KINETICS OF MOISTURE TRANSFER AT CURING UNCOOKED - SMOKED AND UNCOOKED - CURED SAUSAGES.

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INTRODUCTION

The process of curing of uncooked - smoked and uncooked - cured sausages takes place in chambers during 15 - 30 days at the temperature 10 - 15°C and relative humidity 70 - 85 % along with dehydration processes and is followed by a transformation of structures. The primary structure of a viscous-ductility body (minced meat) changes to an elastic structure of a ready product. The transformations of structures can be related to a transition of moisture from one form of link into another and by the nature of the course they can be referred to physic-chemical and chemical reactions of the Ist order (1) In the curing chamber a low temperature and an increased relative humidity create conditions under which the flow of the moisture mass removed from the sausage loaf is rather insignificant and varies very little in time. That eliminates warping of sausage links and a formation of hardening. As this takes place the main portion of the moisture removes from curing sausage links traversing through a transformation of structures. Nevertheless a portion of the moisture initially contained in the minced meat will leave from sausage links in the curing chamber bypassing the transformation of structures, i. e. just by direct drying :

$$\frac{dw}{d\tau} = -\kappa_0 (w - w_p) \qquad (1)$$

where w - a current value of an average (by volume of moisture content), product, kg / kg of a dry substance, %; w_p - equilibrium moisture content, kg / kg , %; κ_0 - velocity ratio of drying, s^{-1}; τ - time, s.

The solution of this equation allows to describe the variation of the average value of the moisture content of the product by time without considering the transformation of structures in the form of an exponential function.

PURPOSE

An attempt is made to explain numerically the correlation between changes accompanying the process of curing of ausages.

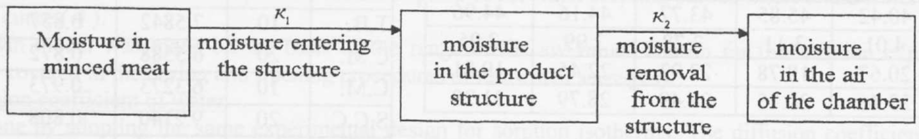
METHODS

In order to obtain summarized thematical relathionships methods of joint solution of functional equations.

RESULTS AND DISCUSSIONS

First we shall observe a dehydration process wherein the whole moisture arrives in the structure of the product as well as removes from it to the atmosphere. The dehydration process of such kind can be represented as the following scheme:

Scheme 1



Let's assume that the moisture departing from minced meat at the destruction of the structure and entering some intermediate structure is kept in it by means of link forces differentiated from the initial ones.

The variation of the moisture content in the minced meat structure will be in conformity with the equation of chemical kinetics of the Ist order, similar to the relation (1)

$$\frac{dw}{d\tau} = -\kappa_1 w, \qquad (2)$$

where κ_1 - velocity ratio of the destruction of a minced meat structure.

Integration of this relation from 1 to W_1 and from 0 to τ gives an exponential function accounting for a relative content of moisture in a minced meat structure.

$$w_1 \; e^{-\kappa_1 \tau} \qquad (3)$$

or taking into account the initial and equilibrium moisture content

$$w_1 = (w_0 - w_p) \cdot e^{-\kappa_1 \tau} + w_p, \qquad (3a)$$

where w_0 - a moisture content of a source minced meat structure, kg/kg, %.

It is of some interest the variation of the moisture content in a product structure with time. It can be obtained from a kinetics equation of the Ist order of the following form.

$$\frac{dw}{d\tau} = -\kappa_2 w + \kappa_1 w_1 \qquad (4)$$

The first addend in the right part accounts for a loss of moisture by the product structure in the atmosphere of the curing chamber, and the second addend accounts for a moisture arrival from the structure of minced meat. As this takes place it is anticipated that some moisture content corresponding to the equilibrium value of the moisture content is necessarily present both in a source minced meat, and in a ready product.

