The influence of temperature on post mortem changes in porcine muscles

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Excessive chilling shortly after slaughter induces cold shortening in porcine and bovine muscles (Fischer et al. 1980). Cold shortening of bovine muscles results in tough meat. This increased toughness can be prevented in practise by a more moderate chilling during the prerigor state or by an acceleration of the biochemical changes post mortem by electrical stimulation. Furthermore shortening of bovine muscles increases the drip loss of beef during storage (Honikel, Hamm 1983). The question arises as to whether undesirable effects of shortening of bovine muscles also apply to porcine muscles, and at which temperatures, to which extent and under which conditions shortening occurs in porcine muscles at all.

Materials and Methods

Detailed studies of biochemical and structural changes of porcine muscles post mortem at various temperatures between 0° and 35°C have been carried out with M. cleidomastoideus from the neck/shoulder region of the pig carcass. This muscle belongs to the red muscle type and shows a parallel orientation of muscle fibers within the muscle structure. Therefore, changes in length of muscle by contraction and stretching by load can be easily detected. The lengths of these excised muscles were about 15 cm with a cross section of about 10 cm^2. The load applied was about 250 g/cm^2 muscle cross section. Further studies on the influence of temperature on drip loss and colour have been carried out with longissimus dorsi muscles after hot-boning which were compared with cold boned samples. The methods used are described by Roncalés et al. (1982) except the measurement of colour brightness (L) which was carried out with the Zeiss-Elrephomat (Zeiss, Oberkochen, Germany).

Results and Discussion

Studies on porcine neck muscles.

Similar to bovine muscles (Honikel et al. 1983) the biochemical changes post mortem (p.m.) in porcine cleidomastoideus muscles depended on muscle temperature. The rate of ATP breakdown p.m. showed a marked minimum at 11-15°C. The onset of rigor mortis which occured at 11-12°C at about 2-3 hours p.m. was in porcine muscles much more rapid than in bovine muscles where the pre-rigor state at 12°C lasted about 15-20 hours (Roncalés et al. 1982). We define the onset of rigor mortis as the beginning loss of extensibility of the muscle by applying a load of 250 g/cm^2 muscle area.

Rigor mortis started at 11°C at pH 6.1 (fig. 1) and at an ATP concentration of about 1.1 μMol/g muscle or at R-value (Honikel, Fischer 1977) of 1.05. At lower and higher temperatues the onset of rigor mortis occured at higher pH (up to pH 6.4) (fig. 1) higher ATP concentration (up to 2 μMol/g muscle and lower R-values (0.9) and earlier (1-1,5 hours) post mortem. The full development of rigor has taken place at pH 5.8 at all temperatures.

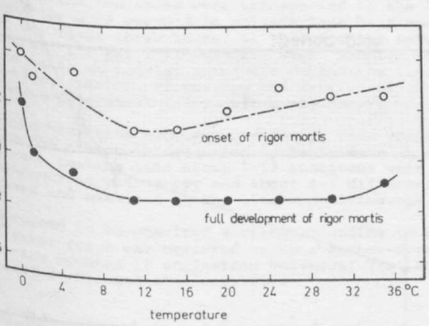

Fig. 1 Influence of the temperature of incubation of M. cleidomastoideus on the pH-value at which the onset of rigor mortis begins and the full development of rigor mortis has been reached.

The shortening of muscles and sarcomeres started in the prerigor state and continued until the full development of rigor mortis. The degree of final sarcomere shortening varied considerably with incubation temperatures (fig. 2). At 0°C and 35°C it amounted to about 50 % with respect to its original length before incubation. We observed the least sarcomere shortening (10 %) at 12-15°C. Muscles as a whole shortened less than sarcomeres to a maximum of 30 % (at 0° and 35°C) and a minimum of 5 %. This minimum was obtained at temperatures of 20-24°C; i.e. about 10°C higher than the minimum sarcomere shortening.

As already reported for bovine muscles (Honikel, Hamm 1983) also the drip loss of muscle pieces of porcine muscles depended very much on the temperature of storage during the first 24 hours post mortem. The drip loss showed a minimum at 12° to 15°C (incubation temperature during the first 24 hours p.m.) which coincides with the temperature range of slowest biochemical changes p.m. and the minimum of sarcomere shortening (fig. 3). Indeed there existed a linear relationship between the final maximum sarcomere shortening at temperatures between 0°C and 35°C and the observed drip loss in these muscles (fig. 4), but there was no linearity between drip loss and maximum muscle shortening (fig. 4). The shortening of sarcomeres exhibited is apparently of greater importance for the drip formation than the shortening of a muscle as a whole which represents the sum of more or less shortened

