The influence of low temperature, type of muscle and electrical stimulation on the course of rigor and tenderness of two beef muscles.

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SUMMARY: The course of rigor, ageing and tenderness has been evaluated for two beef muscles, M.semimembranosus (SM) and M.longissimus (LD), when entering rigor at constant temperatures varying from 10°C to 1°C. The influence of electrical stimulation was also examined.

The course of rigor was followed by the shortening of a muscle strip and the decline of ATP and creatine phosphate (CP). The events during ageing at +4°C were recorded by measuring the Warner-Bratzler shear-force. Sensory properties were assessed after 15 days post-mortem.

The results suggest that the shorter the time to rigor onset, the higher the ATP-level at shortening onset, the more shortening will occur. A temperature region of minimum shortening has been located between 7 and 10°C for SM. The shear-force measurements show that the 1°C-samples cannot be tenderized. A high correlation was obtained between maximum shortening and tenderness assessed 15 days post-mortem, showing the importance of the temperature during the rigor period for tenderness.

INTRODUCTION: Since LOCKER (1960) showed that the degree of shortening of pre-rigor muscle is a factor governing meat tenderness, and LOCKER and HAGYARD (1963) found that shortening during rigor is temperature-dependent, considerable research has been conducted in this field. The influence of different constant temperatures during the rigor period on the course of rigor, ageing and tenderness, has to our knowledge, not been studied yet, when included in the same investigation.

Early post-mortem electrical stimulation is a variable that can improve tenderness, by preventing cold-shortening, as reported by CARSE (1973) for example. By studying the effect of the electrical stimulation of the meat, followed by a rigor period at constant temperature in the cold region, this supposed mechanism by CARSE might be verified.

MATERIALS AND METHODS: M.semimembranosus from young bulls of the Swedish Lowland breed were sampled approximately 10 minutes after debleeding. The non-stimulated M.longissimus dorsi was removed from the carcass 20 minutes post-mortem and the rest of the animal was electrically stimulated (85V, 14Hz for 32 seconds) 25 minutes post mortem.

Samples for rigor measurements were cut from the muscle and the rest of each muscle was wrapped in polyethene bags and brought to a temperature of 1, 4, 7 or 10°C in a water-bath. They were stored at these temperatures until the completion of rigor. The muscles were subsequently stored at +4°C up to 15 days.

Shortening: From each muscle sample, one strip was carefully cut, parallel to the fibre axis. The length was 35 mm and the weight was about 1 gram. The muscle strip was then covered with paraffin oil to provide an anaerobic environment and to minimize dehydration. One end of the strip was glued onto an aluminium disc, which was applied to the measuring apparatus. To record the shortening of muscle, a photo-electric cell was used together with a step-motor. A piece of metal (1.0 gram) was glued onto the free end of the hanging muscle strip. When the muscle shortened, the photo-electric cell followed the strip until the light beam was refracted by the metal piece. The number of steps used by the motor was counted and the longitudinal shortening was calculated. The shortening was registered every 15th minute. Measurements were carried out in a closed chamber and the heating and chilling of the chamber was

achieved using a Peltier-element together with circulation of the air inside the chamber. The accuracy of the temperature recordings was about ±0.5°C.

Energy metabolites: Muscle samples were taken at intervals of 1 hour from the muscle piece kept in a plastic bag. ATP and CP were determined using hexokinase and creatine kinase, respectively, according to the methods described by LOWAY & PASSONNEAU (1972).

Shear-force: Prior to analysis the samples, 3 cm thick, were cooked in their vacuum-bags in a water-bath at 74°C for 60 minutes, and were then rapidly chilled in ice. Pieces with a cross-sectional area of 0.67x1.5 cm were cut from the muscle. The method and the Warner-Bratzler shear device used were described by BOUTON and HARRIS (1978). The analyses were carried out at 2, 8 and 15 days post-mortem.

