangential stresses, as well as pressure and temperature fields.

The above dimensions of the internal time scales of dispersed molecular and cellular systems differ significantly from the typical duration of the process $\tau^{\text{пrou}^*}$ processing. So, Deborah's

number $De = \frac{\tau^{\text{гнуп}^*}}{\tau^{\text{пrou}^*}}$ takes an infinitesimal value. This dimensionless index expresses the local equilibrium, i.e. the presence of a "congruent thermohydrodynamic state" of the continuous phase and dispersed molecular and cellular systems at any time under the influence of high pressure at given spatial coordinates, which greatly facilitates modeling, as it allows us to reflect the technological impact on molecular and cellular reactions as general scalar

quantities Θ^* . In dimensionless form for the relation $\Theta = \frac{\Theta^*}{\Theta_0^*}$ we received the corresponding transfer model:

$$\frac{\partial \Theta}{\partial \tau} + \nabla \cdot (\Theta \vec{U}) = \frac{1}{\text{Re}_0 \text{Sc}_0} \nabla \cdot (D_\Theta \nabla \Theta) + D_{a0} Q_\Theta \quad (12)$$

The left side of the model equation completely coincides with the equation of conservation of mass. For the molecular biocomponent, equation (12) expresses the induced changes that are associated with diffusion, as well as with a qualitative change (activation or deactivation) of

biocomponents. Diffusion effects are based on the existence of inhomogeneous scalar fields Θ . **Parameter** D_Θ in the first term of the right side of equation (12) is given for the diffusion constant of the molecular or cellular process. The magnitude of the diffusion obviously depends on the inverse of the product of the Reynolds test Re_0 and Schmidt's criterion

$$Sc_0 = \frac{V_0^*}{D_\Theta^*} ab$$

Θ . The next Schmidt's criterion evaluates the ratio of diffusion momentum to scalar transfer effect associated with positive or negative "production" Θ , **expresses a dimensionless initial term** $Da_0 Q_\Theta$. **The value of the Damköller criterion** Da_0 sets the intensity of the source Q_Θ . It describes the relationship between the convection time scale and the molecular reaction time scale. For example, in the reaction of the n th order with concentration $c = \Theta$ source intensity $Q_\Theta = -kc^n$

Damköller's criterion is
$$Da_0 = \frac{L_0^* k_0^* c_0^{*n-1}}{u_0^*} .$$

One of the main ideas of equation (12) is that molecules - if the required values of the thermodynamic variable pressure and temperature prevail - react accordingly.

Therefore, cellular responses can be modeled similarly (Cherevko & Poperechny, 2014) Pressure-induced suppression of microorganisms as a scalar quantity depends on the intensity of the source of vital suppression (for example, the pressure in combination with the barosensitivity of the corresponding microorganisms), diffusion transfer of destroyed microorganisms based on pure Brownian motion and convective transfer based on forced coercion. Introducing the initial term into equation (12), we proceeded from the hypothesis that in addition to the local mechanical and thermal equilibrium between the dispersed and continuous phases, there is local homogeneity.

Specifically, this means that the reactions both in the considered place of the processed product and in its immediate spatial environment take place depending on the same local thermohydrodynamic state. Thus, in places with a spatially very small distance between the reactions that take place, there are no mutual influences, no restrictions and slowdowns. Since these interactions are completely unavoidable, we considered it rational to despise the interactions if the average distance s^* between two molecules or microorganisms takes significantly more value than their characteristic length scales l_m i l_c . Checking the probability of

this requires calculating the size of the next criterion, the Knudsen number Kn , which is used in gas dynamics for comparative reasoning.

To achieve the goal of our research, we adapt the definition of Knudsen's number as $Kn = \frac{\bar{s}^*}{l^*}$. As a result, we assumed that local homogeneity approximately exists at low concentrations of dispersed systems, ie for larger values \bar{s}^* . Checking the probability of local homogeneity, ie that no relationships occur between adjacent spatial zones, is also of great importance for scaling. This is due to the fact that the measurement of the kinetic data of the reaction takes place in very small cells operating under pressure, in which the effect of thermohydronechanical distributions is relatively small. Not only local but also, to a certain extent, global homogeneity should prevail approximately here. In contrast, the distributions of thermohydronechanical fields that inevitably occur in large chambers can affect the reaction rate in a way other than that expressed by equation (12).

Given these conditions, we concluded that the transfer of mass, momentum, energy, and scalars has a strong effect on the interaction, however, an exact similarity cannot be achieved. This works, in particular, if the goal is to set specific results of technological influence, such as inactivation of cellular and molecular systems, but it is a significant difficulty not only for scaling, but also for any simplification of modeling and simulation.

