SIMULTANEOUS THAWING AND CURING OF WHOLE PORCINE MUSCLE

Ngapo, T.M., Babare, I.H. and Mawson, R.F.
Food Science Australia, Private Bag 16, Werribee, Victoria 3030, Australia.

SUMMARY

Porcine muscles were frozen in cartons and stored for 3 weeks at -28°C. These blocks of meat were thawed at 4°C in plastic liners in air or recirculating water, or removed from the liners and thawed in recirculating brine. Individual muscles were frozen in a domestic freezer and thawed in brine at 4°C for 12, 20 or 30 h. Brine thawing of meat blocks was almost 3 times faster than the rate in water and 5 times faster than in air. During thawing brine penetrated the muscle and resulted in weight gain compared to losses in water and air. Brine penetration in individual muscles increased with increased immersion time, but after 30 h bulk brine penetration had not reached the muscle centre. Lack of complete penetration might be overcome in an industrial environment where vigorous stirring could encourage penetration during thawing. This thawing process complemented with current methods of injection or tumbling could provide economic benefits to the ham industry through reduction of processing times and drip losses.

INTRODUCTION

Trumic *et al.* (1972) studied the influence of frozen storage duration and thawing methods on the keeping quality and weight changes during thawing and heat treatment of loin, neck and fatty porcine muscle tissues. The meat was thawed in air, saline solutions or brine. Meat thawed in brine resulted in the best keeping quality and greatest wet thawing yield. Later studies (Sibalic *et al.*, 1983a, b) investigated the thawing of pork in brine as an alternative for meat to be used in comminuted products. Frozen pork trimmings were cut into chunks (3 x 3 x 7 cm) and tumbled with brine obtaining a comminuted product. It was concluded that using meat chunks, simultaneous thawing and curing could be accomplished within 24 hours and a 25% gain in meat weight was attainable.

In an industrial environment a typical method of ham production might involve thawing meat in its packaging by placing several bags under a source of flowing 10°C water, each bag containing three or four muscles vacuum packaged together. This process might require 16 hours to achieve 4°C at the meat centre and produce drip loss of 10% of the meat weight. The meat might then be injected and intermittently tumbled for 10 h prior to packaging and cooking. This entire process could take 26 hours to complete. Any reduction in drip loss and processing time would be of economic benefit to the processors.

The present study aims to provide a preliminary investigation of the simultaneous thawing and curing of whole porcine muscle for subsequent use in ham production. A comparison of three thawing media, air, water or brine, and thawing time trials in brine will provide information contributing to the analysis of the feasibility of a combined thawing-curing method for whole muscle.

MATERIALS AND METHODS

Meat. Meat was obtained from a local abattoir where a 1:1 ratio of male to female pigs are slaughtered (22-24 weeks old) derived from crossbreeds of Landrace, Large White and Duroc. Porcine muscles *biceps femoris*, *semimembranosus* and *rectus femoris* were obtained from hindquarters of carcasses stored for 24 hours at 4°C and stored for a further 24 hours before use. The pH was measured in triplicate by insertion of a pH probe into the muscles. Only meat with pH in the range 5.4 to 6.0 was used.

Variation of Thawing Medium. Porcine muscles *biceps femoris*, *semimembranosus* and *rectus femoris* were packed into plastic liners (approx. 20 kg of meat in each) and placed in corrugated cardboard cartons (58 x 37 x 15 cm, head space between plastic liner and box of approx. 4 cm, cardboard thickness of 1.5 mm). The cartons of meat were frozen and stored for 3 weeks in still air at about -28°C at a commercial cold storage facility. To thaw in air at 4°C, meat was removed from three cartons, retained in the liners, and placed onto racks with maximum exposure of the liners to the air. To thaw in water, meat was removed from four cartons, secured in plastic liners, and placed on racks in a tank allowing water circulation around the entirety of each liner. Approximately 800 l of water was circulated at 0.61 l/s by an external pump. The temperature of the water was 4°C at the commencement of thawing and room temperature was maintained at 4°C. Brine thawing was as for water thawing, with adaptations: (a) water was replaced with brine, and (b) the meat was removed from the plastic liners. Brine consisted of 1.5% sodium tripolyphosphate, 1.5% sodium erythorbate, 0.07% sodium nitrite, 2.5% sugar and 10.8% sodium chloride.

