VERY FAST CHILLING OF BEEF STERNOMANDIBULARIS MUSCLE

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INTRODUCTION

This study examines the concept that, if muscle is cooled very quickly so that it reaches 0°C within about 5h of slaughter, without surface freezing, tenderisation is accelerated. The process is thought to result from a rapid, early release of calcium ions due to the sudden drop in temperature (Bowling *et al.* (1987), Dransfield (1994), Jaime *et al.* (1992), Sheridan (1990). These time/temperature conditions are, however, similar to those which would be expected to cause cold shortening in muscle, and hence extreme toughness. The contrast between this and the tenderising effect is attributed to the rate of cooling, which in the former, is faster than that which would lead to cold shortening. However, while a piece of muscle is cooling, the temperature gradient from surface to centre, represents a range of cooling rates. In practice, only small pieces of muscle could be cooled quickly enough to avoid the conditions which lead to cold shortening. The sternomandibularis muscle was selected for this study because it is small enough to be cooled easily to 0°C within 5h of slaughter by holding at -1°C.

EXPERIMENTAL

Pairs of sternomandibularis muscles were removed from 12 beef carcasses at 2h post-slaughter. Temperature, pH and free length were measured before left sides were placed in an oil bath at -1°C. Right sides were placed in an oil bath at 15°C until 18h post-slaughter when they were transferred to the -1°C bath for the remainder of cooling. At 24h all the muscles were cut in half, individually vacuum packed and stored at 1°C until assessment at 2d or 8d post-slaughter.

MEASUREMENTS

Cooling rate - Maximum temperatures in individual muscles were measured at intervals by needle probe to indicate rate of cooling.
Muscle length - The free length of muscles was recorded at 2h, 4h and 18h post-slaughter. Photographs were taken to record muscle shape.
pH - The pH of muscles was determined at 2h, 4h, 24h ad 48h on a 1g sample homogenised in 10ml Na-iodoacetate solution.
Sarcomere length - Sarcomeres were measured at 2d and 8d post-slaughter, using the laser diffraction method (Volyle, 1971).
Texture - At 2 and 8 days post-slaughter the vacuum packed muscle samples were cooked to a centre temperature of 78°C. After cooling, blocks (1 x 1 x 2cm) were cut and the force required to shear them using Volodkevitch-type jaws was measured on a Stevens Compression Tester.
Cooking loss - The liquid accumulating in the bag during cooking was expressed as cooking loss as a percentage of initial raw weight.

RESULTS

Cooling - Table 1 shows the contrast in cooling rates between the paired muscles. The fast chilled muscles were below 1°C within 5h of slaughter, without freezing, while the slowly cooled muscles were above 15°C until 18h slaughter, after which they were chilled quickly to <0°C, but not frozen.

Table 1. Maximum temperatures measured in sternomandibularis muscles during very fast chilling in oil at -1.7°C (VFC) or during slow chilling in oil at 15°C until 18h from slaughter (slow). Mean values of 12 pairs of muscles.

	hours after slaughter						
	2.0	2.5	3.0	5.0	18	19	24
VFC	22.9	2.5	1.1	0.6	-1.7	-1.7	-1.7
Slow	21.9	17.5	16.1	15.3	14.9	2.5	-0.5

Muscle length - By cooling in oil baths, both sets of muscles were free of tension. Table 2 shows that the length of the fast cooled muscles reduced to 48% original by 4h and further to 42% by 18h. Their girth increased accordingly. By contrast, the slowly cooled muscles were 76% of original length at 18h post-slaughter.
pH - Rate of cooling had no significant effect on the rate of pH fall.
Sarcomere length - The laser method used cannot reliably measure sarcomere lengths < 1.1 micron. All the fast chilled muscles had sarcomeres below this limit (Table 2). Slowly cooled muscles had sarcomeres which were easily measured and relatively long with a mean value of 1.8 microns.
Cooking loss - The loss of liquid on cooking was considerably greater from the fast chilled muscles after both ageing periods of 2d and 8d.
Shear force - Mean shear force values (Table 2) showed that fast cooled muscles were tougher but not significantly so, than their slowly cooled counterparts at both 2d and 8d post-slaughter. The greater variability in texture of the fast chilled muscles is indicated by their higher standard deviations.

Table 2. Measurements made at 2d and 8d post-slaughter on very fast chilled and slowly chilled sternomandibularis muscles. Mean values of 12 pairs of muscle with standard deviations.

	VFC	Slow
pH		
2h	6.86 (0.16)	6.92 (0.07)
4h	6.84 (0.16)	6.89 (0.12)
24h	5.76 (0.08)	5.68 (0.10)
48h	5.64 (0.06)	5.68 (0.06)
Free muscle length (cm)		
2h	26.1 (3.9)	27.9 (3.8)
4h	12.4 (1.6)	25.1 (3.3)
18h	11.0 (1.2)	21.2 (3.0)
Sarcomere length (microns)	< 1.11	1.80 (0.09)
Cooking loss (%)		
2d	26.4 (6.4)	18.3 (5.7)
8d	26.5 (7.9)	17.2 (6.6)
Shear force (kg)		
2d	13.64 (2.87)	11.80 (1.87)
8d	10.68 (2.35)	9.53 (1.72)

DISCUSSION

The temperatures in the fast cooled muscles were similar to those which have been used in other trials with very fast chilling. Certainly, no part of the muscle was frozen and all of it was below 1°C by 5 hours from slaughter. The muscles exhibited all the outward characteristics of severe cold-shortening soon after being placed in the low temperature bath. By contrast, the slow cooled muscles, where no part was below 15°C, shortened more slowly to 76% original length by 18h post-slaughter.

Rate of cooling had no effect on pH fall, despite the rapid temperature drop with the fast cooling treatment. Although sarcomere measurement is not always completely reliable, the contrast between the fast cooled and slowly cooled muscles was clearly demonstrated. Sarcomeres from the fast cooled muscles were too short for measurement, being less than 1.1 micron, characteristic of cold-shortening, compared to the longer sarcomeres (1.8 microns) from slow cooling. The 50% higher cooking loss from the fast cooled muscles was also entirely consistent with cold shortening and would be a serious disadvantage commercially.

Despite these clear differences between fast and slow cooling, measurement of shear force did not show corresponding differences in texture. Although shear values at both 2d and 8d for fast chilled muscle were consistent with cold-shortening, the mean differences between these and the slowly cooled muscles were not as great as might have been expected from the results on overall shrinkage, cooking loss and sarcomere length. However, some exceptionally high individual shear values were recorded among samples from the fast chilled muscles and the variability between measurements within the same muscle is shown by the higher standard deviations. This again is characteristic of cold shortened muscle.

CONCLUSION

The fast cooling procedure used in this study to reduce the temperature of beef sternomandibularis muscles to near zero without freezing, had some very pronounced effects which were consistent with cold shortening. Overall muscle length was more than halved, cooking loss increased by 50% and sarcomeres were too short to measure. But, these outward manifestations of cold-shortening were not clearly confirmed in instrumental measurement of texture, where although mean shear values were higher than from slow cooling, the difference was not greatly marked. There was, however, considerably greater variablity within muscles which had been quickly cooled, suggesting that mechanical assessment of texture by shearing might not accurately reflect differences in eating quality produced in this muscle by the two vastly different cooling rates.

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