ON THE DYNAMICS OF CURING AGENTS PENETRATION AND REDISTRIBUTION IN MEAT

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SUMMARY

The character of curing agents penetration and redistribution in pierced and mechanically treated meat has been specified.

As a result of the work conducted it has been established that the samples subjected to mechanical treatment had a higher rate of sodium chloride penetration as compared to the pierced samples, the rate of sodium chloride penetration depending on the distance between punctures. Evidently, the increased rate of curing agents penetration is due either to the disruption of the native meat structure, or to the punctures (microcapillaries), or to mechanical effects (the formation of a new microcapillary system).

INTRODUCTION

In spite of a great number of publications on meat curing (Krause, 1978; Stupin, 1982, Eryomina, 1973; Rust, 1983), the mechanism of curing agents penetration and redistribution is not clear yet. Bolshakov et al (1977, 1981, 1982), when studying the process of meat curing under mechanical effects, have established that curing agents distribution depends greatly on the piezo-conductivity and is described with a filtration equation. In this case, as the authors claim, the filtration rather than the diffusion transfer of curing agents takes place. The filtration theory made it possible, on the whole, to explain meat curing intensification under mechanical effects, but it is difficult to account for no intensification of curing the samples injected and tumbled for 20 min as compared to those injected but not tumbled, though under meat mechanical treatment piezo-conductivity grows, and more intensive penetration and redistribution of curing agents could be expected. It is obvious that brine penetration and redistribution under mechanical treatment of meat is due not only to filtration processes.

The aim of the present study was to specify the character of curing agents penetration and redistribution in meat. The test object was m.longissimus dorsi from chilled carcasses of young beef animals 2 days post mortem (pH 6.2). Samples were cored from it (10 x 10 cm). Some samples were pierced with a needle having the 0.8 mm diameter, the distances between the punctures being 1.7; 2.5; 3.3 mm, respectively. The other samples were treated mechanically for 20 minutes. Samples, which were not subjected to any treatment, served as controls.

Samples were fixed in such a way, that only their bottom ends contacted the brine.

The penetration dynamics was judged by NaCl and $NaNO_2$ penetration depth after every 15 minute interval. Sodium chloride was determined by the standard method, sodium nitrite - by meat colour. For this, samples were cooked in water at 98°C for 3 minutes.

When analyzing the dynamics of sodium chloride and sodium nitrite penetration in all the samples, its unsteadiness should be noted: intensive penetration - retarding - again intensive penetration and penetration rate growth with distances between punctures becoming smaller (see Figure). E.g., the penetration rate in case of controls within the first 60 minutes was 0.45 mm/min, within the following 75-150 min - 0.08 mm/min, then it grew again (0.2 mm/min) and fell again (0.05 mm/min). In the samples with 2.5 mm between punctures, the rate of sodium chloride penetration during the first 30 minutes was approximately 1.0 mm/min, and in the range of 45-135 min - 0.13 mm/min. The samples, subjected to mechanical treatment, had, in general, a higher NaCl penetration rate than other samples. Obviously, a higher rate of curing agents penetration is due either to the disruption of the native meat structure, or to piercing (microcapillaries), or to mechanical treatment (the formation of a new microcapillary system).

To describe the process of meat curing, we use the porous body model. We suppose that, when meat contacts the brine, its swelling and curing ingredients penetration take place simultaneously. When the liquid moves in through capillaries due to capillary forces the rate of the liquid travel is directly proportional to the capillary radius, to the difference in capillary and hydrostatic pressures and inversely proportional to the liquid rise height and to the dynamic viscosity, and is defined with the expression:

$$dl/dt = r^2 \Delta P/8 \mu l \qquad (I)$$

where $\Delta P = P_c - P_h$ is difference between capillary and hydrostatic pressures, $P_c = 2\sigma\Theta \cos \Theta/hr$ and $P_h = \rho g l \sin \alpha$; σ is surface tension, Θ is wetting boundary angle, l is length of a moistured capillary, ρ is liquid density, t is time, g is gravity, α is angle of a capillary slope relative to the horizontal plane. If $dl/dt = O$, it follows from formula I, that the maximum height of penetration is determined with the expression:

$$l_\infty = 2\sigma \cos \Theta/r \rho g \sin \alpha \qquad (2)$$

Then, with account for Eq.2, Eq.I may be written as follows:

$$dl/dt = A(l_\infty - l),$$

where A is proportionally coefficient, which relates the rate of the liquid rise in a capillary to the difference between the maximum possible level of the liquid rise in a capillary and the actual level at a given moment, and it is determined with the expression:

$$A = r^2 \rho g \sin \alpha/8 \mu l \qquad (3)$$

Equation 3 does not, however, take into account the plurality of horizontal pores through which brine is partly distributed, thus lowering the rate of curing ingredients penetration.