The integration of the equation (4) from (w_0 - w_p) to W and from 0 to τ allows to obtain a relation accounting for variations of a moisture content with time in an elastic sausage structure.

$$w = (w_0 - w_p)\frac{\kappa_1}{\kappa_1 - \kappa_2}(e^{-\kappa_2 \tau} - e^{-\kappa_1 \tau}) \qquad (5)$$

During a curing process moisture will be present in a product both in a source, non-destroyed minced meat structure and in an elastic structure characteristic for a ready product. The relation summing over both components has the following form:

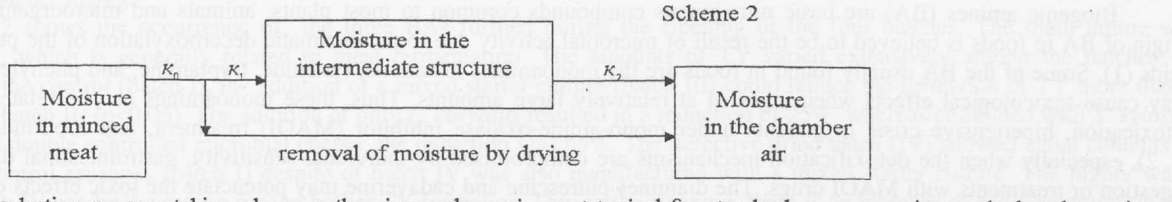
$$w(\tau) = \frac{w_o - w_p}{\kappa_1 - \kappa_2}(\kappa_1 \cdot e^{-\kappa_2 \tau} - \kappa_2 \cdot e^{-\kappa_1 \tau}) + w_p \qquad (6)$$

The derived relationship is identical to the relationship which has already been used before for a description of beef thermal treatment [2]. At curing of uncooked - smoked and uncooked - cured sausages this process is made possible as a special case, for example when removing hardening.

It is worthy of note that in the case $\kappa_1 >> \kappa_2$ and $\kappa_1 >> \kappa$, the relationship (6) practically will not differ from an ordinary exponential function.

Let's consider a process wherein one part of the moisture removed from minced meat arrives in a product structure, and the other part is removed directly by drying (scheme 2).

Scheme 2



The dehydration process taking place on the given scheme is most typical for standard sausage curing such that the moisture from the superficial layers of sausage loaves is intensively removed through evaporation, whereas there is a transformation of structures in the inner part of the loaf at a slight dehydration. The relation accounting for a variation of a moisture content in this case can be obtained by summing up the relation (5) and an exponential function of the form (3a) and a velocity ratio κ_0.

$$w(\tau) = (w_0 - w_p)\left[e^{-\kappa_0\tau} + \frac{\kappa_1}{\kappa_1 - \kappa_2}\left(e^{-\kappa_2\tau} - e^{-\kappa_1\tau}\right)\right] + w_p \qquad (7)$$

The curves obtained by means of computerized calculations for a number of κ_0, κ_1, κ_2 values with the use of the above indicated formulas are sketched on the plot (see Fig. 1).

The plots of relationships (6) and (7) as also is the classical drying curve present lines asymptotic diminishing from the initial value, in doing so the curves shape depends on the relationship of the taken ratio values.

Figure 2 illustrates the correlation of the calculated curves obtained for five values of ratio κ_2 under invariant values of κ_0 and $_1$.

The correlation of moisture content values obtained experimentally during the aging process in the curing chamber (dots in Fig. 2) shows that for uncooked - smoked sausages, with a trading name «Extra», the process can be described with the use of ratios $\kappa_0 = 3{,}8 \cdot 10^{-6}\ s^{-1}$; $\kappa_1 = 1{,}26 \cdot 10^{-6}\ s^{-1}$ and $\kappa_2 = 10^{-6}\ s^{-1}$. It is worth noting that absolute values of these ratios depend on operating conditions of a curing chamber, however the correlation of their quantities may serve as an operational feature of setting up the process efficiently and determine the quality of a ready product. In this instance the correlation comes to 1,0 : 0,33 : 0,26.

