Simultaneous thawing and curing of pork pieces

SLOBODAN ŠIBALIĆ, DEJAN SMILJANIĆ* and MILOVAN DJORDJEVIĆ

Yugoslav Institute of Meat Technology, Beograd

*Veterinary Faculty, Institute for Animal Products, Beograd, Yugoslavia

Summary

The possibility of thawing the frozen pork pieces by mixing them at a certain proportion with the chilled meat and brine has been studied. The thermal balance of such a process has been laid down and several plant experiments performed, which gave encouraging results.

Introduction

The storing of meat in the frozen state is broadly recognized as an adequate means to postpone its use, but in certain instances it rises difficulties in the further processing of the meat. In the production of the fine-cut sausages (e.g. frankfurters), the curing of the frozen meat can be achieved along with its comminution in the bowl-chopper which, however, is not the case when the final product is to include the coarsly cut meat. Since thawing and curing of such pieces take relatively much time, the present work has been aimed to the possibility of performing them simultaneously. The intention has been to accomplish the thawing of the frozen meat-pieces within the limited period of about a day, by mixing them with a certain quantity of chilled meat and brine.

Materials and techniques

The pork trimmings of hams and shoulders were used in all the experiments of the present work. Part of the raw material was used as "chilled meat" and the other part, after being previously quick-frozen in blocks and stored at $-18^{o}C$, as "frozen meat". The average moisture and fat content amounted to 66% and 11% by weight, resp., and the pH value equalled to 6,43.

Frozen meat, cut into 3x3x7 cm pieces was shortly mixed up in a tumbler with the pieces of chilled meat (3x6x6 cm), and the mix (480 kg) was poured into the massaging machine (720 kg capacity), equipped with 3 arms of square cross-section. Thereupon, 120 kg of brine (15% of salt, 2% of polyphosphate, 1,5% of dextrose and 0,05% of nitrite) was added, and the whole content has been massaged for the first 5 hs. acc. to the schedule: 20′ operation - 10′ rest, and after that (up to 24 hs.) acc. to the schedule: 1′ operation - 29′ rest. The moisture and fat content of the product amounted to 69,1% and 8,8%, resp.

The temperatures of the raw materials, of the mix in the massaging vat, as well as of the ambient air, were recorded by the digital thermometer. The thawing and the curing degree were evaluated sensorily. The properties of the cured meat were also chequed in the course of its further processing.

375

Results and discussion

In order to facilitate the choice of the experimental parameters for the process described, its thermal balance has been laid down as follows:

$$H^{p} = \frac{Z.H_{fm} + H_{cm}}{1,25\ (1+Z)} + 0,2\ H_{b} + Q_{o}\ (\frac{kJ}{kg}) \ldots\ldots\ldots\ (1)$$

where H^{p}, H_{fm}, H_{cm} and H_{b} represent the enthalpies of the product (cured meat), frozen meat, chilled meat and brine, resp., and Z is the mass ratio of the frozen to chilled meat used. Q_{o} makes the thermal gain from the surrounding during the process time. The differential change in enthalpy during the thawing of the meat reads:

$$dH = c.dt + dr_m \quad \left(\frac{kJ}{kg}\right)\ldots\ldots\ldots \quad (2)$$

where "c" represents the heat capacity of meat and "r_m" its latent heat of freezing. Both these quantities depend on the moisture content - m_w of meat, as well as on the weight fraction of the frozen water in meat - X. Acc. to J a s p e r and P l a c z e k[1], the heat capacity of meat can be calculated as follows:

$$c = 4{,}184\ (0{,}8-0{,}5\ X)\ .\ m_w + 0{,}837 \quad \left(\frac{kJ}{kg\ K}\right)\ \ldots . \quad (3)$$

and the latent heat of freezing is:

$$r_m = 333{,}84\ .\ m_w .\ X \quad \text{ie.} \quad dr_m = 333{,}84\ .\ m_w\ .\ dX \quad \left(\frac{kJ}{kg}\right)\ldots\ldots \quad (4)$$

The fraction of the frozen water - X is, however, the function of temperature, which, after C h i z h o v[2], can be expressed as follows:

$$X = \frac{1{,}105}{1 + \dfrac{0{,}31}{lg\left[t + (1-t_{cr})\right]}} \quad \left(\frac{kg}{kg}\right)\ldots\ldots \quad (5)$$

wherein the actual (t) and cryoscopic (t_{cr}) temperatures of meat enter as absolute values.