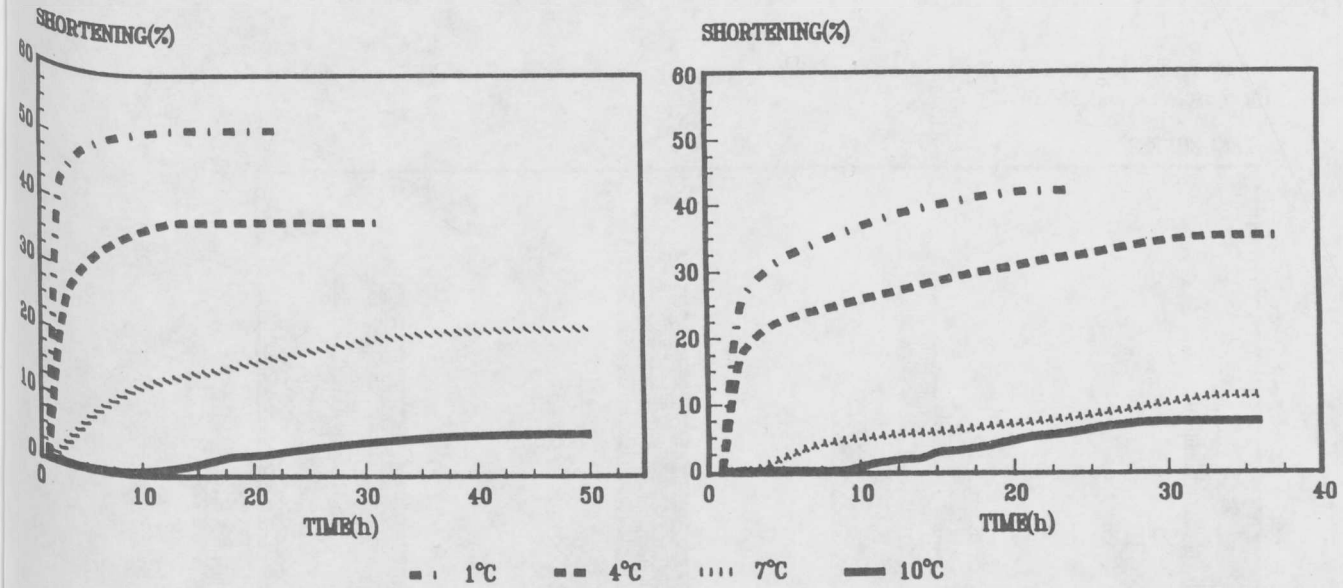
Sensory analysis: At 15 days post-mortem the muscle was cut into 1.5 cm thick slices, which were packed in heat resistant plastic bags. The meat was cooked in a water-bath at 74°C for 60 minutes. Sensory analysis was performed by a trained expert panel of 15 men and women. Tenderness was judged on a scale from 1 to 9 (1 = very tough and 9 = very tender).

Statistical methods: Data were analysed with the New Mathematical Statistics Package (NMSP, 1984) (Pearsons correlation coefficient, Students' t-test).

RESULTS AND DISCUSSION

The course of rigor: It is well known that a decrease in temperature causes an increase in shortening. Results presented in figure 1 show the effect of temperature on shortening. Each curve represents a mean of 4 experiments with a standard deviation of about 5% at 1°C and 1% at 10°C. As shown in figure 1, shortening was found to occur at every pre-rigor temperature; though the degree and speed of contraction varied with temperature and type of muscle. However, the degree of shortening was not significantly influenced by electrical stimulation, which opposes the mechanism of ES, as suggested by CARSE. Experiments performed at 1 and 4°C presented the largest and fastest contraction, without any delay phase. The maximum speed of shortening increased by a factor of about 25 for LD and 50 for SM, when the temperature was decreased from 7 to 4°C. This suggests that a large increase in the release of calcium into the sarcoplasm, according to the mechanism of cold-shortening (CORNFORTH et al 1980), occurs in this temperature region.

Figure 1. Shortening during post-mortem storage at different constant temperatures. Left panel: LD and right panel: SM.



The low degree of shortening at 10°C for both muscles and at 7°C for SM, as well, indicates that the temperature region of minimum shortening differs from the one found by LOCKER and HAGYARD (1963). They found a minimum between 14 and 19°C.

During studies performed at two other temperatures within the same series of experiments, as presented here, we found a shortening of 15% at 15°C and 40% at 37°C for SM, suggesting a minimum of shortening between 7 and 15°C. The coefficient of correlation for maximum shortening versus ATP-level at the onset of shortening rapid phase was high (0.64***), whereas the correlation with the CP-level was lower (0.48**). Shortening rapid phase was defined as the point where the line with the steepest slope of the shortening curve intersected with the slope of the delay phase, or if no delay phase existed, the point where shortening starts.