Until now, the use of the complete transfer equation was absent for scalar quantities. In contrast, numerous simplifications are known, for example, used to describe the temporal dependence of molecular and cellular reactions.

$$\frac{\partial \Theta}{\partial \tau} = D_{a0} Q_{\Theta} \quad (13)$$

Model (13) is the most commonly used mathematical expression (Terziev, 2012) To simplify equation, we introduced the term $\nabla \cdot (\Theta \vec{U})$, which can take into account the effect of convection transfer Θ through the always present in the liquid compressed product velocity field \vec{U} :

$$\frac{\partial \Theta}{\partial \tau} + \nabla \cdot (\Theta \vec{U}) = +D_{a0} Q_{\Theta} \quad (14)$$

Thus, the temperature and flow fields caused by the effect of VT significantly affect the transformation of any target component of the processed product. Thus, the authors (Shazzo Kas'janov, 2000; Bohirov, Shcherbakov & Bakunova, 2013; Tsurkan, Gurich & Polevoda, 2014) showed that these fields really significantly affect the inactivation of microorganisms (*Escherichia coli*) and enzymes (*Bacillus subtilis* α -amylase) in packaged foods.

As a modification for the processed products, it is necessary to solve thermohydrromechanical equations with appropriate initial and boundary conditions in addition to the transfer equation (12) for each scalar quantity. In all cases, models based on these equations predict the existence of thermohydrromechanical inhomogeneities that cause differences in the number of surviving microorganisms, ie mortality as a scalar quantity corresponds to equation (14).

In the case of viscous plastics, the starting point is the thermal equation for temperature T (K):

$$\rho C_p \frac{\partial T}{\partial \tau} - \nabla \cdot (k \nabla T) = \alpha \frac{dP}{d\tau} T \quad \text{в } \Omega^* \times (0, \tau_f) \quad (15)$$

$\rho = \rho(T, P)$ density (kg / m³),

$C_p = C_p(T, P)$ heat capacity (J / (kg.K)),

$k = k(T, P)$ thermal conductivity),

and τ_f time (s)

the right side of the equation denotes an internal increase in temperature due to a change in pressure. Here $P = P(\tau)$ is the pressure (MPa) created in the chamber, and $\alpha = \alpha(T, P)$ is given as:

- coefficient of thermal expansion (K⁻¹) for the fluid that creates pressure in the area ΩP^* , 0, anywhere else.

This condition is the result of the following law (Method for the determination of total nitrite content (control method) (ISO 2918: 1975, IDT): DSTU ISO 2918, 2005 (Kotsiumbas, 2012; Zhuravskaya, 2015)

$$\frac{\Delta T}{\Delta P} = \frac{\alpha T V}{m C_p} = \frac{\alpha T}{\rho C_p}, \quad (16)$$

ΔT - temperature change due to pressure change ΔP , V (m – 3) volume, m (kg) mass.

In the thermal conductivity equation (16), we finally took into account the corresponding initial and limiting conditions depending on the design of the equipment.

$$\left\{ \begin{array}{ll} k \frac{\partial T}{\partial n} = 0 & \rightarrow \Gamma^* \setminus (\Gamma_r^* \cup \Gamma_{up}^*) \times (0, \tau_f), \\ k \frac{\partial T}{\partial n} = h(T_{okp} - T) & \rightarrow \Gamma_{up}^* \times (0, \tau_f), \\ T = T_0 & \rightarrow \Gamma_r^* \times (0, \tau_f), \\ T(0) = T_0 & \rightarrow \Omega^* \end{array} \right. \quad (17)$$

where n - the outer normal unit vector at the boundary of the working area,

T_0 - initial temperature,

T_r - the cooling or heating temperature that remains constant within the known temperature Γ_r^* (which cools or heats the food sample),

T_{ocr} - ambient temperature (constant);

h W / (m² • K) - heat transfer coefficient.

Since we used a cylindrical coordinate system and axial symmetry, we rewrote the system (16, 17) as the following 2-dimensional problem:

$$\left\{ \begin{array}{ll} \rho C_p \frac{\partial T}{\partial \tau} - \frac{1}{r} \frac{\partial}{\partial r} \left(rk \frac{\partial T}{\partial r} \right) - \frac{\partial}{\partial z} \left(k \frac{\partial T}{\partial z} \right) = \alpha \frac{dP}{d\tau} T & \rightarrow \Omega \times (0, \tau_f), \\ k \frac{\partial T}{\partial n} = 0 & \rightarrow \Gamma \setminus (\Gamma_r \cup \Gamma_{up}) \times (0, \tau_f) \\ k \frac{\partial T}{\partial n} = h(T_{okp} - T) & \rightarrow \Gamma_{up} \times (0, \tau_f) \\ T = T_r & \rightarrow \Gamma_r \times (0, \tau_f) \\ T(0) = T_0 & \rightarrow \Omega \end{array} \right. \quad (18)$$

This model is suitable for the case when the filling factor of the food sample inside the chamber is much higher than the filling factor of the pressure medium. If the fill factor of the

food sample inside the chamber is not much higher than the fill factor of the pressure medium, the final solution with this model may be very different from the experimental values.