Combination of the first derivative of the eq.5 with the eqs. 2, 3, 4 and 5 gives the general expression for the differential change of meat enthalpy:

$$\frac{dH}{dt} = \left\langle 3{,}3472 - \frac{2{,}3117}{1 + \dfrac{0{,}31}{lg\left[t + (1-t_{cr})\right]}} + \frac{49{,}6755}{\left[t + (1-t_{cr})\right]\cdot\left\{0{,}31 + lg\left[t + (1-t_{cr})\right]\right\}^2}\right\rangle m_w + 0{,}837 \quad \left(\frac{kJ}{kg\ K}\right) \quad (6)$$

in which the second and the third term equal to zero when the temperature is higher than cryoscopic.

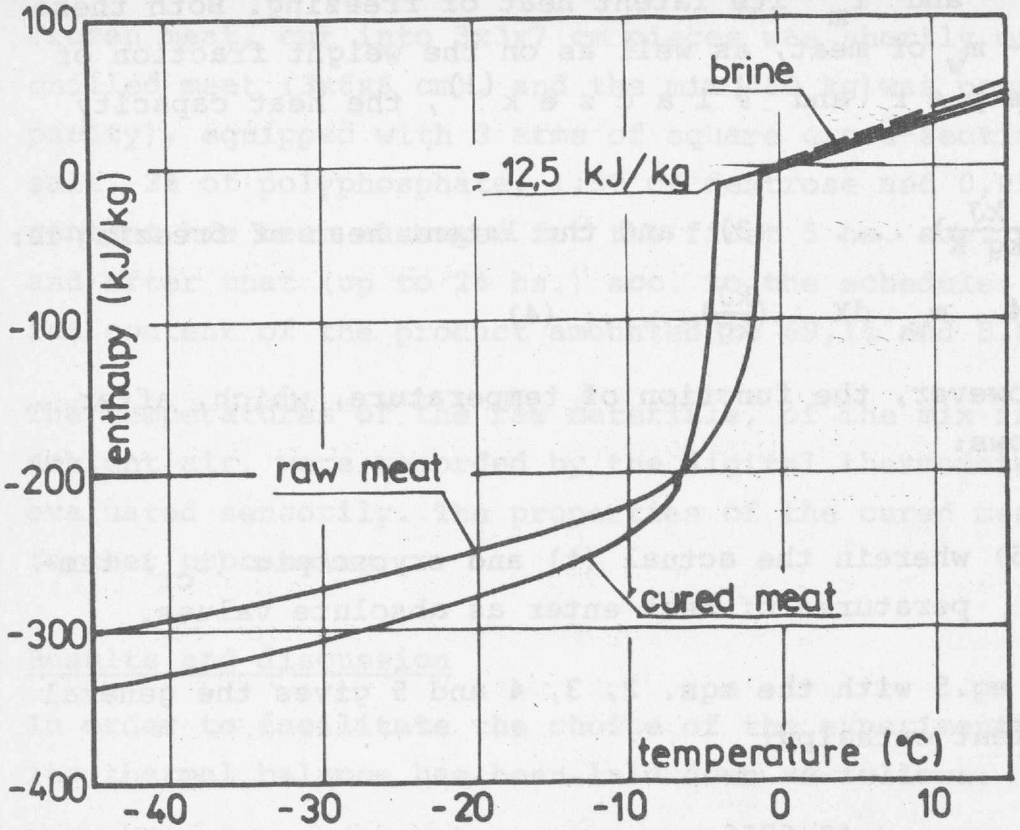

Fig.1. Enthalpies of raw meat, cured meat and brine

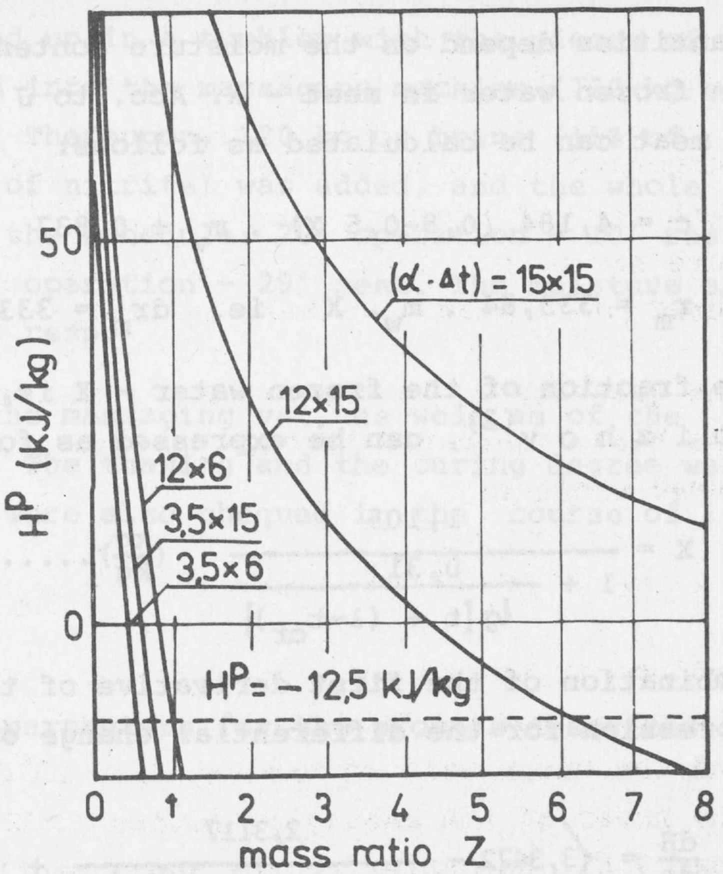

Fig. 2. Enthalpy of the simultaneously thawed and cured meat as the function of the mas-ratio Z

The meat entalpies, which stand in eq. 1, are simply calculated as the integrals of the eq.6, by choosing the reference temperature - t_o:

$$H_i = H_i^t - H_i^o = \int_{t_o}^{t} dH_i \quad \text{.........} \quad (7)$$

Fig.1 represents numerically obtained solutions of the eq. 7 for the raw and the cured meat in the temperature region between -45 and +15°C, along with the enthalpy of the brine (approximated with the 15% aqueous soln. of NaCl)[3] for the temperatures above zero. The reference temperature has been choosen to be 0°C, and the cryoscopic temperatures of the raw (-1°C) and the cured (-4°C) meat have been determined by an independent experiment.

The quantity Q_o in the eq. 1, is the summ of the heat, transfered from the ambient air, and the heat, generated through the operation of the massging device, all brought to 1 kg of the cured product:

$$Q_o = \frac{1}{m_p} \cdot [\alpha.F.\Delta t.\tau + N.\tau_{eff}] \quad \text{.....} \quad (8)$$

where "m_p" amounts to 600 kg; α is the heat transfer coefficient from the surrounding air to the outer wall of the vat (3,5 - 12 W/m^{2}h for the still air); F is the area of the outer vat surface (ca. 5 m^2); Δt is the temperature difference between the ambient air and the outer wall of the vat (5 - 15°C); τ - the duration of the process (16 - 24 h); N is the power of the massiging device (1 HP = 735,5 W) and τ_{eff} is the effective time of massaging (ca. 4 h). Encountering the above mentioned values, eq. 8 can be simplified:

$$Q_o = 0,03\ (\alpha.\Delta t)\cdot\tau + 17,7\ \left(\frac{kJ}{kg}\right) \quad \text{.....} \quad (9)$$

By choosing the values of (α.Δt), as well as of τ, the quantity Q_o becomes defined and can be brought in eq. 1. Now the enthalpy of the cured meat becomes the function of the ratio Z only. Fig.2 shows this function for the various possible values of (α.Δt), along with:

τ = 24 h; t_{fm} = -17°C; t_{cm} = +7°C and t_b = +7°C. The intersection point of curves $H^p = f(Z)$ with the line H^p = -12,5 kJ/kg corresponds approximately to the mass ratio Z_c, necessary for the complete thawing of the meat, which can be easily explained by looking on Fig.1. This critical ratio, Z_c, very strongly depends on the value of the product ($\alpha . \Delta t$), and under the most favourable conditions, it does not excide the value of 6. In practice, it can be expected to be rather less, about 1.