Thawing Time Trials. Twelve muscles were individually wrapped in domestic freezer bags and frozen in a domestic freezer at about -18°C. Two muscles of each *semimembranosus* and *rectus femoris* were used at each thawing time. Frozen muscles were removed from the bags, placed individually in chilled brine (10 l at 4°C) and shaken at 90 cycles/min. Room temperature was 4°C.

Monitoring Temperature Change. Temperature change was monitored using copper constantan thermocouples connected as differential inputs to a DL600 Datataker data logger (DT5 series, Data Electronics Australia Pty Ltd). Thermocouples were inserted into the fresh meat and used throughout the freezing and thawing processes. Using cartons of meat, thermocouples were inserted from the top of the carton to the meat centre at four points along its diagonal axis (3, 13, 24 and 35 cm from the surface to the centre of the carton) of two cartons for each treatment. Using individual muscles, thermocouples were inserted into four of the muscles used at each thawing time; a thermocouple each at the centre and near the surface of each muscle.

Measurement of Brine Penetration. Muscles were removed from the brine at the specified time and secured in permeable casings. The muscles were cooked in a water-bath at 85°C until the centre of the muscle reached 75°C, removed from the casings to domestic freezer bags and stored at 4°C overnight. The distance of brine penetration was measured from the muscle surface to the abrupt colour change observed upon bisecting the muscles indicating termination of brine penetration.

RESULTS AND DISCUSSION

Immersion of cartons of meat in recirculating brine resulted in a faster rate of thawing than water or air thawing and an increase in the total meat weight (Table 1). Many researchers have shown that thawing in air is slower than in water and can be explained by basic principles of heat transfer. Everington and Cooper (1972) discussed that during thawing, as outer layers thaw

their conductivity decreases making heat flow inwards progressively slower. During the first part of the thawing process, the temperature difference between the thawing media and the surface of the product is large, so initially the rate of heat transfer is governed by the magnitude of the surface film coefficient. As thawing continues, the heat transfer rate is limited by the nature of the particular foodstuff - its thermal diffusivity, length of heat flow path and the temperature difference across it.

Direct contact of meat with air or water during the thawing process was not studied. When air thawing without high humidification, retention of meat in the liner minimises desiccation and allows the meat to thaw in its purge maximising reabsorption of the purge. Meat thawed in direct contact with flowing water results in leaching of valuable proteins from the meat surface. This meat does increase in weight, however, water absorption during thawing of muscle intended for ham production is of little advantage; brine penetration is required to achieve the cured product.

Direct contact of recirculating brine with the meat increases the rate of thawing compared with air or water, by providing a larger surface film coefficient (Everington and Cooper, 1972), by increasing the surface area in contact with the thawing medium when the blocks of meat break up and therefore decreasing the length of the heat flow path, and by maintaining a greater temperature difference between the meat and brine. Direct contact of the ice crystals in frozen meat with the recirculating chilled brine induces the crystals to thaw, as a consequence of the temperature (and lower freezing point) of the brine compared with the ice in the frozen meat and the continual movement and therefore replacement of the brine in contact with the meat. These factors encourage penetration of the frozen system by the brine with a resultant thawing front that moves into the meat, and perhaps along the ice crystals in the meat. Rapid penetration of the brine along the ice crystals would take advantage of the expanded meat structure created by the crystals.