As mentioned above, the inhomogeneous temperature distribution is the cause of the inhomogeneous density distribution in the pressure medium and, as a consequence, causes a lifting force during the movement of the fluid. In other words, free convection. This movement of the fluid can affect the temperature distribution. To account for this fact, we used a non-isothermal flow model. We hypothesized that the flow velocity field, u (ms⁻¹), corresponds to the Navier – Stokes equation for a compressed Newtonian fluid according to the original Stokes premise and obtained the following system of equations:

$$\left\{ \begin{array}{l} \rho C_p \frac{\partial T}{\partial \tau} - \nabla \cdot (k \nabla T) + \rho C_p u \cdot \nabla T = \alpha \frac{dP}{d\tau} T \quad \rightarrow \Omega^* \times (0, \tau_f), \\ \rho \frac{\partial u}{\partial \tau} - \nabla \cdot \eta (\nabla u + \nabla u^t) + \rho (u \cdot \nabla) u = \\ = -\nabla p - \frac{2}{3} \nabla (\eta \nabla \cdot u) + \rho g \quad \rightarrow \Omega_p^* \times (0, \tau_f), \\ \frac{\partial p}{\partial \tau} + \nabla \cdot (pu) = 0 \quad \rightarrow \Omega_p^* \times (0, \tau_f), \end{array} \right. \quad (19)$$

where g is the gravitational vector (m / s²);

$\eta = \eta (T, P)$ - dynamic viscosity (Pa• s); $p = p (x, \tau)$ is the pressure that occurs during mass transfer inside the liquid, and $P + p$ is the total pressure (MPa) in the medium that exerts the pressure.

It should be emphasized that in the right part of the first equation (18) can be written $\alpha \frac{d(P+p)}{d\tau} T$ but we have made the assumption that the internal heat resulting from mass transfer can be neglected. In the right part of the second equation we put ∇p because $P = P(\tau)$ depends only on time and therefore $\nabla(P+p) = \nabla p$. Density $\rho = \rho (T, P)$ is a fixed function of the state.

The system of equations (19) was developed taking into account the corresponding points, limits and initial conditions:

$$\begin{cases}
 k \frac{\partial T}{\partial n} = 0 & \rightarrow \Gamma^* \setminus (\Gamma_r^* \cup \Gamma_{up}^*) \times (0, \tau_f) \\
 k \frac{\partial T}{\partial n} = h(T_{okp} - T) & \rightarrow \Gamma_{up}^* \times (0, \tau_f), \\
 T = T_r & \rightarrow \Gamma_r^* \times (0, \tau_f), \\
 u = 0 & \rightarrow \Gamma_p^* \times (0, \tau_f), \\
 T(0) = T_0 & \rightarrow \Omega^*, \\
 p = 10^5 & \rightarrow A_1 \times (0, \tau_f)
 \end{cases} \quad (20)$$

where A_1 - angular point Γ_p^* , which is the boundary of the zone Ω^* .

It should be noted that the state of point A_1 means that the total pressure ($P + p$) at this point is equal to the pressure in the chamber P plus atmospheric pressure. As shown above, for the model with heat transfer due to thermal conductivity, the system of equations (18), the system of equations (19) and (20) can also be rewritten as the equivalent of a 2-dimensional problem using cylindrical coordinates.

3. CONCLUSIONS AND RECOMMENDATIONS

1. The kinetics of biochemical reactions depends on the thermal, chemical and mechanical sensitivity of the processed product, pressure, temperature and chemical potential.
2. One of the effective ways to intensify the heat transfer process is the contact heating of the product by means of steam, which has a technological impact on the processed products.
3. As a modification for the processed products it is necessary to solve the thermohydraulic equations with the corresponding initial and boundary conditions in addition to the transfer equation for each scalar quantity.

Modes of sterilization of meat pate from turkey meat are offered, which were determined by the method in which the actual lethality F_f relative to the microflora should be equal to or exceed the required lethality of the sterilization process F_n ($F_f \geq F_n$).

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