This suggests that the lower the temperature, the shorter the time to rigor onset, the higher the ATP-level at shortening onset and the more shortening will occur.

Meat quality traits: In table 1 shear-force at 2 and 15 days is presented at the different pre-rigor temperatures and for the different muscles.

Table 1. Shear-force at 2 and 15 days post-mortem at different constant pre-rigor temperatures for muscle SM and LD. Mean and standard deviation of the shear force are given

Shear force (kp)

Temperature (°C):		1		4		7		10	
Day:		2	15	2	15	2	15	2	15
Muscle:	LD	30.4 ± 1.1	29.3 ± 1.3	20.3 ± 6.4	5.9 ± 0.7	9.2 ± 3.6	8.1 ± 0.4	9.4 ± 1.9	6.4 ± 1.1
	SM	27.7 ± 2.3	27.8 ± 4.5	23.8 ± 4.2	15.4 ± 5.7	16.4 ± 2.0	10.9 ± 0.9	14.3 ± 0.9	8.4 ± 0.3

As shown in table 1, the samples with a pre-rigor temperature of 1°C could not be tenderized when stored for up to 15 days, whereas this was the case for those muscles entering rigor at the other temperatures.

Figure 2 shows the effect of pre-rigor temperature and electrical stimulation on tenderness 15 days post-mortem for both muscles studied. The effect of electrical stimulation on tenderness was only observed for LD at 1°C (*) and 4°C (**), respectively. Electrical stimulation showed no effect on tenderness for SM at any temperature. However, for both muscles, the effect of electrical stimulation was not observed in the shear-force values in table 1. There was no difference in ultimate tenderness of muscle LD between 7 and 10°C, whereas tenderness decreased markedly when going from 7 to 4°C, suggesting that the limit for cold-shortening is between 4 and 7°C for muscle LD.

Figure 2. Tenderness 15 days post-mortem at different pre-rigor temperatures, with (ES) and without electrical stimulation (NS), for muscle Ld and SM (n=2).