To verify the theoretical conclusions obtained, seven plant experiments were performed, under the different conditions. Compared to the normal procedure (Exps. 1 and 2), described previously, the later experiments were modified in order to reach as high a quantity of the liquid phase as possible in the frozen meat, at the begining of the process, to insure enough time for the diffusion of the brine constituents. These modifications were as follows: Exp.3: All brine and 1/3 of the frozen meat were massaged for one cycle (30'), whereupon the 2nd/3 of the frozen meat was added, and similarly massaged for another cycle (30'). Finaly, the remainder of the frozen meat and the whole of the chilled meat were added, after being previously shortly tumble-mixed. Exp.4: Brine and the frozen meat were massaged for one cycle (30'), and then the chilled meat was added. Exp.5: The same as in Exp.4, except for massaging which lasted 60'. Exp.6: The frozen and the chilled meat were shortly comminuted in the cutter (to the size of 5-10 mm), and than poured into the brine in the vat. Exp.7: The frozen meat was tumble-mixed with dry salt for 40', thereafter poured into the vat together with the necessary quantity of the "saltless" brine, massaged for 60', and than the chilled meat was added.

The main parameters of these experiments, as well as the results obtained appear in the Table 1.

Having in mind the approximations included, as well as the unsteadiness of the parameters encountered, the agreement between the calculated and the observed final temperatures of the cured product seems reasonalby good. Moreover, some differences could be explained. During the

Exp.4 there has been a slight circulation of air in the chamber for mechanical processing, and in the Exp.6 there has been a small temperature rise of meat caused by the action of bowl-chopper, but neither of these circumstances has been included in the calculations.

Table 1. The principal parameters of the plant experiments

Exp. No.	1	2	3	4	5	6	7
Mass ratio Z	1:1	1:1	1:1	1:2,2	1:2,2	1:1	1:1
Duration of the experiment (h)	20	24	20	20	20	20	16
Temperature (^{o}C) of							
frozen meat	-18,5 -43,6 }*	-17	-14,9	-13,8	-17,2	-17,2	-17,3
chilled meat	7,1	6,3	6,9	6,0	6,7	5,6	7,1
brine	7,8	15	8,2	8,5	8,2	7,2	11,2
ambient air	4,8	5,2	2,7	2,7	1,6	1,6	3,5
product measured	-4,8	-4,7	-4,3	-1,0	-2,7	-2,2	-4,3
product calculated**	-4,2	-4,1	-4,2	-2,5	-3,4	-4,2	-4,2

*Two frozen blocks were used in the ratio of 1:1.
**Assuming $\alpha = 3{,}5$ W/m^{2}h, eq. 1 was used to calculate H^p, whereafter the temperature of the product was read from Fig.1.

The modifications applied (Exps.3-7) gave favourable results. While finding of unsuffitiently thawed pieces after 24 hours was positive in Exps. 1 and 2, it was completely negative in all the other experiments. The penetration of the brine constituents into the meat has been satisfactory, as confirmed by the sensory evaluation before and after the thermal treatment of the cured product (2 h; 121^{o}C). The whole of the added brine has been absorbed, and none of the samples, incorporated subsequently in the coarse-cut sausages, revealed any of the technological defects. Moreover, the modifications resulted in the significantly lower formation of the fine mass in the cured product which is expected normally during the process of massaging. The product from the Exp. 7 had practically none of it. On the contrary, Exp.6, concieved primarly to intensify the heat transfer between the frozen and chilled meat pieces, resulted in the considerable comminution of the final product so it was applicable, e.g. as a luncheon meat.

Summing up the results of the present investigation, it seems that its primary goal has been fulfilled. Thawing and curing has been performed within 24 hs. without perceptible loss. On the contrary, 25% gain in weight has been obtained. The experiments performed affirm clearly the applied theoretical approach and give the sound base for planning of the future, more controlable, investigations. Even at this moment, the prediction can be done, that the process in question could be performed completely without admixture of the chilled meat as a heat source, if only the ambient-air temperature could be maintained at the maximum (+10°C) together with the slight circulation of the air ($\alpha \geqslant 15$ W/m^{2}h) (Fig.2). Realization of these conditions seems to be the optimal solution of the problem imposed in the present work.

References:

1. Jasper, W. and Placzek, R.(1977): Kältekonservierung von Fleisch. VEB Fachbuchverlag, Leipzig.
2. Chizhov, G. (1950): Cholodilnaja technika (Moskva), 2.
3. Spravochnik Khimika (1964): "Khimija", Moskva, Leningrad.