PENETRATION OF SALT AND NITRITE IN THE PILOT PROCESS OF CURING AND DEHYDRATION OF DRY-CURED HAM

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BACKGROUND

Diffusion of salt, nitrate and nitrite in meat during curing has been studied by many researches. Simplified models of curing process were developed for experimental purposes to calculate the diffusion constants and to determine interactions between the diffusing substances. However, no uniform theory of curing raw meat of untouched structure has been developed to date and probably it never will be. The number of variable and interfering factors is too great to create an algorithm describing all the occuring phenomena with acceptable estimation error.

In that situation the authors attempted to work in a different way than the others. Instead of developing the next models of the diffusion process, being always far away from what could be accepted for practical application, a pilot production was organized and conducted in conditions very close to those in the commercial practice and, above all, complete hams were used, i.e. the scale was as 1:1.

METHODS

Pilot production of dry-cured ham was carried out. Five porcine hams of similar weight and pH 5,6 to 5,8, from pigs of Large White breed were used in curing process. They were deboned first, formed and the outer layer of skin and fat was maintained. The curing mixture of salt with 300 mg sodium nitrite per 1kg of meat was rubbed onto ham surface and then they were dredged with large amount of coarse-grain rock salt. Each ham was placed into a separate container and cured for 4 weeks at 4÷6°C. After that period salt was removed from the surface and the hams were washed, dried and hanged in a cooling chamber for drying and ripening for 7 weeks at 4÷6°C air temperature relative air humidity approximately 80%. Cylindrical samples representing the hams from one surface to the other were taken with a special sampler. Sampling was carried out each week beginning from the third week of curing. Meat samples were taken according to the programmed sequence of time and in this way samples from different hams were used in the successive examinations. Figure 1 demonstrates the formed hams and sampling points. The sampling holes were filled with solidifying lard and further drying and ripening of hams was continued. The samples were split into three layers and the following determinations were carried out in meat: water content (W) by the drying-oven method; sodium chloride content (S) by Mohr method; nitrate (NA) and nitrite (NI) content by colorimetric method with Griess reagent and reduction of nitrate to nitrite in a column filled with cadmium, using flow injection analysis (Kłossowska).

RESULTS AND DISCUSSION

The concentrations of NaCl in the water fraction of meat, in the sample taken parallely to the subcutaneous fat layer, in the function of time (t_n) are presented in Figure 2. These relationships show nearly linear form and may be approximated by the equations:

$$C_j^n = a_j t_n + b_j \qquad (1)$$

where:

$$C_j^n = \frac{S_j^n}{S_j^n + W_j^n} \cdot 100\% \qquad (2)$$

The values of a_j and b_j constants in the equation (1) and correlation coefficients are given in Table 1.

With the C^n_j values calculated from equation (1) and with the application of Crank - Nicholson equation, the values of effective diffusion coefficients D_{ef} could be calculated according to the equation:

$$D_{ef} = \frac{2(\Delta x)^2}{\Delta t} \cdot \frac{C_j^{n+1} - C_j^n}{(C_{j+1}^{n+1} - 2C_j^{n+1} + C_{j-1}^{n+1}) + (C_{j+1}^n - 2C_j^n + C_{j-1}^n)} \qquad (3)$$

in which: Δx = thickness of meat layer
Δt = time interval

Relationship was found between the calculated D_{ef} values and the drying and ripening time. D_{ef} values for the direction perpendicular to the fat layer declined with time and ranged from $0.72 \cdot 10^{-5} \cdot cm^2 \cdot s^{-1}$ to $0.59 \cdot 10^{-5} \cdot cm^2 \cdot s^{-1}$, while for the direction parallel to the fat layer increased with time and ranged from $0.29 \cdot 10^{-5} \cdot cm^2 \cdot s^{-1}$ to $0.33 \cdot 10^{-5} \cdot cm^2 \cdot s^{-1}$.

The relationship between the sum of nitrite and nitrate concentration in the water fraction of meat and the time t_n point to the much more complicated character of the process. Figure 3 demonstrate that there is a clear maximum of nitritte and nitrate concentrations in the middle time interval. The mode of calculation similar to that for sodium chloride facilitated the calculation of the effective diffusion coefficients for the sum of nitrite and nitrate concentrations in the water fraction of meat over the initial four periods (from 3 to 6 weeks). The effective diffusion coefficients calculated in that way were as follow: from $0.15 \cdot 10^{-5} \cdot cm^2 \cdot s^{-1}$ to $0.10 \cdot 10^{-5} \cdot cm^2 \cdot s^{-1}$ in the case of direction perpendicular to the fat layer and from $0.25 \cdot 10^{-5} \cdot cm^2 \cdot s^{-1}$ to $0.34 \cdot 10^{-5} \cdot cm^2 \cdot s^{-1}$ in the case of direction parallel to the fat layer. The rapid drop of nitrite and nitrate concentrations in the second part of drying and aging period may be ascribed to the accelerated decomposition rate of nitrite to nitrogen oxide, particularly in the ham surface layer. It is difficult to explain the cause of the accelerated decomposition rate of nitrites. Analysis of the change in the nitrite to nitrite and nitrate ratio $P = \frac{NI}{NI + NA}$ during the production process revealed that it was declining at a relatively uniform rate from the beginning of the process. The relationship between the P ratio and the duration of production process is shown in Figure 4. It can be seen that during the whole period the P value was found higher in the surface layer than in the deeper layers, however, the rate of P value decline may be regarded as uniform for all layers of meat. Certain increase of total penetration rate may be ascribed to the formation of nitrates because it has been known that their diffusion rate is higher that of nitrites (Fox). However, it should have no influence on the whole picture of the phenomenon since the increasing salt content in the muscle tissue has, probably, an inhibitory effect on both nitrite and nitrate diffusion rate.