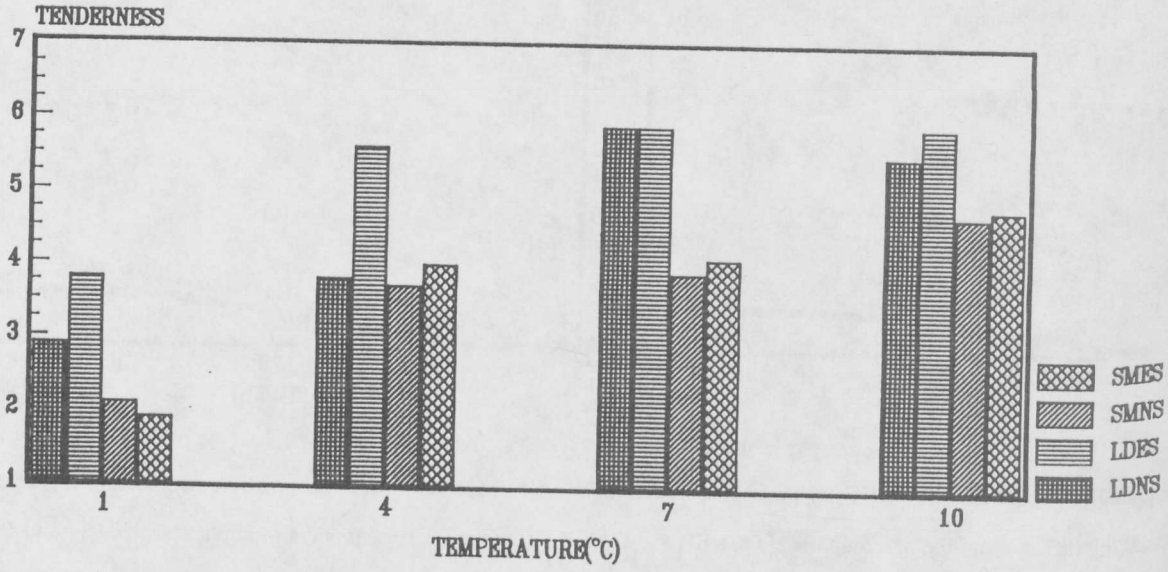
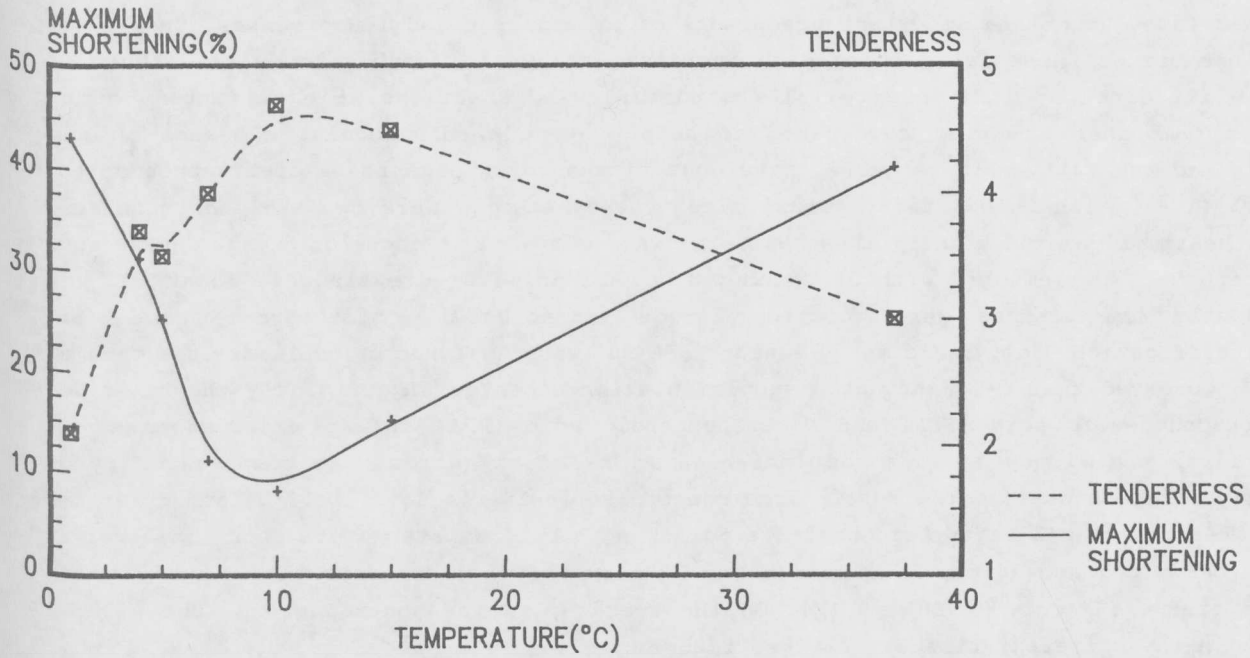


Figure 3 clearly shows that there is a strong relation between maximum shortening and tenderness at 15 days post-mortem, i.e. ven after ageing. The coefficient of correlation was as high as 0.78*** for SM and 0.72** for LD. At the same degree of shortening, D was more tender than SM. The figure also shows a minimum of shortening and a maximum of tenderness at around 10°C for muscle M (an extra set of temperatures within the same experiment is shown). The low maximum shortening (7%) at 10°C for muscle LD igure 1) suggests a region of minimum shortening in the same area as for muscle SM.

Figure 3. Maximum shortening and tenderness 15 days post-mortem versus pre-rigor temperature for muscle SM (n=4).



CONCLUSIONS

* A high correlation was obtained between maximum shortening and tenderness assessed 15 days post-mortem, showing the importance of the temperature during the rigor period for tenderness.

* The effect of electrical stimulation on tenderness was only observed for LD at 1 and 4°C, whereas this effect was not reflected in the degree of shortening during the rigor development. This suggests that E.S. influences the tenderization more than it prevents cold-shortening.

* A muscle with severe shortening can not be tenderized during 14 days of storage at 4°C.

* These results locate a temperature region of minimum shortening between 7 and 15°C for muscles LD and SM.

* Tenderness is influenced by both the type of muscle and the degree of shortening , since at the same degree of shortening, LD was more tender than SM.

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