EFFECTS OF SODIUM CHLORIDE ON THE HYDRATION OF REFRIGERATED AND FROZEN-THAWED PSE PORCINE MUSCLES

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SUMMARY

Slices of normal and PSE Longissimus dorsi muscles, after chilling or freezing-thawing, were immersed in 10%, 15% or 20% and 10% salt concentration brines, respectively. They were then allowed to dry until 15 days after death.
PSE muscles showed a higher loss of water due to drip than the normal during the refrigeration and thawing period. These muscles absorbed more water and salt than the normal during brining with 10% salt solution, while in 20% brine less water migrated from these muscles and slightly more salt was absorbed. This fact, together with the greater dehydration rate led to higher salt concentration at the end of the drying period.
The extent of water and salt exchanges has been related to the salt concentration in brine as well as to the extent of drip loss, the WHC before brining and the condition of cell membranes in muscles.

INTRODUCTION

The curing and drying process of whole PSE porcine muscles leads sometimes to products of very low quality. Excessive weight loss, abnormal dehydration and high content of salt have been recorded as the most frequently claimed defects (Cenci 1985; Severini et al. 1986; Wirth 1986).
Some characteristics of PSE muscles within 45-90' post mortem seem to be of great importance for water and salt exchanges. In fact, at this time PSE muscles show very low pH and water holding capacity (WHC).
However, the type of processed products and the technological options adopted in processing as well as the criteria used to classify the fresh muscles have to be carefully taken into account when any correlation between the PSE condition of the raw meat and the quality of the derived product is investigated.
Moreover, other factors such as the length of storage period before curing, the chilling temperature and the freezing-thawing process of meat can affect the outcome.
Thus, when chilled or frozen-thawed muscles are processed several hours post mortem the question arises whether and what differences exist between normal and PSE meat which affect its behaviour during the curing-drying process.
This experiment was designed to study whether and how some post mortem events which take place in normal and PSE porcine muscles before brining affect the exchanges of water and salt during immersion in brine and then during the drying period.

MATERIALS AND METHODS

Longissimus dorsi muscles taken from crossbred pigs weighing 120-140 Kg were used in this experiment. The pigs were conventionally stunned and slaughtered at a commercial abattoir.
Normal and PSE muscles were selected according to the appearance, the pH and the WHC at 1h and 24h after death. The muscles were kept at a temperature of about 10°C until two-three hours after stunning. At this time slices of about 50g, 1.5cm thick and with about the same surface area, were cut across the long axis of the muscle and were either frozen or used for determining drip loss. The remaining whole muscle was stored at 4°C until 24h post mortem when other refrigerated slices were collected, weighed and cured.

Determination of drip loss. The slice was weighed and hung in a metal netting bag inside a plastic bag for 24h at 4°C. The percent of weight loss at the end of storage was considered as drip loss.

Freezing and thawing process. The slice was weighed and put into a plastic bag at -25°C for 7 days. Then, the slice was hung inside a beaker covered with plastic film, allowed to thaw at 4°C for 24h, weighed again for evaluating drip loss and cured.

Curing and drying process. Each cooled and frozen-thawed slice was hung inside a beaker and immersed in 200ml of sodium chloride solution (brine) at 4°C for 72h and then weighed. The salt concentration in brine was 10%, 15% and 20% for cooled slices and 10% for thawed slices.
Then, the brine was removed and the beaker was covered again with a plastic film. The slices were allowed to drain for 96h at 4°C and weighed.
Finally the beakers were kept uncovered in a controlled chamber at a temperature of 16°C and a relative humidity of 60-70% to allow the slices to dry. The slices were weighed after 2 and 7 days.
At each stage of processing slices were collected for analyses.

Measurement of pH and WHC. The pH at 1h post mortem was measured by using a digital pH-meter (Top Tronic) and a direct insertion probe electrode. The pH at 24h post mortem was determined by a radiometer pH-meter (Orion) using 10g of muscle homogenized in 50ml of 5mM neutral iodacetate solution.
Water holding capacity (WHC) was measured according to the filter-paper absorption method and expressed as value of meat film area/fluid area.

Determination of salt content, moisture and protein content. Sodium chloride content, moisture and protein content were determined according to standard AOAC procedures (AOAC 1984).

