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CHANGE OF MEAT PROTEINS DURING THERMAL TREATMENT

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In order to optimize the heat treatment of beef and control the processing, a dynamic mathematical model was developed and used to calculate the changes of temperature and meat proteins (myosin, tropomyosin, actin, myoglobin) that reflect the true mechanism of energy transfer. This enables the effect of temperature on the condition of meat proteins in layers of the item to be analyzed and the layer in which certain effects occur to be determined.

An equation for the temperature change with meat layer and time was derived. Heat is added during thermal treatment by radiation from energy generators, thermal conductivity, and phase transitions. The proposed dynamic mathematical model is written as follows:

$$\begin{cases} t_{i(J+1)} = (q_i \cdot \tau dh + 1_m \cdot d\tau \cdot (t_{i(j-1)} + t_{i(j+1)}) + m_c \cdot c_m \cdot h_{i,j})/2 \cdot 1_m \cdot Fd\tau + m_c \cdot c_m \cdot dh \\ K_{1i} = 0.00836 - 0.001402\ pH + 5.5 \cdot 10^{-7} \cdot t^2 \\ K_{2i} = -0.278 + 7.325 \cdot 10^{-2} pH - 3.482 \cdot 10^{-5} \cdot t^2 \\ K_{3i} = 2.537 \cdot 10^{-3} - 1.493 \cdot 10^{-4} \cdot t_i + 2.198 \cdot 10^{-5} \cdot t^2 \\ K_{4i} = 2.537 \cdot 10^{-2} - 9.172 \cdot 10^{-3} pH + 3.157 \cdot 10^{-5} \cdot t_i^2 \\ m_{1t.i} = m_0^b - (m_o^b - m_t^b) \cdot e^{-K1i \cdot t} \\ m_{2t.i} = m_0^b - (m_o^b - m_t^b) \cdot e^{-K2i \cdot t} \\ m_{3t.i} = m_0^b - (m_o^b - m_t^b) \cdot e^{-K3i \cdot t} \\ m_{4t.i} = m_0^b - (m_o^b - m_t^b) \cdot e^{-K4i \cdot t} \end{cases}$$

where t is the temperature; q_i is the intensity of the process thermal flux; dh is the cell height; F is the surface area; j is a layer; i is a point in time; l_m is the meat thermal conductivity; c_m is the meat heat capacity; m_c is the cell mass; K_1, K_2, K_3, and K_4 are rate constants for denaturation of actin, tropomyosin, myosin, and myoglobin, respectively; m_0^b is the mass of the initial product at $\tau = 0$; m_t^b is the mass of the processed product at $\tau = 0$; pH is the medium acidity; m_{1t}, m_{2t}, m_{3t}, and m_{4t} are the masses in the processed product (denatured protein) of actin, tropomyosin, myosin, and myoglobin, respectively (a layer in this instance means a cell 5 mm in height or, if three-dimensional, a cube, each face of which is 5 mm). The temperature changes along the meat layers lead to quantitative changes in the proteins (myosin, actin, tropomyosin, myoglobin) that affect the quality of the final product (softness, toughness, consistency).

Heat treatment in the first regime continued for 620; second, 540; third, 490; for the preferred method, 600 s. In the first regime, the time interval for protein denaturation with an input radiant flux of 600 kW/m^2 is 180 s. At 800 kW/m^2, denaturation begins much more quickly than in the first regime. Tropomyosin is 55% denatured. Myosin is 50% denatured, which is 10% less than in the previous regime. For an input radiant flux of 1000 kW/m^2, the item is heated much more strongly. The denaturation process also intensifies. After 360 s, actin is denatured 8% less than in the first regime; 4% less than in the second. The denaturation of myosin in the whole item volume takes 240 s. The mass of denatured myosin is 42%, which is 18% less than in the first heat-treatment regime and 8% less than in the second.

A comparison of bilateral IR energy input indicates that the most suitable heat-treatment regime is two-stage with bilateral IR energy input. Radiant energy of lower density must act on the item. Then, radiant energy of greater density should be applied to form an even surface coloration and greater yield of denatured proteins. Using the preferred method (two-stage

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regime: first stage, 4 kW/m^2 flux density; second 8 kW/m^2), the total mass of denatured myoglobin was 52%; actin, 36; tropomyosin, 51; and myosin, 48.

Let us examine the two-stage regime from the viewpoint of biotechnology. In the first minutes, the lowest density radiant flux is applied because most meat proteins start to denature when a layer reaches 37 °C. Higher temperatures can have a negative effect upon the product quality. With very fast denaturation, there is a high probability that the meat will be tough. Therefore, we recommend first preparing the proteins for denaturation by applying a low-power radiant thermal flux. Then, the flux power is increased to accelerate the denaturation and ensure the highest yield of denatured protein. With such a heat-input regime, the denaturation of meat proteins continues for 480-600 s, of the principal protein myosin, for 140 s at temperatures of 37-53°C. Actin denaturation occurs for 240 s at 37-80°C; tropomyosin, 360 s because this protein is the most stable to high temperatures; myoglobin, 600 s at 30-80°C.

Thus, practically all meat proteins are denatured after 600 s.

Various temperature and thermal-flux density regimes were selected using the mathematical model and a computer program. Based on a comparison and practical use of this model, the regime and results of the last regime are most rational.

REFERENCES

1. M. A. Belyaeva, *Khranenie Pererab. Sel′khozsyr′ya*, 6 (1997).
2. M. A. Belyaeva, *Khranenie Pererab. Sel′khozsyr′ya*, 4 (1999).
3. M.A. Belyaeva, P. R. Ismatullaev, and A. A. Artikov, *Thermal Equipment and Processes in the Production of Meat Items* [in Russian], TKTI, (2003).
4. M. A. Belyaeva, in: Abstracts of the 5th International Symposium, Tashkent (2003), p. 57.