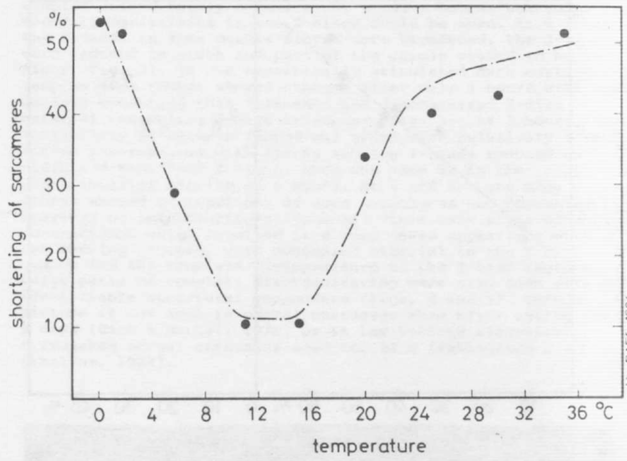

Fig. 2 Influence of the temperature of incubation of M. cleidomastoideus on the final maximum sarcomere shortening after 24 hours.

and unshortened sarcomeres including changes in the series elastic components like the connective tissue.

In summary: Red porcine muscles of normal meat quality showed the slowest biochemical changes post mortem and the minimum shortening of sarcomeres if they were chilled rapidly to 12-15°C before the full development of rigor mortis which at these temperatures is completed after about 6 hours p.m. The minimum of shortening of sarcomeres leads to a minimal drip loss of the meat which is important for the handling of meat. This optimum temperatures range for pork coincided with the optimum temperature range for beef as reported by Honikel et al. (1983) and Powell (1978).

Studies on fast glycolyzing porcine muscle

Very rapid post mortem changes in pork may result in PSE meat. PSE-muscles, showing no shortening of sarcomeres (own unpublished data) are characterized by an early and intensive exudation of drip and a pale colour. The cause for these detrimental characteristics of PSE-meat are the stress suspectibility and the preslaughter stress which lead to an extreme fast glycolysis during and after slaughter. Low pH values (< pH 5.8) and still high tissue temperature (> 38°C) are reached within 45-60 min p.m. If these pH and temperature

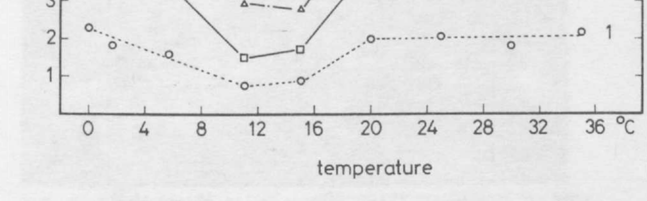

Fig. 3 Relationship between temperature of incubation during the first 24 hours post mortem of M. cleidomastoideus and drip loss of muscle cubes (about 30 g) after storage for 1, 3, 6 and 7 days p.m. From day 2 the samples were stored at 0°C.

conditions prevail, muscle proteins denature resulting in high drip losses and pale colour (Bendall and Wismer-Pedersen 1962; Penny 1977).

Accelerated chilling of PSE-prone muscles with a rapid pH fall within 45 min p.m. prevented the extreme exudation of drip as shown in one example with slices of M. long. dorsi with a pH_1 of 5.4 (fig. 5). Lowering the temperature of this muscle to 20°C between 45 and 60 min p.m. reduced the drip after 4 hours to 6 %, whereas at 38°C and higher the drip loss amounted to more than 10 %. This principal difference also existed after 3 and 5 days of storage (0°C).

Chilling very early p.m. to 20°C had a considerable effect on drip loss. The later the temperature was lowered the less effective was the chilling (fig. 6). Incubation at 41°C for 1 hour after obtaining the meat (45 min p.m.) reduced the effect of chilling remarkably (fig.6). The earlier and the faster the temperature of fast glycolyzing porcine muscle dropped the more pronounced was the effect on drip loss. The reason for this reduction in drip loss is certainly some inhibition of the denaturation of myofibrillar proteins which is a slow process as studies with differential scanning calorimetry have

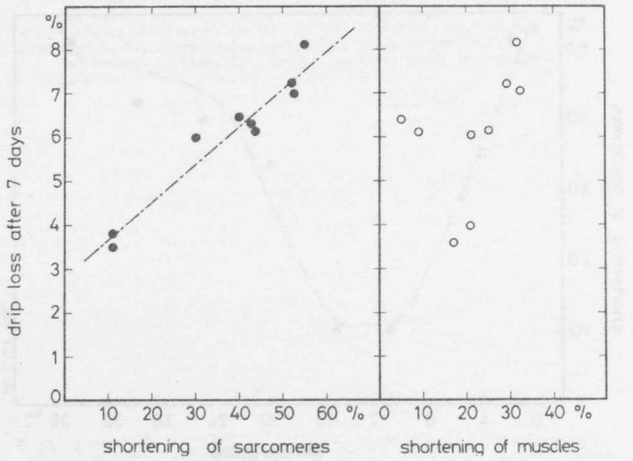

Fig. 4 Relationship between maximum sarcomere and muscle shortening and the drip loss after 7 days of storage. Data are derived from fig. 2 and 3.