RESULTS

All normal muscles used in this experiment showed pH>6.2 and WHC>2.0 at 1h after death. At this time PSE muscles showed pH<5.8 and WHC<1.5 as also observed in a previous study (Severini et al. 1984).
All refrigerated normal and PSE muscles had pH values ranging from 5.43 to 5.70 and WHC values below 1.0 at 24h post mortem. No significant difference was observed between the two groups.
The mean value of the drip loss over the 24h storage period at 4°C was 1.38 in the normal muscles and 3.37 in the PSE muscles. Little difference was observed between the groups of muscles used for the various

parts of the experiment.
The weight changes of refrigerated muscles after brining, draining and drying are shown in fig. 1.
The curves of normal and PSE muscles are very similar at any given salt concentration in brine. However, PSE muscles immersed in 10% salt solution showed a slightly higher weight loss during the last period of drying, reaching final values lower than the normal.
A good correlation was found between the values of weight gain and the salt concentration in brine.
The calculation of water content in muscle before and after brining (moisture% x weight of slice) showed that: 1) the water was absorbed by the muscle during immersion in 10% salt solution; 2) no or little exchanges took place during immersion in 15% salt solution; 3) water migrated from muscle to brine during immersion in 20% salt solution.

The salt uptake during brining was related to the salt concentration in brine and in each stage of processing PSE muscles showed slightly higher values than normal (fig. 2).
The evaluation of salt content in the water within the muscle and in brine showed that the salt tended to reach a balance of concentration between the two. This indicates that salt diffused freely throughout the cell membranes.
The salt concentration during draining and drying increased a little more in the PSE than in normal muscles.

The values of moisture were slightly higher in PSE than in normal muscles at any given time before and after immersion in the different salt solutions (fig. 4).

The variations of moisture were related to weight changes during the processing period.

No significant differences were observed between protein content of normal and PSE muscles, even though the former had slightly higher values at the end of drying period. The muscles cured with a higher salt concentration showed higher protein content values at the end of drying period (fig. 3).
At the end of the processing period (15 days post mortem), the moisture/protein ratio in normal and PSE muscles cured with 10% salt brine was similar to the pre-brining values (3.1 and 3.2). The ratio value was 2.7 in normal and PSE muscles cured in 20% salt brine.

The weight changes in frozen-thawed muscles are shown in fig.1d. When compared with the data obtained on refrigerated muscles (fig. 1) it is shown that weight loss after thawing was much higher than after cooling and higher in PSE than in normal muscles. Thus, the frozen-thawed muscles had a very high weight gain expressed as percent of the weight after thawing. However, this gain proves to be almost the same as in normal refrigerated muscles and slightly lower than in PSE cooled muscle when expressed as percent of weight before freezing.
On the other hand, frozen-thawed normal muscles showed a slightly higher decrease of weight at the end of the drying period.
Fig. 2d shows the salt content in thawed muscles.
Both normal and PSE frozen-thawed muscles absorbed more salt than cooled muscles and showed very similar values expecially at the end of the drying period.
No significant differences were observed in moisture and protein content between frozen-thawed and refrigerated muscles. However, the final values of moisture were slightly lower and the values of protein content were similar to the cooled muscles. This indicates a greater dehydration during the last period of processing which contributed to the increase of salt concentration in meat (fig. 3 and fig. 4).

DISCUSSION

The values of pH and WHC observed at 1h and 24h post mortem indicate that the normal muscles were in a pre rigor state and that development of rigor occurred in PSE muscles when slices were collected for cooling or freezing at 2-3h after death, whereas all muscles were in post rigor state when slices were cut off to be immersed in salt solutions (Honikel et al. 1984).

The different state of the muscles at the beginning of the refrigeration and the length of the storage period at 4°C may explain the differences in drip loss after cooling.
In fact, the amount of drip produced by a muscle is determined by the combined effect of the post-mortem rates of fall of pH and temperature (Penny 1977).
Moreover, the extent of drip loss during the storage of meat post rigor is closely related to the shortening of sarcomeres in the prerigor state and during the onset of rigor mortis and this affects the WHC (Honikel et al. 1986).
However, immediately after rigor development muscles show no, or only little, drip formation and the effect of sarcomere shortening on drip formation becomes evident only during storage of muscle post rigor (Honikel et al. 1980).
The drip loss observed in this experiment 24h after death indicates that PSE muscles reached the rigor state much earlier than the normal muscles and that they probably had a greater shortening of sarcomeres.
Moreover, the large amount of drip in PSE muscles could be related to some damage of the cell membranes.
In fact, a remarkable part of the immobilized water is supposed to be located within the thick filaments and between the thick and thin filaments of the myofibril and the release of drip from muscles seems to be dependent on the state of contraction after the onset of rigor (Offer & TrinicK 1983).
The shrinkage of filament spacing results in release of water into the extracellular space, because of the increased permeability of the cell membrane (Honikel et al. 1986).
A leakage of cell membranes has been suggested to explain why the exudate appears on the surface of PSE muscles as early as 2 to 4h post mortem, while from normal muscles the drip is released much later (Honikel et al. 1986).