When individual brine thawed muscles were cooked, lack of cured colour at the muscle centre indicated that bulk brine penetration had not reached the muscle centre after 30 hours (Table 2). However, small pink areas (1-2 mm diameter) were observed at the muscle centre indicating that brine had penetrated the entire muscle. The small diameter and sparseness of these areas suggested that brine may have penetrated the meat along ice crystals. The size and location of ice crystals formed during meat freezing is dependent on the sample size, the freezing rate and length of storage.

Penetration of brine into the muscle increased with increasing time (Table 2). Towards the centre of the muscle, the rate of progression of the thawing front is faster than the mass diffusion of brine into the meat so that the centre of the muscle thaws without complete cure penetration. Once the meat has thawed, the channels for rapid brine penetration are closed by swelling of the fibre structure. Upon complete thawing, water may be extracted from the muscle as a consequence of osmosis at the brine water interface. The mechanism and kinetics of muscle thawing in brine are complex phenomena requiring further study.

An increase in muscle weight was observed in the muscles thawed in brine (Table 2). This increased weight appeared constant with time. This is unexpected given that the incremental volume of penetration decreases as the brine moves toward the muscle centre and probably reflects a rate of uptake determined by local fibre swelling in addition to progression of the brine boundary.

In the present study the brine did not penetrate the entirety of the muscles. However, brine did penetrate a significant distance into the muscles and produced a significantly reduced thawing time compared with thawing in water in similar conditions. The method used here was to brine thaw individual muscles in 4°C brine with gentle shaking only. Industrially, the muscles could be vigorously stirred in brine at 10°C and tumbling or injection could be used to complement this process producing optimal conditions for increased thaw rate and brine uptake. Thawing in brine is a combination of currently used processing stages requiring decreased processing time, therefore sterilisation of equipment would not vary from methods currently employed and the microbiological safety of the product might be improved.

CONCLUSIONS

This preliminary study of simultaneous thawing and curing of whole porcine muscle shows a much reduced thawing time, and increase in muscle weight and brine penetration when thawed in recirculating brine at 4°C compared with thawing in water or air. Lack of complete penetration of the brine into the muscle might be overcome in industrial conditions and in conjunction with currently used methods, such as tumbling. Detailed investigation of the thawing and brine penetration processes are required to understand and optimise the combined thawing-curing process. It is suggested that this process could provide economic benefits to the ham industry through reduction of both processing time and drip losses.

Table 1. Thawing of meat cartons in three media.

Thaw medium	Approx. time to thaw centre to 4°C (h)	Average carton thaw weight (% of original weight ± 1 s.d.)
air	125	91.3 ± 1.6
water	67	95.3 ± 2.1
brine	23	106.3 ± 1.2

Table 2. Thawing of whole muscle in brine.

Thawing time (h)	Average brine penetration (cm ± 1 s.d.)	Average muscle thaw gain (% of original weight ± 1 s.d.)
12	2.0 ± 0.3	2.3 ± 0.7
20	2.4 ± 0.3	2.5 ± 0.6
30	3.2 ± 0.3	2.5 ± 0.8

REFERENCES

1. Everington, D.W. and Cooper, A. (1972). *Australian Food Manufacture and Distributor,* 42 (3) 32.
2. James, S.J. and Bailey, C. (1984). In "*Thermal Processing and Quality of Foods*", P. Zeuthen, J.C. Cheftel, C. Eriksson, M. Jul, H. Leniger, P. Linko, G. Varela and G. Vos (Ed.). Elsevier Applied Science Publishers Ltd., Barking, Essex, p566-578.
3. Sibalic, S., Djordjevic, M. and Smiljanic, D. (1983a). *Tehnologija Mesa*, **25** (6), 188-194.
4. Sibalic, S., Smiljanic, D. and Djordjevic, M. (1983b). *Proc. of the European Meeting Meat Res. Workers*, **29** (I), 374-381.
5. Trumic, Z., Djordjevic, V., Polic, M., Milanovic, M. and Miljevic, M. (1972). *Tehnologija Mesa*, **13** (1), 7-12.