To take into account side flow of brine, let us view a meat curing model which has "N" vertical through capillary channels bound with the system of side capillaries. Here brine would not move up until the side capillaries are filled. As hydrostatic pressure does not interfere with capillary forces in the course of side pores filling, i.e. $P_c >> \rho g \sin \alpha$, side capillaries are filled much faster than the brine rises.

Then the side flow Q of brine is

$$Q = m\pi R^2 \Delta l, \qquad (4)$$

where Q is amount of brine is side capillaries: m - meat porosity; l - brine height in a capillary; R - radius of meat volume around one through vertical capillary which feeds its side capillaries.

With account for the desired balance achieved we derive the equation for brine travel in the meat, in which the first term characterizes an increase of liquid volume in vertical pores, the second term stimulates liquid's rise due to capillary forces, the third one indicates liquid's flow into horizontal pores thus slowing down the liquid rate in pores:

$$\pi r^2\, dl/dt = \pi r^2 a(l_\infty - l) - m\pi r^2\, dl/dt$$

After transformations we get:

$$dl/dt = a(l_\infty - l) - B\, dl/dt$$

where B is the parameter accounting for slowing down the liquid in vertical pores due to the presence of horizontal pores and described by the equations:

$$B = mR^2/r^2$$

or

$$dl/dt\,(I + B) = A(l \quad - l) \qquad (5)$$

Integrating equation 5 to the initial conditions at t = O, we get

$$l = l_\infty\left(I - \exp\left(-\frac{A}{I + B}\,t\right)\right) \qquad (6)$$

Thus, as is seen from Eq.6, meat curing is realised due to capillary forces till brine penetration depth is less than l_∞. If the width of a meat piece exceeds l_∞, then brine penetrates into it, the latter being beyond l_∞ only because of curing ingredients diffusion, i.e. the mechanism of penetration changes, it becomes substantially slower.

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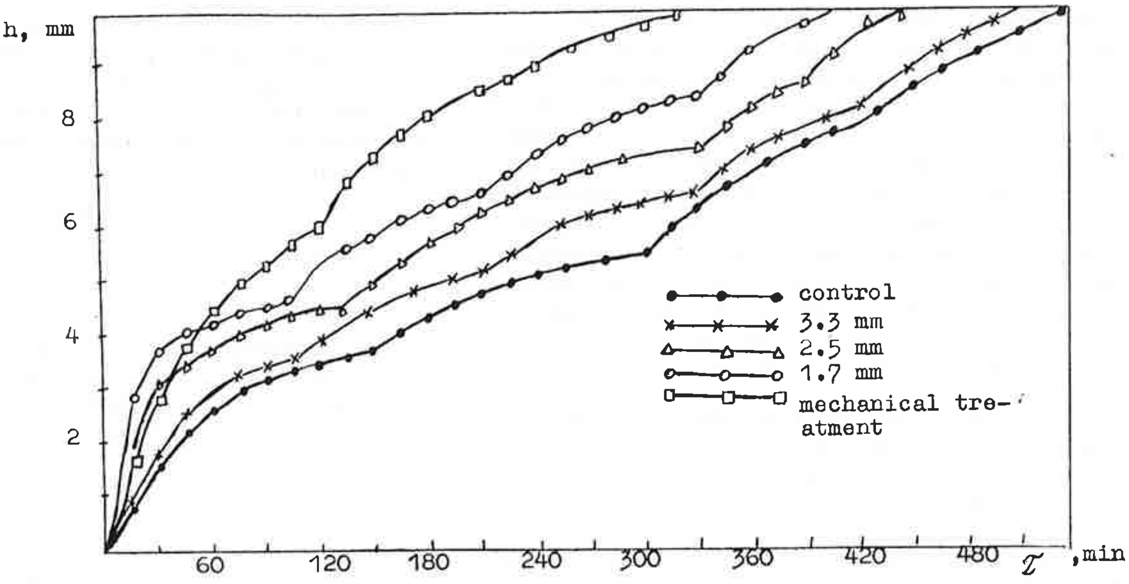

Fig. Curves of sodium chloride penetration into beef subjected to pierceing (distances between punctures being 1.7, 2.5 or 3.3 mm) and mechanical treatment (τ = 20 min).