In this experiment, the normal and PSE muscles at the end of refrigeration and before immersion in salt solution showed very similar pH and WHC values. Thus, they were supposed to have a very similar swelling capacity at this time.
In fact, the swelling ability is partially related to the water holding capacity of muscles which decreases after death and reaches its minimum value in 24 to 48h (Hamm 1960).
The swelling caused by the salt solution is due to the ability of Cl^- ions to remove some transverse

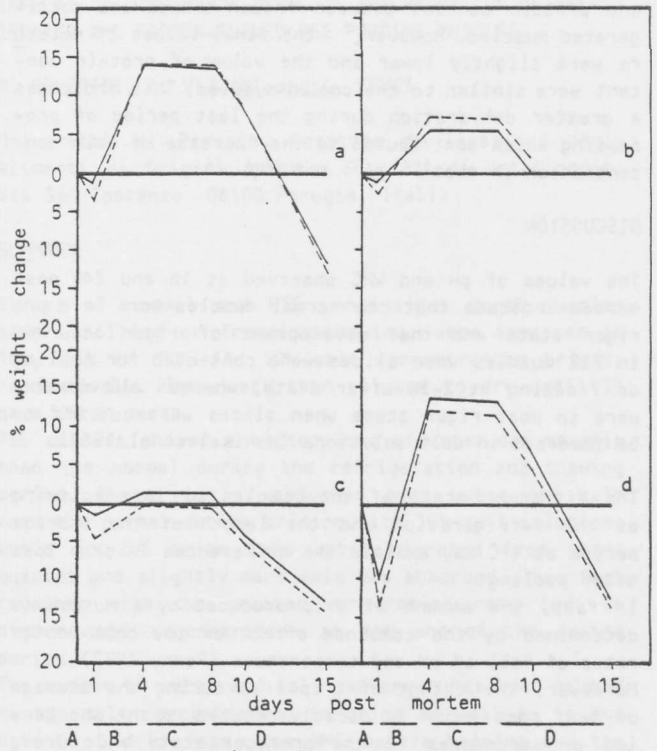

Fig.1. Percentage weight change.
Weight of fresh muscle = 0

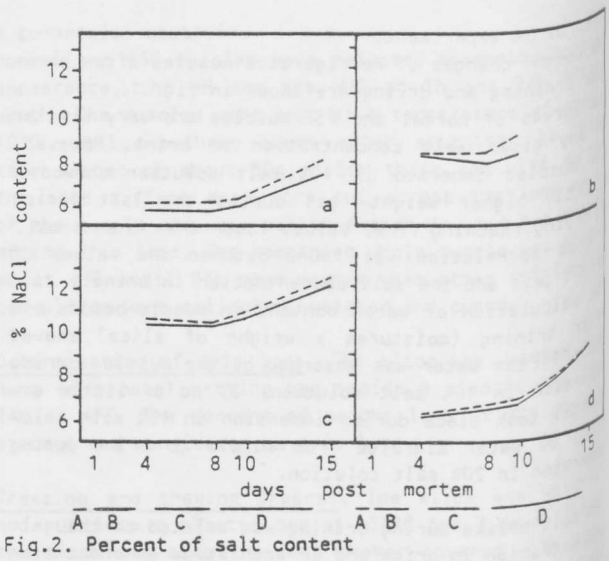

Fig.2. Percent of salt content

Normal muscles ————
PSE muscles --------

A=pre-brining period (1 day); B=brining period (3 days); C=draining period (4 days); D=drying period (7 days). a) mean values of 7 normal and 7 PSE refrigerated muscles, 10% salt brining; b) mean values of 2 normal and 3 PSE refrigerated muscles, 15% salt brining; c) mean values of 5 normal and 4 PSE refrigerated muscles, 20% salt brining; d) mean values of 5 normal and 6 PSE frozen-thawed muscles, 10% salt brining.