The distribution of the experimental dots along the curves obtained analytically with a root-mean square deviation less than 3% supports the acceptability of the chosen 2nd process specifying scheme.

CONCLUSION

The obtained kinetics relationships allow quantitatively to justify the mechanism of the processes taking place at a dehydration of uncooked - smoked and uncooked - cured sausages at curing and, by doing so, is useful in selecting optimal operating processing conditions.

LITERATURE

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2. Nikolaev N. S., Afanasov E. E. Variation of minced meat moisture at processing. «Meat Industry» No. 5, 1995.

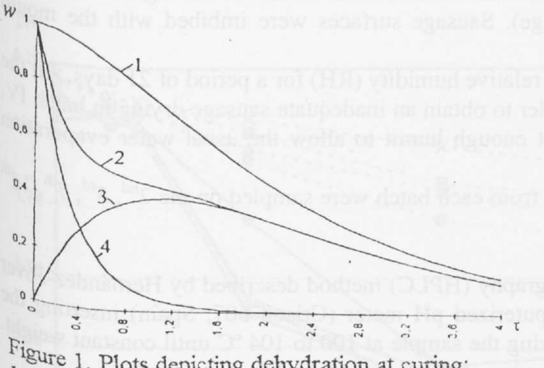


Figure 1. Plots depicting dehydration at curing:
1- scheme 1-(6); 2 - scheme 2-(7); 3 - (3); 4 - (5);
($w_0 = 1$, $w_p = 0$, $\kappa_1 = 1{,}0$, $\kappa_2 = 0{,}8$)

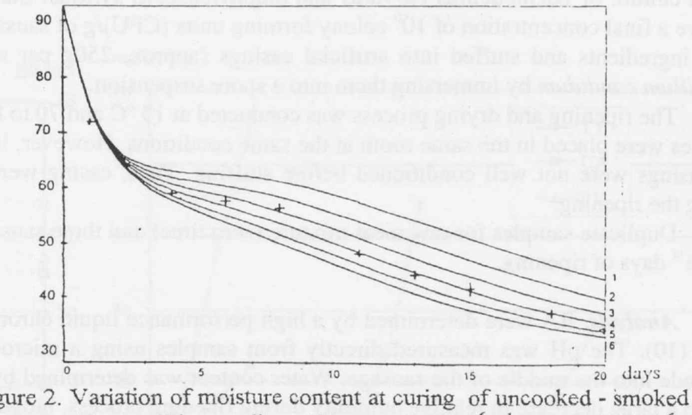
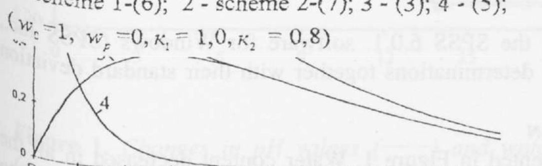
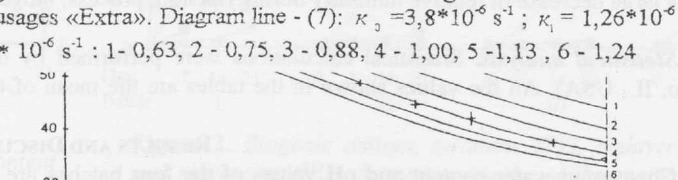


Figure 2. Variation of moisture content at curing of uncooked - smoked sausages «Extra». Diagram line - (7): $\kappa_0 = 3{,}8 \cdot 10^{-6}\ s^{-1}$; $\kappa_1 = 1{,}26 \cdot 10^{-6}\ s^{-1}$
$\kappa_2 \cdot 10^{-6}\ s^{-1}$: 1- 0,63, 2 - 0,75, 3 - 0,88, 4 - 1,00, 5 -1,13, 6 - 1,24





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