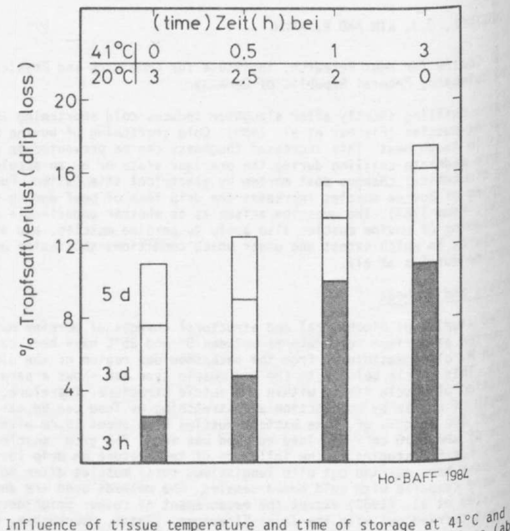

Fig. 6 Influence of tissue temperature and time of storage at 41°C and 20°C between 1 and 4 hours post mortem on the drip loss of slices (about 100 g) of M. long. dorsi of pork (pH_1 5.4) immediately after incubation and after 3 and 5 days of storage.
The first sample was stored at 20°C for 3 hours. The second sample was left 0.5 hours at 41°C followed by storage for 2.5 hours at 20°C, the last sample was incubated for three hours at 41°C. After that time all samples were held at 0°C.

shown (Kim et al. unpublished).

Whereas drip formation is mainly due to denaturation of myofibrillar proteins, the paleness of PSE-meat is mainly caused by changes in sarcoplasmic proteins. Also the denaturation of these proteins could be prevented to some extent by rapid chilling of hot boned samples, which were taken from the carcass at 30 - 45 min p.m. and incubated at the temperatures indicated in fig. 7. The colour brightness (L) of the M. long. dorsi which stayed in the other half of the carcass and was chilled as usual for 24 hours before deboning (fig. 7 gray area) was much higher; i.e. the meat was paler than the meat stored early at temperatures below 40°C.

In summary: In fast glycolyzing muscles of pigs which may develop PSE-meat, the high drip and pale colour could be reduced by rapid chilling of the muscles. Rapid chilling is easy to carry out in hot-boned cuts. As also with slowly glycolyzing muscles it is possible to reduce drip loss and shortening by rapid chilling to 12-15°C, hot boning and rapid chilling of cuts could be advantageous to meat quality. We want to emphasize, however, that we do not believe that by an early and rapid chilling PSE-meat can be completely prevented; we suppose, however, that by hot-boning and rapid chilling the detrimental characteristics of PSE meat could be reduced.

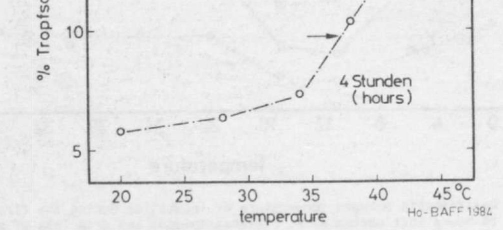

Fig. 5 Influence of tissue temperature between 45 min and 4 hours post mortem on drip loss of slices (100 g) of M. long. dorsi with a pH_1 of 5.4 on drip loss at 4 hours, 3 and 5 days post mortem (storage at 0°C). Hot boned samples were taken from one side of the carcass. Arrows indicate the drip loss of the same muscle and animal in the other side of the carcass which was chilled as usual and was cold boned after 24 hours.

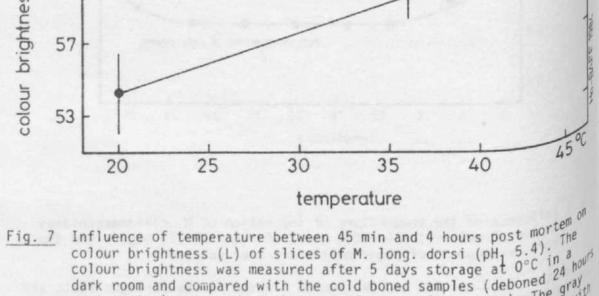

Fig. 7 Influence of temperature between 45 min and 4 hours post mortem on colour brightness (L) of slices of M. long. dorsi (pH_1 5.4). The colour brightness was measured after 5 days storage at 0°C in a dark room and compared with the cold boned samples (deboned 24 hours post mortem) measured at the same time p.m. (gray area). The gray area shows the mean value of the cold boned cuts (centre line) with the standard deviation. The bars indicate the standard deviation of the hot boned samples.

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