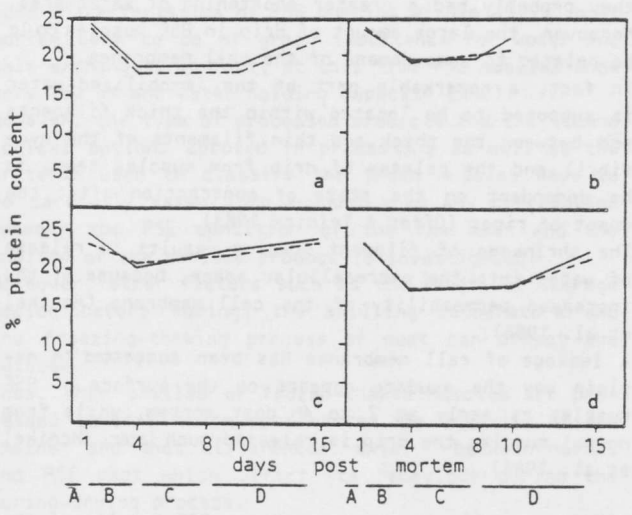

Fig.3. Percent of protein content

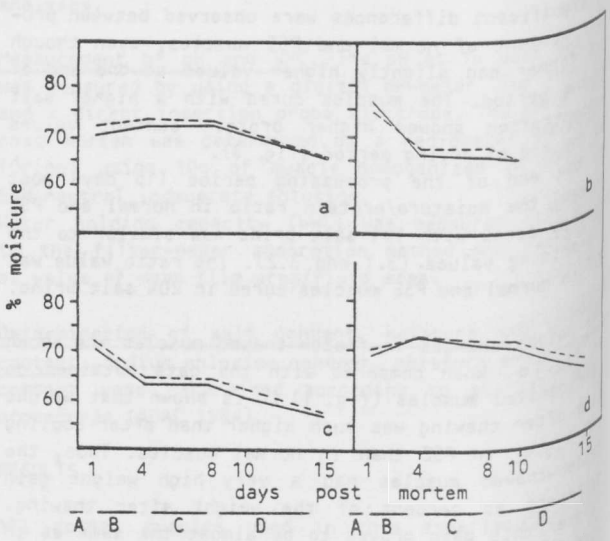

Fig.4. Percent of moisture

A = pre-brining period (1 day); B = brining period (3 days); C = draining period (4 days); D = drying period (7 days). a) mean values of 7 normal and 7 PSE refrigerated muscles, 10% salt brining; b) mean values of 2 normal and 3 PSE refrigerated muscles, 15% salt brining; c) mean values of 5 normal and 4 PSE refrigerated muscles, 20% salt brining; d) mean values of 5 normal and 6 PSE frozen-thawed muscles, 10% salt brining.

Normal muscles ————
PSE muscles --------

structural constraints in myofibril allowing the filament lattice to expand (Offer & Trinick 1983).
Our results show that the refrigerated PSE muscles absorbed more 10% saline solution than normal but reached a similar weight gain expressed as percent of weight before refrigeration.
Thus, even though PSE muscles lost more weight due to the drip, they also regained more weight after brining, reaching final values analogous to normal muscles.
Therefore, it seems that the swelling of the muscle is related to the actual WHC immediately before the brining and that the amount of absorbed water depends on the WHC and the extent of the drip loss.
The greater amount of water absorbed by the PSE muscles results in a higher salt uptake. This fact and the greater water loss during the drying period, probably related to a leakage of cell membranes, cause a higher final salt concentration in PSE muscles.

During the immersion in brine with 15% salt concentration very little water, if any, is absorbed by the muscle and during the immersion in 20% salt solution the water migrates from the muscle to the brine. The extent of migration is slightly higher in normal than in PSE muscles probably because the latter lost more water during the storage period.
However, normal and PSE muscles immersed in solutions with high salt concentrations reached slightly different values of weight gain after brining.

The cell membranes in muscle seem to play an important role in drip loss and salt solution absorption during the brining. This is supported by the results of the experiment carried out on the frozen-thawed muscles.
These muscles showed a very high drip loss due to the thawing, and after brining they reached values of weight gain quite similar to the refrigerated muscles.
This fact shows that the frozen-thawed muscles absorbed enough brine to compensate the higher drip loss before brining.
The greater extent of cold shortening, the thaw shortening and the accelerated rate of glycolytic metabolism may partially explain the high drip loss in normal muscles which were in prerigor state, but not in the PSE muscles where development of rigor mortis occurred at the time of freezing.
Therefore, the disruption of cell membranes has to be taken into consideration to account for the very great amount of early drip released from both normal and PSE muscles.
Actually, the PSE frozen-thawed muscles showed a lower weight gain than the refrigerated muscles and the normal frozen-thawed muscles. This may be attributed to the fact that the dehydration before brining reached extreme values and the swelling ability of the proteins in the thawed PSE muscles failed to recover this loss.
This event was observed also in PSE muscles immersed in brine after a long storage period at 4°C (Severini et al. 1986).

In conclusion, the extent of water and sal exchanges, which occur during brining and affect the hydration and salt concentration in dryed meat, depends on the salt concentration in brine and seems to be related to the drip loss, the WHC before brining and the condition of cell membranes in muscles. All these factors appear to be related to each other.

In fact, the influence the PSE condition exerts on the salt uptake and the hydration seems higher in refrigerated muscles processed 24h post mortem with 10% salt solution than in those processed with higher salt solutions or after freezing and thawing.

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