CONCLUSIONS

1. The examination method of chloride and nitrite penetration in meat is presented on a model of 1:1 scale of the production process of dry-cured ham.
2. Sodium chloride penetration being in accordance with the low of diffusion can be expressed by simple equations if its concentration in meat is calculated as brine concentration.
3. In the initial phase of salting and ripening i.e. until the sixth week, the penetration of nitrites and nitrates was proceeding in accordance with the law of diffusion and afterwards the concentrations of nitrites and nitrates were rapidly decreasing and that phenomenon has dominated the diffusion.
4. The transformation of nitrites into nitrates proceeded over the whole process at a constant rate and the smallest degree of transformation was noted at the surface layer of meat.
5. Penetration of sodium chloride, nitrites and nitrates in the perpendicular direction was twice as fast as in the parallel direction to the fat layer.

REFERENCES

Fox B.J., jr., Diffusion of chloride, nitrite and nitrate in beef and pork. J. Food Sci., 1980, 45, 1740 - 1744

Klossowska B., Determination of nitrite and nitrate in meat products using flow injection analysis, Roczniki Instytutu Przemysłu Miesnego i Tłuszczowego, 1997, T. XXXIV, 179 -188

TABLE 1

Number of layer	Direction					
	Parallel to fat layer			Perpendicular to fat layer		
	1	2	3	6	5	4
Layer denotation	j-1	j	j+1	j-1	j	j+1
a,	1,19	1,23	1,22	0,75	0,98	1,24
b,	5,63	1,92	1,08	9,29	4,22	0,00
r	0,99	0,98	0,97	0,98	0,96	0,98

Fig. 1

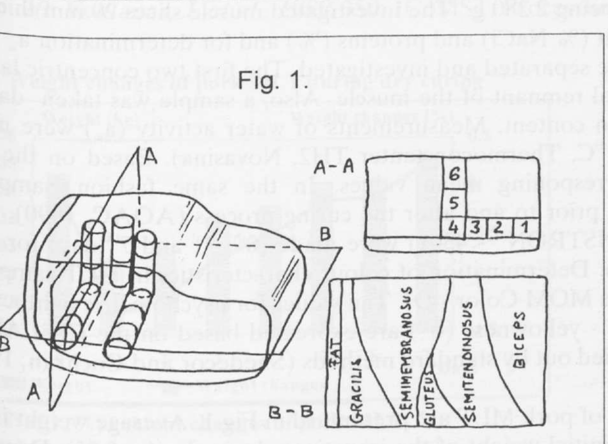

Fig. 2

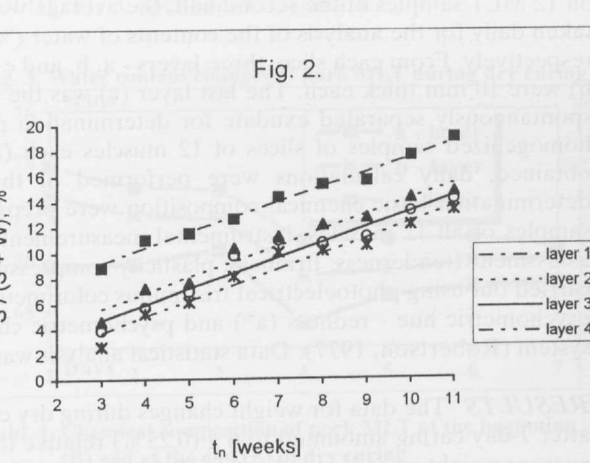

Fig. 3.

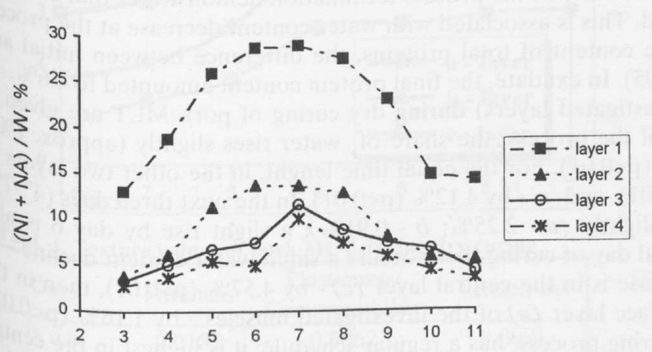

Fig. 4.